



**GE Industrial Systems**

# D30 Line Distance Relay

## Instruction Manual

**D30 revision: 4.4x**

Manual P/N: 1601-0116-**J2** (GEK-112988A)

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System is registered to  
ISO9001:2000  
QMI # 005094  
UL # A3775





## ADDENDUM

This Addendum contains information that relates to the D30 Line Distance Relay relay, version 4.4x. This addendum lists a number of information items that appear in the instruction manual GEK-112988A (revision **J2**) but are not included in the current D30 operations.

The following functions/items are not yet available with the current version of the D30 relay:

- Signal Sources SRC 3 to SRC 6

Version 4.0x and higher releases of the D30 relay includes new hardware (CPU and CT/VT modules).

- The new CPU modules are specified with the following order codes: 9E, 9G, and 9H.
- The new CT/VT modules are specified with the following order codes: 8F, 8G.

The following table maps the relationship between the old CPU and CT/VT modules to the newer versions:

| MODULE | OLD | NEW | DESCRIPTION   |
|--------|-----|-----|---|
| CPU    | 9A  | 9E  | RS485 and RS485 (Modbus RTU, DNP)                           |
|        | 9C  | 9G  | RS485 and 10Base-F (MMS/UCA2, Modbus TCP/IP, DNP)           |
|        | 9D  | 9H  | RS485 and Redundant 10Base-F (MMS/UCA2, Modbus TCP/IP, DNP) |
| CT/VT  | 8A  | 8F  | Standard 4CT/4VT  |
|        | 8B  | 8G  | Sensitive Ground 4CT/4VT                                    |

The new CT/VT modules can only be used with the new CPUs (9E, 9G, 9H), and the old CT/VT modules can only be used with the old CPU modules (9A, 9C, 9D). To prevent any hardware mismatches, the new CPU and CT/VT modules have blue labels and a warning sticker stating **“Attn.: Ensure CPU and DSP module label colors are the same!”**. In the event that there is a mismatch between the CPU and CT/VT module, the relay will not function and a **DSP ERROR** or **HARDWARE MISMATCH** error will be displayed.

All other input/output modules are compatible with the new hardware.

With respect to the firmware, firmware versions 4.0x and higher are only compatible with the new CPU and CT/VT modules. Previous versions of the firmware (3.4x and earlier) are only compatible with the older CPU and CT/VT modules.



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Please read this chapter to help guide you through the initial setup of your new relay.

### 1.1.1 CAUTIONS AND WARNINGS



WARNING



CAUTION

Before attempting to install or use the relay, it is imperative that all **WARNINGS** and **CAUTIONS** in this manual are reviewed to help prevent personal injury, equipment damage, and/or downtime.

### 1.1.2 INSPECTION CHECKLIST

- Open the relay packaging and inspect the unit for physical damage.
- View the rear nameplate and verify that the correct model has been ordered.

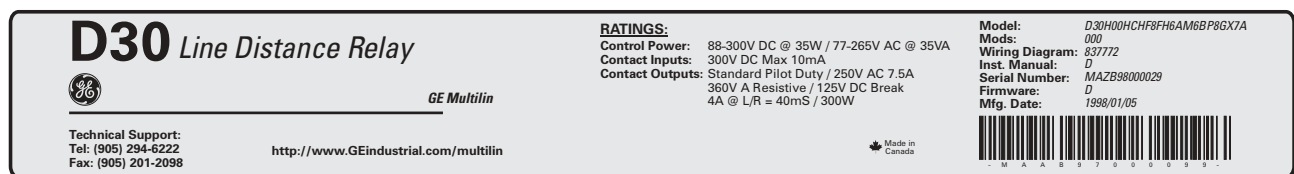


Figure 1-1: REAR NAMEPLATE (EXAMPLE)

- Ensure that the following items are included:
  - Instruction Manual
  - GE enerVista CD (includes the enerVista UR Setup software and manuals in PDF format)
  - mounting screws
  - registration card (attached as the last page of the manual)
- Fill out the registration form and return to GE Multilin (include the serial number located on the rear nameplate).
- For product information, instruction manual updates, and the latest software updates, please visit the GE Multilin website at <http://www.GEindustrial.com/multilin>.



NOTE

If there is any noticeable physical damage, or any of the contents listed are missing, please contact GE Multilin immediately.

#### GE MULTILIN CONTACT INFORMATION AND CALL CENTER FOR PRODUCT SUPPORT:

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**TELEPHONE:** (905) 294-6222, 1-800-547-8629 (North America only)

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**HOME PAGE:** <http://www.GEindustrial.com/multilin>

## 1.2.1 INTRODUCTION TO THE UR

Historically, substation protection, control, and metering functions were performed with electromechanical equipment. This first generation of equipment was gradually replaced by analog electronic equipment, most of which emulated the single-function approach of their electromechanical precursors. Both of these technologies required expensive cabling and auxiliary equipment to produce functioning systems.

Recently, digital electronic equipment has begun to provide protection, control, and metering functions. Initially, this equipment was either single function or had very limited multi-function capability, and did not significantly reduce the cabling and auxiliary equipment required. However, recent digital relays have become quite multi-functional, reducing cabling and auxiliaries significantly. These devices also transfer data to central control facilities and Human Machine Interfaces using electronic communications. The functions performed by these products have become so broad that many users now prefer the term IED (Intelligent Electronic Device).

It is obvious to station designers that the amount of cabling and auxiliary equipment installed in stations can be even further reduced, to 20% to 70% of the levels common in 1990, to achieve large cost reductions. This requires placing even more functions within the IEDs.

Users of power equipment are also interested in reducing cost by improving power quality and personnel productivity, and as always, in increasing system reliability and efficiency. These objectives are realized through software which is used to perform functions at both the station and supervisory levels. The use of these systems is growing rapidly.

High speed communications are required to meet the data transfer rates required by modern automatic control and monitoring systems. In the near future, very high speed communications will be required to perform protection signaling with a performance target response time for a command signal between two IEDs, from transmission to reception, of less than 5 milliseconds. This has been established by the Electric Power Research Institute, a collective body of many American and Canadian power utilities, in their IEC 61850 project. In late 1998, some European utilities began to show an interest in this ongoing initiative.

IEDs with the capabilities outlined above will also provide significantly more power system data than is presently available, enhance operations and maintenance, and permit the use of adaptive system configuration for protection and control systems. This new generation of equipment must also be easily incorporated into automation systems, at both the station and enterprise levels. The GE Multilin Universal Relay (UR) has been developed to meet these goals.

## 1.2.2 HARDWARE ARCHITECTURE

1

## a) UR BASIC DESIGN

The UR is a digital-based device containing a central processing unit (CPU) that handles multiple types of input and output signals. The UR can communicate over a local area network (LAN) with an operator interface, a programming device, or another UR device.

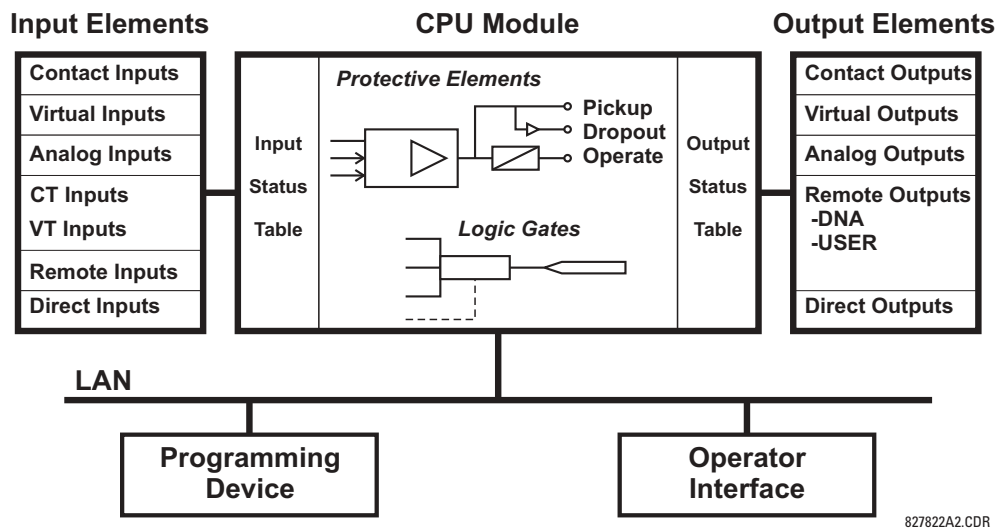


Figure 1-2: UR CONCEPT BLOCK DIAGRAM

The **CPU module** contains firmware that provides protection elements in the form of logic algorithms, as well as programmable logic gates, timers, and latches for control features.

**Input elements** accept a variety of analog or digital signals from the field. The UR isolates and converts these signals into logic signals used by the relay.

**Output elements** convert and isolate the logic signals generated by the relay into digital or analog signals that can be used to control field devices.

## b) UR SIGNAL TYPES

The **contact inputs and outputs** are digital signals associated with connections to hard-wired contacts. Both 'wet' and 'dry' contacts are supported.

The **virtual inputs and outputs** are digital signals associated with UR-series internal logic signals. Virtual inputs include signals generated by the local user interface. The virtual outputs are outputs of FlexLogic™ equations used to customize the device. Virtual outputs can also serve as virtual inputs to FlexLogic™ equations.

The **analog inputs and outputs** are signals that are associated with transducers, such as Resistance Temperature Detectors (RTDs).

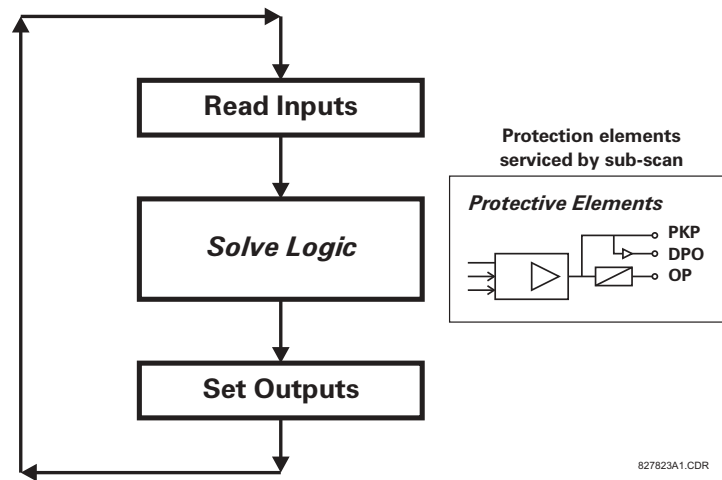
The **CT and VT inputs** refer to analog current transformer and voltage transformer signals used to monitor AC power lines. The UR-series relays support 1 A and 5 A CTs.

The **remote inputs and outputs** provide a means of sharing digital point state information between remote UR-series devices. The remote outputs interface to the remote inputs of other UR-series devices. Remote outputs are FlexLogic™ operands inserted into IEC 61850 GSSE messages and are of two assignment types: DNA standard functions and user-defined (UserSt) functions.

The **direct inputs and outputs** provide a means of sharing digital point states between a number of UR-series IEDs over a dedicated fiber (single or multimode), RS422, or G.703 interface. No switching equipment is required as the IEDs are connected directly in a ring or redundant (dual) ring configuration. This feature is optimized for speed and intended for pilot-aided schemes, distributed logic applications, or the extension of the input/output capabilities of a single relay chassis.

**c) UR SCAN OPERATION**

The UR-series devices operate in a cyclic scan fashion. The device reads the inputs into an input status table, solves the logic program (FlexLogic™ equation), and then sets each output to the appropriate state in an output status table. Any resulting task execution is priority interrupt-driven.



**Figure 1-3: UR-SERIES SCAN OPERATION**

**1.2.3 SOFTWARE ARCHITECTURE**

The firmware (software embedded in the relay) is designed in functional modules which can be installed in any relay as required. This is achieved with Object-Oriented Design and Programming (OOD/OOP) techniques.

Object-Oriented techniques involve the use of 'objects' and 'classes'. An 'object' is defined as "a logical entity that contains both data and code that manipulates that data". A 'class' is the generalized form of similar objects. By using this concept, one can create a Protection Class with the Protection Elements as objects of the class such as Time Overcurrent, Instantaneous Overcurrent, Current Differential, Undervoltage, Overvoltage, Underfrequency, and Distance. These objects represent completely self-contained software modules. The same object-class concept can be used for Metering, Input/Output Control, HMI, Communications, or any functional entity in the system.

Employing OOD/OOP in the software architecture of the Universal Relay achieves the same features as the hardware architecture: modularity, scalability, and flexibility. The application software for any Universal Relay (e.g. Feeder Protection, Transformer Protection, Distance Protection) is constructed by combining objects from the various functionality classes. This results in a 'common look and feel' across the entire family of UR-series platform-based applications.

**1.2.4 IMPORTANT CONCEPTS**

As described above, the architecture of the UR-series relays differ from previous devices. To achieve a general understanding of this device, some sections of Chapter 5 are quite helpful. The most important functions of the relay are contained in "elements". A description of the UR-series elements can be found in the *Introduction to Elements* section in Chapter 5. An example of a simple element, and some of the organization of this manual, can be found in the *Digital Elements* section. A description of how digital signals are used and routed within the relay is contained in the *Introduction to FlexLogic™* section in Chapter 5.

## 1.3.1 PC REQUIREMENTS

1

The faceplate keypad and display or the enerVista UR Setup software interface can be used to communicate with the relay. The enerVista UR Setup software interface is the preferred method to edit settings and view actual values because the PC monitor can display more information in a simple comprehensible format.

The following minimum requirements must be met for the enerVista UR Setup software to properly operate on a PC.

- Pentium class or higher processor (Pentium II 300 MHz or higher recommended)
- Windows 95, 98, 98SE, ME, NT 4.0 (Service Pack 4 or higher), 2000, XP
- Internet Explorer 4.0 or higher
- 128 MB of RAM (256 MB recommended)
- 200 MB of available space on system drive and 200 MB of available space on installation drive
- Video capable of displaying 800 x 600 or higher in high-color mode (16-bit color)
- RS232 and/or Ethernet port for communications to the relay

The following qualified modems have been tested to be compliant with the D30 and the enerVista UR Setup software.

- US Robotics external 56K FaxModem 5686
- US Robotics external Sportster 56K X2
- PCTEL 2304WT V.92 MDC internal modem

## 1.3.2 INSTALLATION

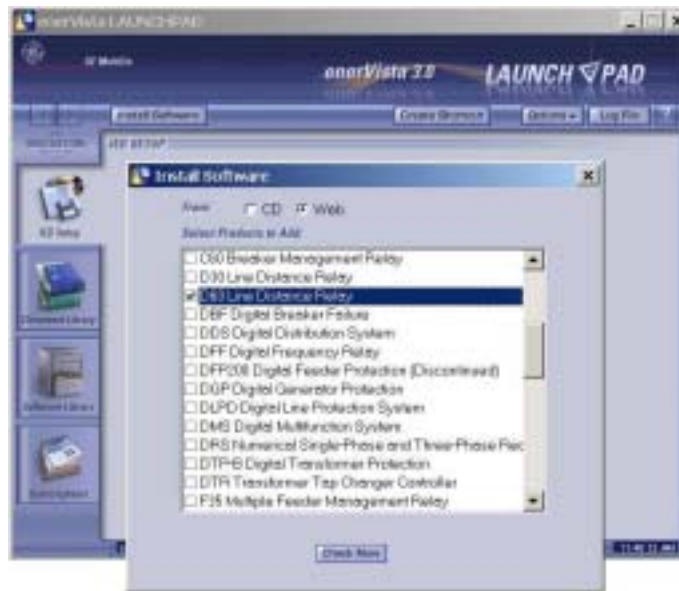
After ensuring the minimum requirements for using enerVista UR Setup are met (see previous section), use the following procedure to install the enerVista UR Setup from the enclosed GE enerVista CD.

1. Insert the GE enerVista CD into your CD-ROM drive.
2. Click the **Install Now** button and follow the installation instructions to install the no-charge enerVista software.
3. When installation is complete, start the enerVista Launchpad application.
4. Click the **IED Setup** section of the **Launch Pad** window.



1

5. In the enerVista Launch Pad window, click the **Install Software** button and select the “D30 Line Distance Relay” from the Install Software window as shown below. Select the “Web” option to ensure the most recent software release, or select “CD” if you do not have a web connection, then click the **Check Now** button to list software items for the D30.



6. Select the D30 software program and release notes (if desired) from the list and click the **Download Now** button to obtain the installation program.



7. enerVista Launchpad will obtain the installation program from the Web or CD. Once the download is complete, double-click the installation program to install the enerVista UR Setup software.
8. Select the complete path, including the new directory name, where the enerVista UR Setup will be installed.
9. Click on **Next** to begin the installation. The files will be installed in the directory indicated and the installation program will automatically create icons and add enerVista UR Setup to the Windows start menu.



10. Click **Finish** to end the installation. The D30 device will be added to the list of installed IEDs in the enerVista Launchpad window, as shown below.



### 1.3.3 CONNECTING ENERVISTA UR SETUP WITH THE D30

This section is intended as a quick start guide to using the enerVista UR Setup software. Please refer to the enerVista UR Setup Help File and Chapter 4 of this manual for more information.

#### a) CONFIGURING AN ETHERNET CONNECTION

Before starting, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay. To setup the relay for Ethernet communications, it will be necessary to define a Site, then add the relay as a Device at that site.

1. Install and start the latest version of the enerVista UR Setup software (available from the GE enerVista CD or online from <http://www.GEindustrial.com/multilin> (see previous section for installation instructions).
2. Select the "UR" device from the enerVista Launchpad to start enerVista UR Setup.
3. Click the **Device Setup** button to open the Device Setup window, then click the **Add Site** button to define a new site.
4. Enter the desired site name in the "Site Name" field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. Click the **OK** button when complete.
5. The new site will appear in the upper-left list in the enerVista UR Setup window. Click on the new site name and then click the **Device Setup** button to re-open the Device Setup window.
6. Click the **Add Device** button to define the new device.
7. Enter the desired name in the "Device Name" field and a description (optional) of the site.
8. Select "Ethernet" from the **Interface** drop-down list. This will display a number of interface parameters that must be entered for proper Ethernet functionality.
  - Enter the relay IP address (from **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **COMMUNICATIONS** ⇒ **NETWORK** ⇒ **IP ADDRESS**) in the "IP Address" field.
  - Enter the relay Modbus address (from the **PRODUCT SETUP** ⇒ **COMMUNICATIONS** ⇒ **MODBUS PROTOCOL** ⇒ **MODBUS SLAVE ADDRESS** setting) in the "Slave Address" field.
  - Enter the Modbus port address (from the **PRODUCT SETUP** ⇒ **COMMUNICATIONS** ⇒ **MODBUS PROTOCOL** ⇒ **MODBUS TCP PORT NUMBER** setting) in the "Modbus Port" field.
9. Click the **Read Order Code** button to connect to the D30 device and upload the order code. If an communications error occurs, ensure that the three enerVista UR Setup values entered in the previous step correspond to the relay setting values.

10. Click **OK** when the relay order code has been received. The new device will be added to the Site List window (or Online window) located in the top left corner of the main enerVista UR Setup window.

The Site Device has now been configured for Ethernet communications. Proceed to Section c) below to begin communications.

#### b) CONFIGURING AN RS232 CONNECTION

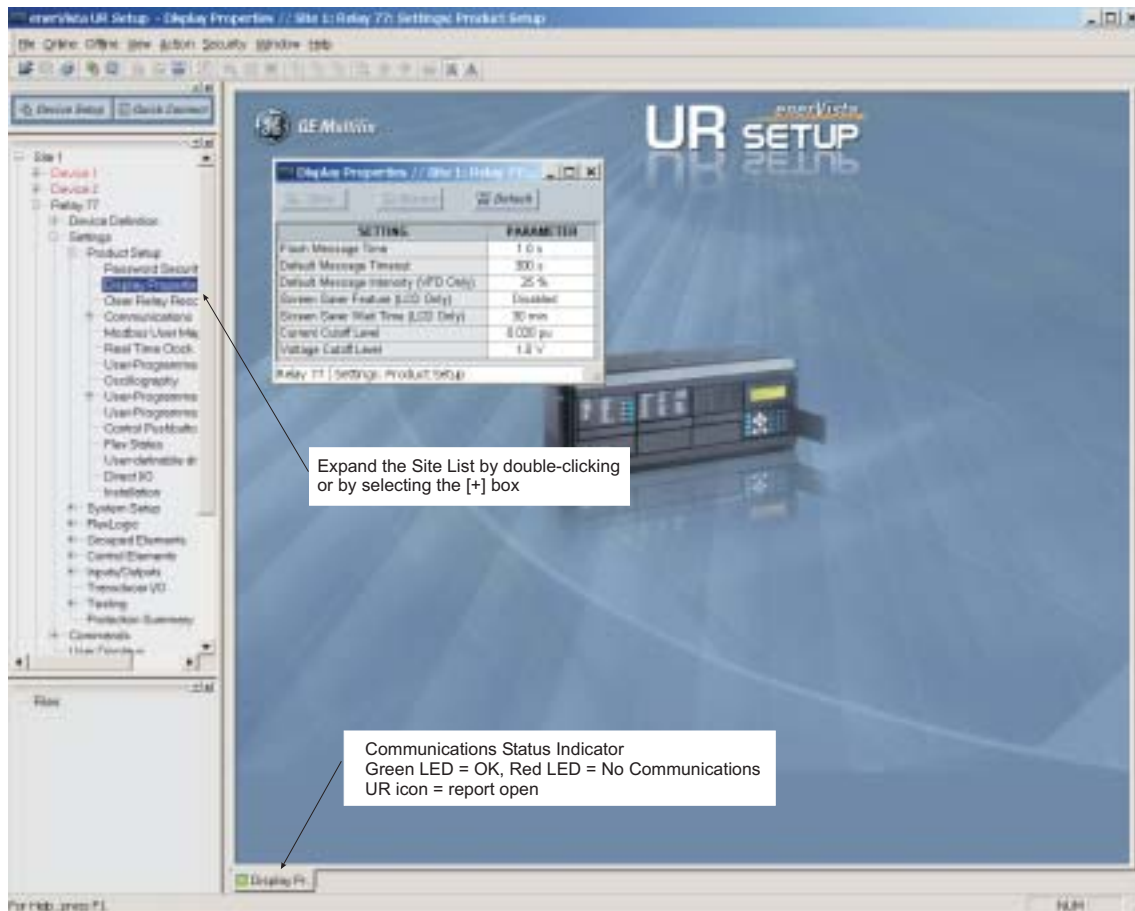
Before starting, verify that the RS232 serial cable is properly connected to the RS232 port on the front panel of the relay.

1. Install and start the latest version of the enerVista UR Setup software (available from the GE enerVista CD or online from <http://www.GEindustrial.com/multilin>).
2. Select the **Device Setup** button to open the Device Setup window and click the **Add Site** button to define a new site.
3. Enter the desired site name in the "Site Name" field. If desired, a short description of site can also be entered along with the display order of devices defined for the site. Click the **OK** button when complete.
4. The new site will appear in the upper-left list in the enerVista UR Setup window. Click on the new site name and then click the **Device Setup** button to re-open the Device Setup window.
5. Click the **Add Device** button to define the new device.
6. Enter the desired name in the "Device Name" field and a description (optional) of the site.
7. Select "Serial" from the **Interface** drop-down list. This will display a number of interface parameters that must be entered for proper serial communications.
  - Enter the relay slave address and COM port values (from the **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **COMMUNICATIONS** ⇒ **SERIAL PORTS** menu) in the "Slave Address" and "COM Port" fields.
  - Enter the physical communications parameters (baud rate and parity settings) in their respective fields.
8. Click the **Read Order Code** button to connect to the D30 device and upload the order code. If an communications error occurs, ensure that the enerVista UR Setup serial communications values entered in the previous step correspond to the relay setting values.
9. Click "OK" when the relay order code has been received. The new device will be added to the Site List window (or Online window) located in the top left corner of the main enerVista UR Setup window.

The Site Device has now been configured for RS232 communications. Proceed to Section c) Connecting to the Relay below to begin communications.

#### c) CONNECTING TO THE RELAY

1. Open the Display Properties window through the Site List tree as shown below:



842743A1.CDR

2. The Display Properties window will open with a status indicator on the lower left of the enerVista UR Setup window.
3. If the status indicator is red, verify that the Ethernet network cable is properly connected to the Ethernet port on the back of the relay and that the relay has been properly setup for communications (steps A and B earlier).  
If a relay icon appears in place of the status indicator, then a report (such as an oscillography or event record) is open. Close the report to re-display the green status indicator.
4. The Display Properties settings can now be edited, printed, or changed according to user specifications.



NOTE

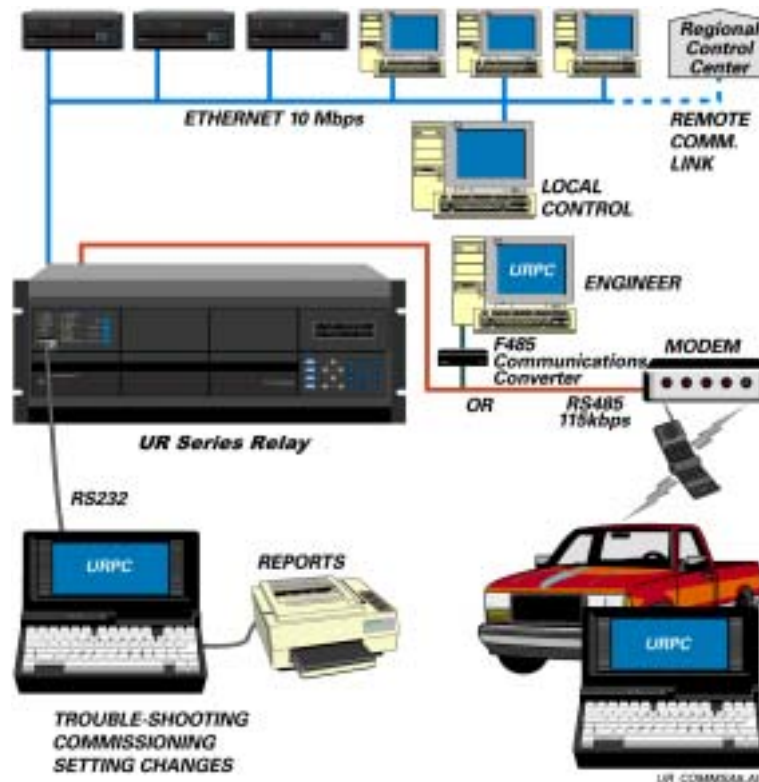
Refer to Chapter 4 in this manual and the enerVista UR Setup Help File for more information about the using the enerVista UR Setup software interface.

## 1.4.1 MOUNTING AND WIRING

Please refer to Chapter 3: Hardware for detailed mounting and wiring instructions. Review all **WARNINGS** and **CAUTIONS** carefully.

## 1.4.2 COMMUNICATIONS

The enerVista UR Setup software communicates to the relay via the faceplate RS232 port or the rear panel RS485 / Ethernet ports. To communicate via the faceplate RS232 port, a standard “straight-through” serial cable is used. The DB-9 male end is connected to the relay and the DB-9 or DB-25 female end is connected to the PC COM1 or COM2 port as described in the CPU Communications Ports section of Chapter 3.



**Figure 1-4: RELAY COMMUNICATIONS OPTIONS**

To communicate through the D30 rear RS485 port from a PC RS232 port, the GE Multilin RS232/RS485 converter box is required. This device (catalog number F485) connects to the computer using a “straight-through” serial cable. A shielded twisted-pair (20, 22, or 24 AWG) connects the F485 converter to the D30 rear communications port. The converter terminals (+, –, GND) are connected to the D30 communication module (+, –, COM) terminals. Refer to the *CPU Communications Ports* section in Chapter 3 for option details. The line should be terminated with an R-C network (i.e. 120  $\Omega$ , 1 nF) as described in the Chapter 3.

## 1.4.3 FACEPLATE DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. An optional liquid crystal display (LCD) is also available. Messages are displayed in English and do not require the aid of an instruction manual for deciphering. While the keypad and display are not actively being used, the display will default to defined messages. Any high priority event driven message will automatically override the default message and appear on the display.

## 1.5.1 FACEPLATE KEYPAD

1

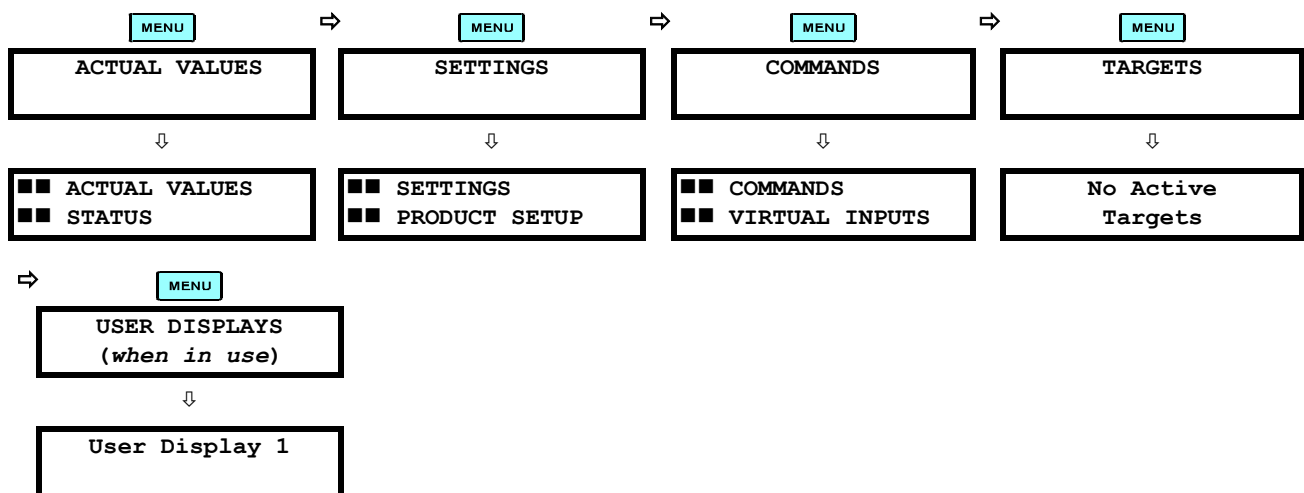
Display messages are organized into 'pages' under the following headings: Actual Values, Settings, Commands, and Targets. The **MENU** key navigates through these pages. Each heading page is broken down further into logical subgroups.

The **▲** **◀** MESSAGE **▶** **▼** keys navigate through the subgroups. The **▲** VALUE **▼** keys scroll increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values may also be entered with the numeric keypad.

The **♦** key initiates and advance to the next character in text edit mode or enters a decimal point. The **HELP** key may be pressed at any time for context sensitive help messages. The **ENTER** key stores altered setting values.

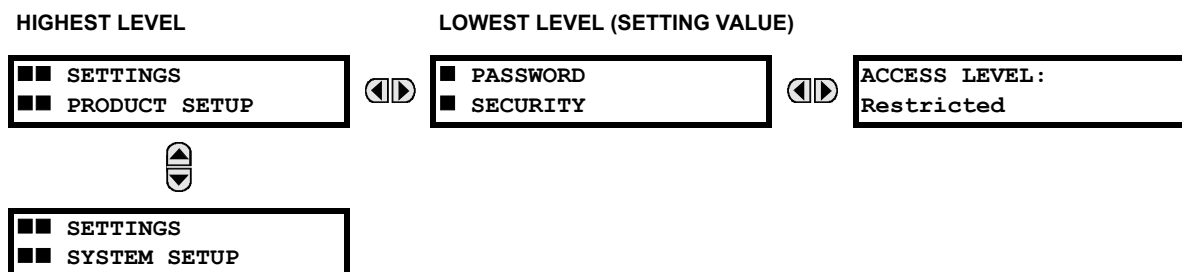
## 1.5.2 MENU NAVIGATION

Press the **MENU** key to select the desired header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the **MENU** key advances through the main heading pages as illustrated below.



## 1.5.3 MENU HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE **▲** and **▼** keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE **▶** key from a header display displays specific information for the header category. Conversely, continually pressing the **◀** MESSAGE key from a setting value or actual value display returns to the header display.






## 1.5.4 RELAY ACTIVATION

The relay is defaulted to the “Not Programmed” state when it leaves the factory. This safeguards against the installation of a relay whose settings have not been entered. When powered up successfully, the Trouble LED will be on and the In Service LED off. The relay in the “Not Programmed” state will block signaling of any output relay. These conditions will remain until the relay is explicitly put in the “Programmed” state.

Select the menu message **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **INSTALLATION** ⇒ **RELAY SETTINGS**

**RELAY SETTINGS:**  
**Not Programmed**

To put the relay in the “Programmed” state, press either of the  VALUE  keys once and then press . The faceplate Trouble LED will turn off and the In Service LED will turn on. The settings for the relay can be programmed manually (refer to Chapter 5) via the faceplate keypad or remotely (refer to the enerVista UR Setup Help file) via the enerVista UR Setup software interface.

## 1.5.5 RELAY PASSWORDS

It is recommended that passwords be set up for each security level and assigned to specific personnel. There are two user password security access levels, COMMAND and SETTING:

## 1. COMMAND

The COMMAND access level restricts the user from making any settings changes, but allows the user to perform the following operations:

- change state of virtual inputs
- clear event records
- clear oscillography records
- operate user-programmable pushbuttons

## 2. SETTING

The SETTING access level allows the user to make any changes to any of the setting values.



Refer to the *Changing Settings* section in Chapter 4 for complete instructions on setting up security level passwords.

## 1.5.6 FLEXLOGIC™ CUSTOMIZATION

FlexLogic™ equation editing is required for setting up user-defined logic for customizing the relay operations. See the *Flex-Logic™* section in Chapter 5 for additional details.

Templated tables for charting all the required settings before entering them via the keypad are available from the GE Multilin website at <http://www.GEindustrial.com/multilin>.

The D30 requires a minimum amount of maintenance when it is commissioned into service. The D30 is a microprocessor-based relay and its characteristics do not change over time. As such no further functional tests are required.

Furthermore the D30 performs a number of ongoing self-tests and takes the necessary action in case of any major errors (see the *Relay Self-Test* section in Chapter 7 for details). However, it is recommended that maintenance on the D30 be scheduled with other system maintenance. This maintenance may involve the following.

In-service maintenance:

1. Visual verification of the analog values integrity such as voltage and current (in comparison to other devices on the corresponding system).
2. Visual verification of active alarms, relay display messages, and LED indications.
3. LED test.
4. Visual inspection for any damage, corrosion, dust, or loose wires.
5. Event recorder file download with further events analysis.

Out-of-service maintenance:

1. Check wiring connections for firmness.
2. Analog values (currents, voltages, RTDs, analog inputs) injection test and metering accuracy verification. Calibrated test equipment is required.
3. Protection elements setpoints verification (analog values injection or visual verification of setting file entries against relay settings schedule).
4. Contact inputs and outputs verification. This test can be conducted by direct change of state forcing or as part of the system functional testing.
5. Visual inspection for any damage, corrosion, or dust.
6. Event recorder file download with further events analysis.
7. LED Test and pushbutton continuity check.

Unscheduled maintenance such as during a disturbance causing system interruption:

1. View the event recorder and oscillography or fault report for correct operation of inputs, outputs, and elements.

If it is concluded that the relay or one of its modules is of concern, contact GE Multilin or one of its representatives for prompt service.





## 2.1.1 OVERVIEW

The D30 Line Distance Relay is a microprocessor-based relay intended for use on transmission lines of any voltage level, without, with, and in the vicinity of series compensation, in three-pole tripping applications. The primary function of the relay consists of three phase and ground distance zones of protection, either mho or quadrilateral as per user selection. The distance elements are optimized to provide good measurement accuracy with a fast operating time, even when used with Capacitive Voltage Transformers, and can be supervised by detection of power swings. The relay also provides directional ground overcurrent elements, which are commonly used as part of an overall line protection system.

D30 phase distance zones can be configured to work with voltages and currents fed from VTs and CTs located independently from one another on either side of a three-phase power transformer. The relay compensates accordingly to preserve reach and correct target information regardless of the location and type of fault. This feature allows backup protection applications for generators and power transformers.

A Close-Into-Fault, or Switch-On-To-Fault, function is performed by the Line Pickup element. Out-of-step tripping, three-pole autoreclosing, synchrocheck, fault location, and many other functions are also available. In addition, overcurrent and undervoltage protection, fault diagnostics, power metering, and RTU functions are provided. The D30 provides phase, neutral, and ground time overcurrent protection. The time overcurrent functions can be programmed with multiple curve shapes or FlexCurve™ for optimum coordination.

Voltage, current, and power metering is built into the relay as a standard feature. Current parameters are available as total waveform RMS magnitude, or as fundamental frequency only RMS magnitude and angle (phasor).

Diagnostic features include an event recorder capable of storing 1024 time-tagged events, oscillography capable of storing up to 64 records with programmable trigger, content and sampling rate. The internal clock used for time-tagging can be synchronized with an IRIG-B signal or via the SNTP protocol over the Ethernet port. This precise time stamping allows the sequence of events to be determined throughout the system. Events can also be programmed (via FlexLogic™ equations) to trigger oscillography data capture which may be set to record the measured parameters before and after the event for viewing on a personal computer (PC). These tools significantly reduce troubleshooting time and simplify report generation in the event of a system fault.

A faceplate RS232 port may be used to connect to a PC for the programming of settings and the monitoring of actual values. A variety of communications modules are available. Two rear RS485 ports allow independent access by operating and engineering staff. All serial ports use the Modbus® RTU protocol. The RS485 ports may be connected to system computers with baud rates up to 115.2 kbps. The RS232 port has a fixed baud rate of 19.2 kbps. Optional communications modules include a 10BaseF Ethernet interface which can be used to provide fast, reliable communications in noisy environments. Another option provides two 10BaseF fiber optic ports for redundancy. The Ethernet port supports IEC 61850, Modbus®/TCP, and TFTP protocols, and allows access to the relay via any standard web browser (D30 web pages). The IEC 60870-5-104 protocol is supported on the Ethernet port. DNP 3.0 and IEC 60870-5-104 cannot be enabled at the same time.

The D30 IEDs use flash memory technology which allows field upgrading as new features are added. The following Single Line Diagram illustrates the relay functionality using ANSI (American National Standards Institute) device numbers.

**Table 2–1: DEVICE NUMBERS AND FUNCTIONS**

| DEVICE NUMBER | FUNCTION                                    | DEVICE NUMBER | FUNCTION                                  |
|---------------|---|---------------|---|
| 21G           | Ground Distance                             | 51_2          | Negative Sequence Time Overcurrent        |
| 21P           | Phase Distance                              | 52            | AC Circuit Breaker                        |
| 25            | Synchrocheck                                | 59N           | Neutral Overvoltage                       |
| 27P           | Phase Undervoltage                          | 59P           | Phase Overvoltage                         |
| 27X           | Auxiliary Undervoltage                      | 59X           | Auxiliary Overvoltage                     |
| 50DD          | Current Disturbance Detector                | 59_2          | Negative Sequence Overvoltage             |
| 50G           | Ground Instantaneous Overcurrent            | 67N           | Neutral Directional Overcurrent           |
| 50N           | Neutral Instantaneous Overcurrent           | 67P           | Phase Directional Overcurrent             |
| 50P           | Phase Instantaneous Overcurrent             | 67_2          | Negative Sequence Directional Overcurrent |
| 50_2          | Negative Sequence Instantaneous Overcurrent | 68            | Power Swing Blocking                      |
| 51G           | Ground Time Overcurrent                     | 78            | Out-of-Step Tripping                      |
| 51N           | Neutral Time Overcurrent                    | 79            | Automatic Recloser                        |
| 51P           | Phase Time Overcurrent                      |               |   |

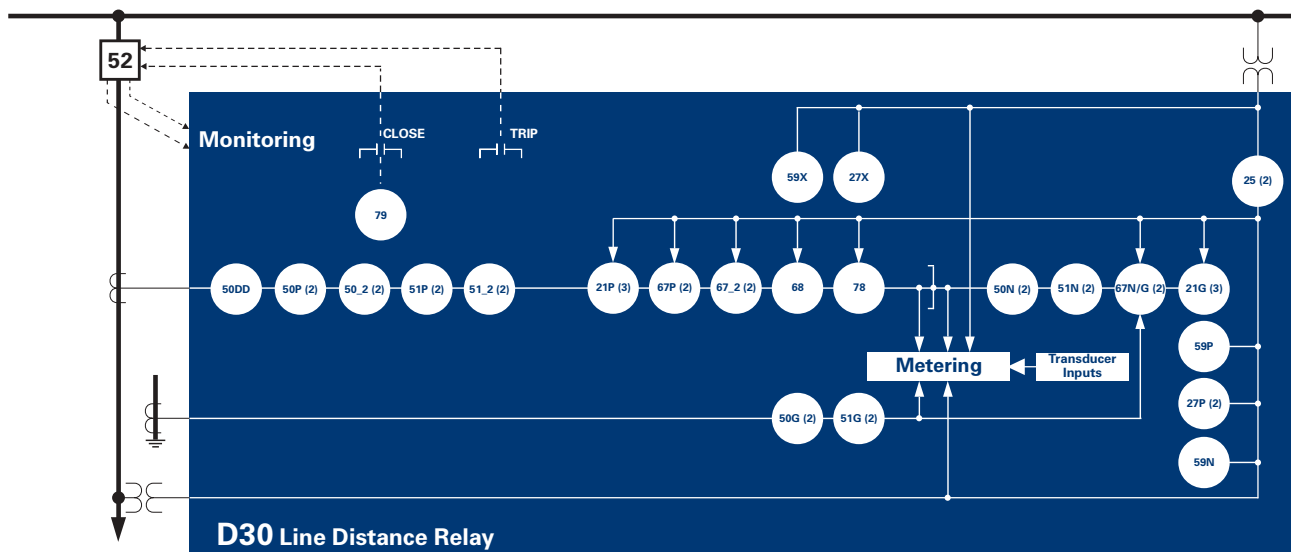


Figure 2-1: SINGLE LINE DIAGRAM

Table 2-2: OTHER DEVICE FUNCTIONS

| FUNCTION                                  | FUNCTION   | FUNCTION                       |
|---|--|--------------------------------|
| Breaker Arcing Current ( $I^2t$ )         | FlexElements™ (16)   | Setting Groups (6)             |
| Breaker Control                           | FlexLogic™ Equations                                       | Time Synchronization over SNTP |
| Contact Inputs (up to 96)                 | IEC 61850 Communications                                   | Time Synchronization over SNTP |
| Contact Outputs (up to 64)                | IEC 61850 Remote Inputs/Outputs (GSSE)                     | Transducer Inputs/Outputs      |
| Control Pushbuttons                       | Line Pickup  | User Definable Displays        |
| Digital Counters (8)                      | Metering: Current, Voltage, Power, Power Factor, Frequency | User Programmable LEDs         |
| Digital Elements (16)                     | Modbus Communications                                      | User Programmable Pushbuttons  |
| Direct Inputs/Outputs (32)                | Modbus User Map  | User Programmable Self-Tests   |
| DNP 3.0 or IEC 60870-5-104 Communications | Non-Volatile Latches                                       | Virtual Inputs (32)            |
| Event Recorder                            | Non-Volatile Selector Switch                               | Virtual Outputs (64)           |
| Fault Detector and Fault Report           | Oscillography  | VT Fuse Failure                |
| Fault Locator                             |  |                                |

## 2.1.2 ORDERING

The relay is available as a 19-inch rack horizontal mount unit or a reduced size ( $\frac{3}{4}$ ) vertical mount unit, and consists of the following modules: power supply, CPU, CT/VT, digital input/output, transducer input/output. Each of these modules can be supplied in a number of configurations specified at the time of ordering. The information required to completely specify the relay is provided in the following table (see Chapter 3 for full details of relay modules).

Table 2–3: D30 ORDER CODES

|   | D30 | - | * | 00 | - | H  | *  | * | - | F | ** | - | H | ** | - | M | ** | - | P | ** | - | U | ** | - | W | ** |  |   |
|---|-----|---|---|----|---|----|----|---|---|---|----|---|---|----|---|---|----|---|---|----|---|---|----|---|---|----|--|---|
|   | D30 | - | * | 00 | - | V  | *  | * | - | F | ** | - | H | ** | - | M | ** |   |   |    |   |   |    |   |   | -  | #  | **  |
| BASE UNIT   | D30 |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | Base Unit  |   |
| CPU   | E   |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | RS485 + RS485 (ModBus RTU, DNP)                                    |   |
|   | G   |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | RS485 + 10BaseF (IEC 61850, Modbus TCP/IP, DNP)                    |   |
|   | H   |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | RS485 + Redundant 10BaseF (IEC 61850, Modbus TCP/IP, DNP)          |   |
| SOFTWARE  | 00  |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | No Software Options  |   |
| MOUNT/<br>FACEPLATE   |     | H | C |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | Horizontal (19" rack)  |   |
|   |     | H | P |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | Horizontal (19" rack) with 16 User-Programmable Pushbuttons        |   |
|   |     | V | F |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | Vertical (3/4 rack)  |   |
| POWER SUPPLY<br>(redundant power<br>supply only available in<br>horizontal mount units) |     | H |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | 125 / 250 V AC/DC power supply                                     |   |
|   |     | H |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | RH 125 / 250 V AC/DC with redundant 125 / 250 V AC/DC power supply |   |
|   |     | L |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | 24 to 48 V (DC only) power supply                                  |   |
|   |     | L |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | RL 24 to 48 V (DC only) with redundant 24 to 48 V DC power supply  |   |
| CT/VT MODULES   |     |   |   |    |   | 8F |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | Standard 4CT/4VT   |   |
|   |     |   |   |    |   | 8G |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | Sensitive Ground 4CT/4VT   |   |
| DIGITAL INPUTS/OUTPUTS  |     |   |   |    |   |    | XX |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | No Module   |
|   |     |   |   |    |   |    | 4A |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 4A 4 Solid-State (No Monitoring) MOSFET Outputs                     |
|   |     |   |   |    |   |    | 4B |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 4B 4 Solid-State (Voltage w/ opt Current) MOSFET Outputs            |
|   |     |   |   |    |   |    | 4C |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 4C 4 Solid-State (Current w/ opt Voltage) MOSFET Outputs            |
|   |     |   |   |    |   |    | 4L |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 4L 14 Form-A (No Monitoring) Latching Outputs                       |
|   |     |   |   |    |   |    | 67 |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 67 8 Form-A (No Monitoring) Outputs                                 |
|   |     |   |   |    |   |    | 6A |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6A 2 Form-A (Volt w/ opt Curr) & 2 Form-C outputs, 8 Digital Inputs |
|   |     |   |   |    |   |    | 6B |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6B 2 Form-A (Volt w/ opt Curr) & 4 Form-C Outputs, 4 Digital Inputs |
|   |     |   |   |    |   |    | 6C |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6C 8 Form-C Outputs   |
|   |     |   |   |    |   |    | 6D |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6D 16 Digital Inputs  |
|   |     |   |   |    |   |    | 6E |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6E 4 Form-C Outputs, 8 Digital Inputs                               |
|   |     |   |   |    |   |    | 6F |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6F 8 Fast Form-C Outputs  |
|   |     |   |   |    |   |    | 6G |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6G 4 Form-A (Voltage w/ opt Current) Outputs, 8 Digital Inputs      |
|   |     |   |   |    |   |    | 6H |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6H 6 Form-A (Voltage w/ opt Current) Outputs, 4 Digital Inputs      |
|   |     |   |   |    |   |    | 6K |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6K 4 Form-C & 4 Fast Form-C Outputs                                 |
|   |     |   |   |    |   |    | 6L |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6L 2 Form-A (Curr w/ opt Volt) & 2 Form-C Outputs, 8 Digital Inputs |
|   |     |   |   |    |   |    | 6M |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6M 2 Form-A (Curr w/ opt Volt) & 4 Form-C Outputs, 4 Digital Inputs |
|   |     |   |   |    |   |    | 6N |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6N 4 Form-A (Current w/ opt Voltage) Outputs, 8 Digital Inputs      |
|   |     |   |   |    |   |    | 6P |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6P 6 Form-A (Current w/ opt Voltage) Outputs, 4 Digital Inputs      |
|   |     |   |   |    |   |    | 6R |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 6R 2 Form-A (No Monitoring) & 2 Form-C Outputs, 8 Digital Inputs    |
|   |     |   |   |    |   | 6S |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | 6S 2 Form-A (No Monitoring) & 4 Form-C Outputs, 4 Digital Inputs   |   |
|   |     |   |   |    |   | 6T |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | 6T 4 Form-A (No Monitoring) Outputs, 8 Digital Inputs              |   |
|   |     |   |   |    |   | 6U |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    | 6U 6 Form-A (No Monitoring) Outputs, 4 Digital Inputs              |   |
| TRANSDUCER<br>INPUTS/OUTPUTS<br>(select a maximum of 3 per unit)                        |     |   |   |    |   | 5A |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 5A 4 dcmA Inputs, 4 dcmA Outputs (only one 5A module is allowed)    |
|   |     |   |   |    |   | 5C |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 5C 8 RTD Inputs   |
|   |     |   |   |    |   | 5D |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 5D 4 RTD Inputs, 4 dcmA Outputs (only one 5D module is allowed)     |
|   |     |   |   |    |   | 5E |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 5E 4 RTD Inputs, 4 dcmA Inputs                                      |
|   |     |   |   |    |   | 5F |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 5F 8 dcmA Inputs  |
| INTER-RELAY<br>COMMUNICATIONS<br>(select a maximum of 1 per unit)                       |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 2A C37.94SM, 1300nm single-mode, ELED, 1 channel single-mode        |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 2B C37.94SM, 1300nm single-mode, ELED, 2 channel single-mode        |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 72 1550 nm, single-mode, LASER, 1 Channel                           |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 73 1550 nm, single-mode, LASER, 2 Channel                           |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 74 Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER       |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 75 Channel 1 - G.703; Channel 2 - 1550 nm, Single-mode LASER        |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 76 IEEE C37.94, 820 nm, multimode, LED, 1 Channel                   |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 77 IEEE C37.94, 820 nm, multimode, LED, 2 Channels                  |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7A 820 nm, multi-mode, LED, 1 Channel                               |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7B 1300 nm, multi-mode, LED, 1 Channel                              |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7C 1300 nm, single-mode, ELED, 1 Channel                            |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7D 1300 nm, single-mode, LASER, 1 Channel                           |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7E Channel 1 - G.703; Channel 2 - 820 nm, multi-mode                |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7F Channel 1 - G.703; Channel 2 - 1300 nm, multi-mode               |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7G Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED         |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7H 820 nm, multi-mode, LED, 2 Channels                              |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7I 1300 nm, multi-mode, LED, 2 Channels                             |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  | 7J 1300 nm, single-mode, ELED, 2 Channels                           |
|   |     |   |   |    |   |    |    |   |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |   |   |    |  |   |



For vertical mounting units, # = slot P for digital and transducer input/output modules; # = slot R for inter-relay communications modules

The order codes for replacement modules to be ordered separately are shown in the following table. When ordering a replacement CPU module or faceplate, please provide the serial number of your existing unit.

**Table 2–4: ORDER CODES FOR REPLACEMENT MODULES**

|  | UR - ** - |   |
|--|-----------|---|
| <b>POWER SUPPLY</b><br>(redundant power supply only available in horizontal mount units) | 1H        | 125 / 250 V AC/DC   |
|  | 1L        | 24 to 48 V (DC only)  |
|  | RH        | redundant 125 / 250 V AC/DC   |
|  | RH        | redundant 24 to 48 V (DC only)  |
| <b>CPU</b>   | 9E        | RS485 and RS485 (ModBus RTU, DNP 3.0)   |
|  | 9G        | RS485 and 10Base-F (IEC 61850, Modbus TCP/IP, DNP 3.0)                          |
|  | 9H        | RS485 and Redundant 10Base-F (IEC 61850, ModBus TCP/IP, DNP 3.0)                |
| <b>FACEPLATE</b>   | 3C        | Horizontal faceplate with display and keypad                                    |
|  | 3F        | Vertical faceplate with display and keypad                                      |
|  | 3P        | Horizontal faceplate with display, keypad, and user-programmable pushbuttons    |
| <b>DIGITAL INPUTS/OUTPUTS</b>  | 4A        | 4 Solid-State (no monitoring) MOSFET Outputs                                    |
|  | 4B        | 4 Solid-State (voltage with optional current) MOSFET Outputs                    |
|  | 4C        | 4 Solid-State (current with optional voltage) MOSFET Outputs                    |
|  | 4L        | 14 Form-A (no monitoring) Latching Outputs                                      |
|  | 67        | 8 Form-A (no monitoring) Outputs  |
|  | 6A        | 2 Form-A (voltage with optional current) and 2 Form-C Outputs, 8 Digital Inputs |
|  | 6B        | 2 Form-A (voltage with optional current) and 4 Form-C Outputs, 4 Digital Inputs |
|  | 6C        | 8 Form-C Outputs  |
|  | 6D        | 16 Digital Inputs   |
|  | 6E        | 4 Form-C Outputs, 8 Digital Inputs  |
|  | 6F        | 8 Fast Form-C Outputs   |
|  | 6G        | 4 Form-A (voltage with optional current) Outputs, 8 Digital Inputs              |
|  | 6H        | 6 Form-A (voltage with optional current) Outputs, 4 Digital Inputs              |
|  | 6K        | 4 Form-C & 4 Fast Form-C Outputs  |
|  | 6L        | 2 Form-A (current with optional voltage) and 2 Form-C Outputs, 8 Digital Inputs |
|  | 6M        | 2 Form-A (current with optional voltage) and 4 Form-C Outputs, 4 Digital Inputs |
|  | 6N        | 4 Form-A (current with optional voltage) Outputs, 8 Digital Inputs              |
|  | 6P        | 6 Form-A (current with optional voltage) Outputs, 4 Digital Inputs              |
|  | 6R        | 2 Form-A (no monitoring) and 2 Form-C Outputs, 8 Digital Inputs                 |
|  | 6S        | 2 Form-A (no monitoring) and 4 Form-C Outputs, 4 Digital Inputs                 |
|  | 6T        | 4 Form-A (no monitoring) Outputs, 8 Digital Inputs                              |
|  | 6U        | 6 Form-A (no monitoring) Outputs, 4 Digital Inputs                              |
| <b>CT/VT MODULES</b><br>(NOT AVAILABLE FOR THE C30)                                      | 8F        | Standard 4CT/4VT  |
|  | 8G        | Sensitive Ground 4CT/4VT  |
|  | 8H        | Standard 8CT  |
|  | 8J        | Sensitive Ground 8CT  |
| <b>UR INTER-RELAY COMMUNICATIONS</b>   | 2A        | C37.94SM, 1300nm single-mode, ELED, 1 channel single-mode                       |
|  | 2B        | C37.94SM, 1300nm single-mode, ELED, 2 channel single-mode                       |
|  | 72        | 1550 nm, single-mode, LASER, 1 Channel  |
|  | 73        | 1550 nm, single-mode, LASER, 2 Channel  |
|  | 74        | Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER                      |
|  | 75        | Channel 1 - G.703; Channel 2 - 1550 nm, Single-mode LASER                       |
|  | 76        | IEEE C37.94, 820 nm, multimode, LED, 1 Channel                                  |
|  | 77        | IEEE C37.94, 820 nm, multimode, LED, 2 Channels                                 |
|  | 7A        | 820 nm, multi-mode, LED, 1 Channel  |
|  | 7B        | 1300 nm, multi-mode, LED, 1 Channel   |
|  | 7C        | 1300 nm, single-mode, ELED, 1 Channel   |
|  | 7D        | 1300 nm, single-mode, LASER, 1 Channel  |
|  | 7E        | Channel 1 - G.703; Channel 2 - 820 nm, multi-mode                               |
|  | 7F        | Channel 1 - G.703; Channel 2 - 1300 nm, multi-mode                              |
|  | 7G        | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode ELED                        |
|  | 7H        | 820 nm, multi-mode, LED, 2 Channels   |
|  | 7I        | 1300 nm, multi-mode, LED, 2 Channels  |
|  | 7J        | 1300 nm, single-mode, ELED, 2 Channels  |
|  | 7K        | 1300 nm, single-mode, LASER, 2 Channels   |
|  | 7L        | Channel 1 - RS422; Channel 2 - 820 nm, multi-mode, LED                          |
|  | 7M        | Channel 1 - RS422; Channel 2 - 1300 nm, multi-mode, LED                         |
|  | 7N        | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, ELED                       |
|  | 7P        | Channel 1 - RS422; Channel 2 - 1300 nm, single-mode, LASER                      |
|  | 7Q        | Channel 1 - G.703; Channel 2 - 1300 nm, single-mode LASER                       |
|  | 7R        | G.703, 1 Channel  |
|  | 7S        | G.703, 2 Channels   |
|  | 7T        | RS422, 1 Channel  |
|  | 7W        | RS422, 2 Channels   |
| <b>TRANSDUCER INPUTS/OUTPUTS</b>   | 5A        | 4 dcmA Inputs, 4 dcmA Outputs (only one 5A module is allowed)                   |
|  | 5C        | 8 RTD Inputs  |
|  | 5D        | 4 RTD Inputs, 4 dcmA Outputs (only one 5D module is allowed)                    |
|  | 5E        | 4 dcmA Inputs, 4 RTD Inputs   |
|  | 5F        | 8 dcmA Inputs   |

## SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE

## 2.2.1 PROTECTION ELEMENTS



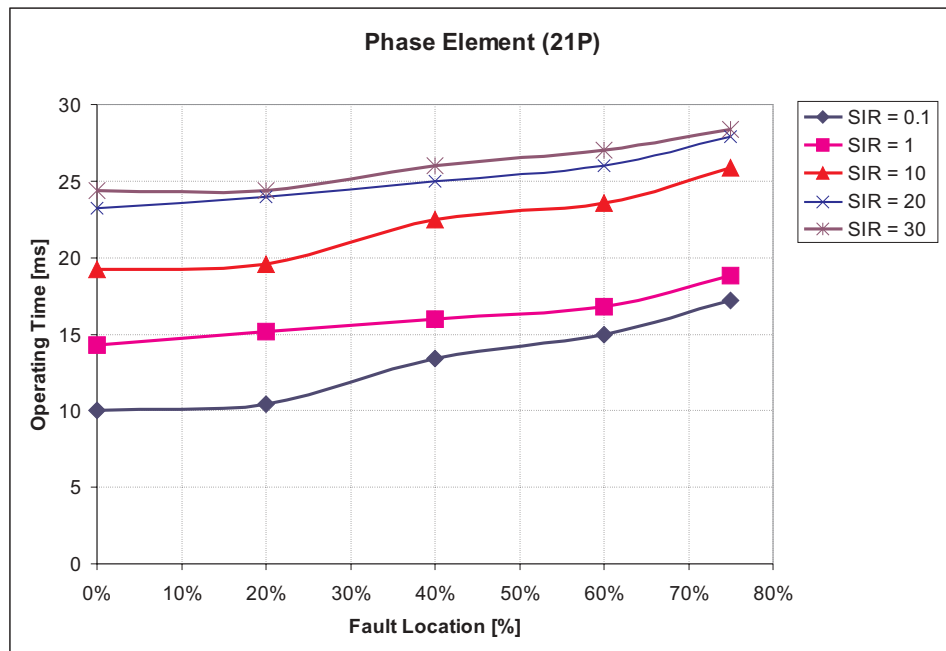
The operating times below include the activation time of a trip rated Form-A output contact unless otherwise indicated. FlexLogic™ operands of a given element are 4 ms faster. This should be taken into account when using FlexLogic™ to interconnect with other protection or control elements of the relay, building FlexLogic™ equations, or interfacing with other IEDs or power system devices via communications or different output contacts.

## PHASE DISTANCE

|                              |  |  |  |
|------------------------------|--|--|--|
| Characteristic:              | Mho (memory polarized or offset) or Quad (memory polarized or non-directional), selectable individually per zone | Left Blinder (Quad only):                                      |  |
| Number of zones:             | 3  | Reach:   | 0.02 to 500 $\Omega$ in steps of 0.01    |
| Directionality:              | forward, reverse, or non-directional per zone  | Characteristic angle:  | 60 to 90° in steps of 1                  |
| Reach (secondary $\Omega$ ): | 0.02 to 250.00 $\Omega$ in steps of 0.01   | Time delay:  | 0.000 to 65.535 s in steps of 0.001      |
| Distance:                    |  | Timing accuracy:   | $\pm 3\%$ or 4 ms, whichever is greater  |
| Characteristic angle:        | 30 to 90° in steps of 1  | Current supervision:   |  |
| Comparator limit angle:      | 30 to 90° in steps of 1  | Level:   | line-to-line current                     |
| Directional supervision:     |  | Pickup:  | 0.050 to 30.000 pu in steps of 0.001     |
| Characteristic angle:        | 30 to 90° in steps of 1  | Dropout:   | 97 to 98%                                |
| Limit angle:                 | 30 to 90° in steps of 1  | Memory duration:   | 5 to 25 cycles in steps of 1             |
| Right blinder (Quad only):   |  | VT location:   | all delta-wye and wye-delta transformers |
| Reach:                       | 0.02 to 500 $\Omega$ in steps of 0.01  | CT location:   | all delta-wye and wye-delta transformers |
| Characteristic angle:        | 60 to 90° in steps of 1  | Voltage supervision pickup (series compensation applications): | 0 to 5.000 pu in steps of 0.001          |

## PHASE DISTANCE OPERATING TIME CURVES

The operating times are response times of a microprocessor part of the relay. See output contacts specifications for estimation of the total response time for a particular application. The operating times are average times including variables such as fault inception angle or type of a voltage source (magnetic VTs and CVTs).



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**GROUND DISTANCE**

Characteristic: Mho (memory polarized or offset) or Quad (memory polarized or non-directional), selectable individually per zone

Reactance polarization: negative-sequence or zero-sequence current

Non-homogeneity angle:  $-40$  to  $40^\circ$  in steps of 1

Number of zones: 3

Directionality: forward, reverse, or non-directional per zone

Reach (secondary  $\Omega$ ): 0.02 to 250.00  $\Omega$  in steps of 0.01

Distance characteristic angle: 30 to  $90^\circ$  in steps of 1

Distance comparator limit angle: 30 to  $90^\circ$  in steps of 1

Directional supervision:

Characteristic angle: 30 to  $90^\circ$  in steps of 1

Limit angle: 30 to  $90^\circ$  in steps of 1

Zero-sequence compensation

Z0/Z1 magnitude: 0.00 to 10.00 in steps of 0.01

Z0/Z1 angle:  $-90$  to  $90^\circ$  in steps of 1

Zero-sequence mutual compensation

Z0M/Z1 magnitude: 0.00 to 7.00 in steps of 0.01

Z0M/Z1 angle:  $-90$  to  $90^\circ$  in steps of 1

Right blinder (Quad only):

Reach: 0.02 to 500  $\Omega$  in steps of 0.01

Characteristic angle: 60 to  $90^\circ$  in steps of 1

Left blinder (Quad only):

Reach: 0.02 to 500  $\Omega$  in steps of 0.01

Characteristic angle: 60 to  $90^\circ$  in steps of 1

Time delay: 0.000 to 65.535 s in steps of 0.001

Timing accuracy:  $\pm 3\%$  or 4 ms, whichever is greater

Current supervision:

Level: neutral current (3I<sub>0</sub>)

Pickup: 0.050 to 30.000 pu in steps of 0.001

Dropout: 97 to 98%

Memory duration: 5 to 25 cycles in steps of 1

Voltage supervision pickup (series compensation applications):

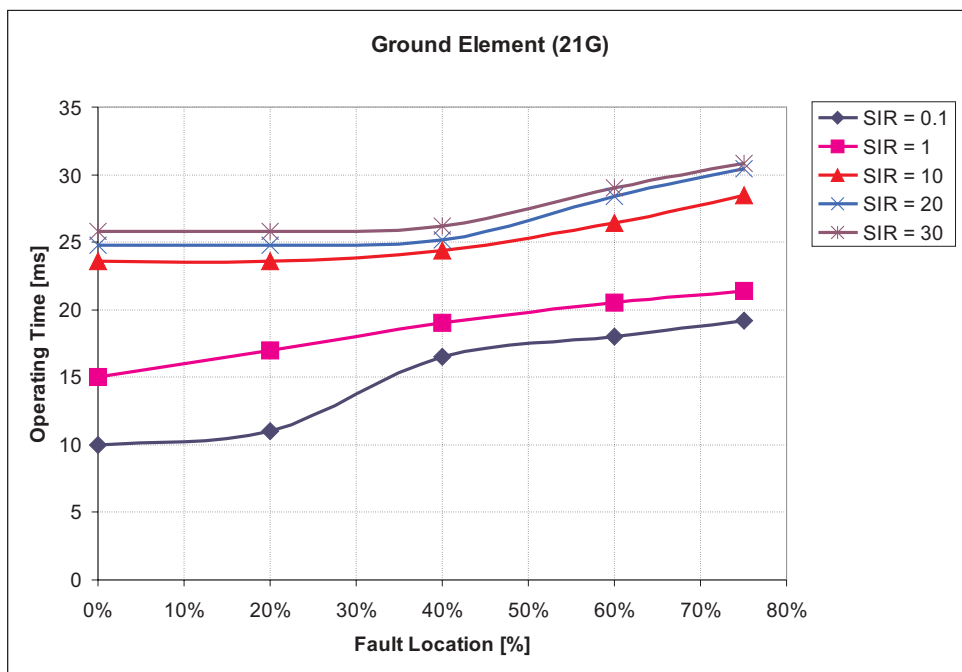
0 to 5.000 pu in steps of 0.001

Operation time: 1 to 1.5 cycles (typical)

Reset time: 1 power cycle (typical)

**GROUND DISTANCE OPERATING TIME CURVES**

The operating times are response times of a microprocessor part of the relay. See output contacts specifications for estimation of the total response time for a particular application. The operating times are average times including variables such as fault inception angle or type of a voltage source (magnetic VTs and CVTs).



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**LINE PICKUP**

|                      |                    |
|----------------------|--------------------|
| Phase IOC:           | 0.000 to 30.000 pu |
| Undervoltage pickup: | 0.000 to 3.000 pu  |
| Overvoltage delay:   | 0.000 to 65.535 s  |

**PHASE/NEUTRAL/GROUND TOC**

|                      |   |
|----------------------|---|
| Current:             | Phasor or RMS   |
| Pickup level:        | 0.000 to 30.000 pu in steps of 0.001  |
| Dropout level:       | 97% to 98% of Pickup  |
| Level accuracy:      |   |
| for 0.1 to 2.0 × CT: | ±0.5% of reading or ±1% of rated (whichever is greater)   |
| for > 2.0 × CT:      | ±1.5% of reading > 2.0 × CT rating  |
| Curve shapes:        | IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; I <sup>2</sup> t; FlexCurves™ (programmable); Definite Time (0.01 s base curve) |
| Curve multiplier:    | Time Dial = 0.00 to 600.00 in steps of 0.01   |
| Reset type:          | Instantaneous/Timed (per IEEE)  |
| Timing accuracy:     | Operate at > 1.03 × actual Pickup<br>±3.5% of operate time or ±½ cycle (whichever is greater)   |

**PHASE/NEUTRAL/GROUND IOC**

|                         |   |
|-------------------------|---|
| Pickup level:           | 0.000 to 30.000 pu in steps of 0.001  |
| Dropout level:          | 97 to 98% of pickup   |
| Level accuracy:         |   |
| 0.1 to 2.0 × CT rating: | ±0.5% of reading or ±1% of rated (whichever is greater)   |
| > 2.0 × CT rating       | ±1.5% of reading  |
| Overreach:              | <2%   |
| Pickup delay:           | 0.00 to 600.00 s in steps of 0.01   |
| Reset delay:            | 0.00 to 600.00 s in steps of 0.01   |
| Operate time:           | <16 ms at 3 × Pickup at 60 Hz (Phase/Ground IOC)<br><20 ms at 3 × Pickup at 60 Hz (Neutral IOC) |
| Timing accuracy:        | Operate at 1.5 × Pickup<br>±3% or ±4 ms (whichever is greater)                                  |

**NEGATIVE SEQUENCE TOC**

|                               |   |
|-------------------------------|---|
| Pickup level:                 | 0.000 to 30.000 pu in steps of 0.001  |
| Dropout level:                | 97% to 98% of Pickup  |
| Level accuracy:               | ±0.5% of reading or ±1% of rated (whichever is greater)<br>from 0.1 to 2.0 × CT rating<br>±1.5% of reading > 2.0 × CT rating  |
| Curve shapes:                 | IEEE Moderately/Very/Extremely Inverse; IEC (and BS) A/B/C and Short Inverse; GE IAC Inverse, Short/Very/Extremely Inverse; I <sup>2</sup> t; FlexCurves™ (programmable); Definite Time (0.01 s base curve) |
| Curve multiplier (Time dial): | 0.00 to 600.00 in steps of 0.01   |
| Reset type:                   | Instantaneous/Timed (per IEEE) and Linear   |
| Timing accuracy:              | Operate at > 1.03 × Actual Pickup<br>±3.5% of operate time or ±½ cycle (whichever is greater)   |

**NEGATIVE SEQUENCE IOC**

|                         |   |
|-------------------------|---|
| Pickup level:           | 0.000 to 30.000 pu in steps of 0.001                            |
| Dropout level:          | 97 to 98% of Pickup   |
| Level accuracy:         |   |
| 0.1 to 2.0 × CT rating: | ±0.5% of reading or ±1% of rated (whichever is greater)         |
| > 2.0 × CT rating:      | ±1.5% of reading  |
| Overreach:              | < 2%  |
| Pickup delay:           | 0.00 to 600.00 s in steps of 0.01                               |
| Reset delay:            | 0.00 to 600.00 s in steps of 0.01                               |
| Operate time:           | < 20 ms at 3 × Pickup at 60 Hz                                  |
| Timing accuracy:        | Operate at 1.5 × Pickup<br>±3% or ± 4 ms (whichever is greater) |

**PHASE DIRECTIONAL OVERCURRENT**

|  |                                     |
|--|-------------------------------------|
| Relay connection:  | 90° (quadrature)                    |
| Quadrature voltage:  |                                     |
| ABC phase seq.: phase A (V <sub>BC</sub> ), phase B (V <sub>CA</sub> ), phase C (V <sub>AB</sub> ) |                                     |
| ACB phase seq.: phase A (V <sub>CB</sub> ), phase B (V <sub>AC</sub> ), phase C (V <sub>BA</sub> ) |                                     |
| Polarizing voltage threshold:  | 0.000 to 3.000 pu in steps of 0.001 |
| Current sensitivity threshold:   | 0.05 pu                             |
| Characteristic angle:  | 0 to 359° in steps of 1             |
| Angle accuracy:  | ±2°                                 |
| Operation time (FlexLogic™ operands):  |                                     |
| Tripping (reverse load, forward fault):  | < 12 ms, typically                  |
| Blocking (forward load, reverse fault):  | < 8 ms, typically                   |



**NEUTRAL DIRECTIONAL OVERCURRENT**

|                       |  |
|-----------------------|--|
| Directionality:       | Co-existing forward and reverse                              |
| Polarizing:           | Voltage, Current, Dual                                       |
| Polarizing voltage:   | V <sub>0</sub> or V <sub>X</sub>                             |
| Polarizing current:   | I <sub>G</sub>   |
| Operating current:    | I <sub>0</sub>   |
| Level sensing:        | $3 \times ( I_0  - K \times  I_1 )$ , I <sub>G</sub>         |
| Restraint, K:         | 0.000 to 0.500 in steps of 0.001                             |
| Characteristic angle: | –90 to 90° in steps of 1                                     |
| Limit angle:          | 40 to 90° in steps of 1, independent for forward and reverse |
| Angle accuracy:       | ±2°  |
| Offset impedance:     | 0.00 to 250.00 Ω in steps of 0.01                            |
| Pickup level:         | 0.05 to 30.00 pu in steps of 0.01                            |
| Dropout level:        | 97 to 98%  |
| Operation time:       | < 16 ms at 3 × Pickup at 60 Hz                               |

**NEGATIVE SEQUENCE DIRECTIONAL OC**

|                       |  |
|-----------------------|--|
| Directionality:       | Co-existing forward and reverse                              |
| Polarizing:           | Voltage  |
| Polarizing voltage:   | V <sub>2</sub>   |
| Operating current:    | I <sub>2</sub>   |
| Level sensing:        |  |
| Zero-sequence:        | $ I_0  - K \times  I_1 $                                     |
| Negative-sequence:    | $ I_2  - K \times  I_1 $                                     |
| Restraint, K:         | 0.000 to 0.500 in steps of 0.001                             |
| Characteristic angle: | 0 to 90° in steps of 1                                       |
| Limit angle:          | 40 to 90° in steps of 1, independent for forward and reverse |
| Angle accuracy:       | ±2°  |
| Offset impedance:     | 0.00 to 250.00 Ω in steps of 0.01                            |
| Pickup level:         | 0.05 to 30.00 pu in steps of 0.01                            |
| Dropout level:        | 97 to 98%  |
| Operation time:       | < 16 ms at 3 × Pickup at 60 Hz                               |

**PHASE UNDERVOLTAGE**

|                   |   |
|-------------------|---|
| Pickup level:     | 0.000 to 3.000 pu in steps of 0.001   |
| Dropout level:    | 102 to 103% of Pickup   |
| Level accuracy:   | ±0.5% of reading from 10 to 208 V   |
| Curve shapes:     | GE IAV Inverse;<br>Definite Time (0.1s base curve)                                  |
| Curve multiplier: | Time Dial = 0.00 to 600.00 in steps of 0.01   |
| Timing accuracy:  | Operate at < 0.90 × Pickup<br>±3.5% of operate time or ±4 ms (whichever is greater) |

**AUXILIARY UNDERVOLTAGE**

|                   |   |
|-------------------|---|
| Pickup level:     | 0.000 to 3.000 pu in steps of 0.001                 |
| Dropout level:    | 102 to 103% of pickup                               |
| Level accuracy:   | ±0.5% of reading from 10 to 208 V                   |
| Curve shapes:     | GE IAV Inverse, Definite Time                       |
| Curve multiplier: | Time Dial = 0 to 600.00 in steps of 0.01            |
| Timing accuracy:  | ±3% of operate time or ±4 ms (whichever is greater) |

**PHASE OVERVOLTAGE**

|                  |                                     |
|------------------|-------------------------------------|
| Pickup level:    | 0.000 to 3.000 pu in steps of 0.001 |
| Dropout level:   | 97 to 98% of Pickup                 |
| Level accuracy:  | ±0.5% of reading from 10 to 208 V   |
| Pickup delay:    | 0.00 to 600.00 in steps of 0.01 s   |
| Operate time:    | < 30 ms at 1.10 × Pickup at 60 Hz   |
| Timing accuracy: | ±3% or ±4 ms (whichever is greater) |

**NEUTRAL OVERVOLTAGE**

|                  |                                     |
|------------------|-------------------------------------|
| Pickup level:    | 0.000 to 1.250 pu in steps of 0.001 |
| Dropout level:   | 97 to 98% of Pickup                 |
| Level accuracy:  | ±0.5% of reading from 10 to 208 V   |
| Pickup delay:    | 0.00 to 600.00 s in steps of 0.01   |
| Reset delay:     | 0.00 to 600.00 s in steps of 0.01   |
| Timing accuracy: | ±3% or ±4 ms (whichever is greater) |
| Operate time:    | < 30 ms at 1.10 × Pickup at 60 Hz   |

**AUXILIARY OVERVOLTAGE**

|                  |   |
|------------------|---|
| Pickup level:    | 0.000 to 3.000 pu in steps of 0.001                 |
| Dropout level:   | 97 to 98% of Pickup                                 |
| Level accuracy:  | ±0.5% of reading from 10 to 208 V                   |
| Pickup delay:    | 0 to 600.00 s in steps of 0.01                      |
| Reset delay:     | 0 to 600.00 s in steps of 0.01                      |
| Timing accuracy: | ±3% of operate time or ±4 ms (whichever is greater) |
| Operate time:    | < 30 ms at 1.10 × pickup at 60 Hz                   |

**NEGATIVE SEQUENCE OVERVOLTAGE**

|                 |                                     |
|-----------------|-------------------------------------|
| Pickup level:   | 0.000 to 1.250 pu in steps of 0.001 |
| Dropout level:  | 97 to 98% of Pickup                 |
| Level accuracy: | ±0.5% of reading from 10 to 208 V   |
| Pickup delay:   | 0 to 600.00 s in steps of 0.01      |
| Reset delay:    | 0 to 600.00 s in steps of 0.01      |
| Time accuracy:  | ±3% or ±20 ms, whichever is greater |
| Operate time:   | < 30 ms at 1.10 × Pickup at 60 Hz   |

**BREAKER ARCING CURRENT**

|                                    |   |
|------------------------------------|---|
| Principle:                         | accumulates breaker duty (I <sup>2</sup> t) and measures fault duration |
| Initiation:                        | programmable per phase from any Flex-Logic™ operand                     |
| Compensation for auxiliary relays: | 0 to 65.535 s in steps of 0.001   |
| Alarm threshold:                   | 0 to 50000 kA <sup>2</sup> -cycle in steps of 1                         |
| Fault duration accuracy:           | 0.25 of a power cycle   |
| Availability:                      | 1 per CT bank with a minimum of 2                                       |

**SYNCHROCHECK**

|                                  |   |
|----------------------------------|---|
| Max voltage difference:          | 0 to 100000 V in steps of 1   |
| Max angle difference:            | 0 to 100° in steps of 1   |
| Max freq. difference:            | 0.00 to 2.00 Hz in steps of 0.01  |
| Hysteresis for max. freq. diff.: | 0.00 to 0.10 Hz in steps of 0.01  |
| Dead source function:            | None, LV1 & DV2, DV1 & LV2, DV1 or DV2, DV1 xor DV2, DV1 & DV2 (L = Live, D = Dead) |



**AUTORECLOSURE**

Single breaker applications, 3-pole tripping schemes  
 Up to 4 reclose attempts before lockout  
 Independent dead time setting before each shot  
 Possibility of changing protection settings after each shot with FlexLogic™

**POWER SWING DETECT**

Functions: Power swing block, Out-of-step trip  
 Characteristic: Mho or Quad  
 Measured impedance: Positive-sequence  
 Blocking / tripping modes: 2-step or 3-step  
 Tripping mode: Early or Delayed  
 Current supervision:  
   Pickup level: 0.050 to 30.000 pu in steps of 0.001  
   Dropout level: 97 to 98% of Pickup  
 Fwd / reverse reach (sec.  $\Omega$ ): 0.10 to 500.00  $\Omega$  in steps of 0.01  
 Left and right blinders (sec.  $\Omega$ ): 0.10 to 500.00  $\Omega$  in steps of 0.01  
 Impedance accuracy:  $\pm 5\%$   
 Fwd / reverse angle impedances: 40 to 90° in steps of 1  
 Angle accuracy:  $\pm 2^\circ$   
 Characteristic limit angles: 40 to 140° in steps of 1  
 Timers: 0.000 to 65.535 s in steps of 0.001  
 Timing accuracy:  $\pm 3\%$  or 4 ms, whichever is greater

**LOAD ENCROACHMENT**

Responds to: Positive-sequence quantities  
 Minimum voltage: 0.000 to 3.000 pu in steps of 0.001  
 Reach (sec.  $\Omega$ ): 0.02 to 250.00  $\Omega$  in steps of 0.01  
 Impedance accuracy:  $\pm 5\%$   
 Angle: 5 to 50° in steps of 1  
 Angle accuracy:  $\pm 2^\circ$   
 Pickup delay: 0 to 65.535 s in steps of 0.001  
 Reset delay: 0 to 65.535 s in steps of 0.001  
 Time accuracy:  $\pm 3\%$  or  $\pm 4$  ms, whichever is greater  
 Operate time: < 30 ms at 60 Hz

**2.2.2 USER PROGRAMMABLE ELEMENTS****FLEXLOGIC™**

Programming language: Reverse Polish Notation with graphical visualization (keypad programmable)  
 Lines of code: 512  
 Internal variables: 64  
 Supported operations: NOT, XOR, OR (2 to 16 inputs), AND (2 to 16 inputs), NOR (2 to 16 inputs), NAND (2 to 16 inputs), Latch (Reset dominant), Edge Detectors, Timers  
 Inputs: any logical variable, contact, or virtual input  
 Number of timers: 32  
 Pickup delay: 0 to 60000 (ms, sec., min.) in steps of 1  
 Dropout delay: 0 to 60000 (ms, sec., min.) in steps of 1

**FLEXCURVES™**

Number: 4 (A through D)  
 Reset points: 40 (0 through 1 of pickup)  
 Operate points: 80 (1 through 20 of pickup)  
 Time delay: 0 to 65535 ms in steps of 1

**FLEX STATES**

Number: up to 256 logical variables grouped under 16 Modbus addresses  
 Programmability: any logical variable, contact, or virtual input

**FLEXELEMENTS™**

Number of elements: 16  
 Operating signal: any analog actual value, or two values in differential mode  
 Operating signal mode: Signed or Absolute Value  
 Operating mode: Level, Delta  
 Comparator direction: Over, Under  
 Pickup Level: -30.000 to 30.000 pu in steps of 0.001  
 Hysteresis: 0.1 to 50.0% in steps of 0.1  
 Delta dt: 20 ms to 60 days  
 Pickup & dropout delay: 0.000 to 65.535 s in steps of 0.001

**NON-VOLATILE LATCHES**

Type: Set-dominant or Reset-dominant  
 Number: 16 (individually programmed)  
 Output: Stored in non-volatile memory  
 Execution sequence: As input prior to protection, control, and FlexLogic™

**USER-PROGRAMMABLE LEDs**

Number: 48 plus Trip and Alarm  
 Programmability: from any logical variable, contact, or virtual input  
 Reset mode: Self-reset or Latched

**LED TEST**

|                        |   |
|------------------------|---|
| Initiation:            | from any digital input or user-programmable condition |
| Number of tests:       | 3, interruptible at any time                          |
| Duration of full test: | approximately 3 minutes                               |
| Test sequence 1:       | all LEDs on   |
| Test sequence 2:       | all LEDs off, one LED at a time on for 1 s            |
| Test sequence 3:       | all LEDs on, one LED at a time off for 1 s            |

**USER-DEFINABLE DISPLAYS**

|                         |   |
|-------------------------|---|
| Number of displays:     | 16  |
| Lines of display:       | 2 × 20 alphanumeric characters                                    |
| Parameters:             | up to 5, any Modbus register addresses                            |
| Invoking and scrolling: | keypad, or any user-programmable condition, including pushbuttons |

**CONTROL PUSHBUTTONS**

|                        |                           |
|------------------------|---------------------------|
| Number of pushbuttons: | 7                         |
| Operation:             | drive FlexLogic™ operands |

**USER-PROGRAMMABLE PUSHBUTTONS (OPTIONAL)**

|                        |                               |
|------------------------|-------------------------------|
| Number of pushbuttons: | 12                            |
| Mode:                  | Self-Reset, Latched           |
| Display message:       | 2 lines of 20 characters each |

**SELECTOR SWITCH**

|                       |  |
|-----------------------|--|
| Number of elements:   | 2  |
| Upper position limit: | 1 to 7 in steps of 1   |
| Selecting mode:       | Time-out or Acknowledge  |
| Time-out timer:       | 3.0 to 60.0 s in steps of 0.1  |
| Control inputs:       | step-up and 3-bit  |
| Power-up mode:        | restore from non-volatile memory or synchronize to a 3-bit control input |

**2.2.3 MONITORING****OSCILLOGRAPHY**

|                  |  |
|------------------|--|
| Maximum records: | 64   |
| Sampling rate:   | 64 samples per power cycle   |
| Triggers:        | Any element pickup, dropout or operate<br>Digital input change of state<br>Digital output change of state<br>FlexLogic™ equation |
| Data:            | AC input channels<br>Element state<br>Digital input state<br>Digital output state  |
| Data storage:    | In non-volatile memory   |

**EVENT RECORDER**

|               |   |
|---------------|---|
| Capacity:     | 1024 events   |
| Time-tag:     | to 1 microsecond  |
| Triggers:     | Any element pickup, dropout or operate<br>Digital input change of state<br>Digital output change of state<br>Self-test events |
| Data storage: | In non-volatile memory  |

**FAULT LOCATOR**

|                      |  |
|----------------------|--|
| Method:              | Single-ended   |
| Maximum accuracy if: | Fault resistance is zero or fault currents from all line terminals are in phase  |
| Relay accuracy:      | ±1.5% (V > 10 V, I > 0.1 pu)   |
| Worst-case accuracy: | $VT_{\%error} + (user\ data)$ $CT_{\%error} + (user\ data)$ $Z_{Line\%error} + (user\ data)$ $METHOD_{\%error} + (Chapter\ 6)$ $RELAY\ ACCURACY_{\%error} + (1.5\%)$ |

**2.2.4 METERING****RMS CURRENT: PHASE, NEUTRAL, AND GROUND**

|                         |  |
|-------------------------|--|
| Accuracy at             |  |
| 0.1 to 2.0 × CT rating: | ±0.25% of reading or ±0.1% of rated (whichever is greater) |
| > 2.0 × CT rating:      | ±1.0% of reading   |

**RMS VOLTAGE**

|           |                                   |
|-----------|-----------------------------------|
| Accuracy: | ±0.5% of reading from 10 to 208 V |
|-----------|-----------------------------------|

**REAL POWER (WATTS)**

|           |  |
|-----------|--|
| Accuracy: | ±1.0% of reading at<br>−0.8 < PF ≤ −1.0 and 0.8 < PF ≤ 1.0 |
|-----------|--|

**REACTIVE POWER (VARs)**

|           |                                     |
|-----------|-------------------------------------|
| Accuracy: | ±1.0% of reading at −0.2 ≤ PF ≤ 0.2 |
|-----------|-------------------------------------|

**APPARENT POWER (VA)**

|           |                  |
|-----------|------------------|
| Accuracy: | ±1.0% of reading |
|-----------|------------------|

**FREQUENCY**

|                     |  |
|---------------------|--|
| Accuracy at         |  |
| V = 0.8 to 1.2 pu:  | ±0.01 Hz (when voltage signal is used for frequency measurement) |
| I = 0.1 to 0.25 pu: | ±0.05 Hz   |
| I > 0.25 pu:        | ±0.02 Hz (when current signal is used for frequency measurement) |

## 2.2.5 INPUTS

**AC CURRENT**

|                          |  |
|--------------------------|--|
| CT rated primary:        | 1 to 50000 A   |
| CT rated secondary:      | 1 A or 5 A by connection   |
| Nominal frequency:       | 20 to 65 Hz  |
| Relay burden:            | < 0.2 VA at rated secondary  |
| Conversion range:        |  |
| Standard CT:             | 0.02 to 46 × CT rating RMS symmetrical   |
| Sensitive Ground module: | 0.002 to 4.6 × CT rating RMS symmetrical   |
| Current withstand:       | 20 ms at 250 times rated<br>1 sec. at 100 times rated<br>continuous at 3 times rated |

**AC VOLTAGE**

|                     |   |
|---------------------|---|
| VT rated secondary: | 50.0 to 240.0 V   |
| VT ratio:           | 1.00 to 24000.00  |
| Nominal frequency:  | 20 to 65 Hz   |
| Relay burden:       | < 0.25 VA at 120 V  |
| Conversion range:   | 1 to 275 V  |
| Voltage withstand:  | continuous at 260 V to neutral<br>1 min./hr at 420 V to neutral |

**CONTACT INPUTS**

|                        |                                |
|------------------------|--------------------------------|
| Dry contacts:          | 1000 Ω maximum                 |
| Wet contacts:          | 300 V DC maximum               |
| Selectable thresholds: | 17 V, 33 V, 84 V, 166 V        |
| Tolerance:             | ±10%                           |
| Recognition time:      | < 1 ms                         |
| Debounce timer:        | 0.0 to 16.0 ms in steps of 0.5 |

**DCMA INPUTS**

|                        |   |
|------------------------|---|
| Current input (mA DC): | 0 to -1, 0 to +1, -1 to +1, 0 to 5, 0 to 10,<br>0 to 20, 4 to 20 (programmable) |
| Input impedance:       | 379 Ω ±10%  |
| Conversion range:      | -1 to + 20 mA DC  |
| Accuracy:              | ±0.2% of full scale   |
| Type:                  | Passive   |

**RTD INPUTS**

|                  |   |
|------------------|---|
| Types (3-wire):  | 100 Ω Platinum, 100 & 120 Ω Nickel, 10 Ω Copper |
| Sensing current: | 5 mA  |
| Range:           | -50 to +250°C                                   |
| Accuracy:        | ±2°C  |
| Isolation:       | 36 V pk-pk                                      |

**IRIG-B INPUT**

|                       |                 |
|-----------------------|-----------------|
| Amplitude modulation: | 1 to 10 V pk-pk |
| DC shift:             | TTL             |
| Input impedance:      | 22 kΩ           |
| Isolation:            | 2 kV            |

**REMOTE INPUTS (MMS GOOSE)**

|                                   |   |
|-----------------------------------|---|
| Number of input points:           | 32, configured from 64 incoming bit pairs |
| Number of remote devices:         | 16  |
| Default states on loss of comms.: | On, Off, Latest/Off, Latest/On            |

**DIRECT INPUTS**

|                                   |   |
|-----------------------------------|---|
| Number of input points:           | 32  |
| No. of remote devices:            | 16  |
| Default states on loss of comms.: | On, Off, Latest/Off, Latest/On                        |
| Ring configuration:               | Yes, No   |
| Data rate:                        | 64 or 128 kbps  |
| CRC:                              | 32-bit  |
| CRC alarm:                        |   |
| Responding to:                    | Rate of messages failing the CRC                      |
| Monitoring message count:         | 10 to 10000 in steps of 1                             |
| Alarm threshold:                  | 1 to 1000 in steps of 1                               |
| Unreturned message alarm:         |   |
| Responding to:                    | Rate of unreturned messages in the ring configuration |
| Monitoring message count:         | 10 to 10000 in steps of 1                             |
| Alarm threshold:                  | 1 to 1000 in steps of 1                               |

## 2.2.6 POWER SUPPLY

**LOW RANGE**

|                     |                       |
|---------------------|-----------------------|
| Nominal DC voltage: | 24 to 48 V at 3 A     |
| Min/max DC voltage: | 20 / 60 V             |
| NOTE:               | Low range is DC only. |

**HIGH RANGE**

|                     |                                 |
|---------------------|---------------------------------|
| Nominal DC voltage: | 125 to 250 V at 0.7 A           |
| Min/max DC voltage: | 88 / 300 V                      |
| Nominal AC voltage: | 100 to 240 V at 50/60 Hz, 0.7 A |
| Min/max AC voltage: | 88 / 265 V at 48 to 62 Hz       |

**ALL RANGES**

|                       |                                       |
|-----------------------|---------------------------------------|
| Volt withstand:       | 2 × Highest Nominal Voltage for 10 ms |
| Voltage loss hold-up: | 50 ms duration at nominal             |
| Power consumption:    | Typical = 15 VA; Max. = 30 VA         |

**INTERNAL FUSE****RATINGS**

|                          |               |
|--------------------------|---------------|
| Low range power supply:  | 7.5 A / 600 V |
| High range power supply: | 5 A / 600 V   |

**INTERRUPTING CAPACITY**

|     |                           |
|-----|---------------------------|
| AC: | 100 000 A RMS symmetrical |
| DC: | 10 000 A                  |

## 2.2.7 OUTPUTS

**FORM-A RELAY**

Make and carry for 0.2 s: 30 A as per ANSI C37.90

Carry continuous: 6 A

Break at L/R of 40 ms: 0.25 A DC max. at 48 V  
0.10 A DC max. at 125 V

Operate time: < 4 ms

Contact material: Silver alloy

**LATCHING RELAY**

Make and carry for 0.2 s: 30 A as per ANSI C37.90

Carry continuous: 6 A

Break at L/R of 40 ms: 0.25 A DC max.

Operate time: < 4 ms

Contact material: Silver alloy

Control: separate operate and reset inputs

Control mode: operate-dominant or reset-dominant

**FORM-A VOLTAGE MONITOR**

Applicable voltage: approx. 15 to 250 V DC

Trickle current: approx. 1 to 2.5 mA

**FORM-A CURRENT MONITOR**

Threshold current: approx. 80 to 100 mA

**FORM-C AND CRITICAL FAILURE RELAY**

Make and carry for 0.2 s: 10 A

Carry continuous: 6 A

Break at L/R of 40 ms: 0.25 A DC max. at 48 V  
0.10 A DC max. at 125 V

Operate time: < 8 ms

Contact material: Silver alloy

**FAST FORM-C RELAY**

Make and carry: 0.1 A max. (resistive load)

Minimum load impedance:

| INPUT<br>VOLTAGE | IMPEDANCE     |               |
|------------------|---------------|---------------|
|                  | 2 W RESISTOR  | 1 W RESISTOR  |
| 250 V DC         | 20 K $\Omega$ | 50 K $\Omega$ |
| 120 V DC         | 5 K $\Omega$  | 2 K $\Omega$  |
| 48 V DC          | 2 K $\Omega$  | 2 K $\Omega$  |
| 24 V DC          | 2 K $\Omega$  | 2 K $\Omega$  |

Note: values for 24 V and 48 V are the same due to a required 95% voltage drop across the load impedance.

Operate time: < 0.6 ms

Internal Limiting Resistor: 100  $\Omega$ , 2 W

**SOLID-STATE OUTPUT RELAY**

Operate and release time: <100  $\mu$ s

Maximum voltage: 265 V DC

Maximum continuous current: 5 A at 45°C; 4 A at 65°C

Make and carry for 0.2 s: as per ANSI C37.90

Breaking capacity:

|   | IEC 647-5 / UL508                 | Utility application<br>(autoreclose scheme)             | Industrial application               |
|---|-----------------------------------|---|--------------------------------------|
| Operations/<br>interval                   | 5000 ops /<br>1 s-On, 9 s-Off     | 5 ops /<br>0.2 s-On,<br>0.2 s-Off<br>within 1<br>minute | 10000 ops /<br>0.2 s-On,<br>30 s-Off |
|   | 1000 ops /<br>0.5 s-On, 0.5 s-Off |   |                                      |
| Break<br>capability<br>(0 to 250 V<br>DC) | 3.2 A<br>L/R = 10 ms              | 10 A<br>L/R = 40 ms                                     | 10 A<br>L/R = 40 ms                  |
|   | 1.6 A<br>L/R = 20 ms              |   |                                      |
|   | 0.8 A<br>L/R = 40 ms              |   |                                      |

**IRIG-B OUTPUT**

Amplitude: 10 V peak-peak RS485 level

Maximum load: 100 ohms

Time delay: 1 ms for AM input  
40  $\mu$ s for DC-shift input

Isolation: 2 kV

**CONTROL POWER EXTERNAL OUTPUT  
(FOR DRY CONTACT INPUT)**

Capacity: 100 mA DC at 48 V DC

Isolation:  $\pm$ 300 Vpk

**REMOTE OUTPUTS (IEC 61850 GSSE)**

Standard output points: 32

User output points: 32

**DIRECT OUTPUTS**

Output points: 32

**DCMA OUTPUTS**

Range: -1 to 1 mA, 0 to 1 mA, 4 to 20 mA

Max. load resistance: 12 k $\Omega$  for -1 to 1 mA range  
12 k $\Omega$  for 0 to 1 mA range  
600  $\Omega$  for 4 to 20 mA range

Accuracy:  $\pm$ 0.75% of full-scale for 0 to 1 mA range  
 $\pm$ 0.5% of full-scale for -1 to 1 mA range  
 $\pm$ 0.75% of full-scale for 0 to 20 mA range

99% Settling time to a step change: 100 ms

Isolation: 1.5 kV

Driving signal: any FlexAnalog quantity

Upper and lower limit for the driving signal: -90 to 90 pu in steps of 0.001

## 2.2.8 COMMUNICATIONS

**RS232**

Front port: 19.2 kbps, Modbus® RTU

**RS485**

1 or 2 rear ports: Up to 115 kbps, Modbus® RTU, isolated together at 36 Vpk

Typical distance: 1200 m

Isolation: 2 kV

**ETHERNET PORT**

10Base-F: 820 nm, multi-mode, supports half-duplex/full-duplex fiber optic with ST connector

Redundant 10Base-F: 820 nm, multi-mode, half-duplex/full-duplex fiber optic with ST connector

10Base-T: RJ45 connector

Power budget: 10 db

Max optical input power: -7.6 dBm

Max optical output power: -20 dBm

Receiver sensitivity: -30 dBm

Typical distance: 1.65 km

SNTP clock synchronization error: <10 ms (typical)

## 2.2.9 INTER-RELAY COMMUNICATIONS

**SHIELDED TWISTED-PAIR INTERFACE OPTIONS**

| INTERFACE TYPE | TYPICAL DISTANCE |
|----------------|------------------|
| RS422          | 1200 m           |
| G.703          | 100 m            |



**RS422 distance is based on transmitter power and does not take into consideration the clock source provided by the user.**

**LINK POWER BUDGET**

| EMITTER, FIBER TYPE       | TRANSMIT POWER | RECEIVED SENSITIVITY | POWER BUDGET |
|---------------------------|----------------|----------------------|--------------|
| 820 nm LED, Multimode     | -20 dBm        | -30 dBm              | 10 dB        |
| 1300 nm LED, Multimode    | -21 dBm        | -30 dBm              | 9 dB         |
| 1300 nm ELED, Singlemode  | -21 dBm        | -30 dBm              | 9 dB         |
| 1300 nm Laser, Singlemode | -1 dBm         | -30 dBm              | 29 dB        |
| 1550 nm Laser, Singlemode | +5 dBm         | -30 dBm              | 35 dB        |



**These Power Budgets are calculated from the manufacturer's worst-case transmitter power and worst case receiver sensitivity.**

**MAXIMUM OPTICAL INPUT POWER**

| EMITTER, FIBER TYPE       | MAX. OPTICAL INPUT POWER |
|---------------------------|--------------------------|
| 820 nm LED, Multimode     | -7.6 dBm                 |
| 1300 nm LED, Multimode    | -11 dBm                  |
| 1300 nm ELED, Singlemode  | -14 dBm                  |
| 1300 nm Laser, Singlemode | -14 dBm                  |
| 1550 nm Laser, Singlemode | -14 dBm                  |

**TYPICAL LINK DISTANCE**

| EMITTER TYPE  | FIBER TYPE | CONNECTOR TYPE | TYPICAL DISTANCE |
|---------------|------------|----------------|------------------|
| 820 nm LED    | Multimode  | ST             | 1.65 km          |
| 1300 nm LED   | Multimode  | ST             | 3.8 km           |
| 1300 nm ELED  | Singlemode | ST             | 11.4 km          |
| 1300 nm Laser | Singlemode | ST             | 64 km            |
| 1550 nm Laser | Singlemode | ST             | 105 km           |



**Typical distances listed are based on the following assumptions for system loss. As actual losses will vary from one installation to another, the distance covered by your system may vary.**

**CONNECTOR LOSSES (TOTAL OF BOTH ENDS)**

ST connector 2 dB

**FIBER LOSSES**

820 nm multimode 3 dB/km

1300 nm multimode 1 dB/km

1300 nm singlemode 0.35 dB/km

1550 nm singlemode 0.25 dB/km

Splice losses: One splice every 2 km, at 0.05 dB loss per splice.

**SYSTEM MARGIN**

3 dB additional loss added to calculations to compensate for all other losses.

Compensated difference in transmitting and receiving (channel asymmetry) channel delays using GPS satellite clock: 10 ms

## 2.2.10 ENVIRONMENTAL

## OPERATING TEMPERATURES

Cold: IEC 60028-2-1, 16 h at -40°C  
 Dry Heat: IEC 60028-2-2, 16 h at +85°C

## OTHER

Humidity (noncondensing): IEC 60068-2-30, 95%, Variant 1, 6 days  
 Altitude: Up to 2000 m  
 Installation Category: II

## 2.2.11 TYPE TESTS

Electrical fast transient: ANSI/IEEE C37.90.1  
 IEC 61000-4-4  
 IEC 60255-22-4  
 Oscillatory transient: ANSI/IEEE C37.90.1  
 IEC 61000-4-12  
 Insulation resistance: IEC 60255-5  
 Dielectric strength: IEC 60255-6  
 ANSI/IEEE C37.90  
 Electrostatic discharge: EN 61000-4-2  
 Surge immunity: EN 61000-4-5  
 RFI susceptibility: ANSI/IEEE C37.90.2  
 IEC 61000-4-3  
 IEC 60255-22-3  
 Ontario Hydro C-5047-77

Conducted RFI: IEC 61000-4-6  
 Voltage dips/interruptions/variatioins:  
 IEC 61000-4-11  
 IEC 60255-11  
 Power frequency magnetic field immunity:  
 IEC 61000-4-8  
 Vibration test (sinusoidal): IEC 60255-21-1  
 Shock and bump: IEC 60255-21-2



NOTE

Type test report available upon request.

## 2.2.12 PRODUCTION TESTS

## THERMAL

Products go through an environmental test based upon an  
 Accepted Quality Level (AQL) sampling process.

## 2.2.13 APPROVALS

## APPROVALS

UL Listed for the USA and Canada

CE:  
 LVD 73/23/EEC: IEC 1010-1  
 EMC 81/336/EEC: EN 50081-2, EN 50082-2

## 2.2.14 MAINTENANCE

## MOUNTING

Attach mounting brackets using 20 inch-pounds (±2 inch-pounds)  
 of torque.

## CLEANING

Normally, cleaning is not required; but for situations where dust  
 has accumulated on the faceplate display, a dry cloth can be used.

## 3.1.1 PANEL CUTOUT

The relay is available as a 19-inch rack horizontal mount unit or as a reduced size ( $\frac{3}{4}$ ) vertical mount unit, with a removable faceplate. The modular design allows the relay to be easily upgraded or repaired by a qualified service person. The faceplate is hinged to allow easy access to the removable modules, and is itself removable to allow mounting on doors with limited rear depth. There is also a removable dust cover that fits over the faceplate, which must be removed when attempting to access the keypad or RS232 communications port.

The vertical and horizontal case dimensions are shown below, along with panel cutout details for panel mounting. When planning the location of your panel cutout, ensure that provision is made for the faceplate to swing open without interference to or from adjacent equipment.

The relay must be mounted such that the faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the keypad and the RS232 communications port. The relay is secured to the panel with the use of four screws supplied with the relay.

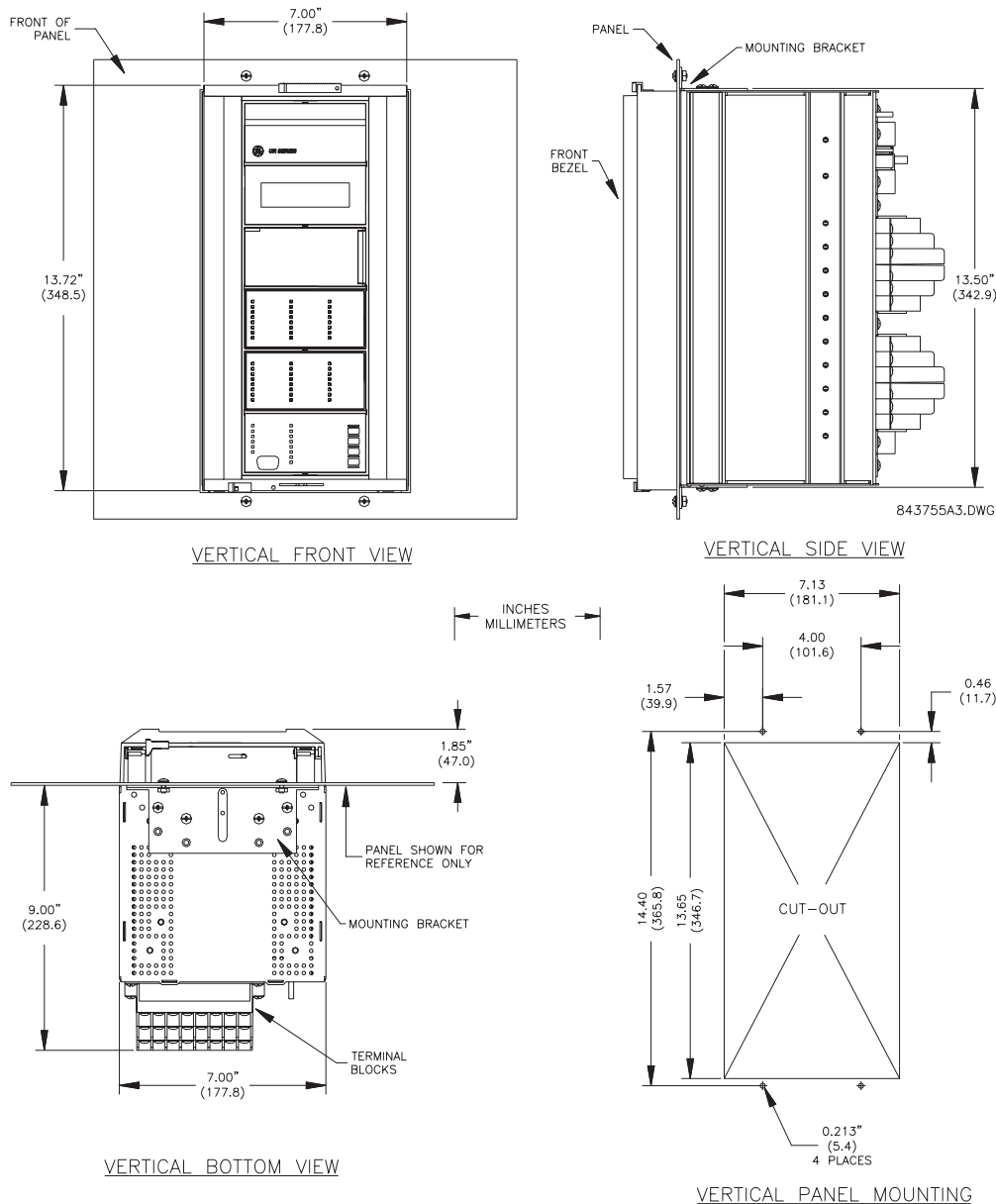


Figure 3-1: D30 VERTICAL MOUNTING AND DIMENSIONS

3

STEP 1 – CREATE THE HOLES AND CUT-OUT INTO THE PANEL AS PER DRAWING 843753.

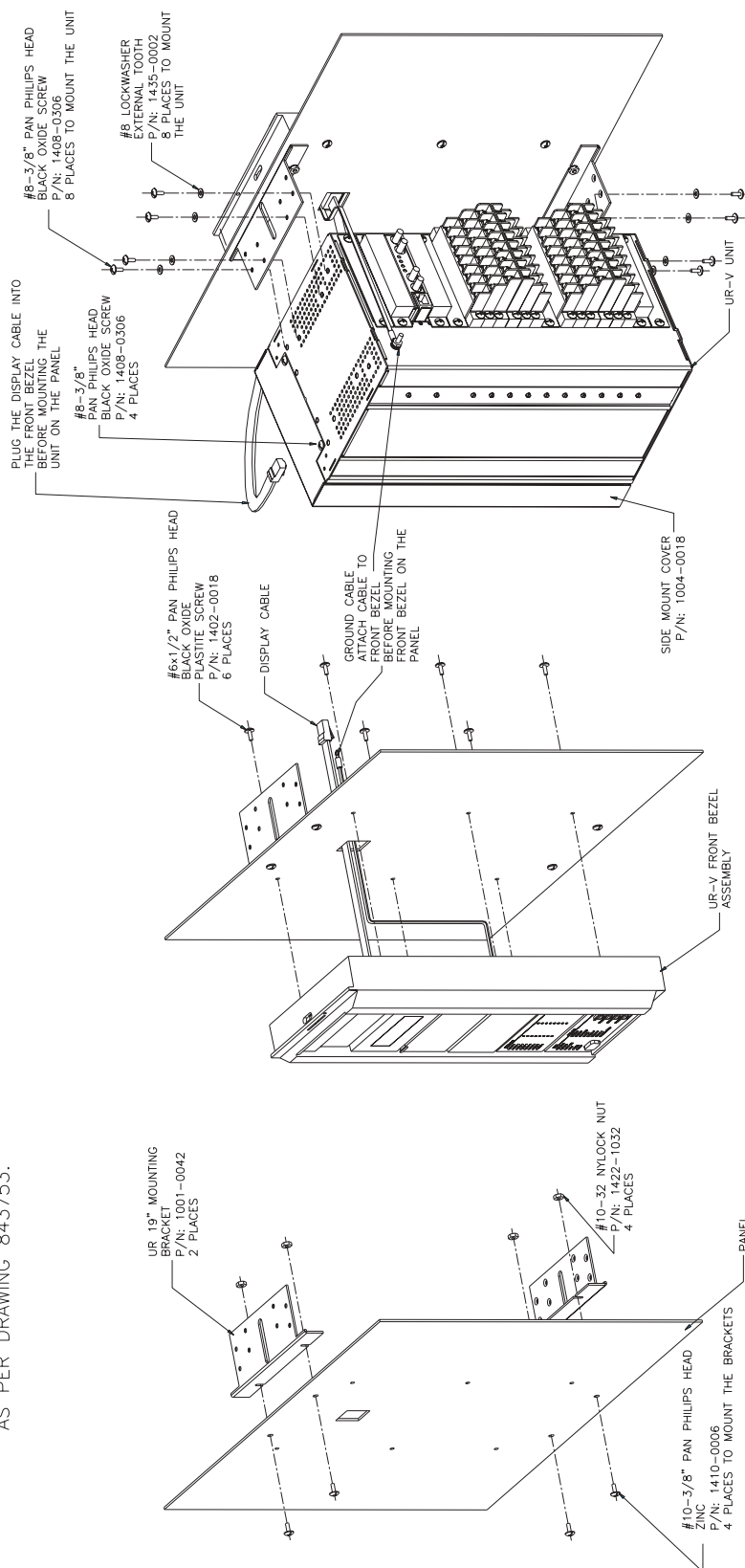
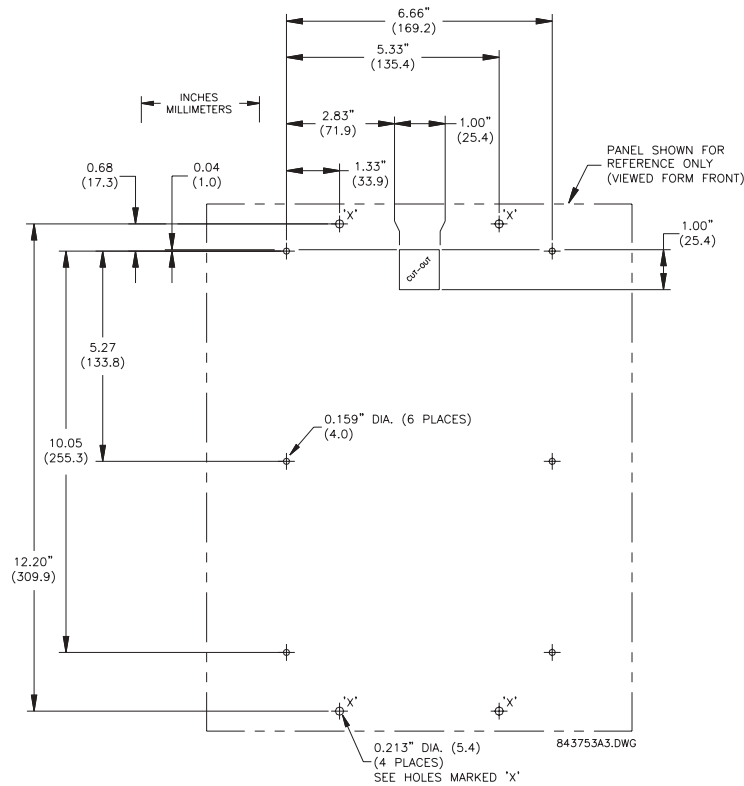
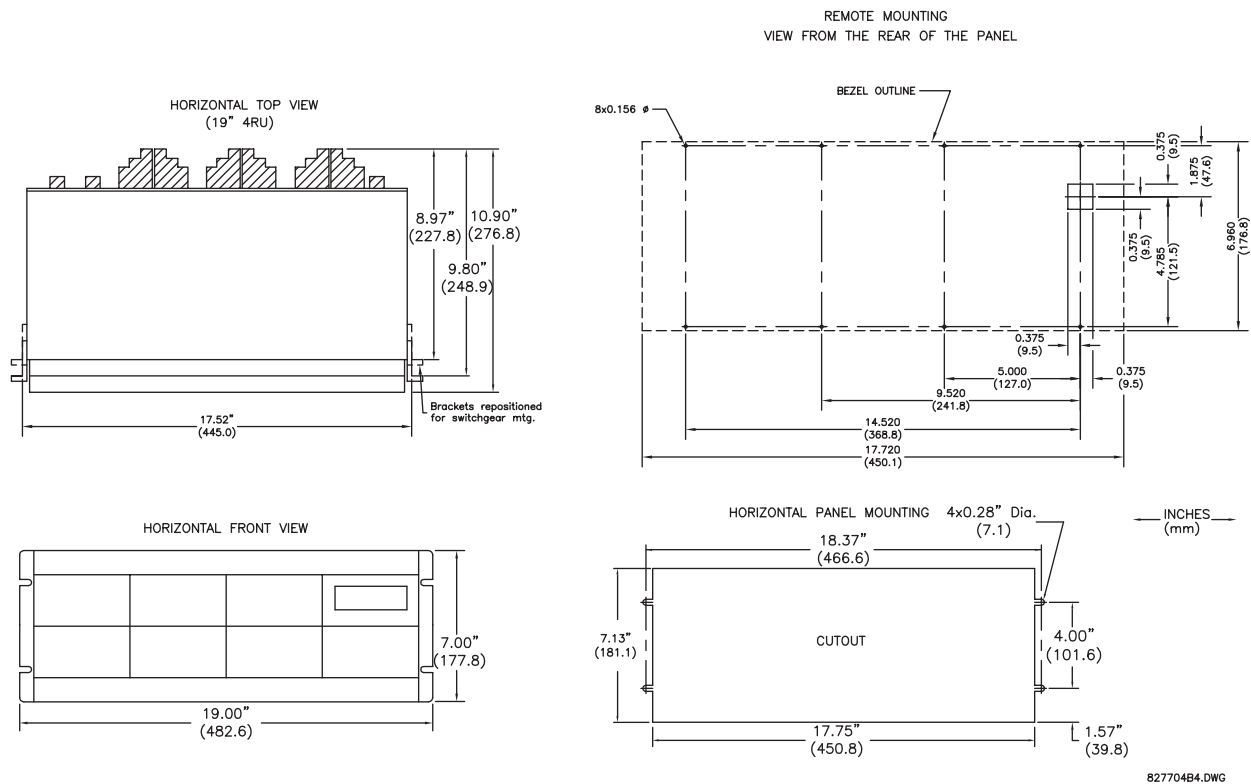


Figure 3-2: D30 VERTICAL SIDE MOUNTING INSTALLATION





### Figure 3–3: D30 VERTICAL SIDE MOUNTING REAR DIMENSIONS



### Figure 3-4: D30 HORIZONTAL MOUNTING AND DIMENSIONS

## 3.1.2 MODULE WITHDRAWAL AND INSERTION



**Module withdrawal and insertion may only be performed when control power has been removed from the unit. Inserting an incorrect module type into a slot may result in personal injury, damage to the unit or connected equipment, or undesired operation!**



**Proper electrostatic discharge protection (i.e. a static strap) must be used when coming in contact with modules while the relay is energized!**

The relay, being modular in design, allows for the withdrawal and insertion of modules. Modules must only be replaced with like modules in their original factory configured slots. The faceplate can be opened to the left, once the sliding latch on the right side has been pushed up, as shown below. This allows for easy accessibility of the modules for withdrawal.



**Figure 3-5: UR MODULE WITHDRAWAL/INSERTION**

- **MODULE WITHDRAWAL:** The ejector/inserter clips, located at the top and bottom of each module, must be pulled simultaneously to release the module for removal. Before performing this action, **control power must be removed from the relay**. Record the original location of the module to ensure that the same or replacement module is inserted into the correct slot. Modules with current input provide automatic shorting of external CT circuits.
- **MODULE INSERTION:** Ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/insert clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module will be fully inserted.



Type 9G and 9H CPU modules are equipped with 10Base-T and 10Base-F Ethernet connectors. These connectors must be individually disconnected from the module before the it can be removed from the chassis.



The version 4.0 release of the D30 relay includes new hardware (CPU and CT/VT modules). The new CPU modules are specified with the following order codes: 9E, 9G, and 9H. The new CT/VT modules are specified with the following order codes: 8F, 8G.

The new CT/VT modules (8F, 8G) can only be used with the new CPUs (9E, 9G, 9H); similarly, the old CT/VT modules (8A, 8B) can only be used with the old CPUs (9A, 9C, 9D). To prevent hardware mismatches, the new CPU and CT/VT modules have blue labels and a warning sticker stating “**Attn.: Ensure CPU and DSP module label colors are the same!**”. In the event that there is a mismatch between the CPU and CT/VT module, the relay will not function and a **DSP ERROR** or **HARDWARE MISMATCH** error will be displayed.

All other input/output modules are compatible with the new hardware. Firmware versions 4.0x and higher are only compatible with the new CPU and CT/VT modules. Previous versions of the firmware (3.4x and earlier) are only compatible with the older CPU and CT/VT modules.

## 3.1.3 REAR TERMINAL LAYOUT

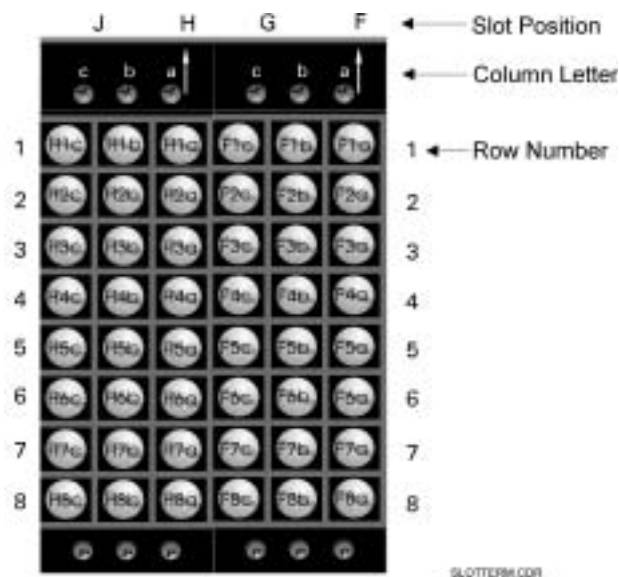


837771A1.CDR

Figure 3-6: D30 REAR TERMINAL VIEW

**Do not touch any rear terminals while the relay is energized!**

The relay follows a convention with respect to terminal number assignments which are three characters long assigned in order by module slot position, row number, and column letter. Two-slot wide modules take their slot designation from the first slot position (nearest to CPU module) which is indicated by an arrow marker on the terminal block. See the following figure for an example of rear terminal assignments.



SLOTTERM.COM

Figure 3-7: EXAMPLE OF MODULES IN F AND H SLOTS

## 3.2.1 TYPICAL WIRING

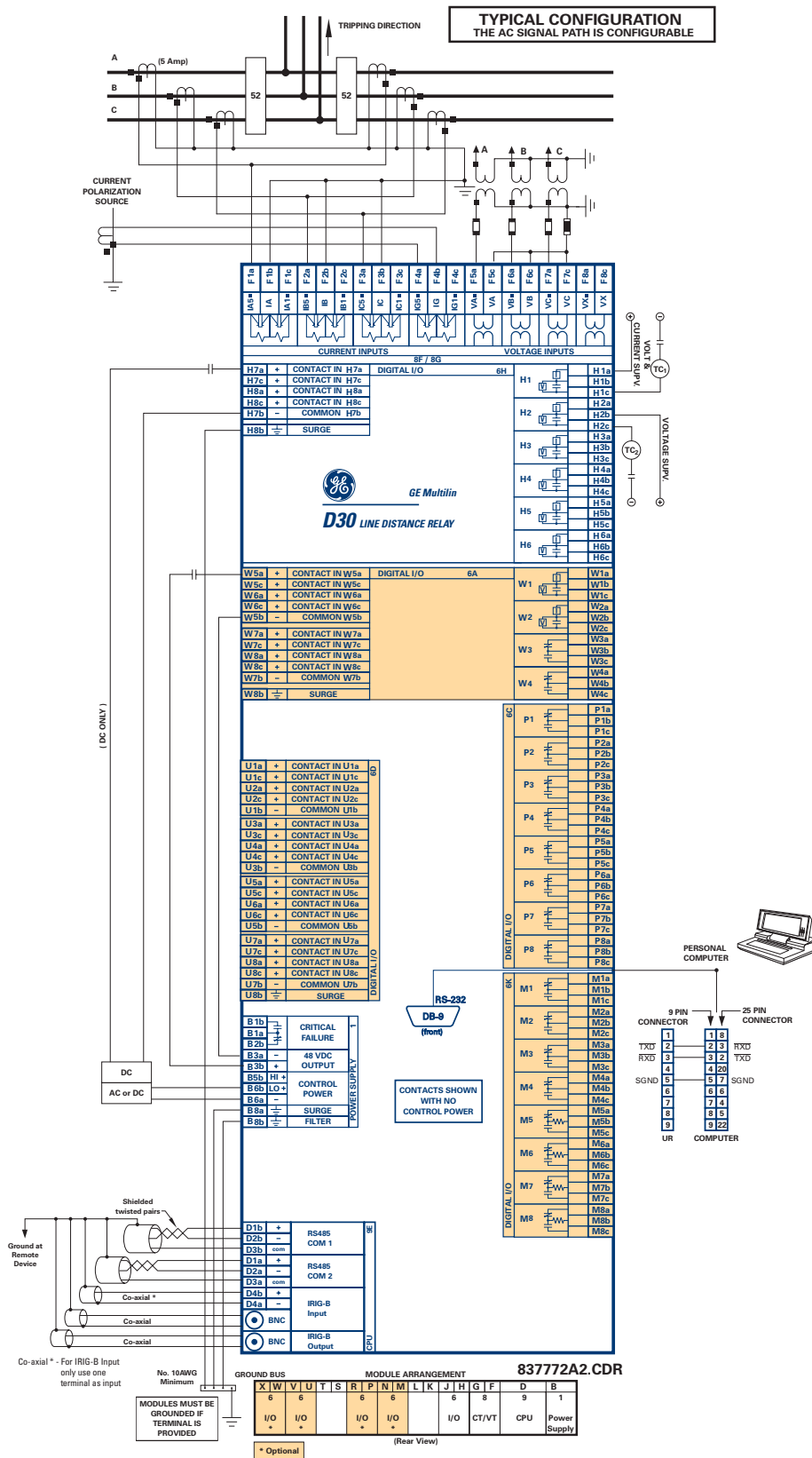


Figure 3-8: TYPICAL WIRING DIAGRAM

This diagram is based on the following order code: D60-E00-HCL-F8F-H6H-M6K-P6C-U6D-W6A. The purpose of this diagram is to provide an example of how the relay is typically wired, not specifically how to wire your own relay. Please refer to the following pages for examples to help you wire your own relay configuration and order code.

## 3.2.2 DIELECTRIC STRENGTH

The dielectric strength of the UR-series module hardware is shown in the following table:

**Table 3–1: DIELECTRIC STRENGTH OF UR-SERIES MODULE HARDWARE**

| MODULE TYPE | MODULE FUNCTION        | TERMINALS              |         | DIELECTRIC STRENGTH (AC) |
|-------------|------------------------|------------------------|---------|--------------------------|
|             |                        | FROM                   | TO      |                          |
| 1           | Power Supply           | High (+); Low (+); (–) | Chassis | 2000 V AC for 1 minute   |
| 1           | Power Supply           | 48 V DC (+) and (–)    | Chassis | 2000 V AC for 1 minute   |
| 1           | Power Supply           | Relay Terminals        | Chassis | 2000 V AC for 1 minute   |
| 2           | Reserved               | N/A                    | N/A     | N/A                      |
| 3           | Reserved               | N/A                    | N/A     | N/A                      |
| 4           | Reserved               | N/A                    | N/A     | N/A                      |
| 5           | Analog Inputs/Outputs  | All except 8b          | Chassis | < 50 V DC                |
| 6           | Digital Inputs/Outputs | All (See Precaution 2) | Chassis | 2000 V AC for 1 minute   |
| 9           | CPU                    | All                    | Chassis | 2000 V AC for 1 minute   |

Filter networks and transient protection clamps are used in module hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI) and electromagnetic interference (EMI). These protective components **can be damaged** by application of the ANSI/IEEE C37.90 specified test voltage for a period longer than the specified one minute.

## 3.2.3 CONTROL POWER



**CONTROL POWER SUPPLIED TO THE RELAY MUST BE CONNECTED TO THE MATCHING POWER SUPPLY RANGE OF THE RELAY. IF THE VOLTAGE IS APPLIED TO THE WRONG TERMINALS, DAMAGE MAY OCCUR!**



**The D30 relay, like almost all electronic relays, contains electrolytic capacitors. These capacitors are well known to be subject to deterioration over time if voltage is not applied periodically. Deterioration can be avoided by powering the relays up once a year.**

The power supply module can be ordered for two possible voltage ranges. Each range has a dedicated input connection for proper operation. The ranges are as shown below (see the Technical Specifications section for additional details):

- LO range: 24 to 48 V (DC only) nominal
- HI range: 125 to 250 V nominal

The power supply module provides power to the relay and supplies power for dry contact input connections.

The power supply module provides 48 V DC power for dry contact input connections and a critical failure relay (see the Typical Wiring Diagram earlier). The critical failure relay is a Form-C that will be energized once control power is applied and the relay has successfully booted up with no critical self-test failures. If on-going self-test diagnostic checks detect a critical failure (see the Self-Test Errors table in Chapter 7) or control power is lost, the relay will de-energize.

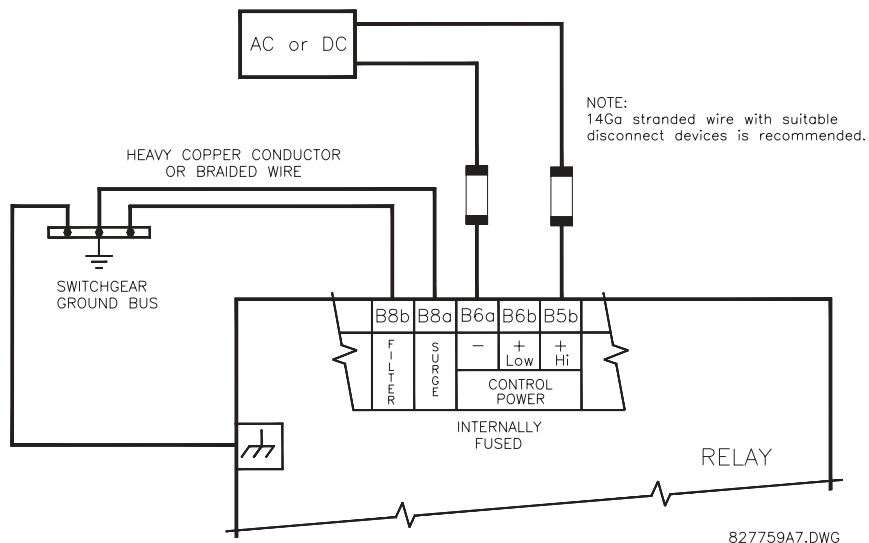


Figure 3-9: CONTROL POWER CONNECTION

## 3.2.4 CT/VT MODULES

A CT/VT module may have voltage inputs on Channels 1 through 4 inclusive, or Channels 5 through 8 inclusive. Channels 1 and 5 are intended for connection to Phase A, and are labeled as such in the relay. Channels 2 and 6 are intended for connection to Phase B, and are labeled as such in the relay. Channels 3 and 7 are intended for connection to Phase C and are labeled as such in the relay. Channels 4 and 8 are intended for connection to a single phase source. If voltage, this channel is labelled the auxiliary voltage (VX). If current, this channel is intended for connection to a CT between a system neutral and ground, and is labelled the ground current (IG).

## a) CT INPUTS



**VERIFY THAT THE CONNECTION MADE TO THE RELAY NOMINAL CURRENT OF 1 A OR 5 A MATCHES THE SECONDARY RATING OF THE CONNECTED CTs. UNMATCHED CTs MAY RESULT IN EQUIPMENT DAMAGE OR INADEQUATE PROTECTION.**

The CT/VT module may be ordered with a standard ground current input that is the same as the phase current inputs (Type 8F) or with a sensitive ground input (Type 8G) which is 10 times more sensitive (see the Technical Specifications section for additional details). Each AC current input has an isolating transformer and an automatic shorting mechanism that shorts the input when the module is withdrawn from the chassis. There are no internal ground connections on the current inputs. Current transformers with 1 to 50000 A primaries and 1 A or 5 A secondaries may be used.

CT connections for both ABC and ACB phase rotations are identical as shown in the *Typical Wiring Diagram*.

## b) VT INPUTS

The phase voltage channels are used for most metering and protection purposes. The auxiliary voltage channel is used as input for the Synchrocheck and Volts/Hertz features.

Substitute the tilde “~” symbol with the slot position of the module in the following figures.

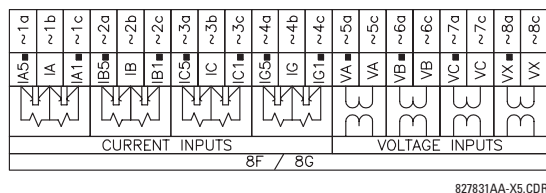


Figure 3-10: CT/VT MODULE WIRING

## 3.2.5 CONTACT INPUTS/OUTPUTS

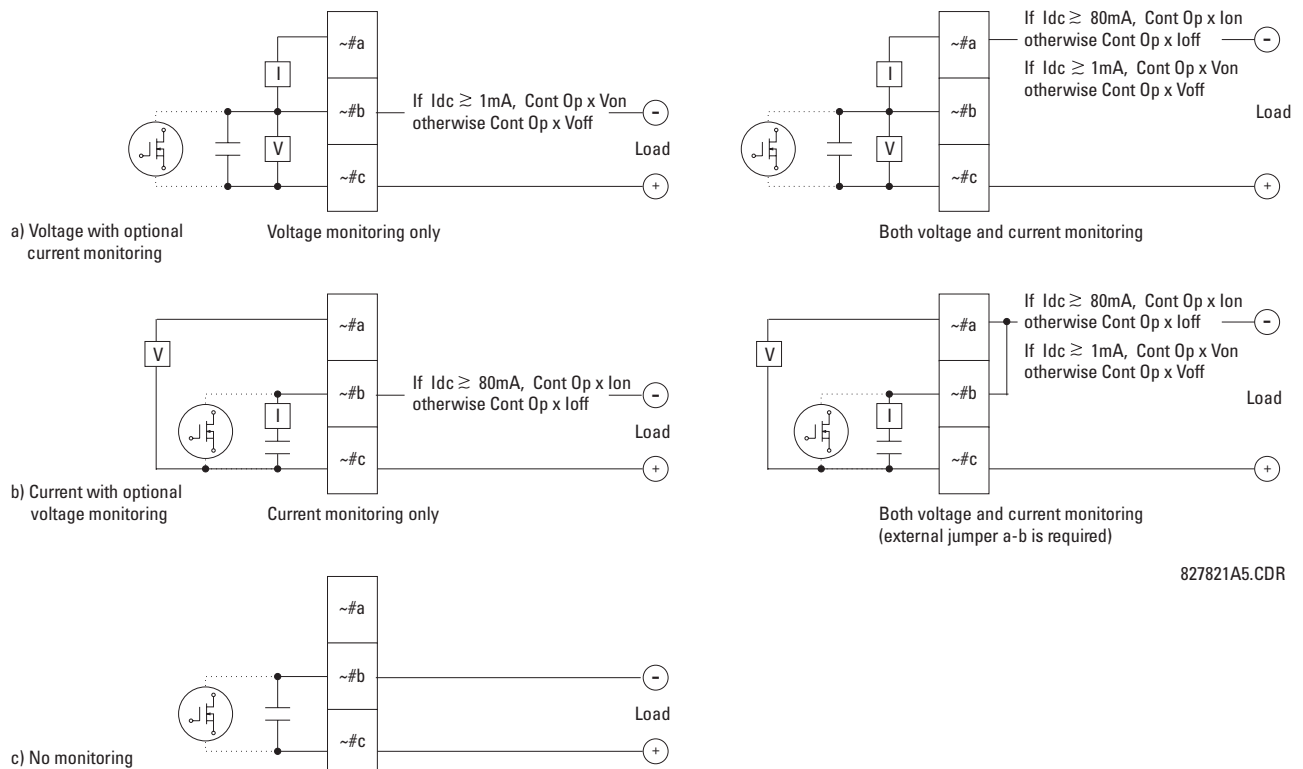
Every digital input/output module has 24 terminal connections. They are arranged as 3 terminals per row, with 8 rows in total. A given row of three terminals may be used for the outputs of one relay. For example, for Form-C relay outputs, the terminals connect to the normally open (NO), normally closed (NC), and common contacts of the relay. For a Form-A output, there are options of using current or voltage detection for feature supervision, depending on the module ordered. The terminal configuration for contact inputs is different for the two applications. When a digital input/output module is ordered with contact inputs, they are arranged in groups of four and use two rows of three terminals. Ideally, each input would be totally isolated from any other input. However, this would require that every input have two dedicated terminals and limit the available number of contacts based on the available number of terminals. So, although each input is individually optically isolated, each group of four inputs uses a single common as a reasonable compromise. This allows each group of four outputs to be supplied by wet contacts from different voltage sources (if required) or a mix of wet and dry contacts.

The tables and diagrams on the following pages illustrate the module types (6A, etc.) and contact arrangements that may be ordered for the relay. Since an entire row is used for a single contact output, the name is assigned using the module slot position and row number. However, since there are two contact inputs per row, these names are assigned by module slot position, row number, and column position.

**UR-SERIES FORM-A / SOLID STATE (SSR) OUTPUT CONTACTS:**

Some Form-A/SSR outputs include circuits to monitor the DC voltage across the output contact when it is open, and the DC current through the output contact when it is closed. Each of the monitors contains a level detector whose output is set to logic "On = 1" when the current in the circuit is above the threshold setting. The voltage monitor is set to "On = 1" when the current is above about 1 to 2.5 mA, and the current monitor is set to "On = 1" when the current exceeds about 80 to 100 mA. The voltage monitor is intended to check the health of the overall trip circuit, and the current monitor can be used to seal-in the output contact until an external contact has interrupted current flow. The block diagrams of the circuits are below above for the Form-A outputs with:

- a) optional voltage monitor
- b) optional current monitor
- c) with no monitoring

**Figure 3-11: FORM-A /SOLID STATE CONTACT FUNCTIONS**

The operation of voltage and current monitors is reflected with the corresponding FlexLogic™ operands (Cont Op # Von, Cont Op # Voff, Cont Op # Ion, and Cont Op # Ioff) which can be used in protection, control and alarm logic. The typical application of the voltage monitor is breaker trip circuit integrity monitoring; a typical application of the current monitor is seal-in of the control command. Refer to the *Digital Elements* section of Chapter 5 for an example of how Form-A/SSR contacts can be applied for breaker trip circuit integrity monitoring.



**Relay contacts must be considered unsafe to touch when the unit is energized! If the relay contacts need to be used for low voltage accessible applications, it is the customer's responsibility to ensure proper insulation levels!**



#### USE OF FORM-A/SSR OUTPUTS IN HIGH IMPEDANCE CIRCUITS

For Form-A/SSR output contacts internally equipped with a voltage measuring circuit across the contact, the circuit has an impedance that can cause a problem when used in conjunction with external high input impedance monitoring equipment such as modern relay test set trigger circuits. These monitoring circuits may continue to read the Form-A contact as being closed after it has closed and subsequently opened, when measured as an impedance.

The solution to this problem is to use the voltage measuring trigger input of the relay test set, and connect the Form-A contact through a voltage-dropping resistor to a DC voltage source. If the 48 V DC output of the power supply is used as a source, a 500  $\Omega$ , 10 W resistor is appropriate. In this configuration, the voltage across either the Form-A contact or the resistor can be used to monitor the state of the output.



Wherever a tilde “~” symbol appears, substitute with the Slot Position of the module; wherever a number sign “#” appears, substitute the contact number



When current monitoring is used to seal-in the Form-A/SSR contact outputs, the FlexLogic™ operand driving the contact output should be given a reset delay of 10 ms to prevent damage of the output contact (in situations when the element initiating the contact output is bouncing, at values in the region of the pickup value).

**Table 3–2: DIGITAL INPUT/OUTPUT MODULE ASSIGNMENTS**

| ~6A I/O MODULE      |                 | ~6B I/O MODULE      |                 | ~6C I/O MODULE      |        | ~6D I/O MODULE      |          |
|---------------------|-----------------|---------------------|-----------------|---------------------|--------|---------------------|----------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT | TERMINAL ASSIGNMENT | OUTPUT OR INPUT | TERMINAL ASSIGNMENT | OUTPUT | TERMINAL ASSIGNMENT | OUTPUT   |
| ~1                  | Form-A          | ~1                  | Form-A          | ~1                  | Form-C | ~1a, ~1c            | 2 Inputs |
| ~2                  | Form-A          | ~2                  | Form-A          | ~2                  | Form-C | ~2a, ~2c            | 2 Inputs |
| ~3                  | Form-C          | ~3                  | Form-C          | ~3                  | Form-C | ~3a, ~3c            | 2 Inputs |
| ~4                  | Form-C          | ~4                  | Form-C          | ~4                  | Form-C | ~4a, ~4c            | 2 Inputs |
| ~5a, ~5c            | 2 Inputs        | ~5                  | Form-C          | ~5                  | Form-C | ~5a, ~5c            | 2 Inputs |
| ~6a, ~6c            | 2 Inputs        | ~6                  | Form-C          | ~6                  | Form-C | ~6a, ~6c            | 2 Inputs |
| ~7a, ~7c            | 2 Inputs        | ~7a, ~7c            | 2 Inputs        | ~7                  | Form-C | ~7a, ~7c            | 2 Inputs |
| ~8a, ~8c            | 2 Inputs        | ~8a, ~8c            | 2 Inputs        | ~8                  | Form-C | ~8a, ~8c            | 2 Inputs |

| ~6E I/O MODULE      |                 | ~6F I/O MODULE      |             | ~6G I/O MODULE      |                 | ~6H I/O MODULE      |                 |
|---------------------|-----------------|---------------------|-------------|---------------------|-----------------|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT | TERMINAL ASSIGNMENT | OUTPUT      | TERMINAL ASSIGNMENT | OUTPUT OR INPUT | TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-C          | ~1                  | Fast Form-C | ~1                  | Form-A          | ~1                  | Form-A          |
| ~2                  | Form-C          | ~2                  | Fast Form-C | ~2                  | Form-A          | ~2                  | Form-A          |
| ~3                  | Form-C          | ~3                  | Fast Form-C | ~3                  | Form-A          | ~3                  | Form-A          |
| ~4                  | Form-C          | ~4                  | Fast Form-C | ~4                  | Form-A          | ~4                  | Form-A          |
| ~5a, ~5c            | 2 Inputs        | ~5                  | Fast Form-C | ~5a, ~5c            | 2 Inputs        | ~5                  | Form-A          |
| ~6a, ~6c            | 2 Inputs        | ~6                  | Fast Form-C | ~6a, ~6c            | 2 Inputs        | ~6                  | Form-A          |
| ~7a, ~7c            | 2 Inputs        | ~7                  | Fast Form-C | ~7a, ~7c            | 2 Inputs        | ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        | ~8                  | Fast Form-C | ~8a, ~8c            | 2 Inputs        | ~8a, ~8c            | 2 Inputs        |



| ~6K I/O MODULE      |             |
|---------------------|-------------|
| TERMINAL ASSIGNMENT | OUTPUT      |
| ~1                  | Form-C      |
| ~2                  | Form-C      |
| ~3                  | Form-C      |
| ~4                  | Form-C      |
| ~5                  | Fast Form-C |
| ~6                  | Fast Form-C |
| ~7                  | Fast Form-C |
| ~8                  | Fast Form-C |

| ~6L I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-C          |
| ~4                  | Form-C          |
| ~5a, ~5c            | 2 Inputs        |
| ~6a, ~6c            | 2 Inputs        |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6M I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-C          |
| ~4                  | Form-C          |
| ~5                  | Form-C          |
| ~6                  | Form-C          |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6N I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-A          |
| ~4                  | Form-A          |
| ~5a, ~5c            | 2 Inputs        |
| ~6a, ~6c            | 2 Inputs        |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6P I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-A          |
| ~4                  | Form-A          |
| ~5                  | Form-A          |
| ~6                  | Form-A          |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6R I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-C          |
| ~4                  | Form-C          |
| ~5a, ~5c            | 2 Inputs        |
| ~6a, ~6c            | 2 Inputs        |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6S I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-C          |
| ~4                  | Form-C          |
| ~5                  | Form-C          |
| ~6                  | Form-C          |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6T I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-A          |
| ~4                  | Form-A          |
| ~5a, ~5c            | 2 Inputs        |
| ~6a, ~6c            | 2 Inputs        |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~6U I/O MODULE      |                 |
|---------------------|-----------------|
| TERMINAL ASSIGNMENT | OUTPUT OR INPUT |
| ~1                  | Form-A          |
| ~2                  | Form-A          |
| ~3                  | Form-A          |
| ~4                  | Form-A          |
| ~5                  | Form-A          |
| ~6                  | Form-A          |
| ~7a, ~7c            | 2 Inputs        |
| ~8a, ~8c            | 2 Inputs        |

| ~67 I/O MODULE      |        |
|---------------------|--------|
| TERMINAL ASSIGNMENT | OUTPUT |
| ~1                  | Form-A |
| ~2                  | Form-A |
| ~3                  | Form-A |
| ~4                  | Form-A |
| ~5                  | Form-A |
| ~6                  | Form-A |
| ~7                  | Form-A |
| ~8                  | Form-A |

| ~4A I/O MODULE      |             |
|---------------------|-------------|
| TERMINAL ASSIGNMENT | OUTPUT      |
| ~1                  | Not Used    |
| ~2                  | Solid-State |
| ~3                  | Not Used    |
| ~4                  | Solid-State |
| ~5                  | Not Used    |
| ~6                  | Solid-State |
| ~7                  | Not Used    |
| ~8                  | Solid-State |

| ~4B I/O MODULE      |             |
|---------------------|-------------|
| TERMINAL ASSIGNMENT | OUTPUT      |
| ~1                  | Not Used    |
| ~2                  | Solid-State |
| ~3                  | Not Used    |
| ~4                  | Solid-State |
| ~5                  | Not Used    |
| ~6                  | Solid-State |
| ~7                  | Not Used    |
| ~8                  | Solid-State |

| ~4C I/O MODULE      |             |
|---------------------|-------------|
| TERMINAL ASSIGNMENT | OUTPUT      |
| ~1                  | Not Used    |
| ~2                  | Solid-State |
| ~3                  | Not Used    |
| ~4                  | Solid-State |
| ~5                  | Not Used    |
| ~6                  | Solid-State |
| ~7                  | Not Used    |
| ~8                  | Solid-State |

| ~4L I/O MODULE      |           |
|---------------------|-----------|
| TERMINAL ASSIGNMENT | OUTPUT    |
| ~1                  | 2 Outputs |
| ~2                  | 2 Outputs |
| ~3                  | 2 Outputs |
| ~4                  | 2 Outputs |
| ~5                  | 2 Outputs |
| ~6                  | 2 Outputs |
| ~7                  | 2 Outputs |
| ~8                  | Not Used  |

| ~5a   | + | CONTACT IN ~5a | DIGITAL I/O | 6A | ~1a | ~1b | ~1c | ~2a | ~2b | ~2c | ~3a | ~3b | ~3c | ~4a | ~4b | ~4c |
|-------|---|----------------|-------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| ~5c   | + | CONTACT IN ~5c |             | ~1 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~6a   | + | CONTACT IN ~6a |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~6c   | + | CONTACT IN ~6c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~5b   | - | COMMON ~5b     |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7a   | + | CONTACT IN ~7a |             | ~2 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7c   | + | CONTACT IN ~7c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8a   | + | CONTACT IN ~8a |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8c   | + | CONTACT IN ~8c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7b   | - | COMMON ~7b     |             | ~3 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8b   | - | COMMON ~8b     |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| SURGE |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
|       |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |

| ~5a   | + | CONTACT IN ~5a | DIGITAL I/O | 6N | ~1a | ~1b | ~1c | ~2a | ~2b | ~2c | ~3a | ~3b | ~3c | ~4a | ~4b | ~4c |
|-------|---|----------------|-------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| ~5c   | + | CONTACT IN ~5c |             | ~1 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~6a   | + | CONTACT IN ~6a |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~6c   | + | CONTACT IN ~6c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~5b   | - | COMMON ~5b     |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7a   | + | CONTACT IN ~7a |             | ~2 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7c   | + | CONTACT IN ~7c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8a   | + | CONTACT IN ~8a |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8c   | + | CONTACT IN ~8c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7b   | - | COMMON ~7b     |             | ~3 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8b   | - | COMMON ~8b     |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| SURGE |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
|       |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |

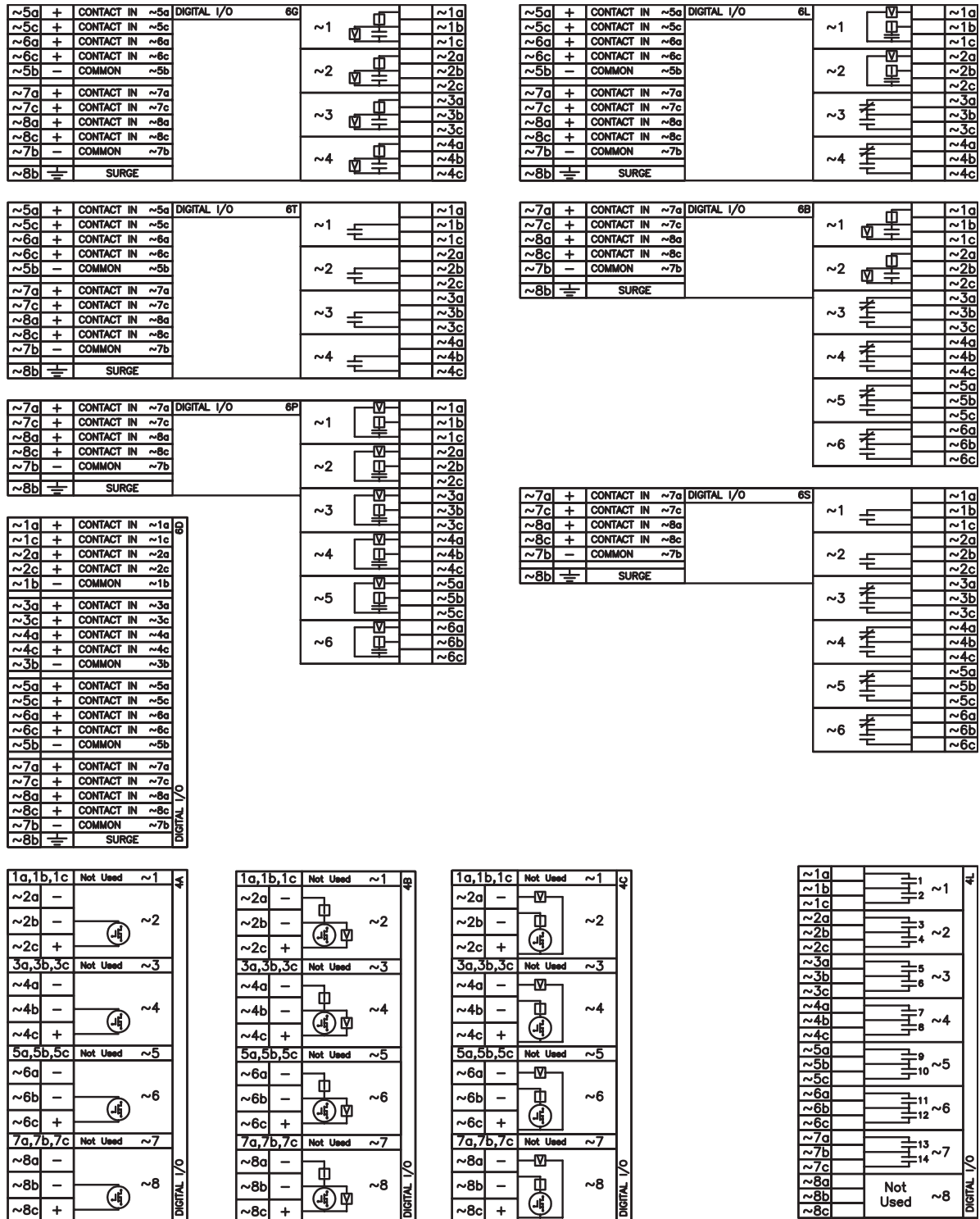
  

| ~7a   | + | CONTACT IN ~7a | DIGITAL I/O | 6H | ~1a | ~1b | ~1c | ~2a | ~2b | ~2c | ~3a | ~3b | ~3c | ~4a | ~4b | ~4c |
|-------|---|----------------|-------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| ~7c   | + | CONTACT IN ~7c |             | ~1 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8a   | + | CONTACT IN ~8a |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8c   | + | CONTACT IN ~8c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7b   | - | COMMON ~7b     |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8b   | - | COMMON ~8b     |             | ~2 |     |     |     |     |     |     |     |     |     |     |     |     |
| SURGE |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
|       |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
|       |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |

| ~7a   | + | CONTACT IN ~7a | DIGITAL I/O | 6U | ~1a | ~1b | ~1c | ~2a | ~2b | ~2c | ~3a | ~3b | ~3c | ~4a | ~4b | ~4c |
|-------|---|----------------|-------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| ~7c   | + | CONTACT IN ~7c |             | ~1 |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8a   | + | CONTACT IN ~8a |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8c   | + | CONTACT IN ~8c |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~7b   | - | COMMON ~7b     |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
| ~8b   | - | COMMON ~8b     |             | ~2 |     |     |     |     |     |     |     |     |     |     |     |     |
| SURGE |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |
|       |   |                |             |    |     |     |     |     |     |     |     |     |     |     |     |     |

827719CY-X1.dwg



⎓ - MOSFET Solid State Contact

827719CY-X2.dwg

Figure 3-13: DIGITAL INPUT/OUTPUT MODULE WIRING (2 of 2)



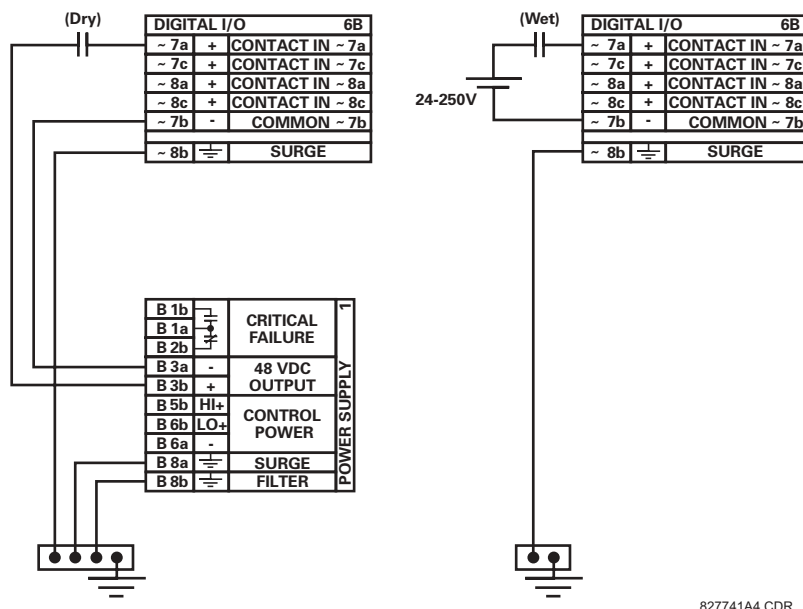
**CORRECT POLARITY MUST BE OBSERVED FOR ALL CONTACT INPUT AND SOLID STATE OUTPUT CONNECTIONS FOR PROPER FUNCTIONALITY.**

A dry contact has one side connected to Terminal B3b. This is the positive 48 V DC voltage rail supplied by the power supply module. The other side of the dry contact is connected to the required contact input terminal. Each contact input group has its own common (negative) terminal which must be connected to the DC negative terminal (B3a) of the power supply module. When a dry contact closes, a current of 1 to 3 mA will flow through the associated circuit.

A wet contact has one side connected to the positive terminal of an external DC power supply. The other side of this contact is connected to the required contact input terminal. In addition, the negative side of the external source must be connected to the relay common (negative) terminal of each contact input group. The maximum external source voltage for this arrangement is 300 V DC.

The voltage threshold at which each group of four contact inputs will detect a closed contact input is programmable as 17 V DC for 24 V sources, 33 V DC for 48 V sources, 84 V DC for 110 to 125 V sources, and 166 V DC for 250 V sources.

3



827741A4.CDR

Figure 3-14: DRY AND WET CONTACT INPUT CONNECTIONS



Wherever a tilde “~” symbol appears, substitute with the Slot Position of the module.

NOTE

Contact outputs may be ordered as Form-A or Form-C. The Form A contacts may be connected for external circuit supervision. These contacts are provided with voltage and current monitoring circuits used to detect the loss of DC voltage in the circuit, and the presence of DC current flowing through the contacts when the Form-A contact closes. If enabled, the current monitoring can be used as a seal-in signal to ensure that the Form-A contact does not attempt to break the energized inductive coil circuit and weld the output contacts.



There is no provision in the relay to detect a DC ground fault on 48 V DC control power external output. We recommend using an external DC supply.

NOTE

## 3.2.6 TRANSDUCER INPUTS/OUTPUTS

Transducer input modules can receive input signals from external dcmA output transducers (dcmA In) or resistance temperature detectors (RTD). Hardware and software is provided to receive signals from these external transducers and convert these signals into a digital format for use as required.

Transducer output modules provide DC current outputs in several standard dcmA ranges. Software is provided to configure virtually any analog quantity used in the relay to drive the analog outputs.

Every transducer input/output module has a total of 24 terminal connections. These connections are arranged as three terminals per row with a total of eight rows. A given row may be used for either inputs or outputs, with terminals in column "a" having positive polarity and terminals in column "c" having negative polarity. Since an entire row is used for a single input/output channel, the name of the channel is assigned using the module slot position and row number.

Each module also requires that a connection from an external ground bus be made to Terminal 8b. The current outputs require a twisted-pair shielded cable, where the shield is grounded at one end only. The figure below illustrates the transducer module types (5A, 5C, 5D, 5E, and 5F) and channel arrangements that may be ordered for the relay.



Wherever a tilde "~" symbol appears, substitute with the Slot Position of the module.

NOTE

|     |   |             |            |
|-----|---|-------------|------------|
| ~1a | + | dcmA In ~1  | 5A         |
| ~1c | - |             |            |
| ~2a | + | dcmA In ~2  |            |
| ~2c | - |             |            |
| ~3a | + | dcmA In ~3  |            |
| ~3c | - |             |            |
| ~4a | + | dcmA In ~4  |            |
| ~4c | - |             |            |
| ~5a | + | dcmA Out ~5 |            |
| ~5c | - |             |            |
| ~6a | + | dcmA Out ~6 |            |
| ~6c | - |             |            |
| ~7a | + | dcmA Out ~7 |            |
| ~7c | - |             |            |
| ~8a | + | dcmA Out ~8 |            |
| ~8c | - |             |            |
| ~8b | ⏏ | SURGE       | ANALOG I/O |

|     |        |                |            |
|-----|--------|----------------|------------|
| ~1a | Hot    | RTD ~1         | 5C         |
| ~1c | Comp   |                |            |
| ~1b | Return | for RTD ~1& ~2 |            |
| ~2a | Hot    | RTD ~2         |            |
| ~2c | Comp   |                |            |
| ~3a | Hot    | RTD ~3         |            |
| ~3c | Comp   |                |            |
| ~3b | Return | for RTD ~3& ~4 |            |
| ~4a | Hot    | RTD ~4         |            |
| ~4c | Comp   |                |            |
| ~5a | Hot    | RTD ~5         |            |
| ~5c | Comp   |                |            |
| ~5b | Return | for RTD ~5& ~6 |            |
| ~6a | Hot    | RTD ~6         |            |
| ~6c | Comp   |                |            |
| ~7a | Hot    | RTD ~7         |            |
| ~7c | Comp   |                |            |
| ~7b | Return | for RTD ~7& ~8 |            |
| ~8a | Hot    | RTD ~8         |            |
| ~8c | Comp   |                |            |
| ~8b | ⏏      | SURGE          | ANALOG I/O |

|     |        |                |            |
|-----|--------|----------------|------------|
| ~1a | Hot    | RTD ~1         | 5D         |
| ~1c | Comp   |                |            |
| ~1b | Return | for RTD ~1& ~2 |            |
| ~2a | Hot    | RTD ~2         |            |
| ~2c | Comp   |                |            |
| ~3a | Hot    | RTD ~3         |            |
| ~3c | Comp   |                |            |
| ~3b | Return | for RTD ~3& ~4 |            |
| ~4a | Hot    | RTD ~4         |            |
| ~4c | Comp   |                |            |
| ~5a | +      | dcmA Out ~5    |            |
| ~5c | -      |                |            |
| ~6a | +      | dcmA Out ~6    |            |
| ~6c | -      |                |            |
| ~7a | +      | dcmA Out ~7    |            |
| ~7c | -      |                |            |
| ~8a | +      | dcmA Out ~8    |            |
| ~8c | -      |                |            |
| ~8b | ⏏      | SURGE          | ANALOG I/O |

|     |        |                |            |
|-----|--------|----------------|------------|
| ~1a | +      | dcmA In ~1     | 5E         |
| ~1c | -      |                |            |
| ~2a | +      | dcmA In ~2     |            |
| ~2c | -      |                |            |
| ~3a | +      | dcmA In ~3     |            |
| ~3c | -      |                |            |
| ~4a | +      | dcmA In ~4     |            |
| ~4c | -      |                |            |
| ~5a | Hot    | RTD ~5         |            |
| ~5c | Comp   |                |            |
| ~5b | Return | for RTD ~5& ~6 |            |
| ~6a | Hot    | RTD ~6         |            |
| ~6c | Comp   |                |            |
| ~7a | Hot    | RTD ~7         |            |
| ~7c | Comp   |                |            |
| ~7b | Return | for RTD ~7& ~8 |            |
| ~8a | Hot    | RTD ~8         |            |
| ~8c | Comp   |                |            |
| ~8b | ⏏      | SURGE          | ANALOG I/O |

|     |   |            |            |
|-----|---|------------|------------|
| ~1a | + | dcmA In ~1 | 5F         |
| ~1c | - |            |            |
| ~2a | + | dcmA In ~2 |            |
| ~2c | - |            |            |
| ~3a | + | dcmA In ~3 |            |
| ~3c | - |            |            |
| ~4a | + | dcmA In ~4 |            |
| ~4c | - |            |            |
| ~5a | + | dcmA In ~5 |            |
| ~5c | - |            |            |
| ~6a | + | dcmA In ~6 |            |
| ~6c | - |            |            |
| ~7a | + | dcmA In ~7 |            |
| ~7c | - |            |            |
| ~8a | + | dcmA In ~8 |            |
| ~8c | - |            |            |
| ~8b | ⏏ | SURGE      | ANALOG I/O |

827831AB-X1.CDR

Figure 3–15: TRANSDUCER INPUT/OUTPUT MODULE WIRING

## 3.2.7 RS232 FACEPLATE PORT

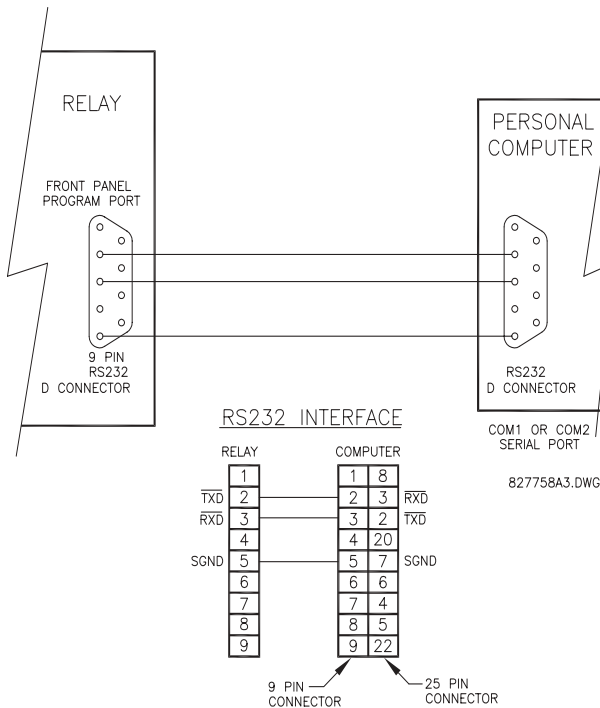
A 9-pin RS232C serial port is located on the relay's faceplate for programming with a portable (personal) computer. All that is required to use this interface is a personal computer running the enerVista UR Setup software provided with the relay. Cabling for the RS232 port is shown in the following figure for both 9 pin and 25 pin connectors.



The baud rate for this port is fixed at **19200 bps**.

Front panel 9 pin RS232 Program port

- 1: N/A
- 2: (TXD)
- 3: (RXD)
- 4: N/A
- 5: (SGND) Signal Ground
- 6: N/A
- 7: N/A
- 8: N/A
- 9: N/A



**Figure 3-16: RS232 FACEPLATE PORT CONNECTION**

## 3.2.8 CPU COMMUNICATION PORTS

## a) OPTIONS

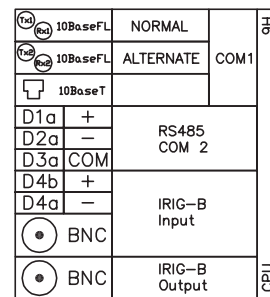
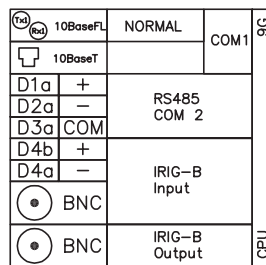
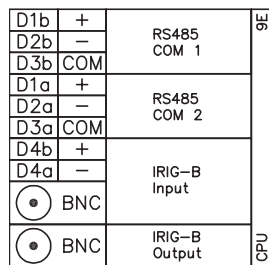
In addition to the RS232 port on the faceplate, the relay provides the user with two additional communication port(s) depending on the CPU module installed.



The 9E, 9G, and 9H CPU modules do not require a surge ground connection.

NOTE

| CPU TYPE | COM1                  | COM2  |
|----------|-----------------------|-------|
| 9E       | RS485                 | RS485 |
| 9G       | 10Base-F and 10Base-T | RS485 |
| 9H       | Redundant 10Base-F    | RS485 |



827831AB-X6.DWG

Figure 3-17: CPU MODULE COMMUNICATIONS WIRING

## b) RS485 PORTS

RS485 data transmission and reception are accomplished over a single twisted pair with transmit and receive data alternating over the same two wires. Through the use of these port(s), continuous monitoring and control from a remote computer, SCADA system or PLC is possible.

To minimize errors from noise, the use of shielded twisted pair wire is recommended. Correct polarity must also be observed. For instance, the relays must be connected with all RS485 "+" terminals connected together, and all RS485 "-" terminals connected together. The COM terminal should be connected to the common wire inside the shield, when provided. To avoid loop currents, the shield should be grounded at one point only. Each relay should also be daisy chained to the next one in the link. A maximum of 32 relays can be connected in this manner without exceeding driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to increase the number of relays on a single channel to more than 32. Star or stub connections should be avoided entirely.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are internally provided at both communication ports. An isolated power supply with an optocoupled data interface also acts to reduce noise coupling. To ensure maximum reliability, all equipment should have similar transient protection devices installed.

Both ends of the RS485 circuit should also be terminated with an impedance as shown below.

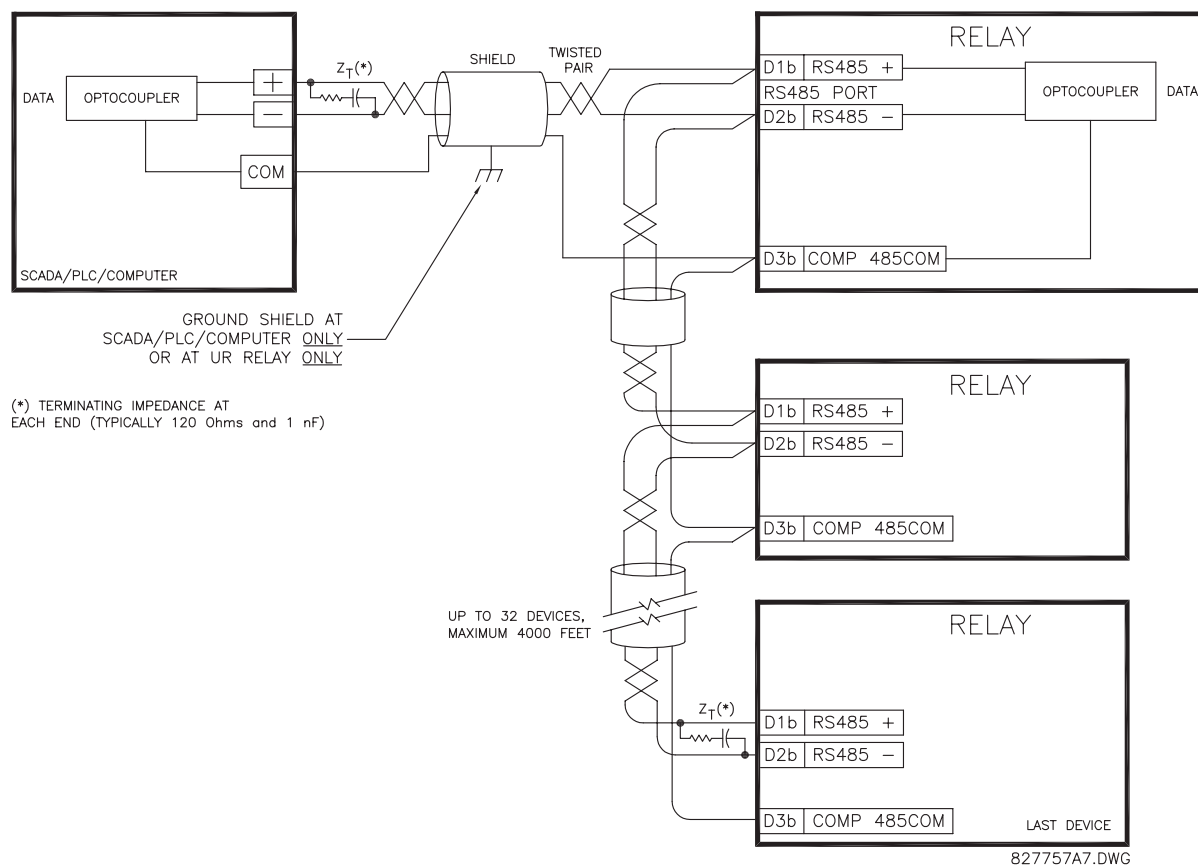


Figure 3-18: RS485 SERIAL CONNECTION

## c) 10BASE-F FIBER OPTIC PORT



CAUTION

**ENSURE THE DUST COVERS ARE INSTALLED WHEN THE FIBER IS NOT IN USE. DIRTY OR SCRATCHED CONNECTORS CAN LEAD TO HIGH LOSSES ON A FIBER LINK.**



CAUTION

**OBSERVING ANY FIBER TRANSMITTER OUTPUT MAY CAUSE INJURY TO THE EYE.**

The fiber optic communication ports allow for fast and efficient communications between relays at 10 Mbps. Optical fiber may be connected to the relay supporting a wavelength of 820 nanometers in multimode. Optical fiber is only available for CPU types 9G and 9H. The 9H CPU has a 10BaseF transmitter and receiver for optical fiber communications and a second pair of identical optical fiber transmitter and receiver for redundancy.

The optical fiber sizes supported include 50/125  $\mu\text{m}$ , 62.5/125  $\mu\text{m}$  and 100/140  $\mu\text{m}$ . The fiber optic port is designed such that the response times will not vary for any core that is 100  $\mu\text{m}$  or less in diameter. For optical power budgeting, splices are required every 1 km for the transmitter/receiver pair (the ST type connector contributes for a connector loss of 0.2 dB). When splicing optical fibers, the diameter and numerical aperture of each fiber must be the same. In order to engage or disengage the ST type connector, only a quarter turn of the coupling is required.



## 3.2.9 IRIG-B

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices within 1 millisecond. The IRIG time code formats are serial, width-modulated codes which can be either DC level shifted or amplitude modulated (AM). Third party equipment is available for generating the IRIG-B signal; this equipment may use a GPS satellite system to obtain the time reference so that devices at different geographic locations can also be synchronized.

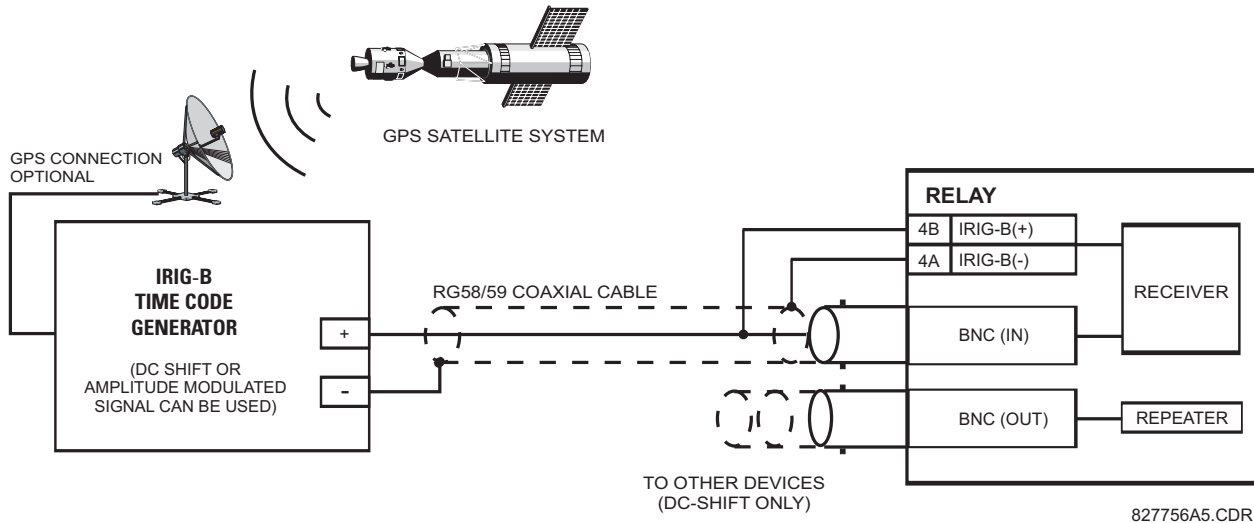


Figure 3-19: IRIG-B CONNECTION

The IRIG-B repeater provides an amplified DC-shift IRIG-B signal to other equipment. By using one IRIG-B serial connection, several UR-series relays can be synchronized. The IRIG-B repeater has a bypass function to maintain the time signal even when a relay in the series is powered down.

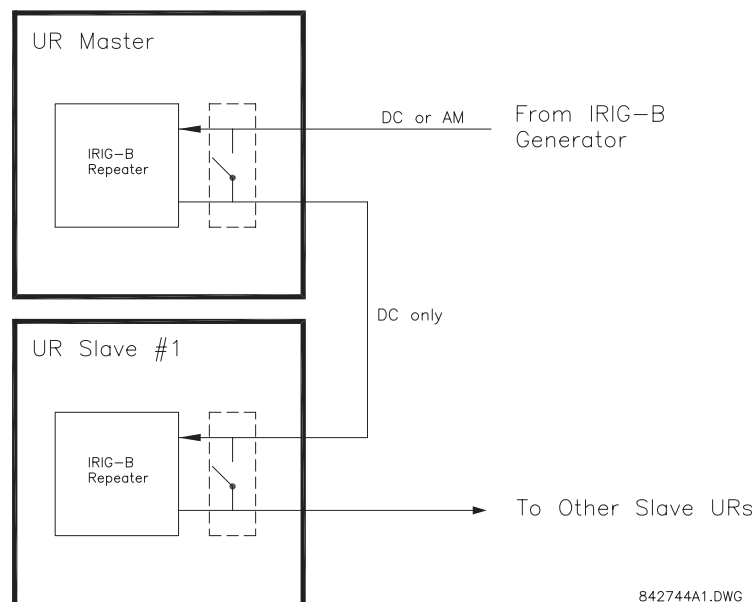


Figure 3-20: IRIG-B REPEATER

## 3.3.1 DESCRIPTION

The D30 direct inputs/outputs feature makes use of the Type 7 series of communications modules. These modules are also used by the L90 Line Differential Relay for inter-relay communications. The direct input/output feature uses the communications channel(s) provided by these modules to exchange digital state information between relays. This feature is available on all UR-series relay models except for the L90 Line Differential relay.

The communications channels are normally connected in a ring configuration as shown below. The transmitter of one module is connected to the receiver of the next module. The transmitter of this second module is then connected to the receiver of the next module in the ring. This is continued to form a communications ring. The figure below illustrates a ring of four UR-series relays with the following connections: UR1-Tx to UR2-Rx, UR2-Tx to UR3-Rx, UR3-Tx to UR4-Rx, and UR4-Tx to UR1-Rx. A maximum of eight (8) UR-series relays can be connected in a single ring

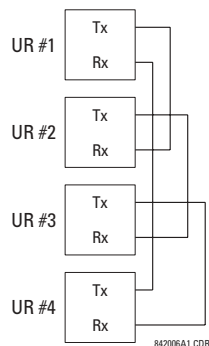


Figure 3–21: DIRECT INPUT/OUTPUT SINGLE CHANNEL CONNECTION

The interconnection for dual-channel Type 7 communications modules is shown below. Two channel modules allow for a redundant ring configuration. That is, two rings can be created to provide an additional independent data path. The required connections are: UR1-Tx1 to UR2-Rx1, UR2-Tx1 to UR3-Rx1, UR3-Tx1 to UR4-Rx1, and UR4-Tx1 to UR1-Rx1 for the first ring; and UR1-Tx2 to UR2-Rx2, UR2-Tx2 to UR3-Rx2, UR3-Tx2 to UR4-Rx2, and UR4-Tx2 to UR1-Rx2 for the second ring.

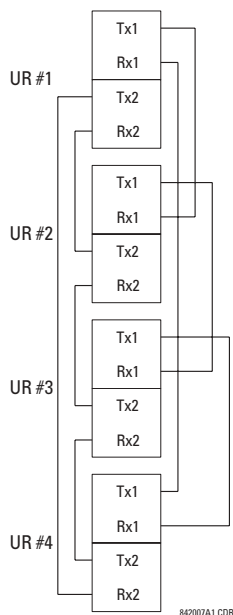
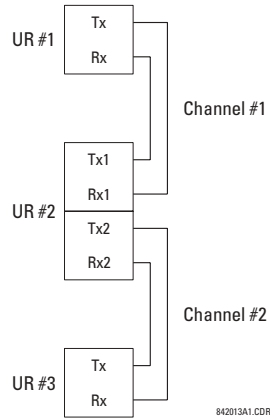


Figure 3–22: DIRECT INPUT/OUTPUT DUAL CHANNEL CONNECTION

The following diagram shows the connection for three UR-series relays using two independent communication channels. UR1 and UR3 have single Type 7 communication modules; UR2 has a dual-channel module. The two communication channels can be of different types, depending on the Type 7 modules used. To allow the direct input/output data to 'cross-over' from Channel 1 to Channel 2 on UR2, the **DIRECT I/O CHANNEL CROSSOVER** setting should be "Enabled" on UR2. This forces UR2 to forward messages received on Rx1 out Tx2, and messages received on Rx2 out Tx1.



**Figure 3–23: DIRECT INPUT/OUTPUT SINGLE/DUAL CHANNEL COMBINATION CONNECTION**

The interconnection requirements are described in further detail in this section for each specific variation of Type 7 communications module. These modules are listed in the following table. All fiber modules use ST type connectors.

**Table 3–3: CHANNEL COMMUNICATION OPTIONS**

| MODULE | SPECIFICATION   |
|--------|---|
| 2A     | C37.94SM, 1300 nm, single-mode, ELED, 1 channel single-mode |
| 2B     | C37.94SM, 1300 nm, single-mode, ELED, 2 channel single-mode |
| 7A     | 820 nm, multi-mode, LED, 1 channel                          |
| 7B     | 1300 nm, multi-mode, LED, 1 channel                         |
| 7C     | 1300 nm, single-mode, ELED, 1 channel                       |
| 7D     | 1300 nm, single-mode, LASER, 1 channel                      |
| 7E     | Channel 1: G.703, Channel 2: 820 nm, multi-mode             |
| 7F     | Channel 1: G.703, Channel 2: 1300 nm, multi-mode            |
| 7G     | Channel 1: G.703, Channel 2: 1300 nm, single-mode ELED      |
| 7H     | 820 nm, multi-mode, LED, 2 channels                         |
| 7I     | 1300 nm, multi-mode, LED, 2 channels                        |
| 7J     | 1300 nm, single-mode, ELED, 2 channels                      |
| 7K     | 1300 nm, single-mode, LASER, 2 channels                     |
| 7L     | Channel 1: RS422, Channel: 820 nm, multi-mode, LED          |
| 7M     | Channel 1: RS422, Channel 2: 1300 nm, multi-mode, LED       |
| 7N     | Channel 1: RS422, Channel 2: 1300 nm, single-mode, ELED     |
| 7P     | Channel 1: RS422, Channel 2: 1300 nm, single-mode, LASER    |
| 7Q     | Channel 1: G.703, Channel 2: 1300 nm, single-mode, LASER    |
| 7R     | G.703, 1 channel  |
| 7S     | G.703, 2 channels   |
| 7T     | RS422, 1 channel  |
| 7W     | RS422, 2 channels   |
| 72     | 1550 nm, single-mode, LASER, 1 channel                      |
| 73     | 1550 nm, single-mode, LASER, 2 channels                     |
| 74     | Channel 1 - RS422; Channel 2 - 1550 nm, single-mode, LASER  |
| 75     | Channel 1 - G.703; Channel 2 - 1550 nm, single-mode, LASER  |
| 76     | IEEE C37.94, 820 nm, multi-mode, LED, 1 channel             |
| 77     | IEEE C37.94, 820 nm, multi-mode, LED, 2 channels            |



**OBSERVING ANY FIBER TRANSMITTER OUTPUT MAY CAUSE INJURY TO THE EYE.**

## 3.3.2 FIBER: LED AND ELED TRANSMITTERS

The following figure shows the configuration for the 7A, 7B, 7C, 7H, 7I, and 7J fiber-only modules.

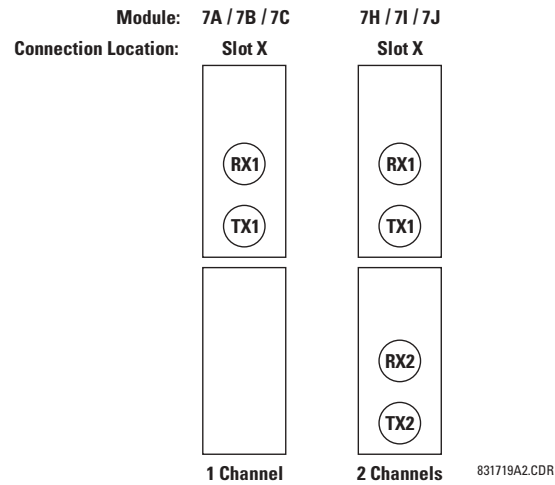


Figure 3–24: LED AND ELED FIBER MODULES

## 3.3.3 FIBER-LASER TRANSMITTERS

The following figure shows the configuration for the 72, 73, 7D, and 7K fiber-laser module.

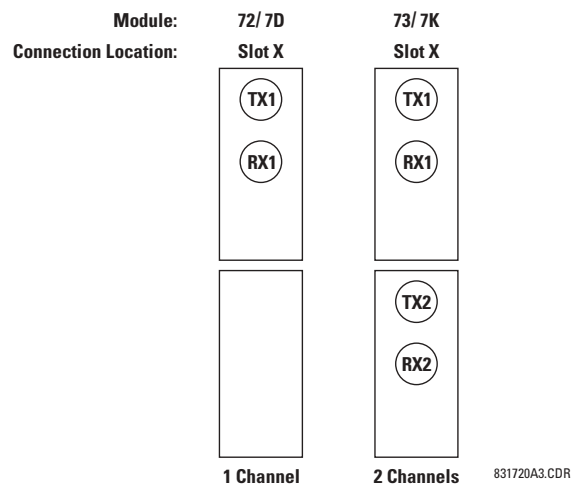


Figure 3–25: LASER FIBER MODULES



When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.

## 3.3.4 G.703 INTERFACE

## a) DESCRIPTION

The following figure shows the 64K ITU G.703 co-directional interface configuration.



**The G.703 module is fixed at 64 kbps only. The SETTINGS ⇒ PRODUCT SETUP ⇒ DIRECT I/O ⇒ DIRECT I/O DATA RATE setting is not applicable to this module.**

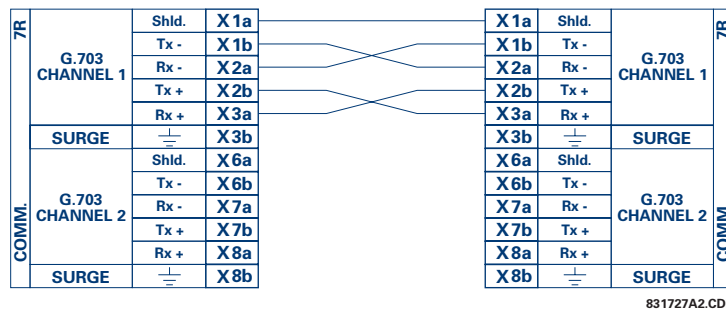
AWG 22 twisted shielded pair is recommended for external connections, with the shield grounded only at one end. Connecting the shield to Pin X1a or X6a grounds the shield since these pins are internally connected to ground. Thus, if Pin X1a or X6a is used, do not ground at the other end. This interface module is protected by surge suppression devices.

|             |                    |       |     |
|-------------|--------------------|-------|-----|
| 7R<br>COMM. | G.703<br>CHANNEL 1 | Shld. | X1a |
|             |                    | Tx -  | X1b |
|             |                    | Rx -  | X2a |
|             |                    | Tx +  | X2b |
|             |                    | Rx +  | X3a |
|             | SURGE              |       | X3b |
|             | G.703<br>CHANNEL 2 | Shld. | X6a |
|             |                    | Tx -  | X6b |
|             |                    | Rx -  | X7a |
|             |                    | Tx +  | X7b |
|             |                    | Rx +  | X8a |
|             | SURGE              |       | X8b |

831727A2-X1.CDR

Figure 3-26: G.703 INTERFACE CONFIGURATION

The following figure shows the typical pin interconnection between two G.703 interfaces. For the actual physical arrangement of these pins, see the Rear Terminal Assignments section earlier in this chapter. All pin interconnections are to be maintained for a connection to a multiplexer.



831727A2.CDR

Figure 3-27: TYPICAL PIN INTERCONNECTION BETWEEN TWO G.703 INTERFACES



Pin nomenclature may differ from one manufacturer to another. Therefore, it is not uncommon to see pinouts numbered TxA, TxB, RxA and RxB. In such cases, it can be assumed that "A" is equivalent to "+" and "B" is equivalent to "-".

## b) G.703 SELECTION SWITCH PROCEDURES

1. Remove the G.703 module (7R or 7S):

The ejector/inserter clips located at the top and at the bottom of each module, must be pulled simultaneously in order to release the module for removal. Before performing this action, **control power must be removed from the relay**. The original location of the module should be recorded to help ensure that the same or replacement module is inserted into the correct slot.

2. Remove the module cover screw.
3. Remove the top cover by sliding it towards the rear and then lift it upwards.
4. Set the Timing Selection Switches (Channel 1, Channel 2) to the desired timing modes.
5. Replace the top cover and the cover screw.

6. Re-insert the G.703 module. Take care to ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/insertor clips located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module will be fully inserted.

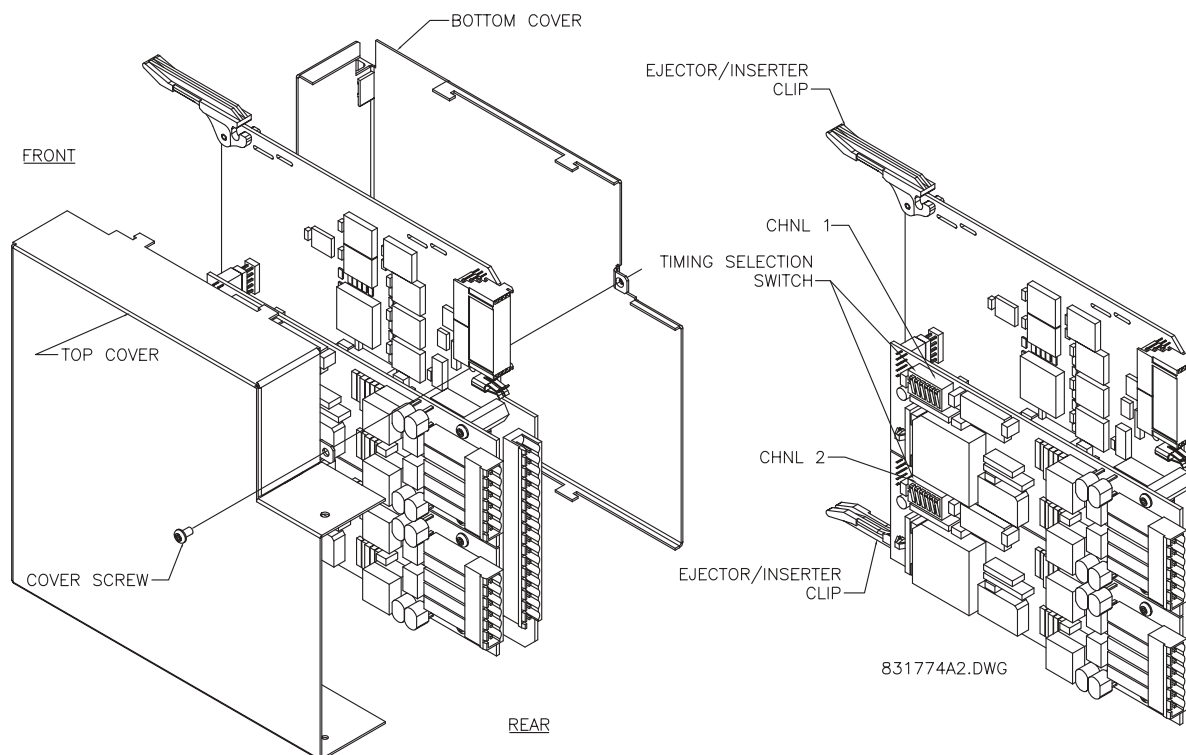


Figure 3-28: G.703 TIMING SELECTION SWITCH SETTING

Table 3-4: G.703 TIMING SELECTIONS

| SWITCHES  | FUNCTION   |
|-----------|--|
| S1        | OFF → Octet Timing Disabled<br>ON → Octet Timing 8 kHz   |
| S5 and S6 | S5 = OFF and S6 = OFF → Loop Timing Mode<br>S5 = ON and S6 = OFF → Internal Timing Mode<br>S5 = OFF and S6 = ON → Minimum Remote Loopback Mode<br>S5 = ON and S6 = ON → Dual Loopback Mode |

#### c) OCTET TIMING (SWITCH S1)

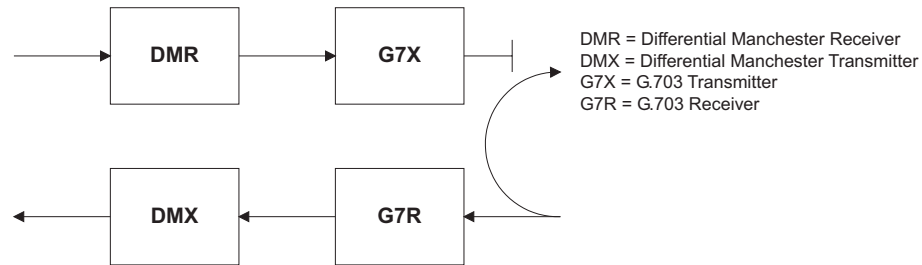
If Octet Timing is enabled (ON), this 8 kHz signal will be asserted during the violation of Bit 8 (LSB) necessary for connecting to higher order systems. When D30s are connected back to back, Octet Timing should be disabled (OFF).

#### d) TIMING MODES (SWITCHES S5 AND S6)

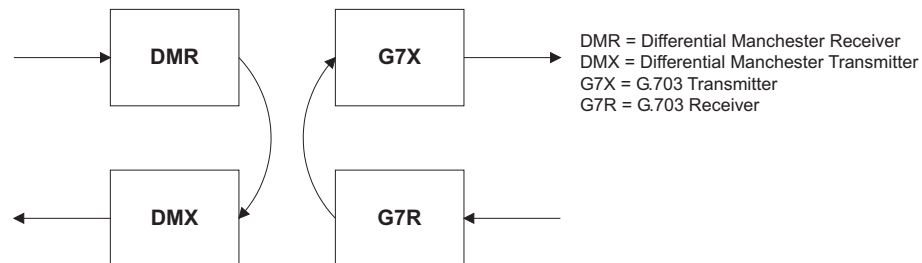
- **Internal Timing Mode:** The system clock generated internally. Therefore, the G.703 timing selection should be in the Internal Timing Mode for back-to-back (UR-to-UR) connections. For Back to Back Connections, set for Octet Timing (S1 = OFF) and Timing Mode = Internal Timing (S5 = ON and S6 = OFF).
- **Loop Timing Mode:** The system clock is derived from the received line signal. Therefore, the G.703 timing selection should be in Loop Timing Mode for connections to higher order systems. For connection to a higher order system (UR-to-multiplexer, factory defaults), set to Octet Timing (S1 = ON) and set Timing Mode = Loop Timing (S5 = OFF and S6 = OFF).

**e) TEST MODES (SWITCHES S5 AND S6)****MINIMUM REMOTE LOOPBACK MODE:**

In Minimum Remote Loopback mode, the multiplexer is enabled to return the data from the external interface without any processing to assist in diagnosing G.703 Line Side problems irrespective of clock rate. Data enters from the G.703 inputs, passes through the data stabilization latch which also restores the proper signal polarity, passes through the multiplexer and then returns to the transmitter. The Differential Received Data is processed and passed to the G.703 Transmitter module after which point the data is discarded. The G.703 Receiver module is fully functional and continues to process data and passes it to the Differential Manchester Transmitter module. Since timing is returned as it is received, the timing source is expected to be from the G.703 line side of the interface.

**DUAL LOOPBACK MODE:**

In Dual Loopback Mode, the multiplexers are active and the functions of the circuit are divided into two with each Receiver/Transmitter pair linked together to deconstruct and then reconstruct their respective signals. Differential Manchester data enters the Differential Manchester Receiver module and then is returned to the Differential Manchester Transmitter module. Likewise, G.703 data enters the G.703 Receiver module and is passed through to the G.703 Transmitter module to be returned as G.703 data. Because of the complete split in the communications path and because, in each case, the clocks are extracted and reconstructed with the outgoing data, in this mode there must be two independent sources of timing. One source lies on the G.703 line side of the interface while the other lies on the Differential Manchester side of the interface.



## 3.3.5 RS422 INTERFACE

## a) DESCRIPTION

The following figure shows the RS422 2-terminal interface configuration at 64 kbps. AWG 22 twisted shielded pair is recommended for external connections. This interface module is protected by surge suppression devices which optically isolated.



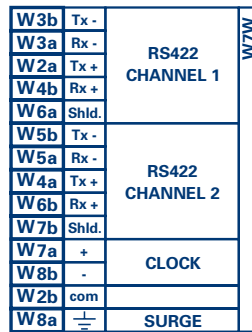
**The RS422 module is fixed at 64 kbps only. The SETTINGS ⇒ PRODUCT SETUP ⇒ DIRECT I/O ⇒ DIRECT I/O DATA RATE setting is not applicable to this module.**

## SHIELD TERMINATION

The shield pins (6a and 7b) are internally connected to the ground pin (8a). Proper shield termination is as follows:

Site 1: Terminate shield to pins 6a and/or 7b; Site 2: Terminate shield to 'COM' pin 2b.

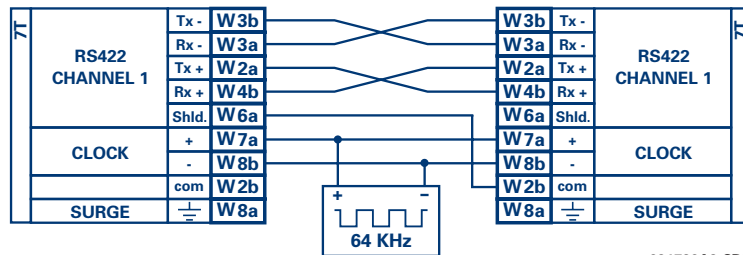
The clock terminating impedance should match the impedance of the line.



RS422.CDR  
p/o 827831A6.CDR

Figure 3-29: RS422 INTERFACE CONFIGURATION

The following figure shows the typical pin interconnection between two RS422 interfaces. All pin interconnections are to be maintained for a connection to a multiplexer.



831728A3.CDR

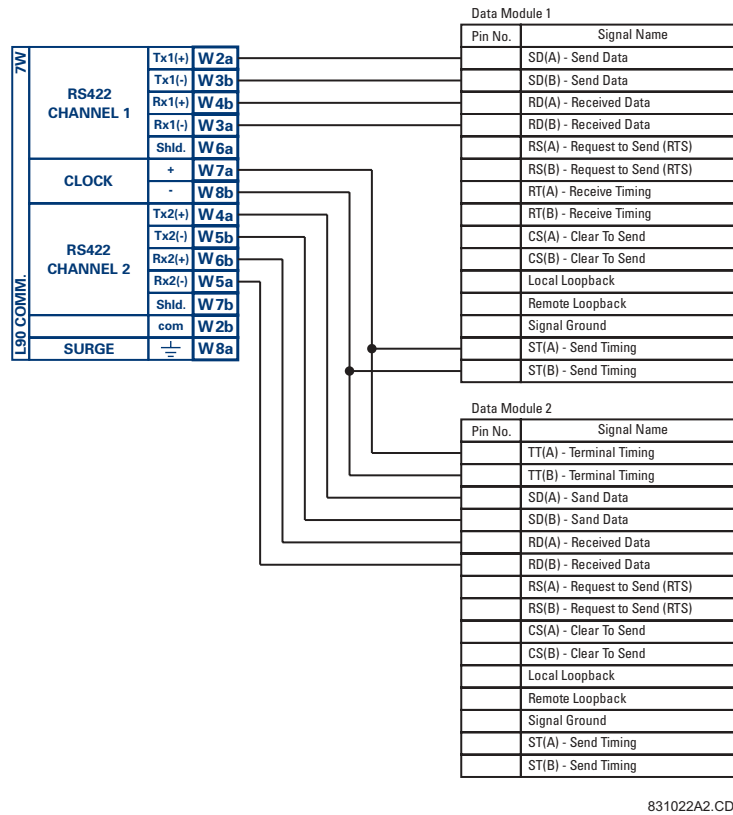
Figure 3-30: TYPICAL PIN INTERCONNECTION BETWEEN TWO RS422 INTERFACES

## b) TWO CHANNEL APPLICATIONS VIA MULTIPLEXERS

The RS422 Interface may be used for '1 channel' or '2 channel' applications over SONET/SDH and/or Multiplexed systems. When used in 1 channel applications, the RS422 interface links to higher order systems in a typical fashion observing Tx, Rx, and Send Timing connections. However, when used in 2 channel applications, certain criteria have to be followed due to the fact that there is 1 clock input for the two RS422 channels. The system will function correctly if the following connections are observed and your Data Module has a feature called Terminal Timing. Terminal Timing is a common feature to most Synchronous Data Units that allows the module to accept timing from an external source. Using the Terminal Timing feature, 2 channel applications can be achieved if these connections are followed: The Send Timing outputs from the Multiplexer - Data Module 1, will connect to the Clock inputs of the UR-RS422 interface in the usual fashion. In addition, the Send Timing outputs of Data Module 1 will also be paralleled to the Terminal Timing inputs of Data Module 2. By using this configuration the timing for both Data Modules and both UR-RS422 channels will be derived from a single clock source. As



a result, data sampling for both of the UR–RS422 channels will be synchronized via the Send Timing leads on Data Module 1 as shown in the following figure. If the Terminal Timing feature is not available or this type of connection is not desired, the G.703 interface is a viable option that does not impose timing restrictions.

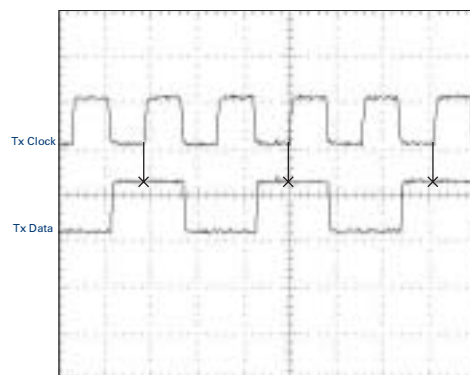


**Figure 3-31: TIMING CONFIGURATION FOR RS422 TWO-CHANNEL, 3-TERMINAL APPLICATION**

Data Module 1 provides timing to the D30 RS422 interface via the ST(A) and ST(B) outputs. Data Module 1 also provides timing to Data Module 2 TT(A) and TT(B) inputs via the ST(A) and AT(B) outputs. The Data Module pin numbers have been omitted in the figure above since they may vary depending on the manufacturer.

### c) TRANSIT TIMING

The RS422 Interface accepts one clock input for Transmit Timing. It is important that the rising edge of the 64 kHz Transmit Timing clock of the Multiplexer Interface is sampling the data in the center of the Transmit Data window. Therefore, it is important to confirm Clock and Data Transitions to ensure Proper System Operation. For example, the following figure shows the positive edge of the Tx Clock in the center of the Tx Data bit.



**Figure 3-32: CLOCK AND DATA TRANSITIONS**

**d) RECEIVE TIMING**

The RS422 Interface utilizes NRZI-MARK Modulation Code and; therefore, does not rely on an Rx Clock to recapture data. NRZI-MARK is an edge-type, invertible, self-clocking code.

To recover the Rx Clock from the data-stream, an integrated DPLL (Digital Phase Lock Loop) circuit is utilized. The DPLL is driven by an internal clock, which is over-sampled 16X, and uses this clock along with the data-stream to generate a data clock that can be used as the SCC (Serial Communication Controller) receive clock.

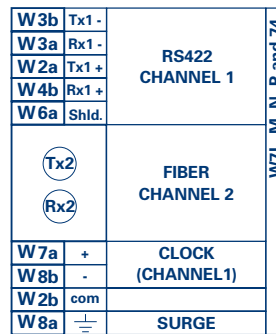
**3.3.6 RS422 AND FIBER INTERFACE**

The following figure shows the combined RS422 plus Fiber interface configuration at 64K baud. The 7L, 7M, 7N, 7P, and 74 modules are used in 2-terminal with a redundant channel or 3-terminal configurations where Channel 1 is employed via the RS422 interface (possibly with a multiplexer) and Channel 2 via direct fiber.

AWG 22 twisted shielded pair is recommended for external RS422 connections and the shield should be grounded only at one end. For the direct fiber channel, power budget issues should be addressed properly.



**When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.**



L907LMNP.CDR  
P/O 827831A6.CDR

**Figure 3–33: RS422 AND FIBER INTERFACE CONNECTION**

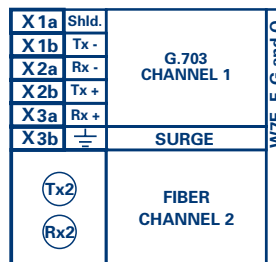
Connections shown above are for multiplexers configured as DCE (Data Communications Equipment) units.

**3.3.7 G.703 AND FIBER INTERFACE**

The figure below shows the combined G.703 plus Fiber interface configuration at 64K baud. The 7E, 7F, 7G, 7Q, and 75 modules are used in configurations where Channel 1 is employed via the G.703 interface (possibly with a multiplexer) and Channel 2 via direct fiber. AWG 22 twisted shielded pair is recommended for external G.703 connections connecting the shield to Pin 1A at one end only. For the direct fiber channel, power budget issues should be addressed properly. See previous sections for more details on the G.703 and Fiber interfaces.



**When using a LASER Interface, attenuators may be necessary to ensure that you do not exceed Maximum Optical Input Power to the receiver.**



**Figure 3–34: G.703 AND FIBER INTERFACE CONNECTION**

### 3.3.8 IEEE C37.94 INTERFACE

The UR-series IEEE C37.94 communication modules (76 and 77) are designed to interface with IEEE C37.94 compliant digital multiplexers and/or an IEEE C37.94 compliant interface converter for use with direct input/output applications for firmware revisions 3.30 and higher. The IEEE C37.94 standard defines a point-to-point optical link for synchronous data between a multiplexer and a teleprotection device. This data is typically 64 kbps, but the standard provides for speeds up to  $64n$  kbps, where  $n = 1, 2, \dots, 12$ . The UR-series C37.94 communication module is 64 kbps only with  $n$  fixed at 1. The frame is a valid International Telecommunications Union (ITU-T) recommended G.704 pattern from the standpoint of framing and data rate. The frame is 256 bits and is repeated at a frame rate of 8000 Hz, with a resultant bit rate of 2048 kbps.

The specifications for the module are as follows:

IEEE standard: C37.94 for  $1 \times 64$  kbps optical fiber interface

Fiber optic cable type: 50 mm or 62.5 mm core diameter optical fiber

Fiber optic mode: multi-mode

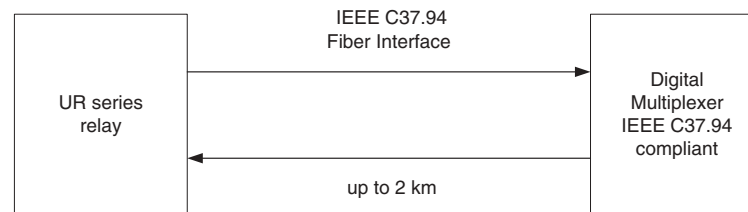
Fiber optic cable length: up to 2 km

Fiber optic connector: type ST

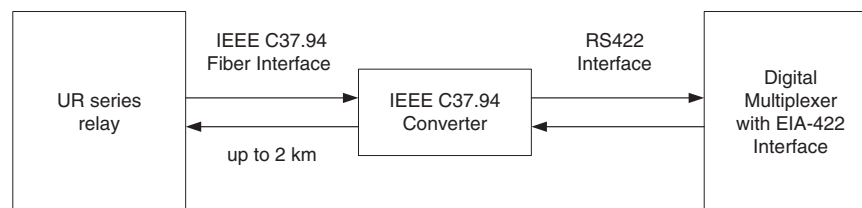
Wavelength: 830  $\pm$ 40 nm

Connection: as per all fiber optic connections, a Tx to Rx connection is required.

The UR-series C37.94 communication module can be connected directly to any compliant digital multiplexer that supports the IEEE C37.94 standard as shown below.



The UR-series C37.94 communication module can be connected to the electrical interface (G.703, RS422, or X.21) of a non-compliant digital multiplexer via an optical-to-electrical interface converter that supports the IEEE C37.94 standard, as shown below.



The UR-series C37.94 communication module has six (6) switches that are used to set the clock configuration. The functions of these control switches is shown below.



| Switch | Internal | Loop Timed |
|--------|----------|------------|
| 1      | ON       | OFF        |
| 2      | ON       | OFF        |
| 3      | OFF      | OFF        |
| 4      | OFF      | OFF        |
| 5      | OFF      | OFF        |
| 6      | OFF      | OFF        |

For the Internal Timing Mode, the system clock is generated internally. Therefore, the timing switch selection should be Internal Timing for Relay 1 and Loop Timed for Relay 2. There must be only one timing source configured.

For the Looped Timing Mode, the system clock is derived from the received line signal. Therefore, the timing selection should be in Loop Timing Mode for connections to higher order systems.

The C37.94 communications module cover removal procedure is as follows:

1. Remove the C37.94 module (76 or 77):

The ejector/inserter clips located at the top and at the bottom of each module, must be pulled simultaneously in order to release the module for removal. Before performing this action, **control power must be removed from the relay**. The original location of the module should be recorded to help ensure that the same or replacement module is inserted into the correct slot.

2. Remove the module cover screw.
3. Remove the top cover by sliding it towards the rear and then lift it upwards.
4. Set the Timing Selection Switches (Channel 1, Channel 2) to the desired timing modes (see description above).
5. Replace the top cover and the cover screw.
6. Re-insert the C37.94 module Take care to ensure that the **correct** module type is inserted into the **correct** slot position. The ejector/inserters located at the top and at the bottom of each module must be in the disengaged position as the module is smoothly inserted into the slot. Once the clips have cleared the raised edge of the chassis, engage the clips simultaneously. When the clips have locked into position, the module will be fully inserted.

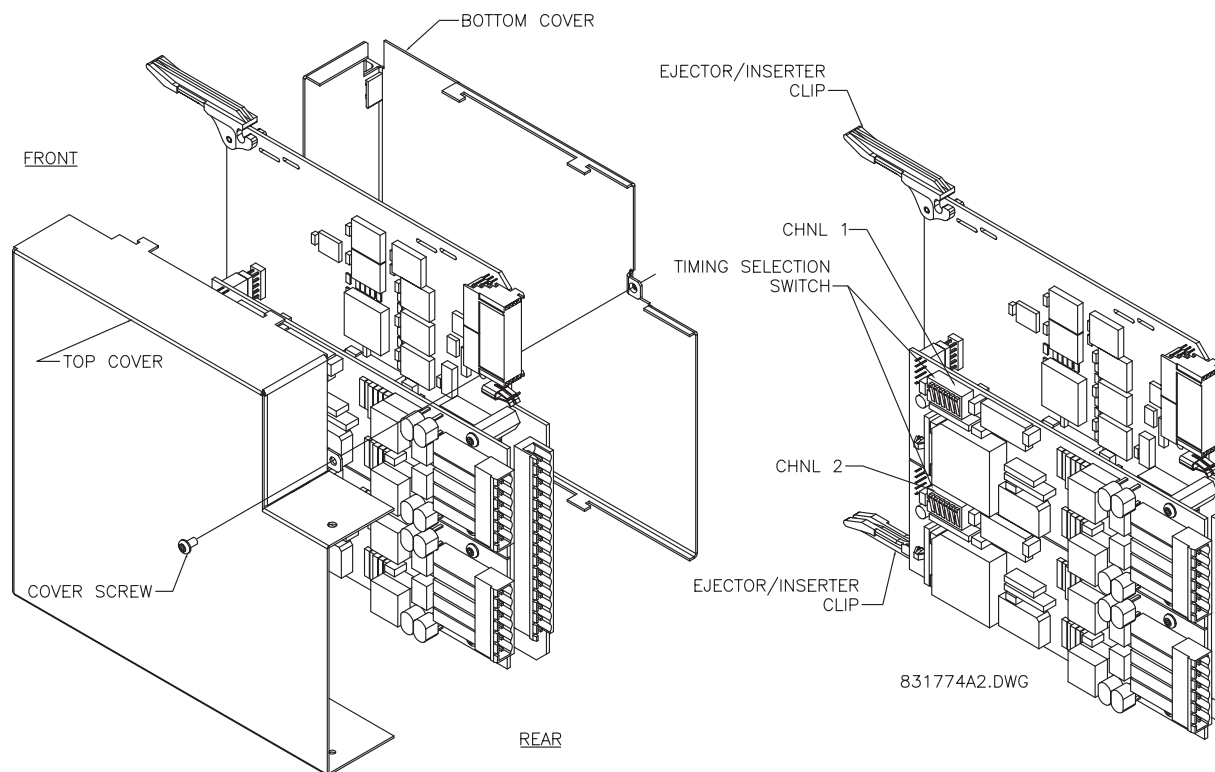


Figure 3–35: C37.94 TIMING SELECTION SWITCH SETTING

## 4.1.1 INTRODUCTION

The enerVista UR Setup software provides a graphical user interface (GUI) as one of two human interfaces to a UR device. The alternate human interface is implemented via the device's faceplate keypad and display (see Faceplate Interface section in this chapter).

The enerVista UR Setup software provides a single facility to configure, monitor, maintain, and trouble-shoot the operation of relay functions, connected over local or wide area communication networks. It can be used while disconnected (i.e. off-line) or connected (i.e. on-line) to a UR device. In off-line mode, settings files can be created for eventual downloading to the device. In on-line mode, you can communicate with the device in real-time.

The enerVista UR Setup software, provided with every D30 relay, can be run from any computer supporting Microsoft Windows® 95, 98, NT, 2000, ME, and XP. This chapter provides a summary of the basic enerVista UR Setup software interface features. The enerVista UR Setup Help File provides details for getting started and using the enerVista UR Setup software interface.

## 4.1.2 CREATING A SITE LIST

To start using the enerVista UR Setup software, a site definition and device definition must first be created. See the enerVista UR Setup Help File or refer to the *Connecting enerVista UR Setup with the D30* section in Chapter 1 for details.

## 4.1.3 ENERVISTA UR SETUP SOFTWARE OVERVIEW

**a) ENGAGING A DEVICE**

The enerVista UR Setup software may be used in on-line mode (relay connected) to directly communicate with a UR relay. Communicating relays are organized and grouped by communication interfaces and into sites. Sites may contain any number of relays selected from the UR product series.

**b) USING SETTINGS FILES**

The enerVista UR Setup software interface supports three ways of handling changes to relay settings:

- In off-line mode (relay disconnected) to create or edit relay settings files for later download to communicating relays.
- While connected to a communicating relay to directly modify any relay settings via relay data view windows, and then save the settings to the relay.
- You can create/edit settings files and then write them to the relay while the interface is connected to the relay.

Settings files are organized on the basis of file names assigned by the user. A settings file contains data pertaining to the following types of relay settings:

- Device Definition
- Product Setup
- System Setup
- FlexLogic™
- Grouped Elements
- Control Elements
- Inputs/Outputs
- Testing

Factory default values are supplied and can be restored after any changes.

**c) CREATING AND EDITION FLEXLOGIC™ EQUATIONS**

You can create or edit a FlexLogic™ equation in order to customize the relay. You can subsequently view the automatically generated logic diagram.

**d) VIEWING ACTUAL VALUES**

You can view real-time relay data such as input/output status and measured parameters.

**e) VIEWING TRIGGERED EVENTS**

While the interface is in either on-line or off-line mode, you can view and analyze data generated by triggered specified parameters, via one of the following:

- **Event Recorder facility:** The event recorder captures contextual data associated with the last 1024 events, listed in chronological order from most recent to oldest.
- **Oscillography facility:** The oscillography waveform traces and digital states are used to provide a visual display of power system and relay operation data captured during specific triggered events.

**f) FILE SUPPORT**

- **Execution:** Any enerVista UR Setup file which is double clicked or opened will launch the application, or provide focus to the already opened application. If the file was a settings file (has a `URS` extension) which had been removed from the Settings List tree menu, it will be added back to the Settings List tree menu.
- **Drag and Drop:** The Site List and Settings List control bar windows are each mutually a drag source and a drop target for device-order-code-compatible files or individual menu items. Also, the Settings List control bar window and any Windows Explorer directory folder are each mutually a file drag source and drop target.

New files which are dropped into the Settings List window are added to the tree which is automatically sorted alphabetically with respect to settings file names. Files or individual menu items which are dropped in the selected device menu in the Site List window will automatically be sent to the on-line communicating device.

**g) FIRMWARE UPGRADES**

The firmware of a D30 device can be upgraded, locally or remotely, via the enerVista UR Setup software. The corresponding instructions are provided by the enerVista UR Setup Help file under the topic “Upgrading Firmware”.



Modbus addresses assigned to firmware modules, features, settings, and corresponding data items (i.e. default values, minimum/maximum values, data type, and item size) may change slightly from version to version of firmware. The addresses are rearranged when new features are added or existing features are enhanced or modified. The **EEPROM DATA ERROR** message displayed after upgrading/downgrading the firmware is a resettable, self-test message intended to inform users that the Modbus addresses have changed with the upgraded firmware. This message does not signal any problems when appearing after firmware upgrades.

## 4.1.4 ENERVISTA UR SETUP SOFTWARE MAIN WINDOW

The enerVista UR Setup software main window supports the following primary display components:

- Title bar which shows the pathname of the active data view
- Main window menu bar
- Main window tool bar
- Site List control bar window
- Settings List control bar window
- Device data view window(s), with common tool bar
- Settings File data view window(s), with common tool bar
- Workspace area with data view tabs
- Status bar

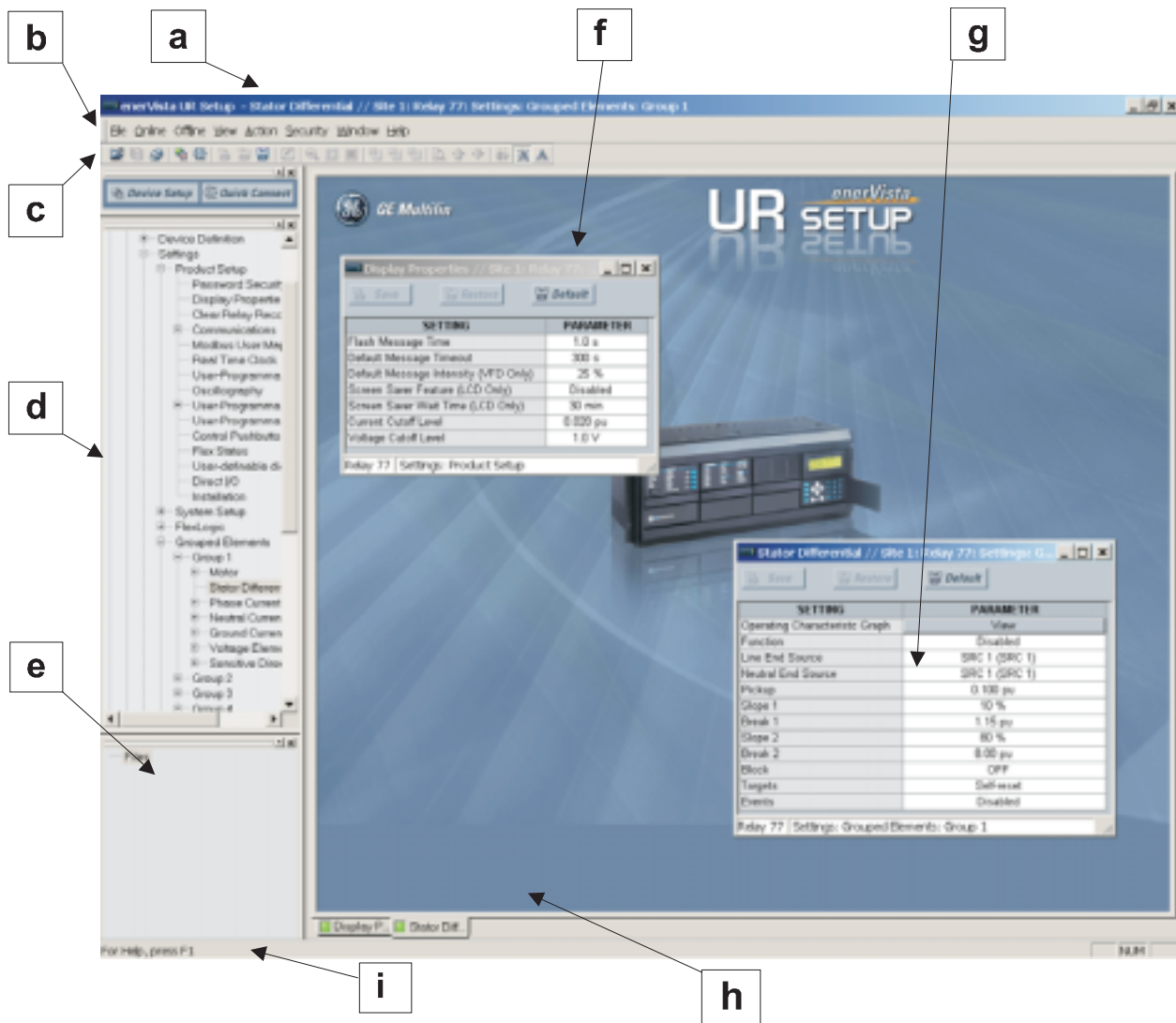


Figure 4-1: ENERVISTA UR SETUP SOFTWARE MAIN WINDOW

## 4.2.1 FACEPLATE

The keypad/display/LED interface is one of two alternate human interfaces supported. The other alternate human interface is implemented via the enerVista UR Setup software. The faceplate interface is available in two configurations: horizontal or vertical. The faceplate interface consists of several functional panels.

The faceplate is hinged to allow easy access to the removable modules. There is also a removable dust cover that fits over the faceplate which must be removed in order to access the keypad panel. The following two figures show the horizontal and vertical arrangement of faceplate panels.

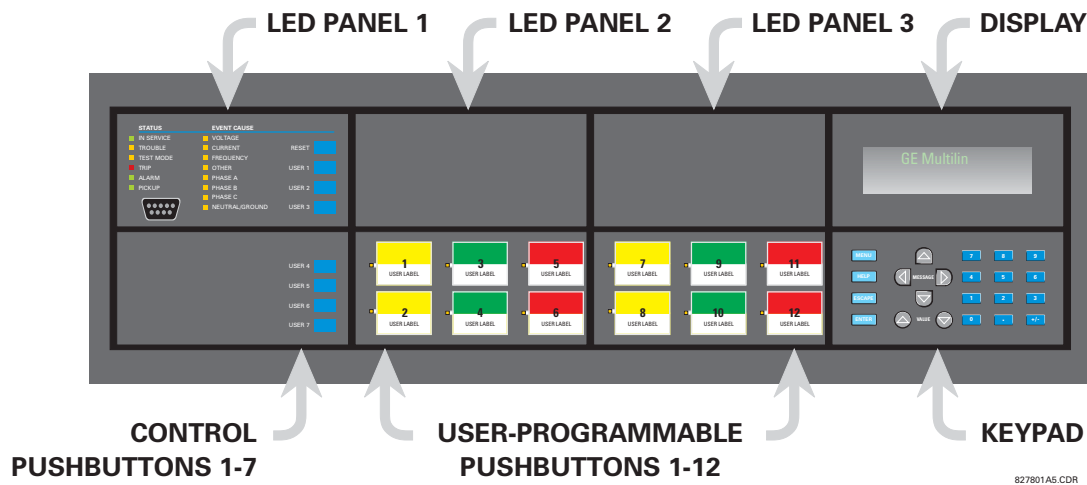


Figure 4-2: UR-SERIES HORIZONTAL FACEPLATE PANELS

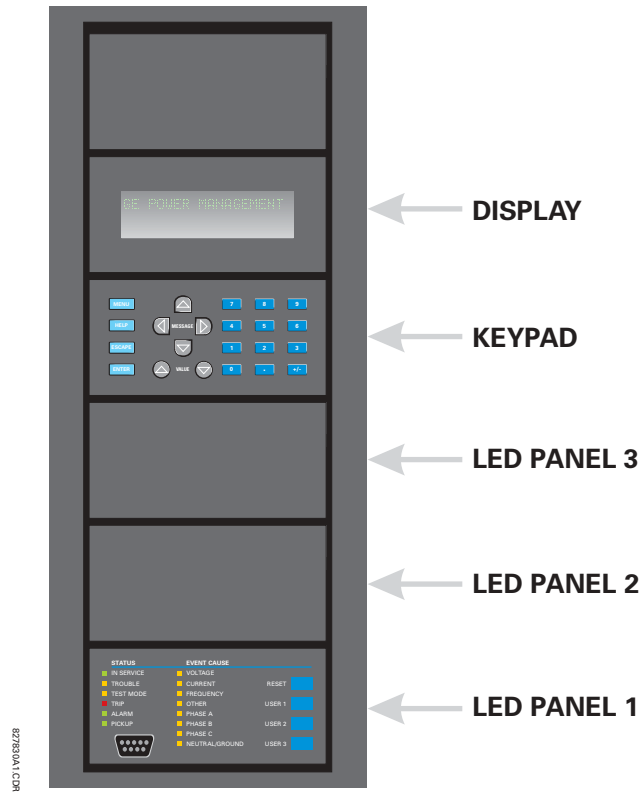


Figure 4-3: UR-SERIES VERTICAL FACEPLATE PANELS



## 4.2.2 LED INDICATORS

## a) LED PANEL 1

This panel provides several LED indicators, several keys, and a communications port. The RESET key is used to reset any latched LED indicator or target message, once the condition has been cleared (these latched conditions can also be reset via the **SETTINGS** ⇒ **INPUT/OUTPUTS** ⇒ **RESETTING** menu). The USER keys are used by the Breaker Control feature. The RS232 port is intended for connection to a portable PC.

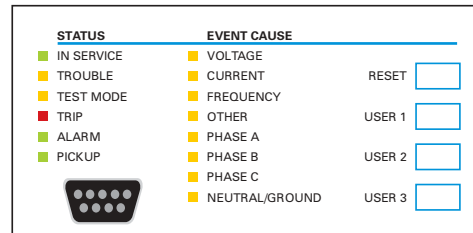


Figure 4-4: LED PANEL 1

## STATUS INDICATORS:

- **IN SERVICE:** Indicates that control power is applied; all monitored inputs/outputs and internal systems are OK; the relay has been programmed.
- **TROUBLE:** Indicates that the relay has detected an internal problem.
- **TEST MODE:** Indicates that the relay is in test mode.
- **TRIP:** Indicates that the selected FlexLogic™ operand serving as a Trip switch has operated. This indicator always latches; the RESET command must be initiated to allow the latch to be reset.
- **ALARM:** Indicates that the selected FlexLogic™ operand serving as an Alarm switch has operated. This indicator is never latched.
- **PICKUP:** Indicates that an element is picked up. This indicator is never latched.

## EVENT CAUSE INDICATORS:

These indicate the input type that was involved in a condition detected by an element that is operated or has a latched flag waiting to be reset.

- **VOLTAGE:** Indicates voltage was involved.
- **CURRENT:** Indicates current was involved.
- **FREQUENCY:** Indicates frequency was involved.
- **OTHER:** Indicates a composite function was involved.
- **PHASE A:** Indicates Phase A was involved.
- **PHASE B:** Indicates Phase B was involved.
- **PHASE C:** Indicates Phase C was involved.
- **NEUTRAL/GROUND:** Indicates neutral or ground was involved.

### b) LED PANELS 2 AND 3

These panels provide 48 amber LED indicators whose operation is controlled by the user. Support for applying a customized label beside every LED is provided.

User customization of LED operation is of maximum benefit in installations where languages other than English are used to communicate with operators. Refer to the User-Programmable LEDs section in Chapter 5 for the settings used to program the operation of the LEDs on these panels.

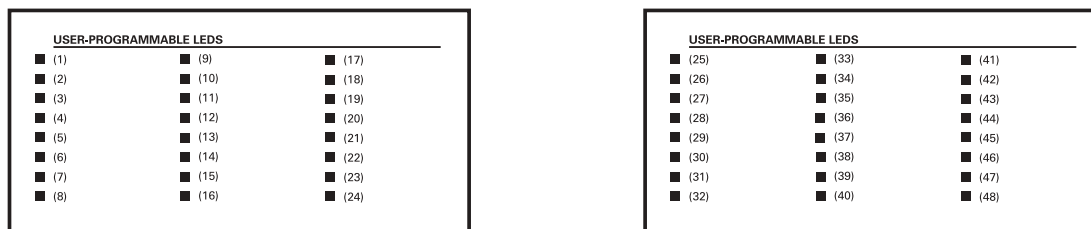


Figure 4-5: LED PANELS 2 AND 3 (INDEX TEMPLATE)

## 4

### c) DEFAULT LABELS FOR LED PANEL 2

The default labels are intended to represent:

- **GROUP 1...6:** The illuminated GROUP is the active settings group.
- **BREAKER n OPEN:** The breaker is open.
- **BREAKER n CLOSED:** The breaker is closed.
- **BREAKER n TROUBLE:** A problem related to the breaker has been detected.
- **SYNCHROCHECK NO n IN-SYNCH:** Voltages have satisfied the synchrocheck element.
- **RECLOSE ENABLED:** The recloser is operational.
- **RECLOSE DISABLED:** The recloser is not operational.
- **RECLOSE IN PROGRESS:** A reclose operation is in progress.
- **RECLOSE LOCKED OUT:** The recloser is not operational and requires a reset.



Firmware revisions 2.9x and earlier support eight user setting groups; revisions 3.0x and higher support six setting groups. For convenience of users using earlier firmware revisions, the relay panel shows eight setting groups. Please note that the LEDs, despite their default labels, are fully user-programmable.

The relay is shipped with the default label for the LED panel 2. The LEDs, however, are not pre-programmed. To match the pre-printed label, the LED settings must be entered as shown in the *User-Programmable LEDs* section of Chapter 5. The LEDs are fully user-programmable. The default labels can be replaced by user-printed labels for both panels as explained in the following section.

| SETTINGS IN USE | BREAKER 1        | SYNCHROCHECK   |
|-----------------|------------------|----------------|
| GROUP 1         | OPEN             | NO1 IN-SYNCH   |
| GROUP 2         | CLOSED           | NO2 IN-SYNCH   |
| GROUP 3         | TROUBLE          |                |
| GROUP 4         |                  | <u>RECLOSE</u> |
| GROUP 5         | <u>BREAKER 2</u> | ENABLED        |
| GROUP 6         | OPEN             | DISABLED       |
| GROUP 7         | CLOSED           | IN PROGRESS    |
| GROUP 8         | TROUBLE          | LOCKED OUT     |

Figure 4-6: LED PANEL 2 (DEFAULT LABELS)

#### d) CUSTOM LABELING OF LEDS

Custom labeling of an LED-only panel is facilitated through a Microsoft Word file available from the following URL:

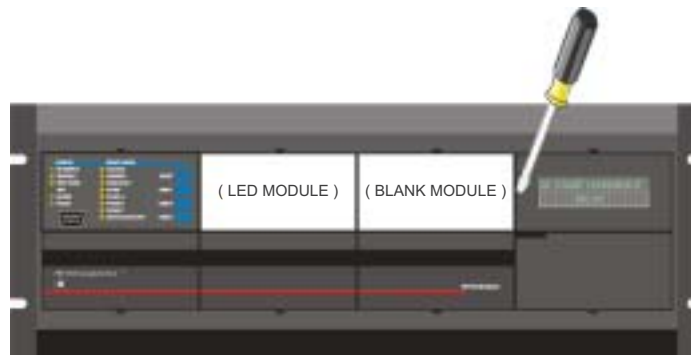
<http://www.GEindustrial.com/multilin/support/ur/>

This file provides templates and instructions for creating appropriate labeling for the LED panel. The following procedures are contained in the downloadable file. The panel templates provide relative LED locations and located example text (x) edit boxes. The following procedure demonstrates how to install/uninstall the custom panel labeling.

1. Remove the clear Lexan Front Cover (GE Multilin Part Number: 1501-0014).



2. Pop out the LED Module and/or the Blank Module with a screwdriver as shown below. Be careful not to damage the plastic.



3. Place the left side of the customized module back to the front panel frame, then snap back the right side.
4. Put the clear Lexan Front Cover back into place.

#### e) CUSTOMIZING THE DISPLAY MODULE

The following items are required to customize the D30 display module:

- Black and white or color printer (color preferred).
  - Microsoft Word 97 or later software for editing the template.
  - 1 each of: 8.5" x 11" white paper, exacto knife, ruler, custom display module (GE Multilin Part Number: 1516-0069), and a custom module cover (GE Multilin Part Number: 1502-0015).
1. Open the LED panel customization template with Microsoft Word. Add text in places of the **LED x** text placeholders on the template(s). Delete unused place holders as required.
  2. When complete, save the Word file to your local PC for future use.
  3. Print the template(s) to a local printer.
  4. From the printout, cut-out the Background Template from the three windows, using the cropmarks as a guide.
  5. Put the Background Template on top of the custom display module (GE Multilin Part Number: 1513-0069) and snap the clear custom module cover (GE Multilin Part Number: 1502-0015) over it and the templates.

## 4.2.3 DISPLAY

All messages are displayed on a 2 × 20 character vacuum fluorescent display to make them visible under poor lighting conditions. An optional liquid crystal display (LCD) is also available. Messages are displayed in English and do not require the aid of an instruction manual for deciphering. While the keypad and display are not actively being used, the display will default to defined messages. Any high priority event driven message will automatically override the default message and appear on the display.

## 4.2.4 KEYPAD

Display messages are organized into 'pages' under the following headings: Actual Values, Settings, Commands, and Targets. The **MENU** key navigates through these pages. Each heading page is broken down further into logical subgroups.

The **▲** **◀** MESSAGE **▶** **▼** keys navigate through the subgroups. The **▲** VALUE **▼** keys scroll increment or decrement numerical setting values when in programming mode. These keys also scroll through alphanumeric values in the text edit mode. Alternatively, values may also be entered with the numeric keypad.

The **■** key initiates and advance to the next character in text edit mode or enters a decimal point. The **HELP** key may be pressed at any time for context sensitive help messages. The **ENTER** key stores altered setting values.

## 4.2.5 BREAKER CONTROL

## a) DESCRIPTION

The D30 can interface with associated circuit breakers. In many cases the application monitors the state of the breaker, which can be presented on faceplate LEDs, along with a breaker trouble indication. Breaker operations can be manually initiated from faceplate keypad or automatically initiated from a FlexLogic™ operand. A setting is provided to assign names to each breaker; this user-assigned name is used for the display of related flash messages. These features are provided for two breakers; the user may use only those portions of the design relevant to a single breaker, which must be breaker No. 1.

For the following discussion it is assumed the **SETTINGS** ⇒ **SYSTEM SETUP** ⇒ **BREAKERS** ⇒ **BREAKER n** ⇒ **BREAKER FUNCTION** setting is "Enabled" for each breaker.

## b) CONTROL MODE SELECTION AND MONITORING

Installations may require that a breaker is operated in the three-pole only mode (3-Pole), or in the one and three-pole (1-Pole) mode, selected by setting. If the mode is selected as 3-pole, a single input tracks the breaker open or closed position. If the mode is selected as 1-Pole, all three breaker pole states must be input to the relay. These inputs must be in agreement to indicate the position of the breaker.

For the following discussion it is assumed the **SETTINGS** ⇒ **SYSTEM SETUP** ⇒ **BREAKERS** ⇒ **BREAKER n** ⇒ **BREAKER PUSH BUTTON CONTROL** setting is "Enabled" for each breaker.

## c) FACEPLATE PUSHBUTTON (USER KEY) CONTROL

After the 30 minute interval during which command functions are permitted after a correct command password, the user cannot open or close a breaker via the keypad. The following discussions begin from the not-permitted state.

## d) CONTROL OF TWO BREAKERS

For the following example setup, the symbol **(Name)** represents the user-programmed variable name.

For this application (setup shown below), the relay is connected and programmed for both breaker No. 1 and breaker No. 2. The USER 1 key performs the selection of which breaker is to be operated by the USER 2 and USER 3 keys. The USER 2 key is used to manually close the breaker and the USER 3 key is used to manually open the breaker.

**ENTER COMMAND  
PASSWORD**

This message appears when the USER 1, USER 2, or USER 3 key is pressed and a **COMMAND PASSWORD** is required; i.e. if **COMMAND PASSWORD** is enabled and no commands have been issued within the last 30 minutes.

**Press USER 1  
To Select Breaker**

This message appears if the correct password is entered or if none is required. This message will be maintained for 30 seconds or until the USER 1 key is pressed again.

**BKR1- (Name) SELECTED  
USER 2=CLS/USER 3=OP**

This message is displayed after the USER 1 key is pressed for the second time. Three possible actions can be performed from this state within 30 seconds as per items (1), (2) and (3) below:

(1)

**USER 2 OFF/ON  
To Close BKR1- (Name)**

If the USER 2 key is pressed, this message appears for 20 seconds. If the USER 2 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to close breaker No. 1.

(2)

**USER 3 OFF/ON  
To Open BKR1- (Name)**

If the USER 3 key is pressed, this message appears for 20 seconds. If the USER 3 key is pressed again within that time, a signal is created that can be programmed to operate an output relay to open breaker No. 1.

(3)

**BKR2- (Name) SELECTED  
USER 2=CLS/USER 3=OP**

If the USER 1 key is pressed at this step, this message appears showing that a different breaker is selected. Three possible actions can be performed from this state as per (1), (2) and (3). Repeatedly pressing the USER 1 key alternates between available breakers. Pressing keys other than USER 1, 2 or 3 at any time aborts the breaker control function.

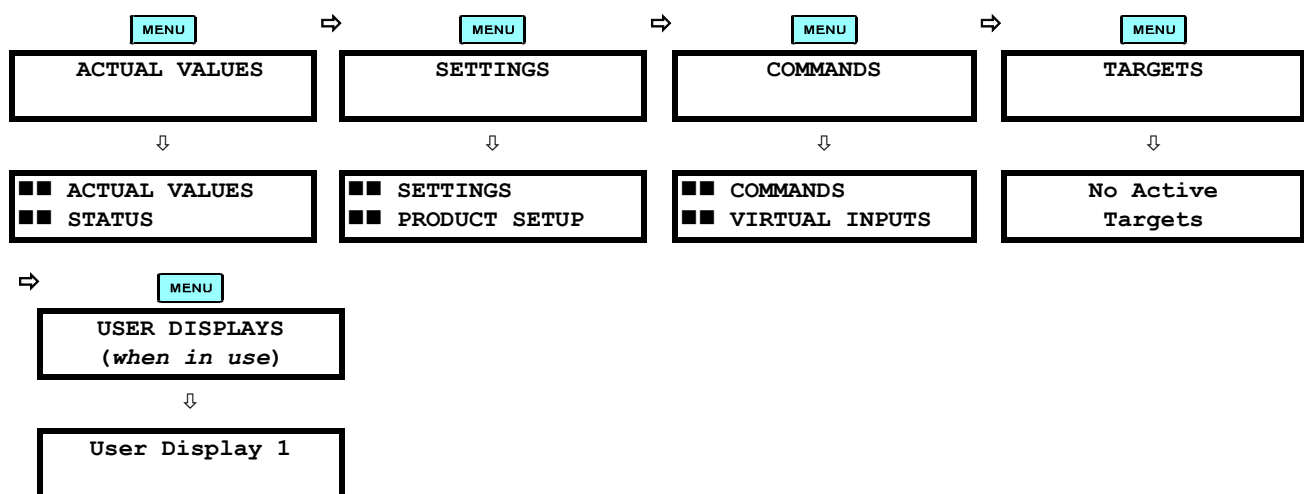
#### e) CONTROL OF ONE BREAKER

For this application the relay is connected and programmed for breaker No. 1 only. Operation for this application is identical to that described for two breakers.

#### 4.2.6 MENUS

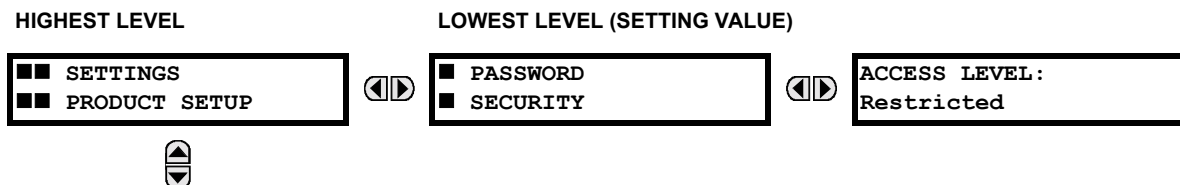
##### a) NAVIGATION

Press the **MENU** key to select the desired header display page (top-level menu). The header title appears momentarily followed by a header display page menu item. Each press of the **MENU** key advances through the main heading pages as illustrated below.

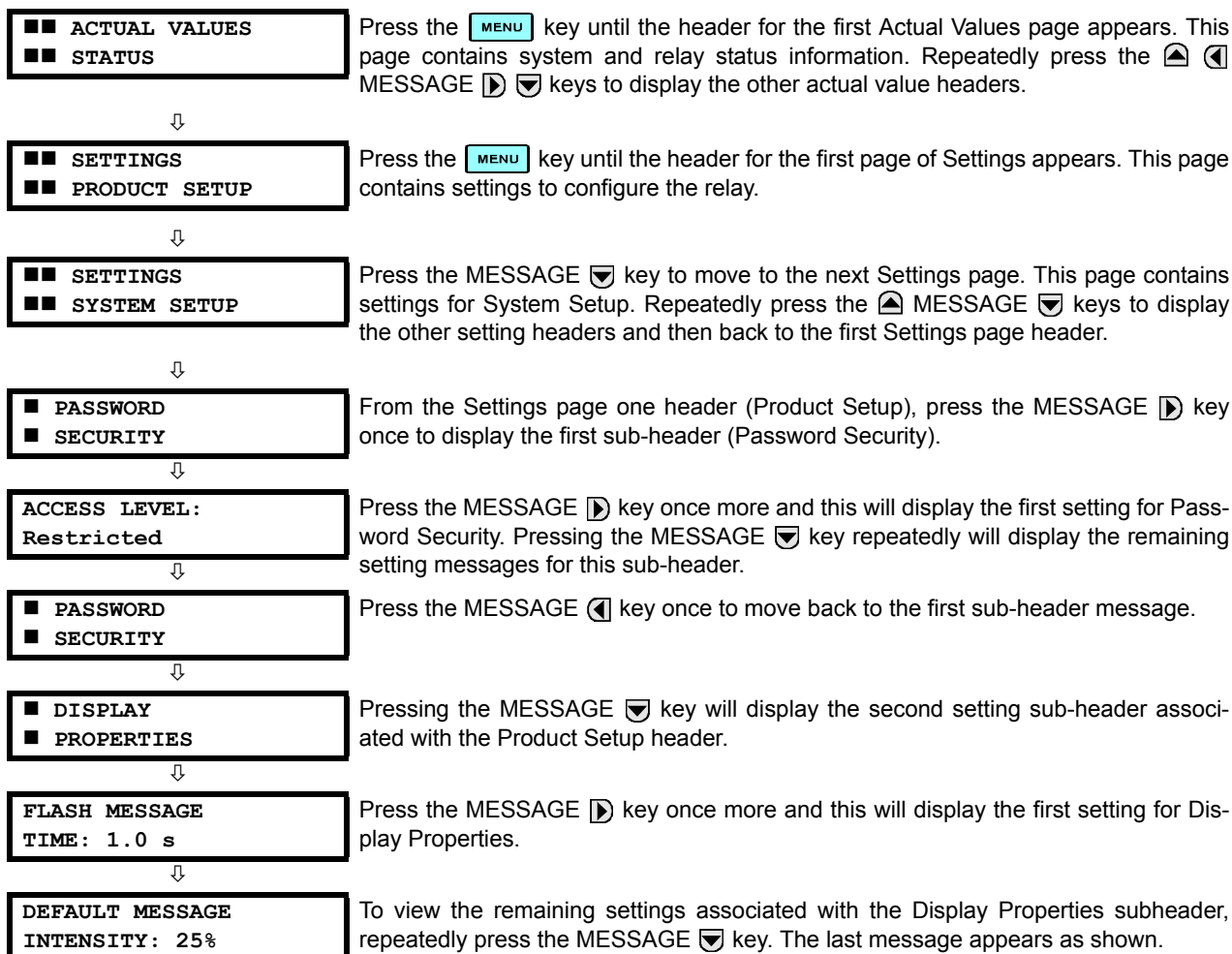


## b) HIERARCHY

The setting and actual value messages are arranged hierarchically. The header display pages are indicated by double scroll bar characters (■ ■), while sub-header pages are indicated by single scroll bar characters (■). The header display pages represent the highest level of the hierarchy and the sub-header display pages fall below this level. The MESSAGE ▲ and ▼ keys move within a group of headers, sub-headers, setting values, or actual values. Continually pressing the MESSAGE ► key from a header display displays specific information for the header category. Conversely, continually pressing the ◀ MESSAGE key from a setting value or actual value display returns to the header display.



## c) EXAMPLE MENU NAVIGATION









## 4.2.7 CHANGING SETTINGS

## a) ENTERING NUMERICAL DATA

Each numerical setting has its own minimum, maximum, and increment value associated with it. These parameters define what values are acceptable for a setting.

|                               |  |
|-------------------------------|--|
| FLASH MESSAGE<br>TIME: 1.0 s  | For example, select the <b>SETTINGS</b> ⇒ <b>PRODUCT SETUP</b> ⇒ <b>DISPLAY PROPERTIES</b> ⇒ <b>FLASH MESSAGE TIME</b> setting.                    |
| ↓                             |  |
| MINIMUM: 0.5<br>MAXIMUM: 10.0 | Press the <b>HELP</b> key to view the minimum and maximum values. Press the <b>HELP</b> key again to view the next context sensitive help message. |

Two methods of editing and storing a numerical setting value are available.



- **0 to 9** and **.** (decimal point): The relay numeric keypad works the same as that of any electronic calculator. A number is entered one digit at a time. The leftmost digit is entered first and the rightmost digit is entered last. Pressing the MESSAGE key or pressing the ESCAPE key, returns the original value to the display.
- **VALUE**  **VALUE** : The VALUE  key increments the displayed value by the step value, up to the maximum value allowed. While at the maximum value, pressing the VALUE  key again will allow the setting selection to continue upward from the minimum value. The VALUE  key decrements the displayed value by the step value, down to the minimum value. While at the minimum value, pressing the VALUE  key again will allow the setting selection to continue downward from the maximum value.

|                                |   |
|--------------------------------|---|
| FLASH MESSAGE<br>TIME: 2.5 s   | As an example, set the flash message time setting to 2.5 seconds. Press the appropriate numeric keys in the sequence "2 . 5". The display message will change as the digits are being entered.  |
| ↓                              |   |
| NEW SETTING<br>HAS BEEN STORED | Until <b>ENTER</b> is pressed, editing changes are not registered by the relay. Therefore, press <b>ENTER</b> to store the new value in memory. This flash message will momentarily appear as confirmation of the storing process. Numerical values which contain decimal places will be rounded-off if more decimal place digits are entered than specified by the step value. |

## b) ENTERING ENUMERATION DATA

Enumeration settings have data values which are part of a set, whose members are explicitly defined by a name. A set is comprised of two or more members.

|                             |  |
|-----------------------------|--|
| ACCESS LEVEL:<br>Restricted | For example, the selections available for <b>ACCESS LEVEL</b> are "Restricted", "Command", "Setting", and "Factory Service". |
|-----------------------------|--|

Enumeration type values are changed using the VALUE keys. The VALUE  key displays the next selection while the VALUE  key displays the previous selection.






|                                |   |
|--------------------------------|---|
| ACCESS LEVEL:<br>Setting       | If the <b>ACCESS LEVEL</b> needs to be "Setting", press the VALUE keys until the proper selection is displayed. Press <b>HELP</b> at any time for the context sensitive help messages.                              |
| ↓                              |   |
| NEW SETTING<br>HAS BEEN STORED | Changes are not registered by the relay until the <b>ENTER</b> key is pressed. Pressing <b>ENTER</b> stores the new value in memory. This flash message momentarily appears as confirmation of the storing process. |

## c) ENTERING ALPHANUMERIC TEXT

Text settings have data values which are fixed in length, but user-defined in character. They may be comprised of upper case letters, lower case letters, numerals, and a selection of special characters.

There are several places where text messages may be programmed to allow the relay to be customized for specific applications. One example is the Message Scratchpad. Use the following procedure to enter alphanumeric text messages.

For example: to enter the text, "Breaker #1"





1. Press  to enter text edit mode.
2. Press the VALUE keys until the character 'B' appears; press  to advance the cursor to the next position.
3. Repeat step 2 for the remaining characters: r,e,a,k,e,r, ,#,1.
4. Press  to store the text.
5. If you have any problem, press  to view context sensitive help. Flash messages will sequentially appear for several seconds each. For the case of a text setting message, pressing  displays how to edit and store new values.

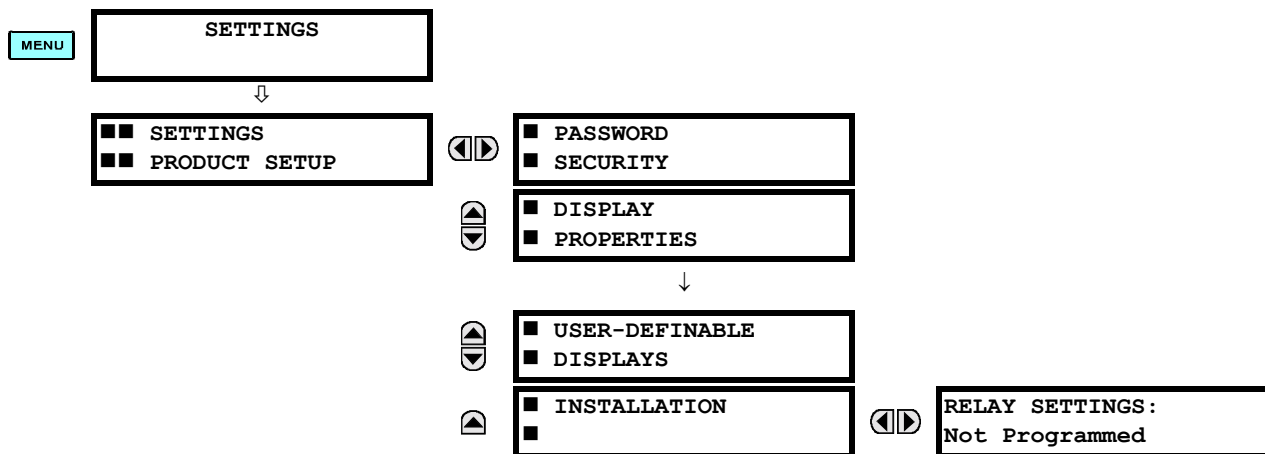
#### d) ACTIVATING THE RELAY


**RELAY SETTINGS:**  
Not Programmed

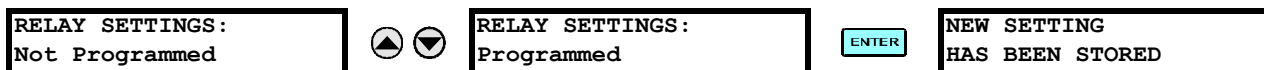
When the relay is powered up, the Trouble LED will be on, the In Service LED off, and this message displayed, indicating the relay is in the "Not Programmed" state and is safeguarding (output relays blocked) against the installation of a relay whose settings have not been entered. This message remains until the relay is explicitly put in the "Programmed" state.

To change the **RELAY SETTINGS: "Not Programmed"** mode to "Programmed", proceed as follows:

1. Press the  key until the **SETTINGS** header flashes momentarily and the **SETTINGS PRODUCT SETUP** message appears on the display.
2. Press the MESSAGE  key until the **PASSWORD SECURITY** message appears on the display.
3. Press the MESSAGE  key until the **INSTALLATION** message appears on the display.
4. Press the MESSAGE  key until the **RELAY SETTINGS: Not Programmed** message is displayed.



5. After the **RELAY SETTINGS: Not Programmed** message appears on the display, press the VALUE keys change the selection to "Programmed".
6. Press the  key.



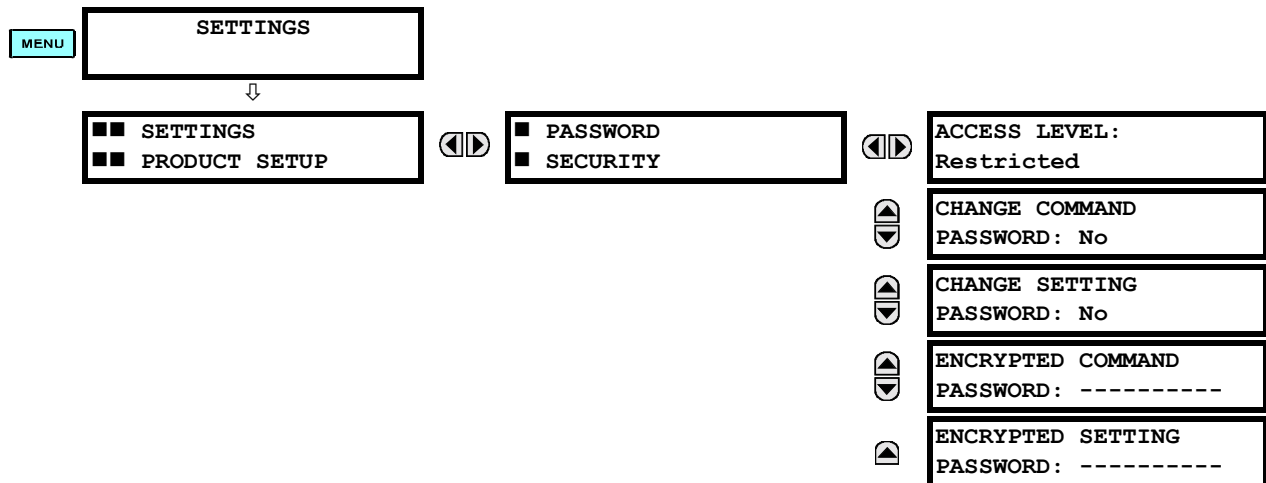
7. When the "NEW SETTING HAS BEEN STORED" message appears, the relay will be in "Programmed" state and the In Service LED will turn on.



**e) ENTERING INITIAL PASSWORDS**

To enter the initial Setting (or Command) Password, proceed as follows:

1. Press the **MENU** key until the **SETTINGS** header flashes momentarily and the **SETTINGS PRODUCT SETUP** message appears on the display.
2. Press the MESSAGE **▶** key until the **ACCESS LEVEL** message appears on the display.
3. Press the MESSAGE **▼** key until the **CHANGE SETTING (or COMMAND) PASSWORD** message appears on the display.



4. After the **CHANGE...PASSWORD** message appears on the display, press the VALUE **▲** key or the VALUE **▼** key to change the selection to "Yes".
5. Press the **ENTER** key and the display will prompt you to **ENTER NEW PASSWORD**.
6. Type in a numerical password (up to 10 characters) and press the **ENTER** key.
7. When the **VERIFY NEW PASSWORD** is displayed, re-type in the same password and press **ENTER**.



8. When the **NEW PASSWORD HAS BEEN STORED** message appears, your new Setting (or Command) Password will be active.

**f) CHANGING EXISTING PASSWORD**

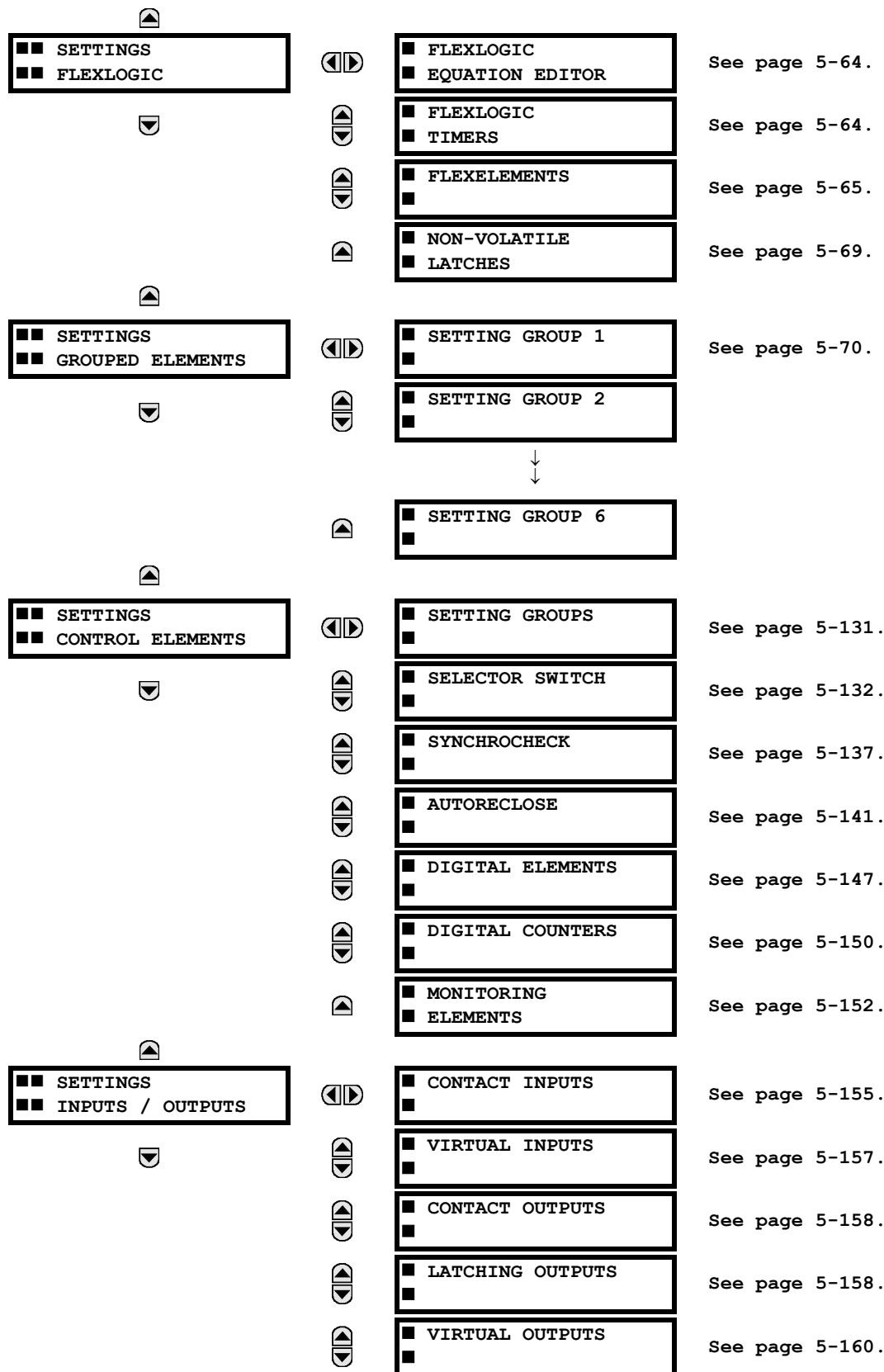
To change an existing password, follow the instructions in the previous section with the following exception. A message will prompt you to type in the existing password (for each security level) before a new password can be entered.

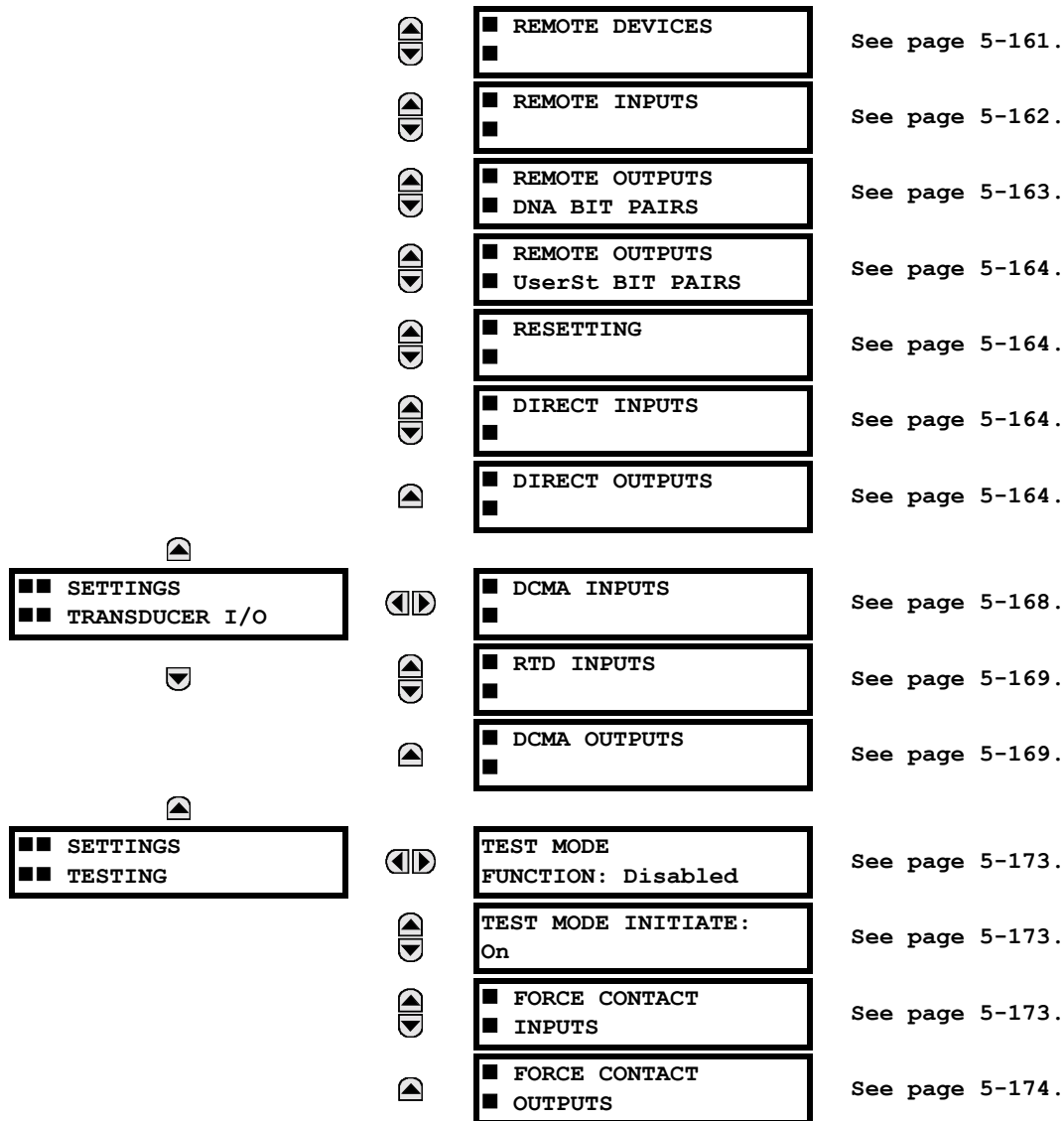
In the event that a password has been lost (forgotten), submit the corresponding Encrypted Password from the **PASSWORD SECURITY** menu to the Factory for decoding.



## 5.1.1 SETTINGS MAIN MENU

|   |    |  |                |
|---|----|--|----------------|
| <div> <div>■ ■ SETTINGS</div> <div>■ ■ PRODUCT SETUP</div> </div> | ◀▶ | <div> <div>■ PASSWORD</div> <div>■ SECURITY</div> </div>             | See page 5-7.  |
| ▼   | ▲▼ | <div> <div>■ DISPLAY</div> <div>■ PROPERTIES</div> </div>            | See page 5-8.  |
|   | ▲▼ | <div> <div>■ CLEAR RELAY</div> <div>■ RECORDS</div> </div>           | See page 5-10. |
|   | ▲▼ | <div> <div>■ COMMUNICATIONS</div> <div>■</div> </div>                | See page 5-11. |
|   | ▲▼ | <div> <div>■ MODBUS USER MAP</div> <div>■</div> </div>               | See page 5-18. |
|   | ▲▼ | <div> <div>■ REAL TIME</div> <div>■ CLOCK</div> </div>               | See page 5-19. |
|   | ▲▼ | <div> <div>■ FAULT REPORTS</div> <div>■</div> </div>                 | See page 5-19. |
|   | ▲▼ | <div> <div>■ OSCILLOGRAPHY</div> <div>■</div> </div>                 | See page 5-20. |
|   | ▲▼ | <div> <div>■ USER-PROGRAMMABLE</div> <div>■ LEDS</div> </div>        | See page 5-22. |
|   | ▲▼ | <div> <div>■ USER-PROGRAMMABLE</div> <div>■ SELF TESTS</div> </div>  | See page 5-25. |
|   | ▲▼ | <div> <div>■ CONTROL</div> <div>■ PUSHBUTTONS</div> </div>           | See page 5-25. |
|   | ▲▼ | <div> <div>■ USER-PROGRAMMABLE</div> <div>■ PUSHBUTTONS</div> </div> | See page 5-26. |
|   | ▲▼ | <div> <div>■ FLEX STATE</div> <div>■ PARAMETERS</div> </div>         | See page 5-28. |
|   | ▲▼ | <div> <div>■ USER-DEFINABLE</div> <div>■ DISPLAYS</div> </div>       | See page 5-28. |
|   | ▲▼ | <div> <div>■ DIRECT I/O</div> <div>■</div> </div>                    | See page 5-30. |
|   | ▲  | <div> <div>■ INSTALLATION</div> <div>■</div> </div>                  | See page 5-36. |
| ▲   | ◀▶ | <div> <div>■ AC INPUTS</div> <div>■</div> </div>                     | See page 5-37. |
| ▼   | ▲▼ | <div> <div>■ POWER SYSTEM</div> <div>■</div> </div>                  | See page 5-38. |
|   | ▲▼ | <div> <div>■ SIGNAL SOURCES</div> <div>■</div> </div>                | See page 5-39. |
|   | ▲▼ | <div> <div>■ BREAKERS</div> <div>■</div> </div>                      | See page 5-41. |
|   | ▲  | <div> <div>■ FLEXCURVES</div> <div>■</div> </div>                    | See page 5-44. |





### 5.1.2 INTRODUCTION TO ELEMENTS

In the design of UR relays, the term “element” is used to describe a feature that is based around a comparator. The comparator is provided with an input (or set of inputs) that is tested against a programmed setting (or group of settings) to determine if the input is within the defined range that will set the output to logic 1, also referred to as “setting the flag”. A single comparator may make multiple tests and provide multiple outputs; for example, the time overcurrent comparator sets a Pickup flag when the current input is above the setting and sets an Operate flag when the input current has been at a level above the pickup setting for the time specified by the time-current curve settings. All comparators, except the Digital Element which uses a logic state as the input, use analog parameter actual values as the input.

Elements are arranged into two classes, GROUPED and CONTROL. Each element classed as a GROUPED element is provided with six alternate sets of settings, in setting groups numbered 1 through 6. The performance of a GROUPED element is defined by the setting group that is active at a given time. The performance of a CONTROL element is independent of the selected active setting group.

The main characteristics of an element are shown on the element logic diagram. This includes the input(s), settings, fixed logic, and the output operands generated (abbreviations used on scheme logic diagrams are defined in Appendix F).

Some settings for current and voltage elements are specified in per-unit (pu) calculated quantities:

$$\text{pu quantity} = (\text{actual quantity}) / (\text{base quantity})$$

- For current elements, the 'base quantity' is the nominal secondary or primary current of the CT. Where the current source is the sum of two CTs with different ratios, the 'base quantity' will be the common secondary or primary current to which the sum is scaled (i.e. normalized to the larger of the 2 rated CT inputs). For example, if CT1 = 300 / 5 A and CT2 = 100 / 5 A, then in order to sum these, CT2 is scaled to the CT1 ratio. In this case, the 'base quantity' will be 5 A secondary or 300 A primary.
- For voltage elements the 'base quantity' is the nominal primary voltage of the protected system which corresponds (based on VT ratio and connection) to secondary VT voltage applied to the relay. For example, on a system with a 13.8 kV nominal primary voltage and with 14400:120 V Delta-connected VTs, the secondary nominal voltage (1 pu) would be:

$$\frac{13800}{14400} \times 120 = 115 \text{ V} \quad (\text{EQ 5.1})$$

For Wye-connected VTs, the secondary nominal voltage (1 pu) would be:

$$\frac{13800}{14400} \times \frac{120}{\sqrt{3}} = 66.4 \text{ V} \quad (\text{EQ 5.2})$$

Many settings are common to most elements and are discussed below:

- **FUNCTION setting:** This setting programs the element to be operational when selected as "Enabled". The factory default is "Disabled". Once programmed to "Enabled", any element associated with the Function becomes active and all options become available.
- **NAME setting:** This setting is used to uniquely identify the element.
- **SOURCE setting:** This setting is used to select the parameter or set of parameters to be monitored.
- **PICKUP setting:** For simple elements, this setting is used to program the level of the measured parameter above or below which the pickup state is established. In more complex elements, a set of settings may be provided to define the range of the measured parameters which will cause the element to pickup.
- **PICKUP DELAY setting:** This setting sets a time-delay-on-pickup, or on-delay, for the duration between the Pickup and Operate output states.
- **RESET DELAY setting:** This setting is used to set a time-delay-on-dropout, or off-delay, for the duration between the Operate output state and the return to logic 0 after the input transits outside the defined pickup range.
- **BLOCK setting:** The default output operand state of all comparators is a logic 0 or "flag not set". The comparator remains in this default state until a logic 1 is asserted at the RUN input, allowing the test to be performed. If the RUN input changes to logic 0 at any time, the comparator returns to the default state. The RUN input is used to supervise the comparator. The BLOCK input is used as one of the inputs to RUN control.
- **TARGET setting:** This setting is used to define the operation of an element target message. When set to Disabled, no target message or illumination of a faceplate LED indicator is issued upon operation of the element. When set to Self-Reset, the target message and LED indication follow the Operate state of the element, and self-resets once the operate element condition clears. When set to Latched, the target message and LED indication will remain visible after the element output returns to logic 0 - until a RESET command is received by the relay.
- **EVENTS setting:** This setting is used to control whether the Pickup, Dropout or Operate states are recorded by the event recorder. When set to Disabled, element pickup, dropout or operate are not recorded as events. When set to Enabled, events are created for:
  - (Element) PKP (pickup)
  - (Element) DPO (dropout)
  - (Element) OP (operate)

The DPO event is created when the measure and decide comparator output transits from the pickup state (logic 1) to the dropout state (logic 0). This could happen when the element is in the operate state if the reset delay time is not '0'.

## 5.1.3 INTRODUCTION TO AC SOURCES

## a) BACKGROUND

The D30 may be used on systems with breaker-and-a-half or ring bus configurations. In these applications, each of the two three-phase sets of individual phase currents (one associated with each breaker) can be used as an input to a breaker failure element. The sum of both breaker phase currents and 3I<sub>0</sub> residual currents may be required for the circuit relaying and metering functions. For a three-winding transformer application, it may be required to calculate watts and vars for each of three windings, using voltage from different sets of VTs. These requirements can be satisfied with a single UR, equipped with sufficient CT and VT input channels, by selecting the parameter to measure. A mechanism is provided to specify the AC parameter (or group of parameters) used as the input to protection/control comparators and some metering elements.

Selection of the parameter(s) to measure is partially performed by the design of a measuring element or protection/control comparator by identifying the type of parameter (fundamental frequency phasor, harmonic phasor, symmetrical component, total waveform RMS magnitude, phase-phase or phase-ground voltage, etc.) to measure. The user completes the process by selecting the instrument transformer input channels to use and some of the parameters calculated from these channels. The input parameters available include the summation of currents from multiple input channels. For the summed currents of phase, 3I<sub>0</sub>, and ground current, current from CTs with different ratios are adjusted to a single ratio before summation.

A mechanism called a “Source” configures the routing of CT and VT input channels to measurement sub-systems. Sources, in the context of UR series relays, refer to the logical grouping of current and voltage signals such that one source contains all the signals required to measure the load or fault in a particular power apparatus. A given source may contain all or some of the following signals: three-phase currents, single-phase ground current, three-phase voltages and an auxiliary voltage from a single VT for checking for synchronism.

To illustrate the concept of Sources, as applied to current inputs only, consider the breaker-and-a-half scheme below. In this application, the current flows as shown by the arrows. Some current flows through the upper bus bar to some other location or power equipment, and some current flows into transformer Winding 1. The current into Winding 1 is the phasor sum (or difference) of the currents in CT1 and CT2 (whether the sum or difference is used depends on the relative polarity of the CT connections). The same considerations apply to transformer Winding 2. The protection elements require access to the net current for transformer protection, but some elements may need access to the individual currents from CT1 and CT2.

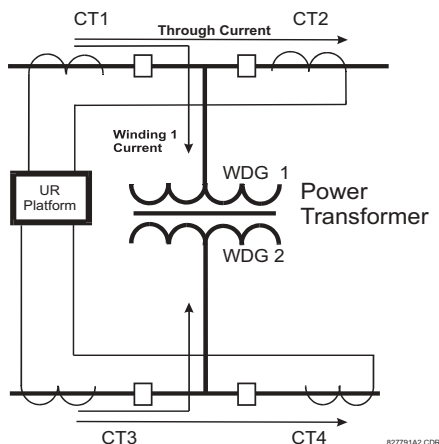


Figure 5–1: BREAKER-AND-A-HALF SCHEME

In conventional analog or electronic relays, the sum of the currents is obtained from an appropriate external connection of all CTs through which any portion of the current for the element being protected could flow. Auxiliary CTs are required to perform ratio matching if the ratios of the primary CTs to be summed are not identical. In the UR series of relays, provisions have been included for all the current signals to be brought to the UR device where grouping, ratio correction and summation are applied internally via configuration settings.

A major advantage of using internal summation is that the individual currents are available to the protection device; for example, as additional information to calculate a restraint current, or to allow the provision of additional protection features that operate on the individual currents such as breaker failure.

Given the flexibility of this approach, it becomes necessary to add configuration settings to the platform to allow the user to select which sets of CT inputs will be added to form the net current into the protected device.

The internal grouping of current and voltage signals forms an internal source. This source can be given a specific name through the settings, and becomes available to protection and metering elements in the UR platform. Individual names can be given to each source to help identify them more clearly for later use. For example, in the scheme shown in the above diagram, the configures one Source to be the sum of CT1 and CT2 and can name this Source as “Wdg 1 Current”.

Once the sources have been configured, the user has them available as selections for the choice of input signal for the protection elements and as metered quantities.

### b) CT/VT MODULE CONFIGURATION

CT and VT input channels are contained in CT/VT modules. The type of input channel can be phase/neutral/other voltage, phase/ground current, or sensitive ground current. The CT/VT modules calculate total waveform RMS levels, fundamental frequency phasors, symmetrical components and harmonics for voltage or current, as allowed by the hardware in each channel. These modules may calculate other parameters as directed by the CPU module.

A CT/VT module contains up to eight input channels, numbered 1 through 8. The channel numbering corresponds to the module terminal numbering 1 through 8 and is arranged as follows: Channels 1, 2, 3 and 4 are always provided as a group, hereafter called a “bank,” and all four are either current or voltage, as are Channels 5, 6, 7 and 8. Channels 1, 2, 3 and 5, 6, 7 are arranged as phase A, B and C respectively. Channels 4 and 8 are either another current or voltage.

Banks are ordered sequentially from the block of lower-numbered channels to the block of higher-numbered channels, and from the CT/VT module with the lowest slot position letter to the module with the highest slot position letter, as follows:

The UR platform allows for a maximum of three sets of three-phase voltages and six sets of three-phase currents. The result of these restrictions leads to the maximum number of CT/VT modules in a chassis to three. The maximum number of sources is six. A summary of CT/VT module configurations is shown below.

| ITEM  | MAXIMUM NUMBER |
|---|----------------|
| CT/VT Module                                    | 1              |
| CT Bank (3 phase channels, 1 ground channel)    | 2              |
| VT Bank (3 phase channels, 1 auxiliary channel) | 1              |

### c) CT/VT INPUT CHANNEL CONFIGURATION

Upon relay startup, configuration settings for every bank of current or voltage input channels in the relay are automatically generated from the order code. Within each bank, a channel identification label is automatically assigned to each bank of channels in a given product. The ‘bank’ naming convention is based on the physical location of the channels, required by the user to know how to connect the relay to external circuits. Bank identification consists of the letter designation of the slot in which the CT/VT module is mounted as the first character, followed by numbers indicating the channel, either 1 or 5.

For three-phase channel sets, the number of the lowest numbered channel identifies the set. For example, F1 represents the three-phase channel set of F1/F2/F3, where F is the slot letter and 1 is the first channel of the set of three channels.

Upon startup, the CPU configures the settings required to characterize the current and voltage inputs, and will display them in the appropriate section in the sequence of the banks (as described above) as follows for a maximum configuration: F1, F5, M1, M5, U1, and U5.

The above section explains how the input channels are identified and configured to the specific application instrument transformers and the connections of these transformers. The specific parameters to be used by each measuring element and comparator, and some actual values are controlled by selecting a specific source. The source is a group of current and voltage input channels selected by the user to facilitate this selection. With this mechanism, a user does not have to make multiple selections of voltage and current for those elements that need both parameters, such as a distance element or a watt calculation. It also gathers associated parameters for display purposes.

The basic idea of arranging a source is to select a point on the power system where information is of interest. An application example of the grouping of parameters in a Source is a transformer winding, on which a three phase voltage is measured, and the sum of the currents from CTs on each of two breakers is required to measure the winding current flow.



## 5.2.1 PASSWORD SECURITY

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ PASSWORD SECURITY

|            |  |                                      |  |
|------------|--|--------------------------------------|--|
| ■ PASSWORD | <div>◀▶</div> <div>MESSAGE ▲▼</div> <div>MESSAGE ▲▼</div> <div>MESSAGE ▲▼</div> <div>MESSAGE ▲</div> | ACCESS LEVEL:<br>Restricted          | Range: Restricted, Command, Setting,<br>Factory Service (for factory use only) |
| ■ SECURITY |  | CHANGE COMMAND<br>PASSWORD: No       | Range: No, Yes   |
|            |  | CHANGE SETTING<br>PASSWORD: No       | Range: No, Yes   |
|            |  | ENCRYPTED COMMAND<br>PASSWORD: ----- | Range: 0 to 9999999999<br>Note: ----- indicates no password                    |
|            |  | ENCRYPTED SETTING<br>PASSWORD: ----- | Range: 0 to 9999999999<br>Note: ----- indicates no password                    |

Two levels of password security are provided: **Command** and **Setting**. Operations under password supervision are:

- **COMMAND:** operating the breakers via faceplate keypad, changing the state of virtual inputs, clearing the event records, clearing the oscillography records, clearing fault reports, changing the date and time, clearing the breaker arcing amps, clearing the data logger, user-programmable pushbuttons
- **SETTING:** changing any setting, test mode operation

The Command and Setting passwords are defaulted to "Null" when the relay is shipped from the factory. When a password is set to "Null", the password security feature is disabled.

Programming a password code is required to enable each access level. A password consists of 1 to 10 numerical characters. When a **CHANGE ... PASSWORD** setting is set to "Yes", the following message sequence is invoked:

1. ENTER NEW PASSWORD: \_\_\_\_\_
2. VERIFY NEW PASSWORD: \_\_\_\_\_
3. NEW PASSWORD HAS BEEN STORED

To gain write access to a "Restricted" setting, set **ACCESS LEVEL** to "Setting" and then change the setting, or attempt to change the setting and follow the prompt to enter the programmed password. If the password is correctly entered, access will be allowed. If no keys are pressed for longer than 30 minutes or control power is cycled, accessibility will automatically revert to the "Restricted" level.

If an entered password is lost (or forgotten), consult the factory with the corresponding **ENCRYPTED PASSWORD**.

The D30 provides a means to raise an alarm upon failed password entry. Should password verification fail while accessing a password-protected level of the relay (either settings or commands), the UNAUTHORIZED ACCESS FlexLogic™ operand is asserted. The operand can be programmed to raise an alarm via contact outputs or communications. This feature can be used to protect against both unauthorized and accidental access attempts.

The UNAUTHORIZED ACCESS operand is reset with the **COMMANDS** ⇒ **CLEAR RECORDS** ⇒ **RESET UNAUTHORIZED ALARMS** command. Therefore, to apply this feature with security, the command level should be password-protected.

The operand does not generate events or targets. If these are required, the operand can be assigned to a digital element programmed with event logs and/or targets enabled.



NOTE

If the **SETTING** and **COMMAND** passwords are identical, this one password allows access to both commands and settings.



NOTE

When enerVista UR Setup is used to access a particular level, the user will continue to have access to that level as long as there are open windows in the enerVista UR Setup software. To re-establish the Password Security feature, all windows must be closed for at least 30 minutes.

## 5.2.2 DISPLAY PROPERTIES

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ DISPLAY PROPERTIES

|   |         |  |   |
|---|---------|--|---|
| <div> <div>■ DISPLAY</div> <div>■ PROPERTIES</div> </div> |         | <div> <div>FLASH MESSAGE</div> <div>TIME: 1.0 s</div> </div>       | Range: 0.5 to 10.0 s in steps of 0.1  |
|   | MESSAGE | <div> <div>DEFAULT MESSAGE</div> <div>TIMEOUT: 300 s</div> </div>  | Range: 10 to 900 s in steps of 1  |
|   | MESSAGE | <div> <div>DEFAULT MESSAGE</div> <div>INTENSITY: 25 %</div> </div> | Range: 25%, 50%, 75%, 100%<br>Visible only if a VFD is installed            |
|   | MESSAGE | <div> <div>SCREEN SAVER</div> <div>FEATURE: Disabled</div> </div>  | Range: Disabled, Enabled<br>Visible only if an LCD is installed             |
|   | MESSAGE | <div> <div>SCREEN SAVER</div> <div>WAIT TIME: 30 min</div> </div>  | Range: 1 to 65535 min. in steps of 1<br>Visible only if an LCD is installed |
|   | MESSAGE | <div> <div>CURRENT CUT-OFF</div> <div>LEVEL: 0.020 pu</div> </div> | Range: 0.002 to 0.020 pu in steps of 0.001                                  |
|   | MESSAGE | <div> <div>VOLTAGE CUT-OFF</div> <div>LEVEL: 1.0 V</div> </div>    | Range: 0.1 to 1.0 V secondary in steps of 0.1                               |

Some relay messaging characteristics can be modified to suit different situations using the display properties settings.

- **FLASH MESSAGE TIME:** Flash messages are status, warning, error, or information messages displayed for several seconds in response to certain key presses during setting programming. These messages override any normal messages. The duration of a flash message on the display can be changed to accommodate different reading rates.
- **DEFAULT MESSAGE TIMEOUT:** If the keypad is inactive for a period of time, the relay automatically reverts to a default message. The inactivity time is modified via this setting to ensure messages remain on the screen long enough during programming or reading of actual values.
- **DEFAULT MESSAGE INTENSITY:** To extend phosphor life in the vacuum fluorescent display, the brightness can be attenuated during default message display. During keypad interrogation, the display always operates at full brightness.
- **SCREEN SAVER FEATURE and SCREEN SAVER WAIT TIME:** These settings are only visible if the D30 has a liquid crystal display (LCD) and control its backlighting. When the **SCREEN SAVER FEATURE** is "Enabled", the LCD backlighting is turned off after the **DEFAULT MESSAGE TIMEOUT** followed by the **SCREEN SAVER WAIT TIME**, providing that no keys have been pressed and no target messages are active. When a keypress occurs or a target becomes active, the LCD backlighting is turned on.
- **CURRENT CUT-OFF LEVEL:** This setting modifies the current cut-off threshold. Very low currents (1 to 2% of the rated value) are very susceptible to noise. Some customers prefer very low currents to display as zero, while others prefer the current be displayed even when the value reflects noise rather than the actual signal. The D30 applies a cut-off value to the magnitudes and angles of the measured currents. If the magnitude is below the cut-off level, it is substituted with zero. This applies to phase and ground current phasors as well as true RMS values and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Note that the cut-off level for the sensitive ground input is 10 times lower than the **CURRENT CUT-OFF LEVEL** setting value. Raw current samples available via oscillography are not subject to cut-off.
- **VOLTAGE CUT-OFF LEVEL:** This setting modifies the voltage cut-off threshold. Very low secondary voltage measurements (at the fractional volt level) can be affected by noise. Some customers prefer these low voltages to be displayed as zero, while others prefer the voltage to be displayed even when the value reflects noise rather than the actual signal. The D30 applies a cut-off value to the magnitudes and angles of the measured voltages. If the magnitude is below the cut-off level, it is substituted with zero. This operation applies to phase and auxiliary voltages, and symmetrical components. The cut-off operation applies to quantities used for metering, protection, and control, as well as those used by communications protocols. Raw samples of the voltages available via oscillography are not subject cut-off. This setting relates to the actual measured voltage at the VT secondary inputs. It can be converted to per-unit values (pu) by dividing by the **PHASE VT SECONDARY** setting value. For example, a **PHASE VT SECONDARY** setting of "66.4 V" and a **VOLTAGE CUT-OFF LEVEL** setting of "1.0 V" gives a cut-off value of  $1.0 \text{ V} / 66.4 \text{ V} = 0.015 \text{ pu}$ .

The **CURRENT CUT-OFF LEVEL** and the **VOLTAGE CUT-OFF LEVEL** are used to determine the metered power cut-off levels. The power cut-off level is calculated as follows:

$$\text{power cut-off level} = \text{CURRENT CUT-OFF LEVEL} \times \text{VOLTAGE CUT-OFF LEVEL} \times 1.0 \text{ pu current} \times 1.0 \text{ pu voltage} \quad (\text{EQ 5.3})$$

For example, given the following settings:

**CURRENT CUT-OFF LEVEL:** "0.02 pu"

**VOLTAGE CUT-OFF LEVEL:** "1.0 V"

**PHASE CT PRIMARY:** "100 A"

**PHASE VT SECONDARY:** "66.4 V"

**PHASE VT RATIO:** "208.00 : 1".

We have:

1.0 pu current = CT primary = "100 A", and

1.0 pu voltage = **PHASE VT SECONDARY** x **PHASE VT RATIO** = 66.4 V x 208 = 13811.2 V

The power cut-off is therefore:

$$\begin{aligned} \text{power cut-off} &= \text{CURRENT CUT-OFF LEVEL} \times \text{VOLTAGE CUT-OFF LEVEL} \times 1.0 \text{ pu current} \times 1.0 \text{ pu voltage} \\ &= 0.02 \text{ pu} \times 0.015 \text{ pu} \times 100 \text{ A} \times 13811.2 \text{ V} \\ &= 416 \text{ watts} \end{aligned}$$

Any calculated power value below this cut-off will not be displayed. As well, the three-phase energy data will not accumulate if the total power from all three phases does not exceed the power cut-off.



**Lower the VOLTAGE CUT-OFF LEVEL and CURRENT CUT-OFF LEVEL with care as the relay accepts lower signals as valid measurements. Unless dictated otherwise by a specific application, the default settings of "0.02 pu" for CURRENT CUT-OFF LEVEL and "1.0 V" for VOLTAGE CUT-OFF LEVEL are recommended.**

## 5.2.3 CLEAR RELAY RECORDS

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ CLEAR RELAY RECORDS

|  |   |                             |  |
|--|---|-----------------------------|--|
| <div> <div>CLEAR RELAY RECORDS</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲</div> </div> | CLEAR FAULT REPORTS:<br>Off | Range: FlexLogic™ operand  |
|  |   | CLEAR EVENT RECORDS:<br>Off | Range: FlexLogic™ operand  |
|  |   | CLEAR OSCILLOGRAPHY?<br>No  | Range: FlexLogic™ operand  |
|  |   | CLEAR ARC AMPS 1:<br>Off    | Range: FlexLogic™ operand  |
|  |   | CLEAR ARC AMPS 2:<br>Off    | Range: FlexLogic™ operand  |
|  |   | RESET UNAUTH ACCESS:<br>Off | Range: FlexLogic™ operand  |
|  |   | CLEAR DIR I/O STATS:<br>Off | Range: FlexLogic™ operand.<br>Valid only for units with Direct I/O module. |

Selected records can be cleared from user-programmable conditions with FlexLogic™ operands. Assigning user-programmable pushbuttons to clear specific records are typical applications for these commands. Since the D30 responds to rising edges of the configured FlexLogic™ operands, they must be asserted for at least 50 ms to take effect.

Clearing records with user-programmable operands is not protected by the command password. However, user-programmable pushbuttons are protected by the command password. Thus, if they are used to clear records, the user-programmable pushbuttons can provide extra security if required.

For example, to assign User-Programmable Pushbutton 1 to clear demand records, the following settings should be applied.

1. Assign the clear demand function to Pushbutton 1 by making the following change in the **SETTINGS ⇒ PRODUCT SETUP ⇒ CLEAR RELAY RECORDS** menu:

**CLEAR DEMAND:** "PUSHBUTTON 1 ON"

2. Set the properties for User-Programmable Pushbutton 1 by making the following changes in the **SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE PUSHBUTTONS ⇒ USER PUSHBUTTON 1** menu:

**PUSHBUTTON 1 FUNCTION:** "Self-reset"

**PUSHBTN 1 DROP-OUT TIME:** "0.20 s"

## 5.2.4 COMMUNICATIONS

## a) MAIN MENU

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS

|                  |    |                                 |                |
|------------------|----|---------------------------------|----------------|
| ■ COMMUNICATIONS | ◀▶ | ■ SERIAL PORTS                  | See below.     |
| MESSAGE          | ▲▼ | ■ NETWORK                       | See page 5-12. |
| MESSAGE          | ▲▼ | ■ MODBUS PROTOCOL               | See page 5-12. |
| MESSAGE          | ▲▼ | ■ DNP PROTOCOL                  | See page 5-13. |
| MESSAGE          | ▲▼ | ■ IEC 61850 PROTOCOL            | See page 5-15. |
| MESSAGE          | ▲▼ | ■ WEB SERVER<br>■ HTTP PROTOCOL | See page 5-16. |
| MESSAGE          | ▲▼ | ■ TFTP PROTOCOL                 | See page 5-16. |
| MESSAGE          | ▲▼ | ■ IEC 60870-5-104<br>■ PROTOCOL | See page 5-17. |
| MESSAGE          | ▲  | ■ SNTP PROTOCOL                 | See page 5-18. |

## b) SERIAL PORTS

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ SERIAL PORTS

|                |    |                                       |   |
|----------------|----|---------------------------------------|---|
| ■ SERIAL PORTS | ◀▶ | RS485 COM1 BAUD<br>RATE: 19200        | Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200. Only active if CPU 9E is ordered. |
| MESSAGE        | ▲▼ | RS485 COM1 PARITY:<br>None            | Range: None, Odd, Even<br>Only active if CPU Type 9E is ordered   |
| MESSAGE        | ▲▼ | RS485 COM1 RESPONSE<br>MIN TIME: 0 ms | Range: 0 to 1000 ms in steps of 10<br>Only active if CPU Type 9E is ordered   |
| MESSAGE        | ▲▼ | RS485 COM2 BAUD<br>RATE: 19200        | Range: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, 115200                                    |
| MESSAGE        | ▲▼ | RS485 COM2 PARITY:<br>None            | Range: None, Odd, Even  |
| MESSAGE        | ▲  | RS485 COM2 RESPONSE<br>MIN TIME: 0 ms | Range: 0 to 1000 ms in steps of 10  |

The D30 is equipped with up to 3 independent serial communication ports. The faceplate RS232 port is intended for local use and is fixed at 19200 baud and no parity. The rear COM1 port type is selected when ordering: either an Ethernet or RS485 port. The rear COM2 port is RS485. The RS485 ports have settings for baud rate and parity. It is important that these parameters agree with the settings used on the computer or other equipment that is connected to these ports. Any of these ports may be connected to a computer running enerVista UR Setup. This software can download and upload setting files, view measured parameters, and upgrade the relay firmware. A maximum of 32 relays can be daisy-chained and connected to a DCS, PLC or PC using the RS485 ports.



**For each RS485 port, the minimum time before the port will transmit after receiving data from a host can be set. This feature allows operation with hosts which hold the RS485 transmitter active for some time after each transmission.**

## c) NETWORK

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ NETWORK

|   |  |  |
|---|--|--|
| <div> <div>■ NETWORK</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>IP ADDRESS:<br/>0.0.0.0</div> </div>                                | <div>Range: Standard IP address format<br/>Only active if CPU Type 9G or 9H is ordered.</div>                            |
|   | <div> <div>▲▼</div> <div>SUBNET IP MASK:<br/>0.0.0.0</div> </div>                            | <div>Range: Standard IP address format<br/>Only active if CPU Type 9G or 9H is ordered.</div>                            |
|   | <div> <div>▲▼</div> <div>GATEWAY IP ADDRESS:<br/>0.0.0.0</div> </div>                        | <div>Range: Standard IP address format<br/>Only active if CPU Type 9G or 9H is ordered.</div>                            |
|   | <div> <div>▲▼</div> <div> <div>■ OSI NETWORK</div> <div>■ ADDRESS (NSAP)</div> </div> </div> | <div>Range: Press the MESSAGE ⇒ key to enter the OSI NETWORK ADDRESS. Only active if CPU Type 9G or 9H is ordered.</div> |
|   | <div> <div>▲</div> <div>ETHERNET OPERATION<br/>MODE: Full-Duplex</div> </div>                | <div>Range: Half-Duplex, Full-Duplex<br/>Only active if CPU Type 9G or 9H is ordered.</div>                              |

These messages appear only if the D30 is ordered with an Ethernet card.

The IP addresses are used with the DNP, Modbus/TCP, IEC 61580, IEC 60870-5-104, TFTP, and HTTP protocols. The NSAP address is used with the IEC 61850 protocol over the OSI (CLNP/TP4) stack only. Each network protocol has a setting for the **TCP/UDP PORT NUMBER**. These settings are used only in advanced network configurations and should normally be left at their default values, but may be changed if required (for example, to allow access to multiple UR-series relays behind a router). By setting a different **TCP/UDP PORT NUMBER** for a given protocol on each UR-series relay, the router can map the relays to the same external IP address. The client software (enerVista UR Setup, for example) must be configured to use the correct port number if these settings are used.

5



NOTE

When the NSAP address, any TCP/UDP Port Number, or any User Map setting (when used with DNP) is changed, it will not become active until power to the relay has been cycled (OFF/ON).



WARNING

**Do not set more than one protocol to use the same TCP/UDP PORT NUMBER, as this will result in unreliable operation of those protocols.**

## d) MODBUS PROTOCOL

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ MODBUS PROTOCOL

|  |  |  |
|--|--|--|
| <div> <div>■ MODBUS PROTOCOL</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>MODBUS SLAVE<br/>ADDRESS: 254</div> </div>  | <div>Range: 1 to 254 in steps of 1</div>   |
|  | <div> <div>▲</div> <div>MODBUS TCP PORT<br/>NUMBER: 502</div> </div> | <div>Range: 1 to 65535 in steps of 1</div> |

The serial communication ports utilize the Modbus protocol, unless configured for DNP operation (see the DNP Protocol description below). This allows the enerVista UR Setup software to be used. The UR operates as a Modbus slave device only. When using Modbus protocol on the RS232 port, the D30 will respond regardless of the **MODBUS SLAVE ADDRESS** programmed. For the RS485 ports each D30 must have a unique address from 1 to 254. Address 0 is the broadcast address which all Modbus slave devices listen to. Addresses do not have to be sequential, but no two devices can have the same address or conflicts resulting in errors will occur. Generally, each device added to the link should use the next higher address starting at 1. Refer to Appendix B for more information on the Modbus protocol.

## e) DNP PROTOCOL

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ DNP PROTOCOL

|                |    |                     |                    |  |
|----------------|----|---------------------|--------------------|--|
| ■ DNP PROTOCOL |    | DNP PORT:           | NONE               | Range: NONE, COM1 - RS485, COM2 - RS485, FRONT PANEL - RS232, NETWORK    |
|                |    | DNP ADDRESS:        | 255                | Range: 0 to 65519 in steps of 1  |
| MESSAGE        | ▲▼ | ■ DNP NETWORK       |                    | Range: Press the MESSAGE ⇒ key to enter the DNP NETWORK CLIENT ADDRESSES |
|                |    | ■ CLIENT ADDRESSES  |                    |  |
| MESSAGE        | ▲▼ | DNP TCP/UDP PORT    | NUMBER: 20000      | Range: 1 to 65535 in steps of 1  |
| MESSAGE        | ▲▼ | DNP UNSOL RESPONSE  | FUNCTION: Disabled | Range: Enabled, Disabled   |
| MESSAGE        | ▲▼ | DNP UNSOL RESPONSE  | TIMEOUT: 5 s       | Range: 0 to 60 s in steps of 1   |
| MESSAGE        | ▲▼ | DNP UNSOL RESPONSE  | MAX RETRIES: 10    | Range: 1 to 255 in steps of 1  |
| MESSAGE        | ▲▼ | DNP UNSOL RESPONSE  | DEST ADDRESS: 1    | Range: 0 to 65519 in steps of 1  |
| MESSAGE        | ▲▼ | USER MAP FOR DNP    | ANALOGS: Disabled  | Range: Enabled, Disabled   |
| MESSAGE        | ▲▼ | NUMBER OF SOURCES   | IN ANALOG LIST: 1  | Range: 1 to 2 in steps of 1  |
| MESSAGE        | ▲▼ | DNP CURRENT SCALE   | FACTOR: 1          | Range: 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 100000                 |
| MESSAGE        | ▲▼ | DNP VOLTAGE SCALE   | FACTOR: 1          | Range: 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 100000                 |
| MESSAGE        | ▲▼ | DNP POWER SCALE     | FACTOR: 1          | Range: 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 100000                 |
| MESSAGE        | ▲▼ | DNP ENERGY SCALE    | FACTOR: 1          | Range: 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 100000                 |
| MESSAGE        | ▲▼ | DNP OTHER SCALE     | FACTOR: 1          | Range: 0.001, 0.01, 0.1, 1, 10, 100, 1000, 10000, 100000                 |
| MESSAGE        | ▲▼ | DNP CURRENT DEFAULT | DEADBAND: 30000    | Range: 0 to 65535 in steps of 1  |
| MESSAGE        | ▲▼ | DNP VOLTAGE DEFAULT | DEADBAND: 30000    | Range: 0 to 65535 in steps of 1  |
| MESSAGE        | ▲▼ | DNP POWER DEFAULT   | DEADBAND: 30000    | Range: 0 to 65535 in steps of 1  |
| MESSAGE        | ▲▼ | DNP ENERGY DEFAULT  | DEADBAND: 30000    | Range: 0 to 65535 in steps of 1  |
| MESSAGE        | ▲▼ | DNP OTHER DEFAULT   | DEADBAND: 30000    | Range: 0 to 65535 in steps of 1  |
| MESSAGE        | ▲▼ | DNP TIME SYNC IIN   | PERIOD: 1440 min   | Range: 1 to 10080 min. in steps of 1                                     |



|         |  |                                       |                                 |
|---------|--|---------------------------------------|---------------------------------|
| MESSAGE |  | DNP MESSAGE FRAGMENT<br>SIZE: 240     | Range: 30 to 2048 in steps of 1 |
| MESSAGE |  | ■ DNP BINARY INPUTS<br>■ USER MAP     |                                 |
| MESSAGE |  | DNP OBJECT 1<br>DEFAULT VARIATION: 2  | Range: 1, 2                     |
| MESSAGE |  | DNP OBJECT 2<br>DEFAULT VARIATION: 2  | Range: 1, 2                     |
| MESSAGE |  | DNP OBJECT 20<br>DEFAULT VARIATION: 1 | Range: 1, 2, 5, 6               |
| MESSAGE |  | DNP OBJECT 21<br>DEFAULT VARIATION: 1 | Range: 1, 2, 9, 10              |
| MESSAGE |  | DNP OBJECT 22<br>DEFAULT VARIATION: 1 | Range: 1, 2, 5, 6               |
| MESSAGE |  | DNP OBJECT 23<br>DEFAULT VARIATION: 2 | Range: 1, 2, 5, 6               |
| MESSAGE |  | DNP OBJECT 30<br>DEFAULT VARIATION: 1 | Range: 1, 2, 3, 4, 5            |
| MESSAGE |  | DNP OBJECT 32<br>DEFAULT VARIATION: 1 | Range: 1, 2, 3, 4, 5, 7         |

The D30 supports the Distributed Network Protocol (DNP) version 3.0. The D30 can be used as a DNP slave device connected to a single DNP master (usually an RTU or a SCADA master station). Since the D30 maintains one set of DNP data change buffers and connection information, only one DNP master should actively communicate with the D30 at one time. The **DNP PORT** setting selects the communications port assigned to the DNP protocol; only a single port can be assigned. Once DNP is assigned to a serial port, the Modbus protocol is disabled on that port. Note that COM1 can be used only in non-ethernet UR relays. When this setting is set to “Network”, the DNP protocol can be used over either TCP/IP or UDP/IP. Refer to Appendix E for more information on the DNP protocol. The **DNP ADDRESS** setting is the DNP slave address. This number identifies the D30 on a DNP communications link. Each DNP slave should be assigned a unique address. The **DNP NETWORK CLIENT ADDRESS** setting can force the D30 to respond to a maximum of five specific DNP masters.

The **DNP UNSOL RESPONSE FUNCTION** should be “Disabled” for RS485 applications since there is no collision avoidance mechanism. The **DNP UNSOL RESPONSE TIMEOUT** sets the time the D30 waits for a DNP master to confirm an unsolicited response. The **DNP UNSOL RESPONSE MAX RETRIES** setting determines the number of times the D30 retransmits an unsolicited response without receiving confirmation from the master; a value of “255” allows infinite re-tries. The **DNP UNSOL RESPONSE DEST ADDRESS** is the DNP address to which all unsolicited responses are sent. The IP address to which unsolicited responses are sent is determined by the D30 from the current TCP connection or the most recent UDP message.

The **USER MAP FOR DNP ANALOGS** setting allows the large pre-defined Analog Inputs points list to be replaced by the much smaller Modbus User Map. This can be useful for users wishing to read only selected Analog Input points from the D30. See Appendix E for more information.

The **NUMBER OF SOURCES IN ANALOG LIST** setting allows the selection of the number of current/voltage source values that are included in the Analog Inputs points list. This allows the list to be customized to contain data for only the sources that are configured. This setting is relevant only when the User Map is not used.

The **DNP SCALE FACTOR** settings are numbers used to scale Analog Input point values. These settings group the D30 Analog Input data into types: current, voltage, power, energy, and other. Each setting represents the scale factor for all Analog Input points of that type. For example, if the **DNP VOLTAGE SCALE FACTOR** setting is set to a value of 1000, all DNP Analog Input points that are voltages will be returned with values 1000 times smaller (e.g. a value of 72000 V on the D30 will be returned as 72). These settings are useful when analog input values must be adjusted to fit within certain ranges in DNP masters. Note that a scale factor of 0.1 is equivalent to a multiplier of 10 (i.e. the value will be 10 times larger).

The **DNP DEFAULT DEADBAND** settings determine when to trigger unsolicited responses containing Analog Input data. These settings group the D30 Analog Input data into types: current, voltage, power, energy, and other. Each setting represents the default deadband value for all Analog Input points of that type. For example, to trigger unsolicited responses from the D30



when any current values change by 15 A, the **DNP CURRENT DEFAULT DEADBAND** setting should be set to “15”. Note that these settings are the deadband default values. DNP Object 34 points can be used to change deadband values, from the default, for each individual DNP Analog Input point. Whenever power is removed and re-applied to the D30, the default deadbands will be in effect.

The **DNP TIME SYNC IIN PERIOD** setting determines how often the Need Time Internal Indication (IIN) bit is set by the D30. Changing this time allows the DNP master to send time synchronization commands more or less often, as required.

The **DNP MESSAGE FRAGMENT SIZE** setting determines the size, in bytes, at which message fragmentation occurs. Large fragment sizes allow for more efficient throughput; smaller fragment sizes cause more application layer confirmations to be necessary which can provide for more robust data transfer over noisy communication channels.

The **DNP BINARY INPUTS USER MAP** setting allows for the creation of a custom DNP Binary Inputs points list. The default DNP Binary Inputs list contains 928 points representing various binary states (contact inputs and outputs, virtual inputs and outputs, protection element states, etc.). If not all of these points are required in the DNP master, a custom Binary Inputs points list can be created by selecting up to 58 blocks of 16 points. Each block represents 16 binary input points. Block 1 represents binary input points 0 to 15, block 2 represents binary input points 16 to 31, block 3 represents binary input points 32 to 47, etc. The minimum number of binary input points that can be selected is 16 (1 block). If all of the **BIN INPUT BLOCK X** settings are set to “Not Used”, the standard list of 928 points will be in effect. The D30 will form the binary inputs points list from the **BIN INPUT BLOCK X** settings up to the first occurrence of a setting value of “Not Used”.



**When using the User Maps for DNP data points (analog inputs and/or binary inputs) for relays with ethernet installed, check the “DNP Points Lists” D30 web page to ensure the desired points lists are created. This web page can be viewed using a web browser by entering the D30 IP address to access the D30 “Main Menu”, then by selecting the “Device Information Menu” > “DNP Points Lists” menu item.**

The **DNP OBJECT N DEFAULT VARIATION** settings allow the user to select the DNP default variation number for object types 1, 2, 20, 21, 22, 23, 30, and 32. The default variation refers to the variation response when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. Refer to the *DNP Implementation* section in Appendix E for additional details.

## f) IEC 61850 PROTOCOL

**PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ IEC 61850 PROTOCOL**

|  |  |  |   |
|--|--|--|---|
| <input checked="" type="checkbox"/> IEC 61850 PROTOCOL |  | <b>DEFAULT GSSE UPDATE TIME:</b> 60 s    | Range: 1 to 60 s in steps of 1. See UserSt Bit Pairs in the Remote Outputs section of this Chapter. |
| MESSAGE  |  | <b>LOGICAL DEVICE NAME:</b><br>IECDevice | Range: Up to 16 alphanumeric characters representing the name of the IEC 61850 logical device.      |
| MESSAGE  |  | <b>IEC/MMS TCP PORT NUMBER:</b> 102      | Range: 1 to 65535 in steps of 1   |
| MESSAGE  |  | <b>GSSE FUNCTION:</b><br>Enabled         | Range: Disabled, Enabled  |

The D30 supports the Manufacturing Message Specification (MMS) protocol as specified by IEC 61850. MMS is supported over two protocol stacks: TCP/IP over ethernet and TP4/CLNP (OSI) over ethernet. The D30 operates as an IEC 61850 server. The *Remote Inputs/Outputs* section in this chapter describe the peer-to-peer GSSE message scheme.



The **LOGICAL DEVICE NAME** setting represents the MMS domain name (IEC 61850 logical device) where all IEC/MMS objects are located. The **GSSE FUNCTION** setting allows for the blocking of GSSE messages from the D30. This can be used during testing or to prevent the relay from sending GSSE messages during normal operation.



**Since GSSE messages are multicast ethernet by specification, router networks must not be used for IEC/MMS.**

## g) WEB SERVER HTTP PROTOCOL






PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ WEB SERVER HTTP PROTOCOL

|   |   |                             |                                 |
|---|---|-----------------------------|---------------------------------|
| <input checked="" type="checkbox"/> WEB SERVER<br><input checked="" type="checkbox"/> HTTP PROTOCOL |   | HTTP TCP PORT<br>NUMBER: 80 | Range: 1 to 65535 in steps of 1 |
|---|---|-----------------------------|---------------------------------|

The D30 contains an embedded web server and is capable of transferring web pages to a web browser such as Microsoft Internet Explorer or Netscape Navigator. This feature is available only if the D30 has the ethernet option installed. The web pages are organized as a series of menus that can be accessed starting at the D30 “Main Menu”. Web pages are available showing DNP and IEC 60870-5-104 points lists, Modbus registers, Event Records, Fault Reports, etc. The web pages can be accessed by connecting the UR and a computer to an ethernet network. The Main Menu will be displayed in the web browser on the computer simply by entering the IP address of the D30 into the “Address” box on the web browser.

## h) TFTP PROTOCOL

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ TFTP PROTOCOL

|   |   |                                   |                                 |
|---|---|-----------------------------------|---------------------------------|
| <input checked="" type="checkbox"/> TFTP PROTOCOL |   | TFTP MAIN UDP PORT<br>NUMBER: 69  | Range: 1 to 65535 in steps of 1 |
| MESSAGE   |   | TFTP DATA UDP PORT 1<br>NUMBER: 0 | Range: 0 to 65535 in steps of 1 |
| MESSAGE   |    | TFTP DATA UDP PORT 2<br>NUMBER: 0 | Range: 0 to 65535 in steps of 1 |

The Trivial File Transfer Protocol (TFTP) can be used to transfer files from the UR over a network. The D30 operates as a TFTP server. TFTP client software is available from various sources, including Microsoft Windows NT. The `dir.txt` file obtained from the D30 contains a list and description of all available files (event records, oscillography, etc.).

## i) IEC 60870-5-104 PROTOCOL

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ IEC 60870-5-104 PROTOCOL

|   |  |   |                                   |
|---|--|---|-----------------------------------|
| <input checked="" type="checkbox"/> IEC 60870-5-104<br><input checked="" type="checkbox"/> PROTOCOL |  | IEC 60870-5-104<br>FUNCTION: Disabled   | Range: Enabled, Disabled          |
| MESSAGE   |  | IEC TCP PORT<br>NUMBER: 2404  | Range: 1 to 65535 in steps of 1   |
| MESSAGE   |  | <input checked="" type="checkbox"/> IEC NETWORK<br><input checked="" type="checkbox"/> CLIENT ADDRESSES |                                   |
| MESSAGE   |  | IEC COMMON ADDRESS<br>OF ASDU: 0  | Range: 0 to 65535 in steps of 1   |
| MESSAGE   |  | IEC CYCLIC DATA<br>PERIOD: 60 s   | Range: 1 to 65535 s in steps of 1 |
| MESSAGE   |  | NUMBER OF SOURCES<br>IN MMENC1 LIST: 1  | Range: 1 to 2 in steps of 1       |
| MESSAGE   |  | IEC CURRENT DEFAULT<br>THRESHOLD: 30000   | Range: 0 to 65535 in steps of 1   |
| MESSAGE   |  | IEC VOLTAGE DEFAULT<br>THRESHOLD: 30000   | Range: 0 to 65535 in steps of 1   |
| MESSAGE   |  | IEC POWER DEFAULT<br>THRESHOLD: 30000   | Range: 0 to 65535 in steps of 1   |
| MESSAGE   |  | IEC ENERGY DEFAULT<br>THRESHOLD: 30000  | Range: 0 to 65535 in steps of 1   |
| MESSAGE   |  | IEC OTHER DEFAULT<br>THRESHOLD: 30000   | Range: 0 to 65535 in steps of 1   |

The D30 supports the IEC 60870-5-104 protocol. The D30 can be used as an IEC 60870-5-104 slave device connected to a maximum of two masters (usually either an RTU or a SCADA master station). Since the D30 maintains two sets of IEC 60870-5-104 data change buffers, no more than two masters should actively communicate with the D30 at one time.

The **NUMBER OF SOURCES IN MMENC1 LIST** setting allows the selection of the number of current/voltage source values that are included in the M\_ME\_NC\_1 (measured value, short floating point) Analog points list. This allows the list to be customized to contain data for only the sources that are configured.

The IEC ----- **DEFAULT THRESHOLD** settings are the values used by the UR to determine when to trigger spontaneous responses containing M\_ME\_NC\_1 analog data. These settings group the UR analog data into types: current, voltage, power, energy, and other. Each setting represents the default threshold value for all M\_ME\_NC\_1 analog points of that type. For example, in order to trigger spontaneous responses from the UR when any current values change by 15 A, the **IEC CURRENT DEFAULT THRESHOLD** setting should be set to 15. Note that these settings are the default values of the dead-bands. P\_ME\_NC\_1 (Parameter of measured value, short floating point value) points can be used to change threshold values, from the default, for each individual M\_ME\_NC\_1 analog point. Whenever power is removed and re-applied to the UR, the default thresholds will be in effect.



**The IEC 60870-5-104 and DNP protocols can not be used at the same time. When the IEC 60870-5-104 FUNCTION setting is set to “Enabled”, the DNP protocol will not be operational. When this setting is changed it will not become active until power to the relay has been cycled (Off/On).**

## j) SNTP PROTOCOL

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ SNTP PROTOCOL

|  |    |  |                                   |
|--|----|--|-----------------------------------|
| <div>■ SNTP PROTOCOL</div> <div>MESSAGE</div> <div>MESSAGE</div> | ◀▶ | <div>SNTP FUNCTION:</div> <div>Disabled</div>      | Range: Enabled, Disabled          |
|  | ▲▼ | <div>SNTP SERVER IP ADDR:</div> <div>0.0.0.0</div> | Range: Standard IP address format |
|  | ▲▼ | <div>SNTP UDP PORT</div> <div>NUMBER: 123</div>    | Range: 0 to 65535 in steps of 1   |

The D30 supports the Simple Network Time Protocol specified in RFC-2030. With SNTP, the D30 can obtain clock time over an Ethernet network. The D30 acts as an SNTP client to receive time values from an SNTP/NTP server, usually a dedicated product using a GPS receiver to provide an accurate time. Both unicast and broadcast SNTP are supported.

If SNTP functionality is enabled at the same time as IRIG-B, the IRIG-B signal provides the time value to the D30 clock for as long as a valid signal is present. If the IRIG-B signal is removed, the time obtained from the SNTP server is used. If either SNTP or IRIG-B is enabled, the D30 clock value cannot be changed using the front panel keypad.

To use SNTP in unicast mode, **SNTP SERVER IP ADDR** must be set to the SNTP/NTP server IP address. Once this address is set and **SNTP FUNCTION** is “Enabled”, the D30 attempts to obtain time values from the SNTP/NTP server. Since many time values are obtained and averaged, it generally takes three to four minutes until the D30 clock is closely synchronized with the SNTP/NTP server. It may take up to one minute for the D30 to signal an SNTP self-test error if the server is offline.

To use SNTP in broadcast mode, set the **SNTP SERVER IP ADDR** setting to “0.0.0.0” and **SNTP FUNCTION** to “Enabled”. The D30 then listens to SNTP messages sent to the “all ones” broadcast address for the subnet. The D30 waits up to eighteen minutes (>1024 seconds) without receiving an SNTP broadcast message before signaling an SNTP self-test error.

The UR-series relays do not support the multicast or anycast SNTP functionality.

## 5.2.5 MODBUS USER MAP

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ MODBUS USER MAP

|   |   |   |                                 |
|---|---|---|---------------------------------|
| <div>■ MODBUS USER MAP</div> <div>MESSAGE</div> | ◀▶  | <div>ADDRESS 1: 0</div> <div>VALUE: 0</div> | Range: 0 to 65535 in steps of 1 |
|   | ↓   |   |                                 |
| ▲▼  | <div>ADDRESS 256: 0</div> <div>VALUE: 0</div> | Range: 0 to 65535 in steps of 1             |                                 |




The Modbus User Map provides read-only access for up to 256 registers. To obtain a memory map value, enter the desired address in the **ADDRESS** line (this value must be converted from hex to decimal format). The corresponding value is displayed in the **VALUE** line. A value of “0” in subsequent register **ADDRESS** lines automatically returns values for the previous **ADDRESS** lines incremented by “1”. An address value of “0” in the initial register means “none” and values of “0” will be displayed for all registers. Different **ADDRESS** values can be entered as required in any of the register positions.



These settings can also be used with the DNP protocol. See the DNP Analog Input Points section in Appendix E for details.

## 5.2.6 REAL TIME CLOCK

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ REAL TIME CLOCK
















|  |   |                                     |  |
|--|---|-------------------------------------|--|
| <input checked="" type="checkbox"/> REAL TIME<br><input checked="" type="checkbox"/> CLOCK |   | IRIG-B SIGNAL TYPE:<br>None         | Range: None, DC Shift, Amplitude Modulated |
| MESSAGE  |    | REAL TIME CLOCK<br>EVENTS: Disabled | Range: Disabled, Enabled                   |

The date and time for the relay clock can be synchronized to other relays using an IRIG-B signal. It has the same accuracy as an electronic watch, approximately  $\pm 1$  minute per month. An IRIG-B signal may be connected to the relay to synchronize the clock to a known time base and to other relays. If an IRIG-B signal is used, only the current year needs to be entered. See also the **COMMANDS** ⇒ **SET DATE AND TIME** menu for manually setting the relay clock.

The **REAL TIME CLOCK EVENTS** setting allows changes to the date and/or time to be captured in the event record.

## 5.2.7 FAULT REPORTS

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ FAULT REPORTS ⇒ FAULT REPORT 1

|   |   |   |  |
|---|---|---|--|
| <input checked="" type="checkbox"/> FAULT REPORT 1<br><input checked="" type="checkbox"/> |       | FAULT REPORT 1<br>SOURCE: SRC 1         | Range: SRC 1, SRC 2                      |
| MESSAGE   |       | FAULT REPORT 1 TRIG:<br>Off             | Range: FlexLogic™ operand                |
| MESSAGE   |       | FAULT REPORT 1 Z1<br>MAG: 3.00 Ω        | Range: 0.01 to 250.00 Ω in steps of 0.01 |
| MESSAGE   |     | FAULT REPORT 1 Z1<br>ANGLE: 75°         | Range: 25 to 90° in steps of 1           |
| MESSAGE   |   | FAULT REPORT 1 Z0<br>MAG: 9.00 Ω        | Range: 0.01 to 650.00 Ω in steps of 0.01 |
| MESSAGE   |   | FAULT REPORT 1 Z0<br>ANGLE: 75°         | Range: 25 to 90° in steps of 1           |
| MESSAGE   |   | FAULT REPORT 1 LINE<br>LENGTH UNITS: km | Range: km, miles                         |
| MESSAGE   |    | FAULT REP 1 LENGTH<br>(km ): 100.0      | Range: 0.0 to 2000.0 in steps of 0.1     |

The D30 relay supports one fault report and an associated fault locator. The signal source and trigger condition, as well as the characteristics of the line or feeder, are entered in this menu.

The fault report stores data, in non-volatile memory, pertinent to an event when triggered. The captured data contained in the `FaultReport.txt` file includes:

- Fault report number
- Name of the relay, programmed by the user
- Firmware revision of the relay
- Date and time of trigger
- Name of trigger (specific operand)
- Line/Feeder ID via the name of a configured signal source
- Active setting group at the time of trigger
- Pre-fault current and voltage phasors (one-quarter cycle before the trigger)
- Fault current and voltage phasors (three-quarter cycle after the trigger)

- Elements operated at the time of triggering
- Events: 9 before trigger and 7 after trigger (only available via the relay webpage)
- Fault duration times for each breaker (created by the Breaker Arcing Current feature)

The captured data also includes the fault type and the distance to the fault location, as well as the reclose shot number (when applicable). The Fault Locator does not report fault type or location if the source VTs are connected in the Delta configuration. To include fault duration times in the fault report, the user must enable and configure Breaker Arcing Current feature for each of the breakers. Fault duration is reported on a per-phase basis.

The trigger can be any FlexLogic™ operand, but in most applications it is expected to be the same operand, usually a virtual output, that is used to drive an output relay to trip a breaker. To prevent the overwriting of fault events, the disturbance detector should not be used to trigger a fault report. A FAULT RPT TRIG event is automatically created when the report is triggered.

If a number of protection elements are ORed to create a fault report trigger, the first operation of any element causing the OR gate output to become high triggers a fault report. However, If other elements operate during the fault and the first operated element has not been reset (the OR gate output is still high), the fault report is not triggered again. Considering the reset time of protection elements, there is very little chance that fault report can be triggered twice in this manner. As the fault report must capture a usable amount of pre and post-fault data, it can not be triggered faster than every 20 ms.

Each fault report is stored as a file; the relay capacity is fifteen (15) files. An sixteenth (16th) trigger overwrites the oldest file.

The enerVista UR Setup software is required to view all captured data. The relay faceplate display can be used to view the date and time of trigger, the fault type, the distance location of the fault, and the reclose shot number.

The **FAULT REPORT 1 SOURCE** setting selects the source for input currents and voltages and disturbance detection. The **FAULT 1 REPORT TRIG** setting assigns the FlexLogic™ operand representing the protection element/elements requiring operational fault location calculations. The distance to fault calculations are initiated by this signal. The **FAULT REPORT 1 Z1 MAG** and **FAULT REPORT 1 Z0 MAG** impedances are entered in secondary ohms.

See the **ACTUAL VALUES** ⇒ **RECORDS** ⇒ **FAULT REPORTS** menu for additional details.

## 5.2.8 OSCILLOGRAPHY

### a) MAIN MENU

**PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ OSCILLOGRAPHY**

|  |    |  |   |
|--|----|--|---|
| <input checked="" type="checkbox"/> <b>OSCILLOGRAPHY</b> | ◀▶ | <b>NUMBER OF RECORDS:</b><br>15  | Range: 1 to 64 in steps of 1            |
| MESSAGE  | ▲▼ | <b>TRIGGER MODE:</b><br>Automatic Overwrite  | Range: Automatic Overwrite, Protected   |
| MESSAGE  | ▲▼ | <b>TRIGGER POSITION:</b><br>50%  | Range: 0 to 100% in steps of 1          |
| MESSAGE  | ▲▼ | <b>TRIGGER SOURCE:</b><br>Off  | Range: FlexLogic™ operand               |
| MESSAGE  | ▲▼ | <b>AC INPUT WAVEFORMS:</b><br>16 samples/cycle   | Range: Off, 8, 16, 32, 64 samples/cycle |
| MESSAGE  | ▲▼ | <input checked="" type="checkbox"/> <b>DIGITAL CHANNELS</b><br><input checked="" type="checkbox"/> |   |
| MESSAGE  | ▲  | <input checked="" type="checkbox"/> <b>ANALOG CHANNELS</b><br><input checked="" type="checkbox"/>  |   |

Oscillography records contain waveforms captured at the sampling rate as well as other relay data at the point of trigger. Oscillography records are triggered by a programmable FlexLogic™ operand. Multiple oscillography records may be captured simultaneously.

The **NUMBER OF RECORDS** is selectable, but the number of cycles captured in a single record varies considerably based on other factors such as sample rate and the number of operational CT/VT modules. There is a fixed amount of data storage for oscillography; the more data captured, the less the number of cycles captured per record. See the **ACTUAL VALUES** ⇨ ⇩ **RECORDS** ⇨ ⇩ **OSCILLOGRAPHY** menu to view the number of cycles captured per record. The following table provides sample configurations with corresponding cycles/record.

**Table 5–1: OSCILLOGRAPHY CYCLES/RECORD EXAMPLE**

| # RECORDS | # CT/VTS | SAMPLE RATE | # DIGITALS | # ANALOGS | CYCLES/RECORD |
|-----------|----------|-------------|------------|-----------|---------------|
| 1         | 1        | 8           | 0          | 0         | 1872.0        |
| 1         | 1        | 16          | 16         | 0         | 1685.0        |
| 8         | 1        | 16          | 16         | 0         | 276.0         |
| 8         | 1        | 16          | 16         | 4         | 219.5         |
| 8         | 2        | 16          | 16         | 4         | 93.5          |
| 8         | 2        | 16          | 64         | 16        | 93.5          |
| 8         | 2        | 32          | 64         | 16        | 57.6          |
| 8         | 2        | 64          | 64         | 16        | 32.3          |
| 32        | 2        | 64          | 64         | 16        | 9.5           |

A new record may automatically overwrite an older record if **TRIGGER MODE** is set to “Automatic Overwrite”.

Set the **TRIGGER POSITION** to a percentage of the total buffer size (e.g. 10%, 50%, 75%, etc.). A trigger position of 25% consists of 25% pre- and 75% post-trigger data. The **TRIGGER SOURCE** is always captured in oscillography and may be any FlexLogic™ parameter (element state, contact input, virtual output, etc.). The relay sampling rate is 64 samples per cycle.

The **AC INPUT WAVEFORMS** setting determines the sampling rate at which AC input signals (i.e. current and voltage) are stored. Reducing the sampling rate allows longer records to be stored. This setting has no effect on the internal sampling rate of the relay which is always 64 samples per cycle, i.e. it has no effect on the fundamental calculations of the device.



**When changes are made to the oscillography settings, all existing oscillography records will be CLEARED.**

## b) DIGITAL CHANNELS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ OSCILLOGRAPHY ⇨ DIGITAL CHANNELS**

☒ **DIGITAL CHANNELS**

DIGITAL CHANNEL 1:

Off

Range: FlexLogic™ operand

↓

MESSAGE

DIGITAL CHANNEL 63:

Off

Range: FlexLogic™ operand

A **DIGITAL CHANNEL** setting selects the FlexLogic™ operand state recorded in an oscillography trace. The length of each oscillography trace depends in part on the number of parameters selected here. Parameters set to “Off” are ignored. Upon startup, the relay will automatically prepare the parameter list.

## c) ANALOG CHANNELS

**PATH: SETTINGS ⇨ PRODUCT SETUP ⇨ OSCILLOGRAPHY ⇨ ANALOG CHANNELS**

☒ **ANALOG CHANNELS**

ANALOG CHANNEL 1:

Off

Range: Off, any FlexAnalog parameter  
See Appendix A for complete list.

↓

MESSAGE

ANALOG CHANNEL 16:

Off

Range: Off, any FlexAnalog parameter  
See Appendix A for complete list.

An **ANALOG CHANNEL** setting selects the metering actual value recorded in an oscillography trace. The length of each oscillography trace depends in part on the number of parameters selected here. Parameters set to “Off” are ignored. The parameters available in a given relay are dependent on: (a) the type of relay, (b) the type and number of CT/VT hardware modules installed, and (c) the type and number of Analog Input hardware modules installed. Upon startup, the relay will automatically prepare the parameter list. A list of all possible analog metering actual value parameters is presented in Appendix A: *FlexAnalog Parameters*. The parameter index number shown in any of the tables is used to expedite the selection of the parameter on the relay display. It can be quite time-consuming to scan through the list of parameters via the relay keypad/display - entering this number via the relay keypad will cause the corresponding parameter to be displayed.

All eight CT/VT module channels are stored in the oscillography file. The CT/VT module channels are named as follows:

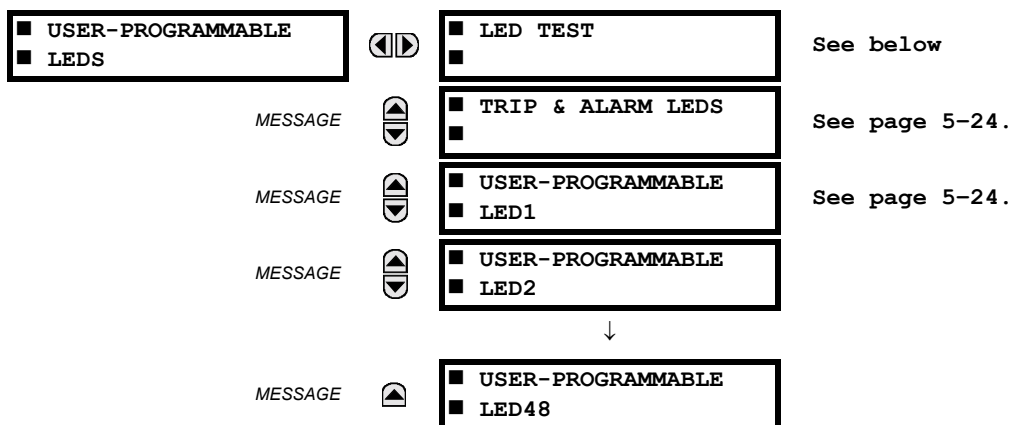
`<slot_letter><terminal_number>—<I or V><phase A, B, or C, or 4th input>`

The fourth current input in a bank is called IG, and the fourth voltage input in a bank is called VX. For example, F2-IB designates the IB signal on Terminal 2 of the CT/VT module in slot F. If there are no CT/VT modules and Analog Input modules, no analog traces will appear in the file; only the digital traces will appear.

### 5.2.9 USER-PROGRAMMABLE LEDS

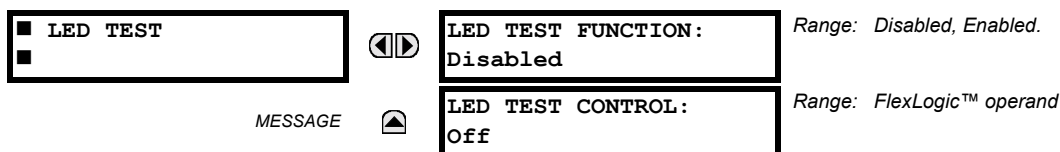
#### a) MAIN MENU

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE LEDS



#### b) LED TEST

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE LEDS ⇒ LED TEST



When enabled, the LED Test can be initiated from any digital input or user-programmable condition such as user-programmable pushbutton. The control operand is configured under the **LED TEST CONTROL** setting. The test covers all LEDs, including the LEDs of the optional user-programmable pushbuttons.

The test consists of three stages.

**Stage 1:** All 62 LEDs on the relay are illuminated. This is a quick test to verify if any of the LEDs is “burned”. This stage lasts as long as the control input is on, up to a maximum of 1 minute. After 1 minute, the test will end.

**Stage 2:** All the LEDs are turned off, and then one LED at a time turns on for 1 second, then back off. The test routine starts at the top left panel, moving from the top to bottom of each LED column. This test checks for hardware failures that lead to more than one LED being turned on from a single logic point. This stage can be interrupted at any time.

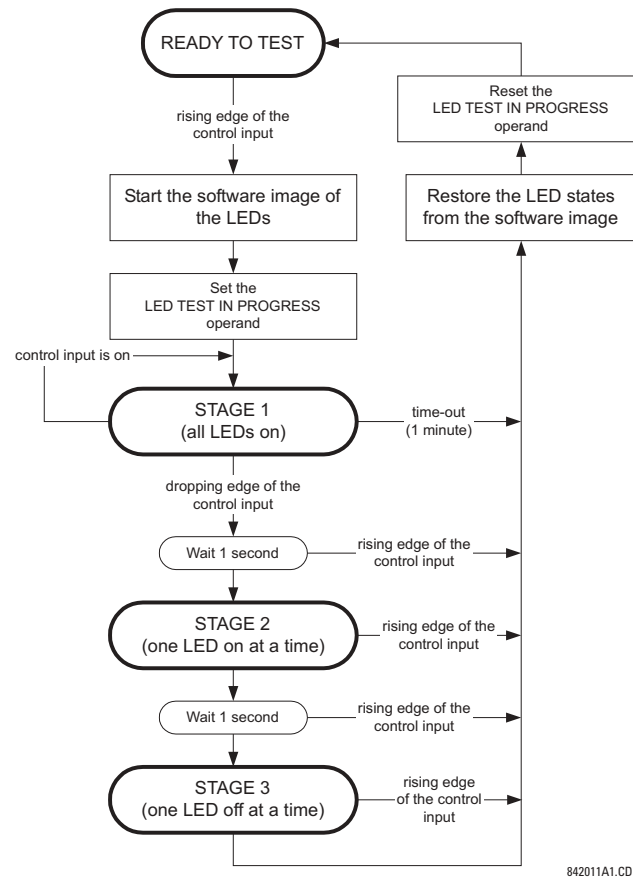
**Stage 3:** All the LEDs are turned on. One LED at a time turns off for 1 second, then back on. The test routine starts at the top left panel moving from top to bottom of each column of the LEDs. This test checks for hardware failures that lead to more than one LED being turned off from a single logic point. This stage can be interrupted at any time.



When testing is in progress, the LEDs are controlled by the test sequence, rather than the protection, control, and monitoring features. However, the LED control mechanism accepts all the changes to LED states generated by the relay and stores the actual LED states (On or Off) in memory. When the test completes, the LEDs reflect the actual state resulting from relay response during testing. The Reset pushbutton will not clear any targets when the LED Test is in progress.

A dedicated FlexLogic™ operand, LED TEST IN PROGRESS, is set for the duration of the test. When the test sequence is initiated, the LED Test Initiated event is stored in the Event Recorder.

The entire test procedure is user-controlled. In particular, Stage 1 can last as long as necessary, and Stages 2 and 3 can be interrupted. The test responds to the position and rising edges of the control input defined by the **LED TEST CONTROL** setting. The control pulses must last at least 250 ms to take effect. The following diagram explains how the test is executed.



842011A1.CDR

Figure 5–2: LED TEST SEQUENCE

#### APPLICATION EXAMPLE 1:

Assume one needs to check if any of the LEDs is “burned” through User-Programmable Pushbutton 1. The following settings should be applied. Configure User-Programmable Pushbutton 1 by making the following entries in the **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **USER-PROGRAMMABLE PUSHBUTTONS** ⇒ **USER PUSHBUTTON 1** menu:

**PUSHBUTTON 1 FUNCTION:** “Self-reset”

**PUSHBTN 1 DROP-OUT TIME:** “0.10 s”

Configure the LED test to recognize User-Programmable Pushbutton 1 by making the following entries in the **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **USER-PROGRAMMABLE LEDS** ⇒ **LED TEST** menu:

**LED TEST FUNCTION:** “Enabled”

**LED TEST CONTROL:** “PUSHBUTTON 1 ON”

The test will be initiated when the User-Programmable Pushbutton 1 is pressed. The pushbutton should remain pressed for as long as the LEDs are being visually inspected. When finished, the pushbutton should be released. The relay will then automatically start Stage 2. At this point forward, test may be aborted by pressing the pushbutton.

**APPLICATION EXAMPLE 2:**

Assume one needs to check if any LEDs are “burned” as well as exercise one LED at a time to check for other failures. This is to be performed via User-Programmable Pushbutton 1.

After applying the settings in Application Example 1, hold down the pushbutton as long as necessary to test all LEDs. Next, release the pushbutton to automatically start Stage 2. Once Stage 2 has started, the pushbutton can be released. When Stage 2 is completed, Stage 3 will automatically start. The test may be aborted at any time by pressing the pushbutton.

**c) TRIP AND ALARM LEDS**

**PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE LEDS ⇒ TRIP & ALARM LEDS**

■ TRIP & ALARM LEDS  
 ■

◀▶

TRIP LED INPUT:  
 Off

Range: FlexLogic™ operand

MESSAGE ▲

ALARM LED INPUT:  
 Off

Range: FlexLogic™ operand

The Trip and Alarm LEDs are on LED Panel 1. Each indicator can be programmed to become illuminated when the selected FlexLogic™ operand is in the Logic 1 state.

**d) USER-PROGRAMMABLE LED 1(48)**

**PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE LEDS ⇒ USER-PROGRAMMABLE LED 1(48)**

■ USER-PROGRAMMABLE  
 ■ LED 1

◀▶

LED 1 OPERAND:  
 Off

Range: FlexLogic™ operand

MESSAGE ▲

LED 1 TYPE:  
 Self-Reset

Range: Self-Reset, Latched

There are 48 amber LEDs across the relay faceplate LED panels. Each of these indicators can be programmed to illuminate when the selected FlexLogic™ operand is in the Logic 1 state.

- LEDs 1 through 24 inclusive are on LED Panel 2; LEDs 25 through 48 inclusive are on LED Panel 3.

Refer to the LED Indicators section in Chapter 4 for the locations of these indexed LEDs. This menu selects the operands to control these LEDs. Support for applying user-customized labels to these LEDs is provided. If the **LED X TYPE** setting is “Self-Reset” (default setting), the LED illumination will track the state of the selected LED operand. If the **LED X TYPE** setting is ‘Latched’, the LED, once lit, remains so until reset by the faceplate RESET button, from a remote device via a communications channel, or from any programmed operand, even if the LED operand state de-asserts.

**Table 5–2: RECOMMENDED SETTINGS FOR LED PANEL 2 LABELS**

| SETTING        | PARAMETER           | SETTING        | PARAMETER         |
|----------------|---------------------|----------------|-------------------|
| LED 1 Operand  | SETTING GROUP ACT 1 | LED 13 Operand | Off               |
| LED 2 Operand  | SETTING GROUP ACT 2 | LED 14 Operand | BREAKER 2 OPEN    |
| LED 3 Operand  | SETTING GROUP ACT 3 | LED 15 Operand | BREAKER 2 CLOSED  |
| LED 4 Operand  | SETTING GROUP ACT 4 | LED 16 Operand | BREAKER 2 TROUBLE |
| LED 5 Operand  | SETTING GROUP ACT 5 | LED 17 Operand | SYNC 1 SYNC OP    |
| LED 6 Operand  | SETTING GROUP ACT 6 | LED 18 Operand | SYNC 2 SYNC OP    |
| LED 7 Operand  | Off                 | LED 19 Operand | Off               |
| LED 8 Operand  | Off                 | LED 20 Operand | Off               |
| LED 9 Operand  | BREAKER 1 OPEN      | LED 21 Operand | AR ENABLED        |
| LED 10 Operand | BREAKER 1 CLOSED    | LED 22 Operand | AR DISABLED       |
| LED 11 Operand | BREAKER 1 TROUBLE   | LED 23 Operand | AR RIP            |
| LED 12 Operand | Off                 | LED 24 Operand | AR LO             |

Refer to the *Control of Setting Groups* example in the *Control Elements* section of this chapter for group activation.

## 5.2.10 USER-PROGRAMMABLE SELF TESTS

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE SELF TESTS

|         |  |  |   |
|---------|--|--|---|
| MESSAGE |  | <b>PRI. ETHERNET FAIL</b><br><b>FUNCTION: Disabled</b> | Range: Disabled, Enabled.<br>Valid for units equipped with CPU Type C or D. |
| MESSAGE |  | <b>SEC. ETHERNET FAIL</b><br><b>FUNCTION: Disabled</b> | Range: Disabled, Enabled.<br>Valid for units equipped with CPU Type D.      |
| MESSAGE |  | <b>BATTERY FAIL</b><br><b>FUNCTION: Enabled</b>        | Range: Disabled, Enabled.   |
| MESSAGE |  | <b>SNTP FAIL</b><br><b>FUNCTION: Enabled</b>           | Range: Disabled, Enabled.<br>Valid for units equipped with CPU Type C or D. |
| MESSAGE |  | <b>IRIG-B FAIL</b><br><b>FUNCTION: Enabled</b>         | Range: Disabled, Enabled.   |

All major self-test alarms are reported automatically with their corresponding FlexLogic™ operands, events, and targets. Most of the Minor Alarms can be disabled if desired.

When in the “Disabled” mode, minor alarms will not assert a FlexLogic™ operand, write to the event recorder, display target messages. Moreover, they will not trigger the **ANY MINOR ALARM** or **ANY SELF-TEST** messages. When in the “Enabled” mode, minor alarms continue to function along with other major and minor alarms. Refer to the Relay Self-Tests section in Chapter 7 for additional information on major and minor self-test alarms.

## 5.2.11 CONTROL PUSHBUTTONS

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ CONTROL PUSHBUTTONS ⇒ CONTROL PUSHBUTTON 1(7)

|  |         |  |                          |
|--|---------|--|--------------------------|
| <input checked="" type="checkbox"/> CONTROL      |         | <b>CONTROL PUSHBUTTON 1</b><br><b>FUNCTION: Disabled</b> | Range: Disabled, Enabled |
| <input checked="" type="checkbox"/> PUSHBUTTON 1 | MESSAGE | <b>CONTROL PUSHBUTTON 1</b><br><b>EVENTS: Disabled</b>   | Range: Disabled, Enabled |

The three standard pushbuttons located on the top left panel of the faceplate are user-programmable and can be used for various applications such as performing an LED test, switching setting groups, and invoking and scrolling through user-programmable displays, etc. Firmware revisions 3.2x and older use these three pushbuttons for manual breaker control. This functionality has been retained – if the Breaker Control feature is configured to use the three pushbuttons, they cannot be used as user-programmable control pushbuttons. The location of the control pushbuttons in the following figure.

An additional four control pushbuttons are included when the D30 is ordered with twelve user programmable pushbuttons.

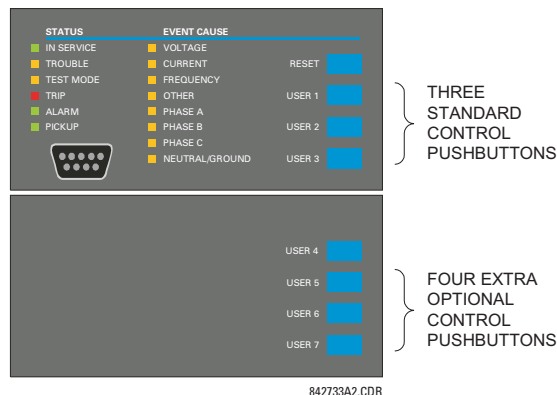


Figure 5–3: CONTROL PUSHBUTTONS

The control pushbuttons are typically not used for critical operations. As such, they are not protected by the control password. However, by supervising their output operands, the user can dynamically enable or disable the control pushbuttons for security reasons.

Each control pushbutton asserts its own FlexLogic™ operand, CONTROL PUSHBTN 1(7) ON. These operands should be configured appropriately to perform the desired function. The operand remains asserted as long as the pushbutton is pressed and resets when the pushbutton is released. A dropout delay of 100 ms is incorporated to ensure fast pushbutton manipulation will be recognized by various features that may use control pushbuttons as inputs.

An event is logged in the Event Record (as per user setting) when a control pushbutton is pressed; no event is logged when the pushbutton is released. The faceplate keys (including control keys) cannot be operated simultaneously – a given key must be released before the next one can be pressed.

The control pushbuttons become user-programmable only if the Breaker Control feature is not configured for manual control via the User 1 through User 7 pushbuttons as shown below. If configured for manual control, the Breaker Control feature typically uses the larger, optional user-programmable pushbuttons, making the control pushbuttons available for other user applications.

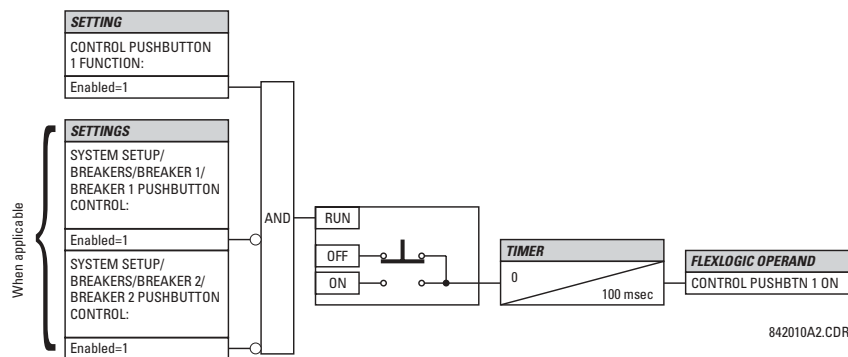


Figure 5-4: CONTROL PUSHBUTTON LOGIC

### 5.2.12 USER-PROGRAMMABLE PUSHBUTTONS

**PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE PUSHBUTTONS ⇒ USER PUSHBUTTON 1(12)**

|                          |  |   |
|--------------------------|--|---|
| <b>USER PUSHBUTTON 1</b> | <b>PUSHBUTTON 1</b>                    | Range: Self-Reset, Latched, Disabled    |
|                          | <b>FUNCTION: Disabled</b>              |   |
| MESSAGE                  | <b>PUSHBTN 1 ID TEXT:</b>              | Range: Up to 20 alphanumeric characters |
| MESSAGE                  | <b>PUSHBTN 1 ON TEXT:</b>              | Range: Up to 20 alphanumeric characters |
| MESSAGE                  | <b>PUSHBTN 1 OFF TEXT:</b>             | Range: Up to 20 alphanumeric characters |
| MESSAGE                  | <b>PUSHBTN 1 DROP-OUT TIME: 0.00 s</b> | Range: 0 to 60.00 s in steps of 0.01    |
| MESSAGE                  | <b>PUSHBUTTON 1 TARGETS: Disabled</b>  | Range: Self-Reset, Latched, Disabled    |
| MESSAGE                  | <b>PUSHBUTTON 1 EVENTS: Disabled</b>   | Range: Disabled, Enabled                |

The D30 has 12 optional user-programmable pushbuttons available, each configured via 12 identical menus. The pushbuttons provide an easy and error-free method of manually entering digital information (On, Off) into FlexLogic™ equations as well as protection and control elements. Typical applications include breaker control, autorecloser blocking, ground protection blocking, and setting groups changes.

The user-configurable pushbuttons are shown below. They can be custom labeled with a factory-provided template, available online at <http://www.GEindustrial.com/multilin>.



Figure 5-5: USER-PROGRAMMABLE PUSHBUTTONS

Each pushbutton asserts its own On and Off FlexLogic™ operands, respectively. FlexLogic™ operands should be used to program desired pushbutton actions. The operand names are PUSHBUTTON 1 ON and PUSHBUTTON 1 OFF.

A pushbutton may be programmed to latch or self-reset. An indicating LED next to each pushbutton signals the present status of the corresponding "On" FlexLogic™ operand. When set to "Latched", the state of each pushbutton is stored in non-volatile memory which is maintained during any supply power loss.

Pushbuttons states can be logged by the Event Recorder and displayed as target messages. User-defined messages can also be associated with each pushbutton and displayed when the pushbutton is ON.

- PUSHBUTTON 1 FUNCTION:** This setting selects the characteristic of the pushbutton. If set to "Disabled", the pushbutton is deactivated and the corresponding FlexLogic™ operands (both "On" and "Off") are de-asserted. If set to "Self-reset", the control logic of the pushbutton asserts the "On" corresponding FlexLogic™ operand as long as the pushbutton is being pressed. As soon as the pushbutton is released, the FlexLogic™ operand is de-asserted. The "Off" operand is asserted/de-asserted accordingly.
 

If set to "Latched", the control logic alternates the state of the corresponding FlexLogic™ operand between "On" and "Off" on each push of the button. When operating in "Latched" mode, FlexLogic™ operand states are stored in non-volatile memory. Should power be lost, the correct pushbutton state is retained upon subsequent power up of the relay.
- PUSHBTN 1 ID TEXT:** This setting specifies the top 20-character line of the user-programmable message and is intended to provide ID information of the pushbutton. Refer to the User-Definable Displays section for instructions on how to enter alphanumeric characters from the keypad.
- PUSHBTN 1 ON TEXT:** This setting specifies the bottom 20-character line of the user-programmable message and is displayed when the pushbutton is in the "on" position. Refer to the User-Definable Displays section for instructions on entering alphanumeric characters from the keypad.
- PUSHBTN 1 OFF TEXT:** This setting specifies the bottom 20-character line of the user-programmable message and is displayed when the pushbutton is activated from the On to the Off position and the **PUSHBUTTON 1 FUNCTION** is "Latched". This message is not displayed when the **PUSHBUTTON 1 FUNCTION** is "Self-reset" as the pushbutton operand status is implied to be "Off" upon its release. All user text messaging durations for the pushbuttons are configured with the **PRODUCT SETUP** ⇒ **DISPLAY PROPERTIES** ⇒ **FLASH MESSAGE TIME** setting.
- PUSHBTN 1 DROP-OUT TIME:** This setting specifies a drop-out time delay for a pushbutton in the self-reset mode. A typical applications for this setting is providing a select-before-operate functionality. The selecting pushbutton should have the drop-out time set to a desired value. The operating pushbutton should be logically ANDed with the selecting pushbutton in FlexLogic™. The selecting pushbutton LED remains on for the duration of the drop-out time, signaling the time window for the intended operation.

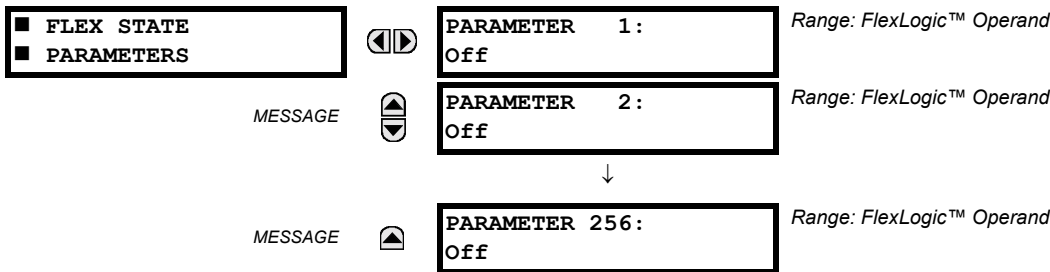
For example, consider a relay with the following settings: **PUSHBTN 1 ID TEXT:** "AUTORECLOSER", **PUSHBTN 1 ON TEXT:** "DISABLED - CALL 2199", and **PUSHBTN 1 OFF TEXT:** "ENABLED". When Pushbutton 1 changes its state to the "On" position, the following **AUTOCLOSER DISABLED – Call 2199** message is displayed: When Pushbutton 1 changes its state to the "Off" position, the message will change to **AUTORECLOSER ENABLED**.



User-programmable pushbuttons require a type HP relay faceplate. If an HP-type faceplate was ordered separately, the relay order code must be changed to indicate the HP faceplate option. This can be done via enerVista UR Setup with the **Maintenance > Enable Pushbutton** command.

## 5.2.13 FLEX STATE PARAMETERS

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ FLEX STATE PARAMETERS



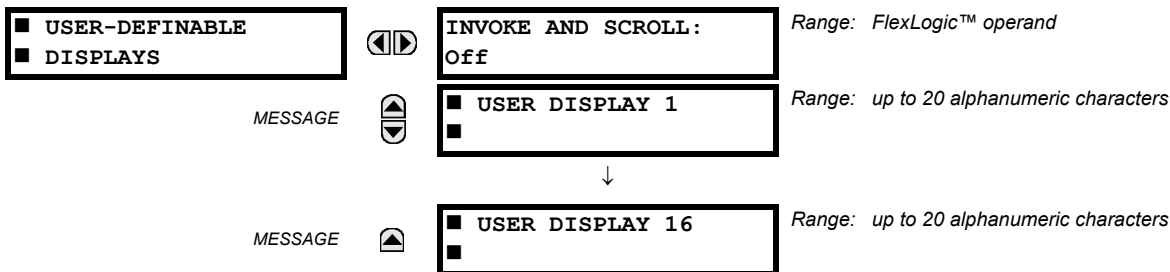
This feature provides a mechanism where any of 256 selected FlexLogic™ operand states can be used for efficient monitoring. The feature allows user-customized access to the FlexLogic™ operand states in the relay. The state bits are packed so that 16 states may be read out in a single Modbus register. The state bits can be configured so that all of the states which are of interest to the user are available in a minimum number of Modbus registers.

The state bits may be read out in the "Flex States" register array beginning at Modbus address 900 hex. 16 states are packed into each register, with the lowest-numbered state in the lowest-order bit. There are 16 registers in total to accommodate the 256 state bits.

## 5.2.14 USER-DEFINABLE DISPLAYS

## a) MAIN MENU

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-DEFINABLE DISPLAYS



This menu provides a mechanism for manually creating up to 16 user-defined information displays in a convenient viewing sequence in the **USER DISPLAYS** menu (between the **TARGETS** and **ACTUAL VALUES** top-level menus). The sub-menus facilitate text entry and Modbus Register data pointer options for defining the User Display content.

Once programmed, the user-definable displays can be viewed in two ways.

- **KEYPAD:** Use the Menu key to select the **USER DISPLAYS** menu item to access the first user-definable display (note that only the programmed screens are displayed). The screens can be scrolled using the Up and Down keys. The display disappears after the default message time-out period specified by the **PRODUCT SETUP ⇒ DISPLAY PROPERTIES ⇒ DEFAULT MESSAGE TIMEOUT** setting.
- **USER-PROGRAMMABLE CONTROL INPUT:** The user-definable displays also respond to the **INVOKE AND SCROLL** setting. Any FlexLogic™ operand (in particular, the user-programmable pushbutton operands), can be used to navigate the programmed displays.

On the rising edge of the configured operand (such as when the pushbutton is pressed), the displays are invoked by showing the last user-definable display shown during the previous activity. From this moment onward, the operand acts exactly as the Down key and allows scrolling through the configured displays. The last display wraps up to the first one. The **INVOKE AND SCROLL** input and the Down keypad key operate concurrently.

When the default timer expires (set by the **DEFAULT MESSAGE TIMEOUT** setting), the relay will start to cycle through the user displays. The next activity of the **INVOKE AND SCROLL** input stops the cycling at the currently displayed user display, not at the first user-defined display. The **INVOKE AND SCROLL** pulses must last for at least 250 ms to take effect.

## b) USER DISPLAY 1(16)

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ USER-DEFINABLE DISPLAYS ⇒ USER DISPLAY 1(16)

|                  |    |                     |   |
|------------------|----|---------------------|---|
| ■ USER DISPLAY 1 | ◀▶ | DISP 1 TOP LINE:    | Range: up to 20 alphanumeric characters |
| MESSAGE          | ▲▼ | DISP 1 BOTTOM LINE: | Range: up to 20 alphanumeric characters |
| MESSAGE          | ▲▼ | DISP 1 ITEM 1<br>0  | Range: 0 to 65535 in steps of 1         |
| MESSAGE          | ▲▼ | DISP 1 ITEM 2<br>0  | Range: 0 to 65535 in steps of 1         |
| MESSAGE          | ▲▼ | DISP 1 ITEM 3<br>0  | Range: 0 to 65535 in steps of 1         |
| MESSAGE          | ▲▼ | DISP 1 ITEM 4<br>0  | Range: 0 to 65535 in steps of 1         |
| MESSAGE          | ▲  | DISP 1 ITEM 5:<br>0 | Range: 0 to 65535 in steps of 1         |

Any existing system display can be automatically copied into an available user display by selecting the existing display and pressing the **ENTER** key. The display will then prompt **ADD TO USER DISPLAY LIST?**. After selecting “Yes”, a message indicates that the selected display has been added to the user display list. When this type of entry occurs, the sub-menus are automatically configured with the proper content – this content may subsequently be edited.

This menu is used **to enter** user-defined text and/or user-selected Modbus-registered data fields into the particular user display. Each user display consists of two 20-character lines (top and bottom). The tilde (~) character is used to mark the start of a data field - the length of the data field needs to be accounted for. Up to 5 separate data fields (**ITEM 1(5)**) can be entered in a user display - the *n*th tilde (~) refers to the *n*th item.

A User Display may be entered from the faceplate keypad or the enerVista UR Setup interface (preferred for convenience). The following procedure shows how to enter text characters in the top and bottom lines from the faceplate keypad:

1. Select the line to be edited.
2. Press the **■** key to enter text edit mode.
3. Use either Value key to scroll through the characters. A space is selected like a character.
4. Press the **■** key to advance the cursor to the next position.
5. Repeat step 3 and continue entering characters until the desired text is displayed.
6. The **HELP** key may be pressed at any time for context sensitive help information.
7. Press the **ENTER** key to store the new settings.

To enter a numerical value for any of the 5 items (the *decimal form* of the selected Modbus address) from the faceplate keypad, use the number keypad. Use the value of ‘0’ for any items not being used. Use the **HELP** key at any selected system display (setting, actual value, or command) which has a Modbus address, to view the *hexadecimal form* of the Modbus address, then manually convert it to decimal form before entering it (enerVista UR Setup usage conveniently facilitates this conversion).

Use the **MENU** key to go to the user displays menu **to view** the user-defined content. The current user displays will show in sequence, changing every 4 seconds. While viewing a user display, press the **ENTER** key and then select the ‘Yes’ option **to remove** the display from the user display list. Use the **MENU** key again **to exit** the user displays menu.



An example User Display setup and result is shown below:

|  |   |  |   |
|--|---|--|---|
| <div> <div>■ USER DISPLAY 1</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲</div> </div> | <div>DISP 1 TOP LINE:<br/>Current X ~ A</div>      | Shows user-defined text with first Tilde marker.  |
|  |   | <div>DISP 1 BOTTOM LINE:<br/>Current Y ~ A</div>   | Shows user-defined text with second Tilde marker.   |
|  |   | <div>DISP 1 ITEM 1:<br/>6016</div>                 | Shows decimal form of user-selected Modbus Register Address, corresponding to first Tilde marker. |
|  |   | <div>DISP 1 ITEM 2:<br/>6357</div>                 | Shows decimal form of user-selected Modbus Register Address, corresponding to 2nd Tilde marker.   |
|  |   | <div>DISP 1 ITEM 3:<br/>0</div>                    | This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.      |
|  |   | <div>DISP 1 ITEM 4:<br/>0</div>                    | This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.      |
| <div> <div>USER DISPLAYS</div> <div>→</div> </div>   |   | <div>DISP 1 ITEM 5:<br/>0</div>                    | This item is not being used - there is no corresponding Tilde marker in Top or Bottom lines.      |
|  |   | <div>Current X 0.850 A<br/>Current Y 0.327 A</div> | Shows the resultant display content.  |

### a) MAIN MENU

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ DIRECT I/O

|   |   |   |                          |
|---|---|---|--------------------------|
| <div> <div>■ DIRECT I/O</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲</div> </div> | <div>DIRECT OUTPUT<br/>DEVICE ID: 1</div>             | Range: 1 to 16           |
|   |   | <div>DIRECT I/O CH1 RING<br/>CONFIGURATION: Yes</div> | Range: Yes, No           |
|   |   | <div>DIRECT I/O CH2 RING<br/>CONFIGURATION: Yes</div> | Range: Yes, No           |
|   |   | <div>DIRECT I/O DATA<br/>RATE: 64 kbps</div>          | Range: 64 kbps, 128 kbps |
|   |   | <div>DIRECT I/O CHANNEL<br/>CROSSOVER: Disabled</div> | Range: Disabled, Enabled |
|   |   | <div>■ CRC ALARM CH1</div>                            | See page 5-34.           |
|   |   | <div>■ CRC ALARM CH2</div>                            | See page 5-34.           |
|   |   | <div>■ UNRETURNED<br/>■ MESSAGES ALARM CH1</div>      | See page 5-36.           |
|   |   | <div>■ UNRETURNED<br/>■ MESSAGES ALARM CH2</div>      | See page 5-36.           |

Direct inputs/outputs are intended for exchange of status information (inputs and outputs) between UR-series relays connected directly via Type-7 digital communications cards. The mechanism is very similar to IEC 61850 GSSE, except that communications takes place over a non-switchable isolated network and is optimized for speed. On Type 7 cards that support two channels, direct output messages are sent from both channels simultaneously. This effectively sends direct output



messages both ways around a ring configuration. On Type 7 cards that support one channel, direct output messages are sent only in one direction. Messages will be resent (forwarded) when it is determined that the message did not originate at the receiver.

Direct output message timing is similar to GSSE message timing. Integrity messages (with no state changes) are sent at least every 1000 ms. Messages with state changes are sent within the main pass scanning the inputs and asserting the outputs unless the communication channel bandwidth has been exceeded. Two Self-Tests are performed and signaled by the following FlexLogic™ operands:

1. **DIRECT RING BREAK** (direct input/output ring break). This FlexLogic™ operand indicates that direct output messages sent from a UR-series relay are not being received back by the relay.
2. **DIRECT DEVICE 1(16) OFF** (direct device offline). This FlexLogic™ operand indicates that direct output messages from at least one direct device are not being received.

Direct input/output settings are similar to remote input/output settings. The equivalent of the remote device name strings for direct inputs/outputs is the **DIRECT OUTPUT DEVICE ID**. The **DIRECT OUTPUT DEVICE ID** identifies the relay in all direct output messages. All UR-series IEDs in a ring should have unique numbers assigned. The IED ID is used to identify the sender of the direct input/output message.

If the direct input/output scheme is configured to operate in a ring (**DIRECT I/O RING CONFIGURATION**: “Yes”), all direct output messages should be received back. If not, the Direct Input/Output Ring Break self-test is triggered. The self-test error is signaled by the **DIRECT RING BREAK** FlexLogic™ operand.

Select the **DIRECT I/O DATA RATE** to match the data capabilities of the communications channel. Back-to-back connections of the local relays configured with the 7A, 7B, 7C, 7D, 7H, 7I, 7J, 7K, 72 and 73 fiber optic communication cards may be set to 128 kbps. For local relays configured with all other communication cards (i.e. 7E, 7F, 7G, 7L, 7M, 7N, 7P, 7R, 7S, 7T, 7W, 74, 75, 76 and 77), the baud rate will be set to 64 kbps. All IEDs communicating over direct inputs/outputs must be set to the same data rate. UR-series IEDs equipped with dual-channel communications cards apply the same data rate to both channels. Delivery time for direct input/output messages is approximately 0.2 of a power system cycle at 128 kbps and 0.4 of a power system cycle at 64 kbps, per each ‘bridge’.



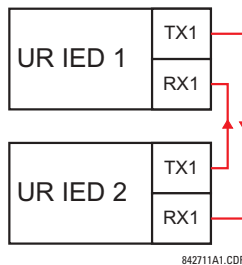
**The G.703 and RS422 modules are fixed at 64 kbps only. The **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **DIRECT I/O** ⇒ **DIRECT I/O DATA RATE** setting is not applicable to these modules.**

The **DIRECT I/O CHANNEL CROSSOVER** setting applies to D30s with dual-channel communication cards and allows crossing over messages from Channel 1 to Channel 2. This places all UR-series IEDs into one direct input/output network regardless of the physical media of the two communication channels.

The following application examples illustrate the basic concepts for direct input/output configuration. Please refer to the *Inputs/Outputs* section in this chapter for information on configuring FlexLogic™ operands (flags, bits) to be exchanged.

#### EXAMPLE 1: EXTENDING THE INPUT/OUTPUT CAPABILITIES OF A UR-SERIES RELAY

Consider an application that requires additional quantities of digital inputs and/or output contacts and/or lines of programmable logic that exceed the capabilities of a single UR-series chassis. The problem is solved by adding an extra UR-series IED, such as the C30, to satisfy the additional input/output and programmable logic requirements. The two IEDs are connected via single-channel digital communication cards as shown in the figure below.



**Figure 5–6: INPUT/OUTPUT EXTENSION VIA DIRECT I/Os**

In the above application, the following settings should be applied:

UR IED 1: **DIRECT OUTPUT DEVICE ID:** "1"  
**DIRECT I/O RING CONFIGURATION:** "Yes"  
**DIRECT I/O DATA RATE:** "128 kbps"

UR IED 2: **DIRECT OUTPUT DEVICE ID:** "2"  
**DIRECT I/O RING CONFIGURATION:** "Yes"  
**DIRECT I/O DATA RATE:** "128 kbps"

The message delivery time is about 0.2 of power cycle in both ways (at 128 kbps); i.e., from Device 1 to Device 2, and from Device 2 to Device 1. Different communications cards can be selected by the user for this back-to-back connection (fiber, G.703, or RS422).

### EXAMPLE 2: INTERLOCKING BUSBAR PROTECTION

A simple interlocking busbar protection scheme could be accomplished by sending a blocking signal from downstream devices, say 2, 3, and 4, to the upstream device that monitors a single incomer of the busbar, as shown below.

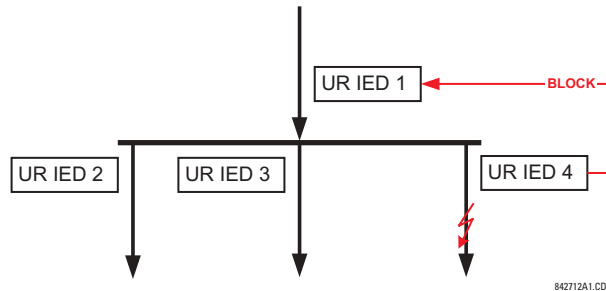


Figure 5-7: SAMPLE INTERLOCKING BUSBAR PROTECTION SCHEME

For increased reliability, a dual-ring configuration (shown below) is recommended for this application.

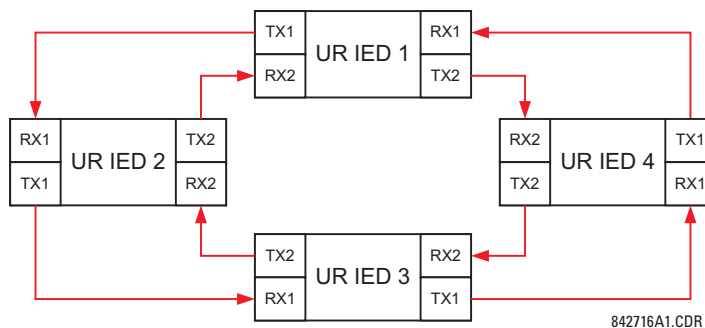


Figure 5-8: INTERLOCKING BUS PROTECTION SCHEME VIA DIRECT I/Os

In the above application, the following settings should be applied:

|  |  |
|--|--|
| UR IED 1: <b>DIRECT OUTPUT DEVICE ID:</b> "1"<br><b>DIRECT I/O RING CONFIGURATION:</b> "Yes" | UR IED 2: <b>DIRECT OUTPUT DEVICE ID:</b> "2"<br><b>DIRECT I/O RING CONFIGURATION:</b> "Yes" |
| UR IED 3: <b>DIRECT OUTPUT DEVICE ID:</b> "3"<br><b>DIRECT I/O RING CONFIGURATION:</b> "Yes" | UR IED 4: <b>DIRECT OUTPUT DEVICE ID:</b> "4"<br><b>DIRECT I/O RING CONFIGURATION:</b> "Yes" |

Message delivery time is approximately 0.2 of power system cycle (at 128 kbps) times number of 'bridges' between the origin and destination. Dual-ring configuration effectively reduces the maximum 'communications distance' by a factor of two.

In this configuration the following delivery times are expected (at 128 kbps) if both rings are healthy:

IED 1 to IED 2: 0.2 of power system cycle; IED 1 to IED 3: 0.4 of power system cycle;  
 IED 1 to IED 4: 0.2 of power system cycle; IED 2 to IED 3: 0.2 of power system cycle;  
 IED 2 to IED 4: 0.4 of power system cycle; IED 3 to IED 4: 0.2 of power system cycle

If one ring is broken (say TX2/RX2) the delivery times are as follows:

IED 1 to IED 2: 0.2 of power system cycle; IED 1 to IED 3: 0.4 of power system cycle;  
 IED 1 to IED 4: 0.6 of power system cycle; IED 2 to IED 3: 0.2 of power system cycle;  
 IED 2 to IED 4: 0.4 of power system cycle; IED 3 to IED 4: 0.2 of power system cycle

A coordinating timer for this bus protection scheme could be selected to cover the worst case scenario (0.4 of power system cycle). Upon detecting a broken ring, the coordination time should be adaptively increased to 0.6 of power system cycle. The complete application requires addressing a number of issues such as failure of both the communications rings, failure or out-of-service conditions of one of the relays, etc. Self-monitoring flags of the direct inputs/outputs feature would be primarily used to address these concerns.

### EXAMPLE 3: PILOT-AIDED SCHEMES

Consider the three-terminal line protection application shown below:

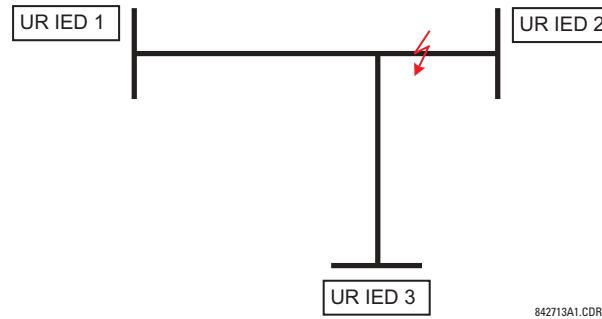


Figure 5-9: THREE-TERMINAL LINE APPLICATION

A permissive pilot-aided scheme could be implemented in a two-ring configuration as shown below (IEDs 1 and 2 constitute a first ring, while IEDs 2 and 3 constitute a second ring):

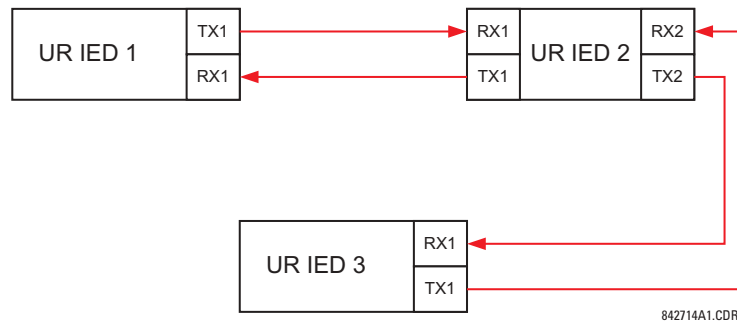


Figure 5-10: SINGLE-CHANNEL OPEN LOOP CONFIGURATION

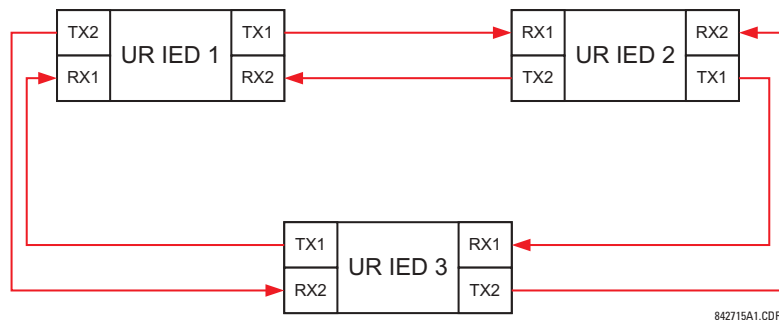
In the above application, the following settings should be applied:

|           |   |           |   |
|-----------|---|-----------|---|
| UR IED 1: | <b>DIRECT OUTPUT DEVICE ID: "1"</b>         | UR IED 2: | <b>DIRECT OUTPUT DEVICE ID: "2"</b>         |
|           | <b>DIRECT I/O RING CONFIGURATION: "Yes"</b> |           | <b>DIRECT I/O RING CONFIGURATION: "Yes"</b> |
| UR IED 3: | <b>DIRECT OUTPUT DEVICE ID: "3"</b>         |           |   |
|           | <b>DIRECT I/O RING CONFIGURATION: "Yes"</b> |           |   |

In this configuration the following delivery times are expected (at 128 kbps):

IED 1 to IED 2: 0.2 of power system cycle; IED 1 to IED 3: 0.5 of power system cycle;  
 IED 2 to IED 3: 0.2 of power system cycle

In the above scheme, IEDs 1 and 3 do not communicate directly. IED 2 must be configured to forward the messages as explained in the *Inputs/Outputs* section. A blocking pilot-aided scheme should be implemented with more security and, ideally, faster message delivery time. This could be accomplished using a dual-ring configuration as shown below.



**Figure 5-11: DUAL-CHANNEL CLOSED LOOP (DUAL-RING) CONFIGURATION**

In the above application, the following settings should be applied:

|           |   |           |   |
|-----------|---|-----------|---|
| UR IED 1: | <b>DIRECT OUTPUT DEVICE ID:</b> "1"         | UR IED 2: | <b>DIRECT OUTPUT DEVICE ID:</b> "2"         |
|           | <b>DIRECT I/O RING CONFIGURATION:</b> "Yes" |           | <b>DIRECT I/O RING CONFIGURATION:</b> "Yes" |
| UR IED 3: | <b>DIRECT OUTPUT DEVICE ID:</b> "3"         |           |   |
|           | <b>DIRECT I/O RING CONFIGURATION:</b> "Yes" |           |   |

In this configuration the following delivery times are expected (at 128 kbps) if both the rings are healthy:

IED 1 to IED 2: 0.2 of power system cycle; IED 1 to IED 3: 0.2 of power system cycle;  
IED 2 to IED 3: 0.2 of power system cycle

The two communications configurations could be applied to both permissive and blocking schemes. Speed, reliability and cost should be taken into account when selecting the required architecture.

5

#### b) CRC ALARM CH1(2)

**PATH:** SETTINGS ⇒ PRODUCT SETUP ⇒ DIRECT I/O ⇒ CRC ALARM CH1(2)

|  |   |                                   |
|--|---|-----------------------------------|
| <div> <div>CRC ALARM CH1</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>CRC ALARM CH1</div> <div>FUNCTION: Disabled</div> </div> | Range: Enabled, Disabled          |
|  | <div> <div>CRC ALARM CH1</div> <div>MESSAGE COUNT: 600</div> </div> | Range: 100 to 10000 in steps of 1 |
|  | <div> <div>CRC ALARM CH1</div> <div>THRESHOLD: 10</div> </div>      | Range: 1 to 1000 in steps of 1    |
|  | <div> <div>CRC ALARM CH1</div> <div>EVENTS: Disabled</div> </div>   | Range: Enabled, Disabled          |

The D30 checks integrity of the incoming direct input/output messages using a 32-bit CRC. The CRC Alarm function is available for monitoring the communication medium noise by tracking the rate of messages failing the CRC check. The monitoring function counts all incoming messages, including messages that failed the CRC check. A separate counter adds up messages that failed the CRC check. When the failed CRC counter reaches the user-defined level specified by the **CRC ALARM CH1 THRESHOLD** setting within the user-defined message count **CRC ALARM 1 CH1 COUNT**, the DIR IO CH1 CRC ALARM FlexLogic™ operand is set.

When the total message counter reaches the user-defined maximum specified by the **CRC ALARM CH1 MESSAGE COUNT** setting, both the counters reset and the monitoring process is restarted.

The operand shall be configured to drive an output contact, user-programmable LED, or selected communication-based output. Latching and acknowledging conditions - if required - should be programmed accordingly.

The CRC Alarm function is available on a per-channel basis. The total number of direct input/output messages that failed the CRC check is available as the **ACTUAL VALUES ⇒ STATUS ⇒ DIRECT INPUTS ⇒ CRC FAIL COUNT CH1(2)** actual value.

#### Message Count and Length of the Monitoring Window:

To monitor communications integrity, the relay sends 1 message per second (at 64 kbps) or 2 messages per second (128 kbps) even if there is no change in the direct outputs. For example, setting the **CRC ALARM CH1 MESSAGE COUNT** to “10000”, corresponds a time window of about 160 minutes at 64 kbps and 80 minutes at 128 kbps. If the messages are sent faster as a result of direct outputs activity, the monitoring time interval will shorten. This should be taken into account when determining the **CRC ALARM CH1 MESSAGE COUNT** setting. For example, if the requirement is a maximum monitoring time interval of 10 minutes at 64 kbps, then the **CRC ALARM CH1 MESSAGE COUNT** should be set to  $10 \times 60 \times 1 = 600$ .

**Correlation of Failed CRC and Bit Error Rate (BER):**

The CRC check may fail if one or more bits in a packet are corrupted. Therefore, an exact correlation between the CRC fail rate and the BER is not possible. Under certain assumptions an approximation can be made as follows. A direct input/output packet containing 20 bytes results in 160 bits of data being sent and therefore, a transmission of 63 packets is equivalent to 10,000 bits. A BER of  $10^{-4}$  implies 1 bit error for every 10,000 bits sent/received. Assuming the best case of only 1 bit error in a failed packet, having 1 failed packet for every 63 received is about equal to a BER of  $10^{-4}$ .

## c) UNRETURNED MESSAGES ALARM CH1(2)

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ DIRECT I/O ⇒ UNRETURNED MESSAGES ALARM CH1(2)

|   |         |  |                                   |
|---|---------|--|-----------------------------------|
| <div>■ UNRETURNED</div> <div>■ MESSAGES ALARM CH1</div> |         | UNRET MSGS ALARM CH1<br>FUNCTION: Disabled | Range: Enabled, Disabled          |
|   | MESSAGE | UNRET MSGS ALARM CH1<br>MESSAGE COUNT: 600 | Range: 100 to 10000 in steps of 1 |
|   | MESSAGE | UNRET MSGS ALARM CH1<br>THRESHOLD: 10      | Range: 1 to 1000 in steps of 1    |
|   | MESSAGE | UNRET MSGS ALARM CH1<br>EVENTS: Disabled   | Range: Enabled, Disabled          |

The D30 checks integrity of the direct input/output communication ring by counting unreturned messages. In the ring configuration, all messages originating at a given device should return within a pre-defined period of time. The Unreturned Messages Alarm function is available for monitoring the integrity of the communication ring by tracking the rate of unreturned messages. This function counts all the outgoing messages and a separate counter adds the messages have failed to return. When the unreturned messages counter reaches the user-definable level specified by the **UNRET MSGS ALARM CH1 THRESHOLD** setting and within the user-defined message count **UNRET MSGS ALARM CH1 COUNT**, the DIR IO CH1 UNRET ALM FlexLogic™ operand is set.

When the total message counter reaches the user-defined maximum specified by the **UNRET MSGS ALARM CH1 MESSAGE COUNT** setting, both the counters reset and the monitoring process is restarted.

The operand shall be configured to drive an output contact, user-programmable LED, or selected communication-based output. Latching and acknowledging conditions, if required, should be programmed accordingly.

The Unreturned Messages Alarm function is available on a per-channel basis and is active only in the ring configuration. The total number of unreturned input/output messages is available as the **ACTUAL VALUES ⇒ STATUS ⇒ DIRECT INPUTS ⇒ UNRETURNED MSG COUNT CH1(2)** actual value.

## 5.2.16 INSTALLATION

PATH: SETTINGS ⇒ PRODUCT SETUP ⇒ INSTALLATION

|  |         |                                   |   |
|--|---------|-----------------------------------|---|
| <div>■ INSTALLATION</div> <div>■</div> |         | RELAY SETTINGS:<br>Not Programmed | Range: Not Programmed, Programmed       |
|  | MESSAGE | RELAY NAME:<br>Relay-1            | Range: up to 20 alphanumeric characters |

To safeguard against the installation of a relay without any entered settings, the unit will not allow signaling of any output relay until **RELAY SETTINGS** is set to "Programmed". This setting is defaulted to "Not Programmed" when at the factory. The **UNIT NOT PROGRAMMED** self-test error message is displayed until the relay is put into the "Programmed" state.

The **RELAY NAME** setting allows the user to uniquely identify a relay. This name will appear on generated reports. This name is also used to identify specific devices which are engaged in automatically sending/receiving data over the Ethernet communications channel using the IEC 61850 protocol.

## 5.3.1 AC INPUTS

## a) CURRENT BANKS

PATH: SETTINGS ⇒ SYSTEM SETUP ⇒ AC INPUTS ⇒ CURRENT BANK F1(F5)

|                   |    |                                |                                   |
|-------------------|----|--------------------------------|-----------------------------------|
| ■ CURRENT BANK F1 | ◀▶ | PHASE CT F1<br>PRIMARY: 1 A    | Range: 1 to 65000 A in steps of 1 |
| MESSAGE           | ▲▼ | PHASE CT F1<br>SECONDARY: 1 A  | Range: 1 A, 5 A                   |
| MESSAGE           | ▲▼ | GROUND CT F1<br>PRIMARY: 1 A   | Range: 1 to 65000 A in steps of 1 |
| MESSAGE           | ▲  | GROUND CT F1<br>SECONDARY: 1 A | Range: 1 A, 5 A                   |

Two banks of phase/ground CTs can be set, where the current banks are denoted in the following format (X represents the module slot position letter):

**Xa**, where **X** = {F} and **a** = {1, 5}.

See the *Introduction to AC Sources* section at the beginning of this chapter for additional details.

These settings are critical for all features that have settings dependent on current measurements. When the relay is ordered, the CT module must be specified to include a standard or sensitive ground input. As the phase CTs are connected in Wye (star), the calculated phasor sum of the three phase currents ( $I_A + I_B + I_C = \text{Neutral Current} = 3I_o$ ) is used as the input for the neutral overcurrent elements. In addition, a zero-sequence (core balance) CT which senses current in all of the circuit primary conductors, or a CT in a neutral grounding conductor may also be used. For this configuration, the ground CT primary rating must be entered. To detect low level ground fault currents, the sensitive ground input may be used. In this case, the sensitive ground CT primary rating must be entered. Refer to Chapter 3 for more details on CT connections.

Enter the rated CT primary current values. For both 1000:5 and 1000:1 CTs, the entry would be 1000. For correct operation, the CT secondary rating must match the setting (which must also correspond to the specific CT connections used).

The following example illustrates how multiple CT inputs (current banks) are summed as one source current. Given If the following current banks:

F1: CT bank with 500:1 ratio; F5: CT bank with 1000: ratio

The following rule applies:

$$\text{SRC 1} = \text{F1} + \text{F5} \quad (\text{EQ 5.4})$$

1 pu is the highest primary current. In this case, 1000 is entered and the secondary current from the 500:1 and 800:1 ratio CTs will be adjusted to that created by a 1000:1 CT before summation. If a protection element is set up to act on SRC 1 currents, then a pickup level of 1 pu will operate on 1000 A primary.

The same rule applies for current sums from CTs with different secondary taps (5 A and 1 A).

## b) VOLTAGE BANKS

PATH: SETTINGS ⇒ ⚙ SYSTEM SETUP ⇒ ⚙ AC INPUTS ⇒ ⚙ VOLTAGE BANK F5

|   |   |  |
|---|---|--|
| <div>■ VOLTAGE BANK F5</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> | <div>⏪ ⏩</div> <div>PHASE VT F5<br/>CONNECTION: Wye</div>       | Range: Wye, Delta                        |
|   | <div>⏪ ⏩</div> <div>PHASE VT F5<br/>SECONDARY: 66.4 V</div>     | Range: 50.0 to 240.0 V in steps of 0.1   |
|   | <div>⏪ ⏩</div> <div>PHASE VT F5<br/>RATIO: 1.00 :1</div>        | Range: 1.00 to 24000.00 in steps of 0.01 |
|   | <div>⏪ ⏩</div> <div>AUXILIARY VT F5<br/>CONNECTION: Vag</div>   | Range: Vn, Vag, Vbg, Vcg, Vab, Vbc, Vca  |
|   | <div>⏪ ⏩</div> <div>AUXILIARY VT F5<br/>SECONDARY: 66.4 V</div> | Range: 50.0 to 240.0 V in steps of 0.1   |
|   | <div>⏪ ⏩</div> <div>AUXILIARY VT F5<br/>RATIO: 1.00 :1</div>    | Range: 1.00 to 24000.00 in steps of 0.01 |

One bank of phase/auxiliary VTs can be set, where voltage banks are denoted in the following format (X represents the module slot position letter):

**Xa**, where **X** = {F} and **a** = {5}.

See the *Introduction to AC Sources* section at the beginning of this chapter for additional details.

With VTs installed, the relay can perform voltage measurements as well as power calculations. Enter the **PHASE VT F5 CONNECTION** made to the system as “Wye” or “Delta”. An open-delta source VT connection would be entered as “Delta”. See the *Typical Wiring Diagram* in Chapter 3 for details.



The nominal **PHASE VT F5 SECONDARY** voltage setting is the voltage across the relay input terminals when nominal voltage is applied to the VT primary.

For example, on a system with a 13.8 kV nominal primary voltage and with a 14400:120 volt VT in a Delta connection, the secondary voltage would be 115, i.e.  $(13800 / 14400) \times 120$ . For a Wye connection, the voltage value entered must be the phase to neutral voltage which would be  $115 / \sqrt{3} = 66.4$ .

On a 14.4 kV system with a Delta connection and a VT primary to secondary turns ratio of 14400:120, the voltage value entered would be 120, i.e.  $14400 / 120$ .

## 5.3.2 POWER SYSTEM

PATH: SETTINGS ⇒ ⚙ SYSTEM SETUP ⇒ ⚙ POWER SYSTEM

|  |  |                                  |
|--|--|----------------------------------|
| <div>■ POWER SYSTEM</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> | <div>⏪ ⏩</div> <div>NOMINAL FREQUENCY:<br/>60 Hz</div>             | Range: 25 to 60 Hz in steps of 1 |
|  | <div>⏪ ⏩</div> <div>PHASE ROTATION:<br/>ABC</div>                  | Range: ABC, ACB                  |
|  | <div>⏪ ⏩</div> <div>FREQUENCY AND PHASE<br/>REFERENCE: SRC 1</div> | Range: SRC 1, SRC 2              |
|  | <div>⏪ ⏩</div> <div>FREQUENCY TRACKING:<br/>Enabled</div>          | Range: Disabled, Enabled         |

The power system **NOMINAL FREQUENCY** value is used as a default to set the digital sampling rate if the system frequency cannot be measured from available signals. This may happen if the signals are not present or are heavily distorted. Before reverting to the nominal frequency, the frequency tracking algorithm holds the last valid frequency measurement for a safe period of time while waiting for the signals to reappear or for the distortions to decay.



The phase sequence of the power system is required to properly calculate sequence components and power parameters. The **PHASE ROTATION** setting matches the power system phase sequence. Note that this setting informs the relay of the actual system phase sequence, either ABC or ACB. CT and VT inputs on the relay, labeled as A, B, and C, must be connected to system phases A, B, and C for correct operation.

The **FREQUENCY AND PHASE REFERENCE** setting determines which signal source is used (and hence which AC signal) for phase angle reference. The AC signal used is prioritized based on the AC inputs that are configured for the signal source: phase voltages takes precedence, followed by auxiliary voltage, then phase currents, and finally ground current.

For three phase selection, phase A is used for angle referencing ( $V_{\text{ANGLE REF}} = V_A$ ), while Clarke transformation of the phase signals is used for frequency metering and tracking ( $V_{\text{FREQUENCY}} = (2V_A - V_B - V_C)/3$ ) for better performance during fault, open pole, and VT and CT fail conditions.

The phase reference and frequency tracking AC signals are selected based upon the Source configuration, regardless of whether or not a particular signal is actually applied to the relay.

Phase angle of the reference signal will always display zero degrees and all other phase angles will be relative to this signal. If the pre-selected reference signal is not measurable at a given time, the phase angles are not referenced.

The phase angle referencing is done via a phase locked loop, which can synchronize independent UR-series relays if they have the same AC signal reference. These results in very precise correlation of time tagging in the event recorder between different UR-series relays provided the relays have an IRIG-B connection.



**FREQUENCY TRACKING** should only be set to "Disabled" in very unusual circumstances; consult the factory for special variable-frequency applications.

### 5.3.3 SIGNAL SOURCES

**PATH: SETTINGS ⇒ SYSTEM SETUP ⇒ SIGNAL SOURCES ⇒ SOURCE 1(2)**

|   |   |   |
|---|---|---|
| <div> <div>■ SOURCE 1</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>SOURCE 1 NAME:</div> <div>SRC 1</div> </div>     | Range: up to 6 alphanumeric characters  |
| <div> <div>▲▼</div> <div>MESSAGE</div> </div>         | <div> <div>▲▼</div> <div>SOURCE 1 PHASE CT:</div> <div>None</div> </div>  | Range: None, F1, F5, F1+F5,... up to a combination of any 5 CTs. Only Phase CT inputs are displayed.  |
| <div> <div>▲▼</div> <div>MESSAGE</div> </div>         | <div> <div>▲▼</div> <div>SOURCE 1 GROUND CT:</div> <div>None</div> </div> | Range: None, F1, F5, F1+F5,... up to a combination of any 5 CTs. Only Ground CT inputs are displayed. |
| <div> <div>▲▼</div> <div>MESSAGE</div> </div>         | <div> <div>▲▼</div> <div>SOURCE 1 PHASE VT:</div> <div>None</div> </div>  | Range: None, F1, F5<br>Only phase voltage inputs will be displayed.                                   |
| <div> <div>▲</div> <div>MESSAGE</div> </div>          | <div> <div>▲</div> <div>SOURCE 1 AUX VT:</div> <div>None</div> </div>     | Range: None, F1, F5<br>Only auxiliary voltage inputs will be displayed.                               |

Two identical source menus are available. The "SRC 1" text can be replaced by with a user-defined name appropriate for the associated source.

"F" represents the module slot position. The number directly following this letter represents either the first bank of four channels (1, 2, 3, 4) called "1" or the second bank of four channels (5, 6, 7, 8) called "5" in a particular CT/VT module. Refer to the Introduction to AC Sources section at the beginning of this chapter for additional details on this concept.

It is possible to select the sum of up to five (5) CTs. The first channel displayed is the CT to which all others will be referred. For example, the selection "F1+F5" indicates the sum of each phase from channels "F1" and "F5", scaled to whichever CT has the higher ratio. Selecting "None" hides the associated actual values.

The approach used to configure the AC sources consists of several steps; first step is to specify the information about each CT and VT input. For CT inputs, this is the nominal primary and secondary current. For VTs, this is the connection type, ratio and nominal secondary voltage. Once the inputs have been specified, the configuration for each Source is entered, including specifying which CTs will be summed together.

### User Selection of AC Parameters for Comparator Elements:

CT/VT modules automatically calculate all current and voltage parameters from the available inputs. Users must select the specific input parameters to be measured by every element in the relevant settings menu. The internal design of the element specifies which type of parameter to use and provides a setting for Source selection. In elements where the parameter may be either fundamental or RMS magnitude, such as phase time overcurrent, two settings are provided. One setting specifies the Source, the second setting selects between fundamental phasor and RMS.

### AC Input Actual Values:

The calculated parameters associated with the configured voltage and current inputs are displayed in the current and voltage sections of actual values. Only the phasor quantities associated with the actual AC physical input channels will be displayed here. All parameters contained within a configured source are displayed in the sources section of the actual values.

### Disturbance Detectors (Internal):

The 50DD element is a sensitive current disturbance detector that detects any disturbance on the protected system. 50DD is intended for use in conjunction with measuring elements, blocking of current based elements (to prevent maloperation as a result of the wrong settings), and starting oscillography data capture. A disturbance detector is provided for each Source.

The 50DD function responds to the changes in magnitude of the sequence currents. The disturbance detector scheme logic is as follows:

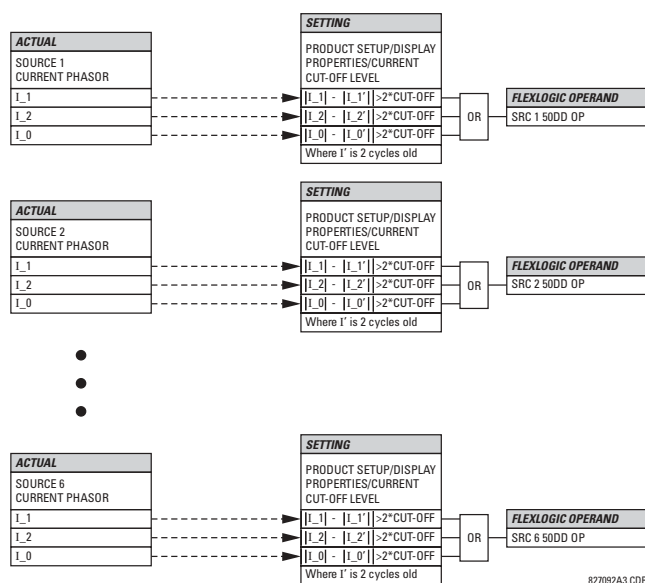


Figure 5-12: DISTURBANCE DETECTOR LOGIC DIAGRAM

The disturbance detector responds to the change in currents of twice the current cut-off level. The default cut-off threshold is 0.02 pu; thus by default the disturbance detector responds to a change of 0.04 pu. The metering sensitivity setting (**PRODUCT SETUP** ⇒ **DISPLAY PROPERTIES** ⇒ **CURRENT CUT-OFF LEVEL**) controls the sensitivity of the disturbance detector accordingly.

## 5.3.4 BREAKERS

PATH: SETTINGS ⇒ SYSTEM SETUP ⇒ BREAKERS ⇒ BREAKER 1(2)

|             |    |   |   |
|-------------|----|---|---|
| ■ BREAKER 1 | ◀▶ | BREAKER 1<br>FUNCTION: Disabled           | Range: Disabled, Enabled                          |
| MESSAGE     | ▲▼ | BREAKER1 PUSH BUTTON<br>CONTROL: Disabled | Range: Disabled, Enabled                          |
| MESSAGE     | ▲▼ | BREAKER 1 NAME:<br>Bkr 1                  | Range: up to 6 alphanumeric characters            |
| MESSAGE     | ▲▼ | BREAKER 1 MODE:<br>3-Pole                 | Range: 3-Pole, 1-Pole                             |
| MESSAGE     | ▲▼ | BREAKER 1 OPEN:<br>Off                    | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | BREAKER 1 CLOSE:<br>Off                   | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | BREAKER 1 $\phi$ A/3-POLE:<br>Off         | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | BREAKER 1 $\phi$ B:<br>Off                | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | BREAKER 1 $\phi$ C:<br>Off                | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | BREAKER 1 EXT ALARM:<br>Off               | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | BREAKER 1 ALARM<br>DELAY: 0.000 s         | Range: 0.000 to 1 000 000.000 s in steps of 0.001 |
| MESSAGE     | ▲▼ | MANUAL CLOSE RECALI<br>TIME: 0.000 s      | Range: 0.000 to 1 000 000.000 s in steps of 0.001 |
| MESSAGE     | ▲▼ | BREAKER 1 OUT OF SV:<br>Off               | Range: FlexLogic™ operand                         |
| MESSAGE     | ▲▼ | XCBR ST.LOC OPERAND:<br>Off               | Range: FlexLogic™ operand                         |

A description of the operation of the breaker control and status monitoring features is provided in Chapter 4. Only information concerning programming of the associated settings is covered here. These features are provided for two breakers; a user may use only those portions of the design relevant to a single breaker, which must be Breaker 1.

- **BREAKER 1(2) FUNCTION:** Set to "Enable" to allow the operation of any breaker control feature.
- **BREAKER1(2) PUSH BUTTON CONTROL:** Set to "Enable" to allow faceplate push button operations.
- **BREAKER 1(2) NAME:** Assign a user-defined name (up to 6 characters) to the breaker. This name will be used in flash messages related to Breaker 1.
- **BREAKER 1(2) MODE:** Selects "3-pole" mode, where all breaker poles are operated simultaneously, or "1-pole" mode where all breaker poles are operated either independently or simultaneously.
- **BREAKER 1(2) OPEN:** Selects an operand that creates a programmable signal to operate an output relay to open Breaker No. 1.
- **BREAKER 1(2) CLOSE:** Selects an operand that creates a programmable signal to operate an output relay to close Breaker No. 1.
- **BREAKER 1(2)  $\phi$ A/3-POLE:** Selects an operand, usually a contact input connected to a breaker auxiliary position tracking mechanism. This input can be either a 52/a or 52/b contact, or a combination the 52/a and 52/b contacts, that

must be programmed to create a logic 0 when the breaker is open. If **BREAKER 1 MODE** is selected as "3-Pole", this setting selects a single input as the operand used to track the breaker open or closed position. If the mode is selected as "1-Pole", the input mentioned above is used to track phase A and settings **BREAKER 1  $\Phi$ B** and **BREAKER 1  $\Phi$ C** select operands to track phases B and C, respectively.

- **BREAKER 1(2) FB:** If the mode is selected as 3-pole, this setting has no function. If the mode is selected as 1-pole, this input is used to track phase B as above for phase A.
- **BREAKER 1(2) FC:** If the mode is selected as 3-pole, this setting has no function. If the mode is selected as 1-pole, this input is used to track phase C as above for phase A.
- **BREAKER 1(2) EXT ALARM:** Selects an operand, usually an external contact input, connected to a breaker alarm reporting contact.
- **BREAKER 1(2) ALARM DELAY:** Sets the delay interval during which a disagreement of status among the three pole position tracking operands will not declare a pole disagreement, to allow for non-simultaneous operation of the poles.
- **MANUAL CLOSE RECAL1 TIME:** Sets the interval required to maintain setting changes in effect after an operator has initiated a manual close command to operate a circuit breaker.
- **BREAKER 1(2) OUT OF SV:** Selects an operand indicating that Breaker 1(2) is out-of-service.
- **XCBR ST.LOC OPERAND:** Selects a FlexLogic™ operand to provide a value for the IEC 61850 XCBR1(2) St.Loc data item.

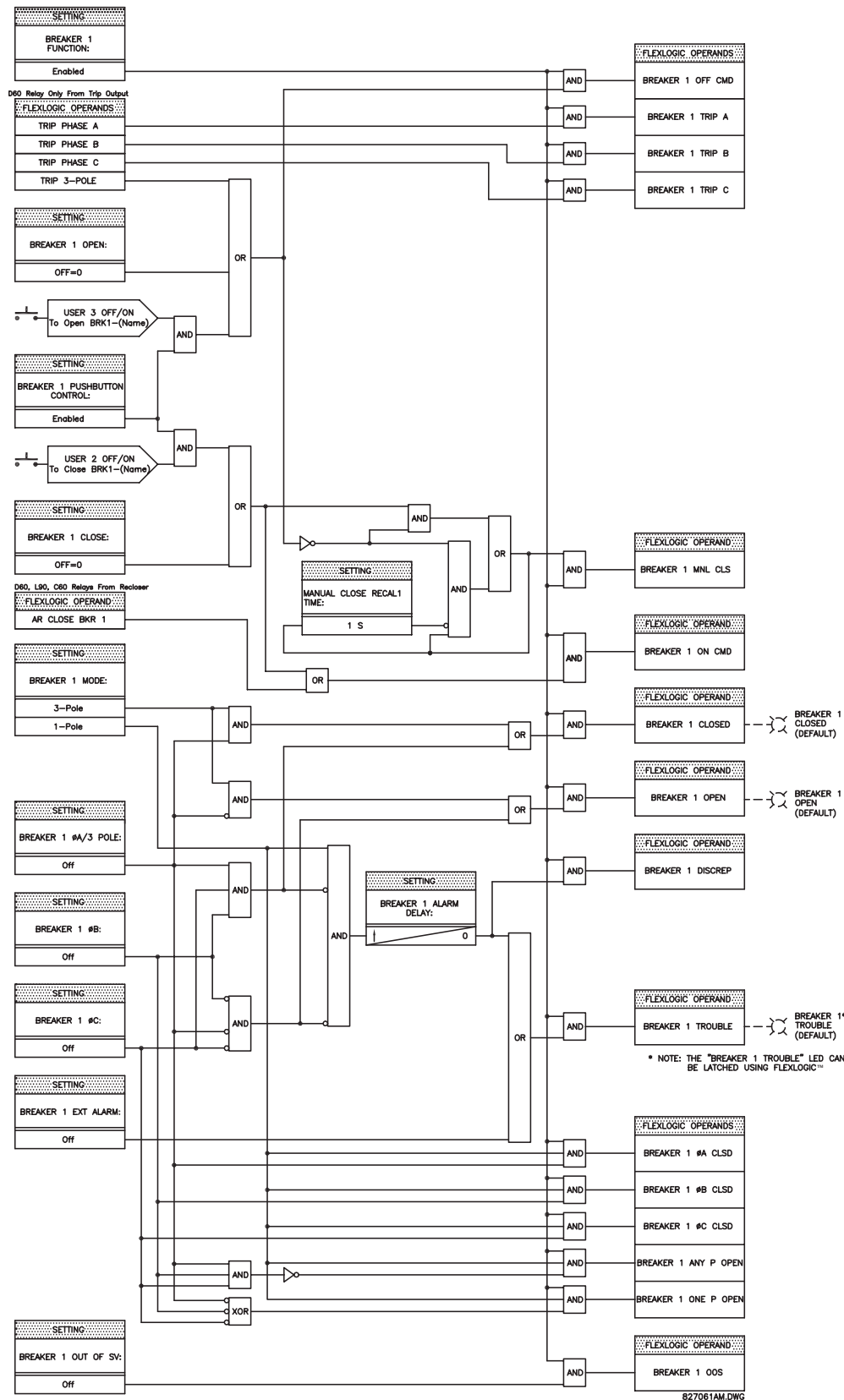


Figure 5-13: DUAL BREAKER CONTROL SCHEME LOGIC

## 5.3.5 FLEXCURVES™

## a) SETTINGS

PATH: SETTINGS ⇒ SYSTEM SETUP ⇒ FLEXCURVES ⇒ FLEXCURVE A(D)

FLEXCURVE A



FLEXCURVE A TIME AT

0.00 xPKP: 0 ms

Range: 0 to 65535 ms in steps of 1

FlexCurves™ A through D have settings for entering times to Reset/Operate at the following pickup levels: 0.00 to 0.98 / 1.03 to 20.00. This data is converted into 2 continuous curves by linear interpolation between data points. To enter a custom FlexCurve™, enter the Reset/Operate time (using the ▲ VALUE ▼ keys) for each selected pickup point (using the ▲ MESSAGE ▼ keys) for the desired protection curve (A, B, C, or D).

Table 5–3: FLEXCURVE™ TABLE

| RESET | TIME MS | RESET | TIME MS | OPERATE | TIME MS | OPERATE | TIME MS | OPERATE | TIME MS | OPERATE | TIME MS |
|-------|---------|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0.00  |         | 0.68  |         | 1.03    |         | 2.9     |         | 4.9     |         | 10.5    |         |
| 0.05  |         | 0.70  |         | 1.05    |         | 3.0     |         | 5.0     |         | 11.0    |         |
| 0.10  |         | 0.72  |         | 1.1     |         | 3.1     |         | 5.1     |         | 11.5    |         |
| 0.15  |         | 0.74  |         | 1.2     |         | 3.2     |         | 5.2     |         | 12.0    |         |
| 0.20  |         | 0.76  |         | 1.3     |         | 3.3     |         | 5.3     |         | 12.5    |         |
| 0.25  |         | 0.78  |         | 1.4     |         | 3.4     |         | 5.4     |         | 13.0    |         |
| 0.30  |         | 0.80  |         | 1.5     |         | 3.5     |         | 5.5     |         | 13.5    |         |
| 0.35  |         | 0.82  |         | 1.6     |         | 3.6     |         | 5.6     |         | 14.0    |         |
| 0.40  |         | 0.84  |         | 1.7     |         | 3.7     |         | 5.7     |         | 14.5    |         |
| 0.45  |         | 0.86  |         | 1.8     |         | 3.8     |         | 5.8     |         | 15.0    |         |
| 0.48  |         | 0.88  |         | 1.9     |         | 3.9     |         | 5.9     |         | 15.5    |         |
| 0.50  |         | 0.90  |         | 2.0     |         | 4.0     |         | 6.0     |         | 16.0    |         |
| 0.52  |         | 0.91  |         | 2.1     |         | 4.1     |         | 6.5     |         | 16.5    |         |
| 0.54  |         | 0.92  |         | 2.2     |         | 4.2     |         | 7.0     |         | 17.0    |         |
| 0.56  |         | 0.93  |         | 2.3     |         | 4.3     |         | 7.5     |         | 17.5    |         |
| 0.58  |         | 0.94  |         | 2.4     |         | 4.4     |         | 8.0     |         | 18.0    |         |
| 0.60  |         | 0.95  |         | 2.5     |         | 4.5     |         | 8.5     |         | 18.5    |         |
| 0.62  |         | 0.96  |         | 2.6     |         | 4.6     |         | 9.0     |         | 19.0    |         |
| 0.64  |         | 0.97  |         | 2.7     |         | 4.7     |         | 9.5     |         | 19.5    |         |
| 0.66  |         | 0.98  |         | 2.8     |         | 4.8     |         | 10.0    |         | 20.0    |         |



The relay using a given FlexCurve™ applies linear approximation for times between the user-entered points. Special care must be applied when setting the two points that are close to the multiple of pickup of 1, i.e. 0.98 pu and 1.03 pu. It is recommended to set the two times to a similar value; otherwise, the linear approximation may result in undesired behavior for the operating quantity that is close to 1.00 pu.

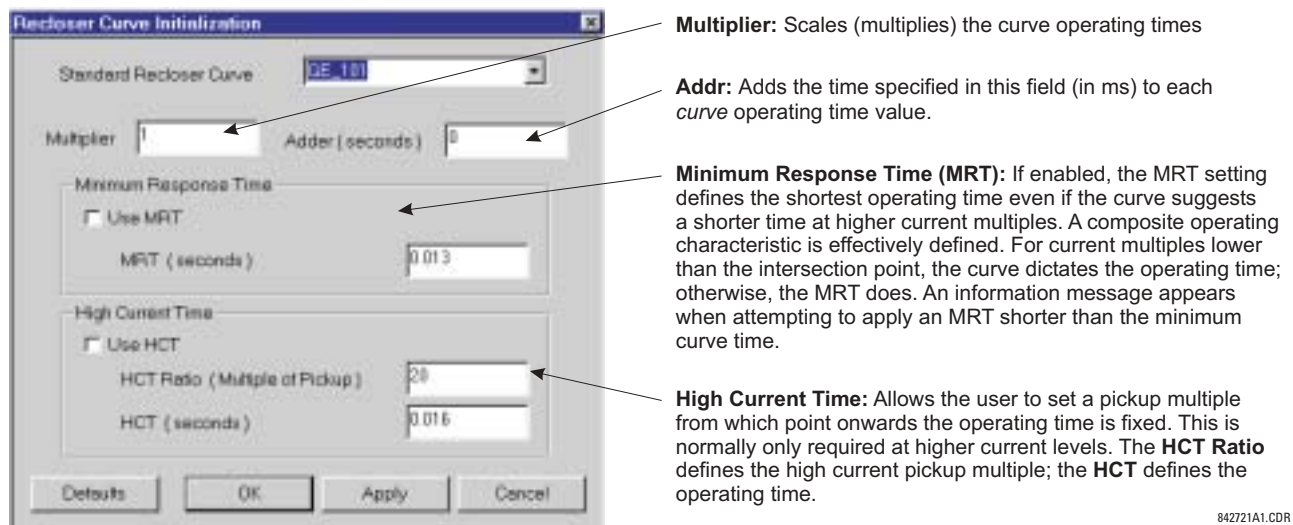
### b) FLEXCURVE™ CONFIGURATION WITH ENERVISTA UR SETUP

The enerVista UR Setup software allows for easy configuration and management of FlexCurves™ and their associated data points. Prospective FlexCurves™ can be configured from a selection of standard curves to provide the best approximate fit, then specific data points can be edited afterwards. Alternately, curve data can be imported from a specified file (.csv format) by selecting the **Import Data From** enerVista UR Setup setting.

Curves and data can be exported, viewed, and cleared by clicking the appropriate buttons. FlexCurves™ are customized by editing the operating time (ms) values at pre-defined per-unit current multiples. Note that the pickup multiples start at zero (implying the "reset time"), operating time below pickup, and operating time above pickup.

### c) RECLOSER CURVE EDITING

Recloser Curve selection is special in that recloser curves can be shaped into a composite curve with a minimum response time and a fixed time above a specified pickup multiples. There are 41 recloser curve types supported. These definite operating times are useful to coordinate operating times, typically at higher currents and where upstream and downstream protective devices have different operating characteristics. The Recloser Curve configuration window shown below appears when the Initialize From enerVista UR Setup setting is set to "Recloser Curve" and the Initialize FlexCurve button is clicked.



842721A1.CDR

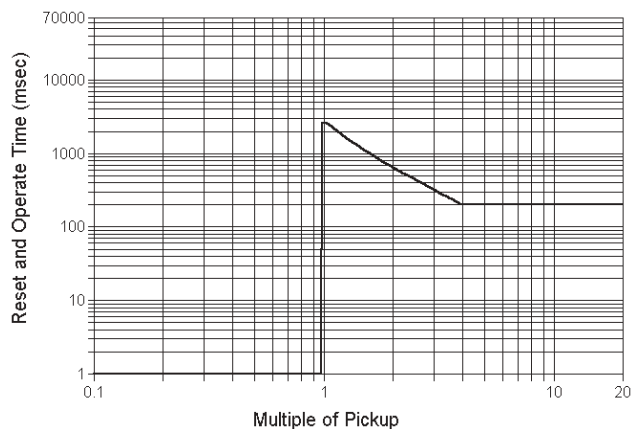
Figure 5-14: RECLOSER CURVE INITIALIZATION



Multiplier and Adder settings only affect the curve portion of the characteristic and not the MRT and HCT settings. The HCT settings override the MRT settings for multiples of pickup greater than the HCT Ratio.

**d) EXAMPLE**

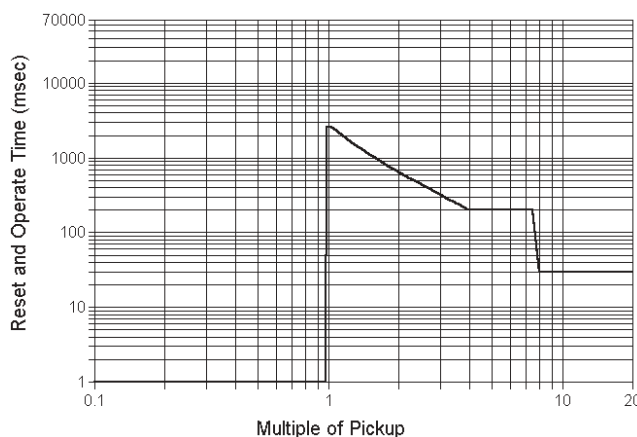
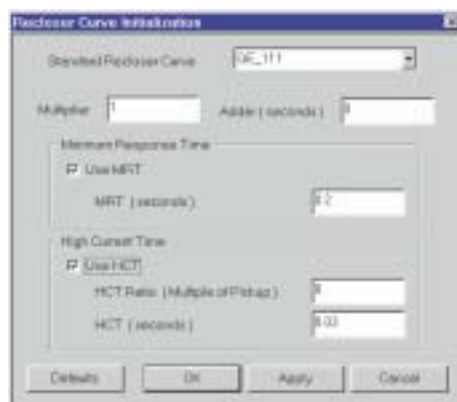
A composite curve can be created from the GE\_111 standard with MRT = 200 ms and HCT initially disabled and then enabled at 8 times pickup with an operating time of 30 ms. At approximately 4 times pickup, the curve operating time is equal to the MRT and from then onwards the operating time remains at 200 ms (see below).



842719A1.CDR

**Figure 5-15: COMPOSITE RECLOSER CURVE WITH HCT DISABLED**

With the HCT feature enabled, the operating time reduces to 30 ms for pickup multiples exceeding 8 times pickup.

**5**

842729A1.CDR

**Figure 5-16: COMPOSITE RECLOSER CURVE WITH HCT ENABLED**

Configuring a composite curve with an increase in operating time at increased pickup multiples is not allowed. If this is attempted, the enerVista UR Setup software generates an error message and discards the proposed changes.

**e) STANDARD RECLOSER CURVES**

The standard Recloser curves available for the D30 are displayed in the following graphs.



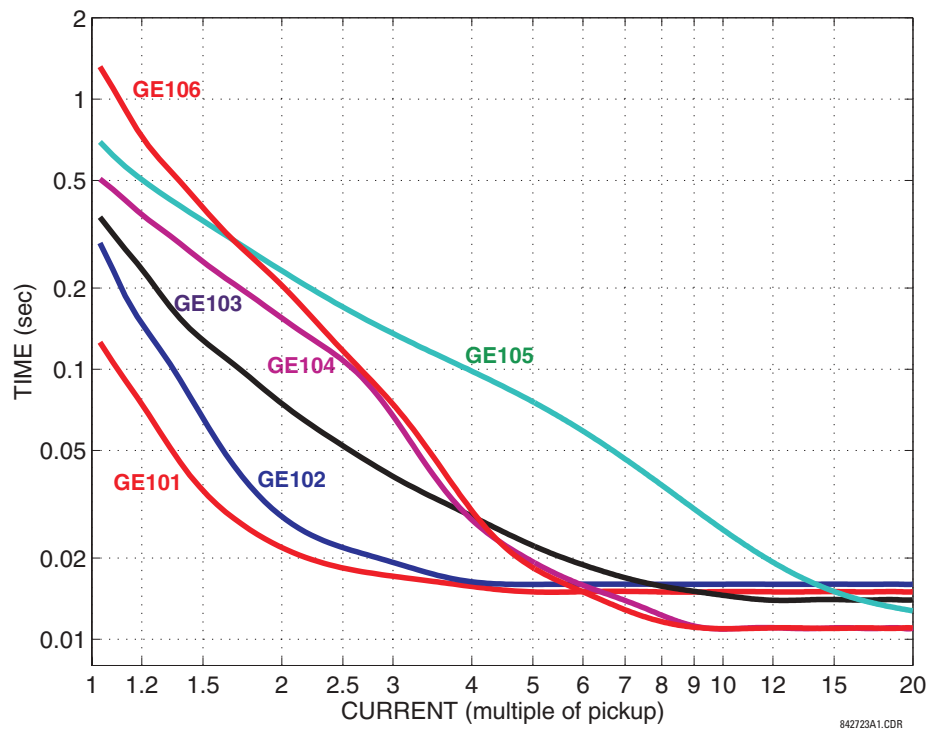


Figure 5-17: RECLOSER CURVES GE101 TO GE106

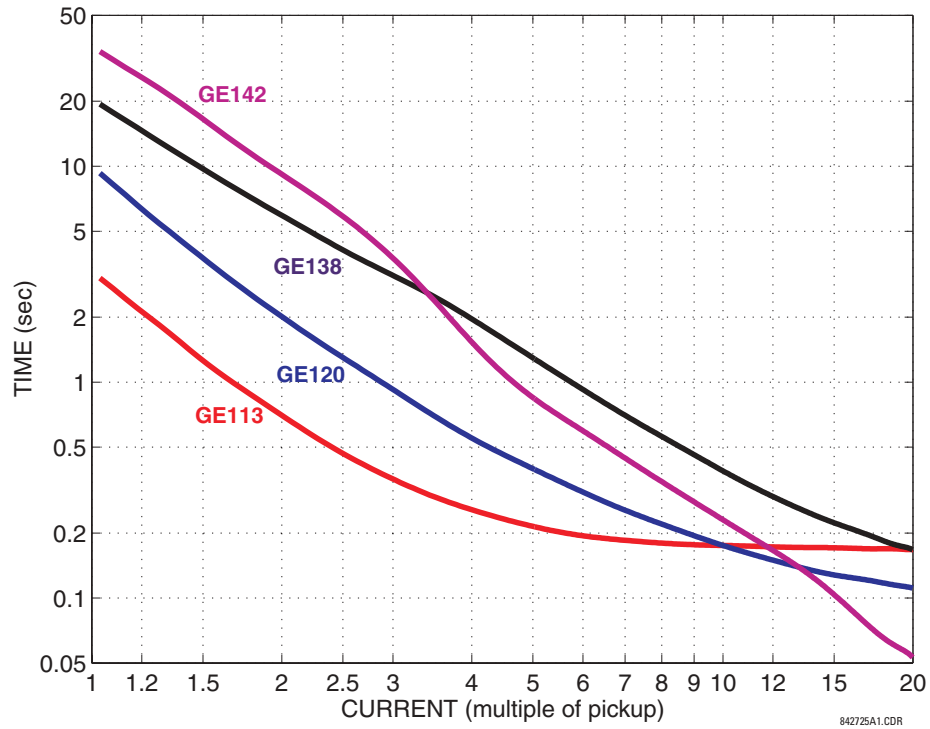


Figure 5-18: RECLOSER CURVES GE113, GE120, GE138 AND GE142

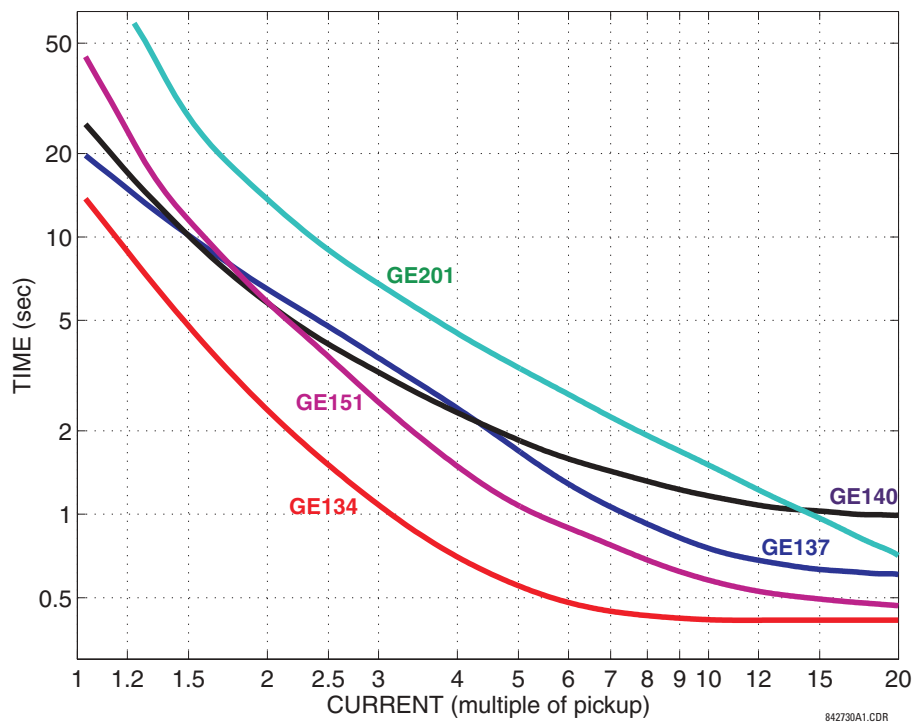


Figure 5-19: RECLOSER CURVES GE134, GE137, GE140, GE151 AND GE201

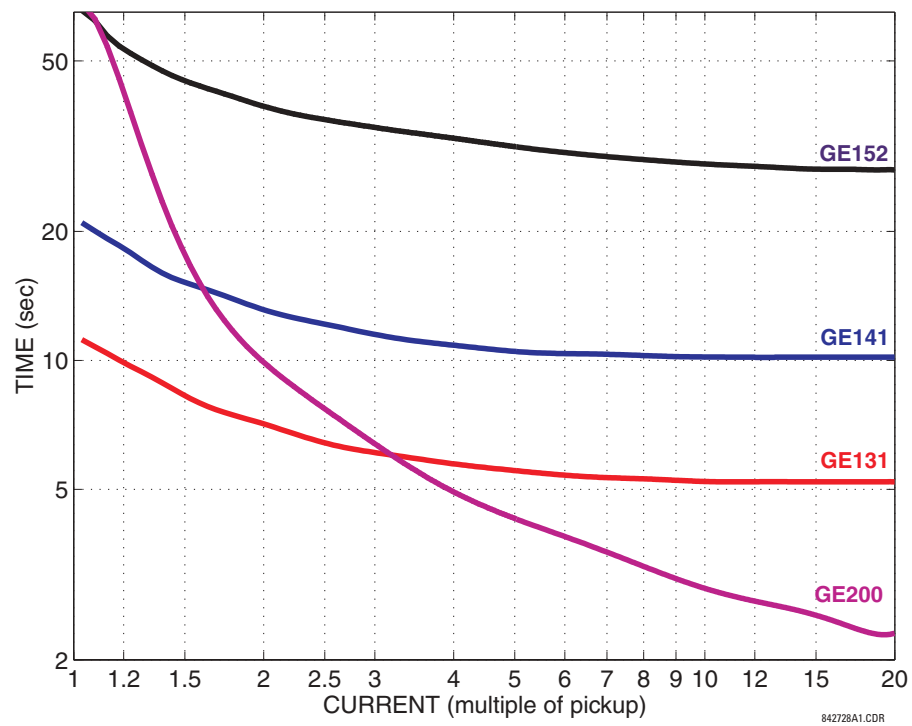


Figure 5-20: RECLOSER CURVES GE131, GE141, GE152, AND GE200

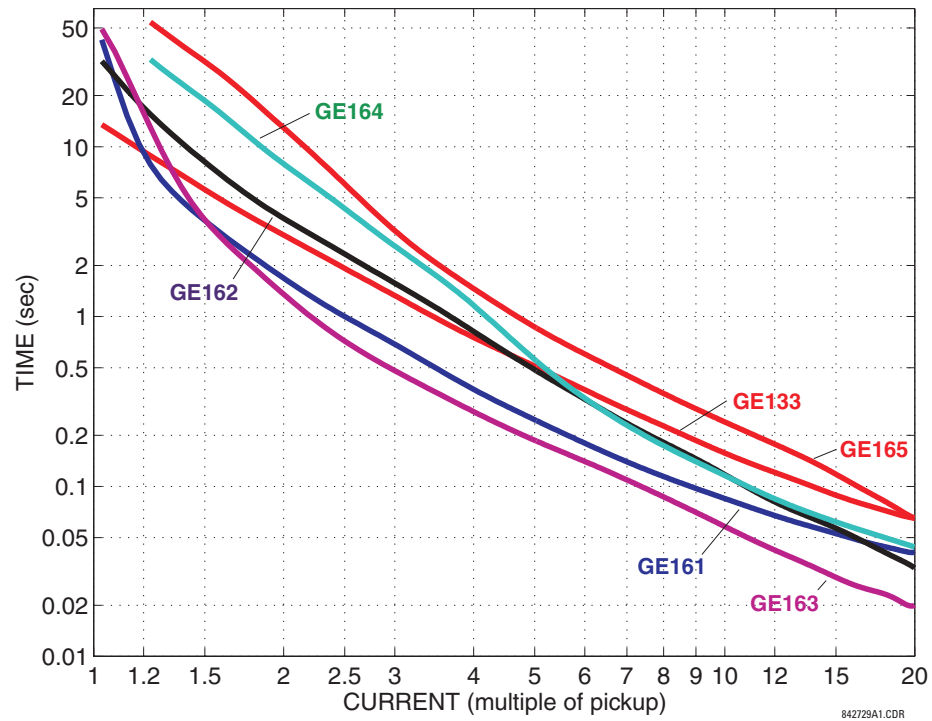


Figure 5-21: RECLOSER CURVES GE133, GE161, GE162, GE163, GE164 AND GE165

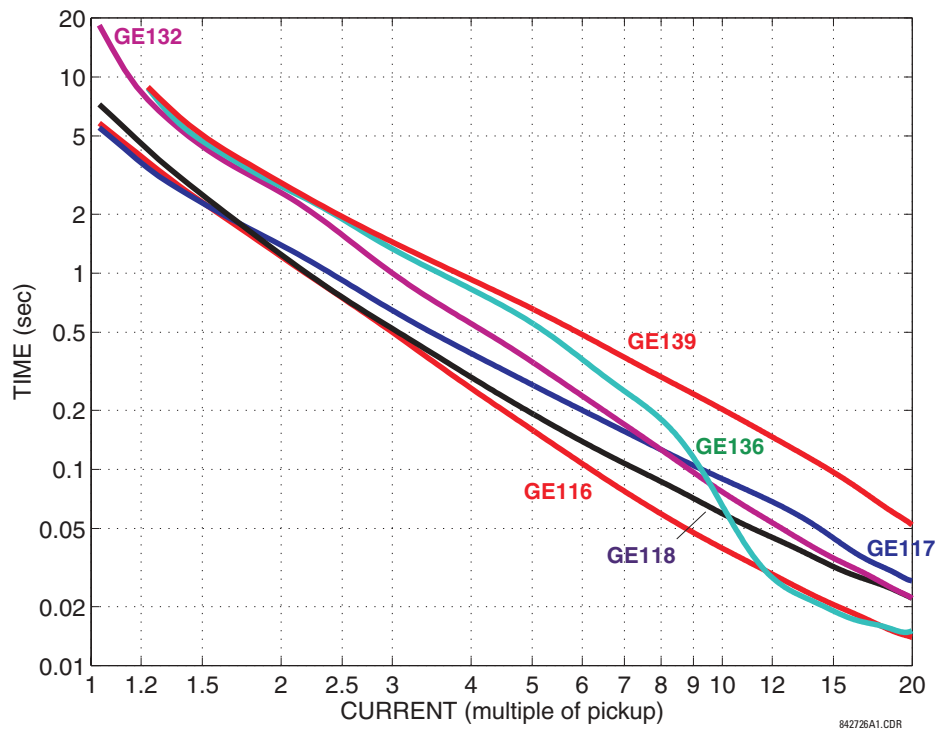


Figure 5-22: RECLOSER CURVES GE116, GE117, GE118, GE132, GE136, AND GE139

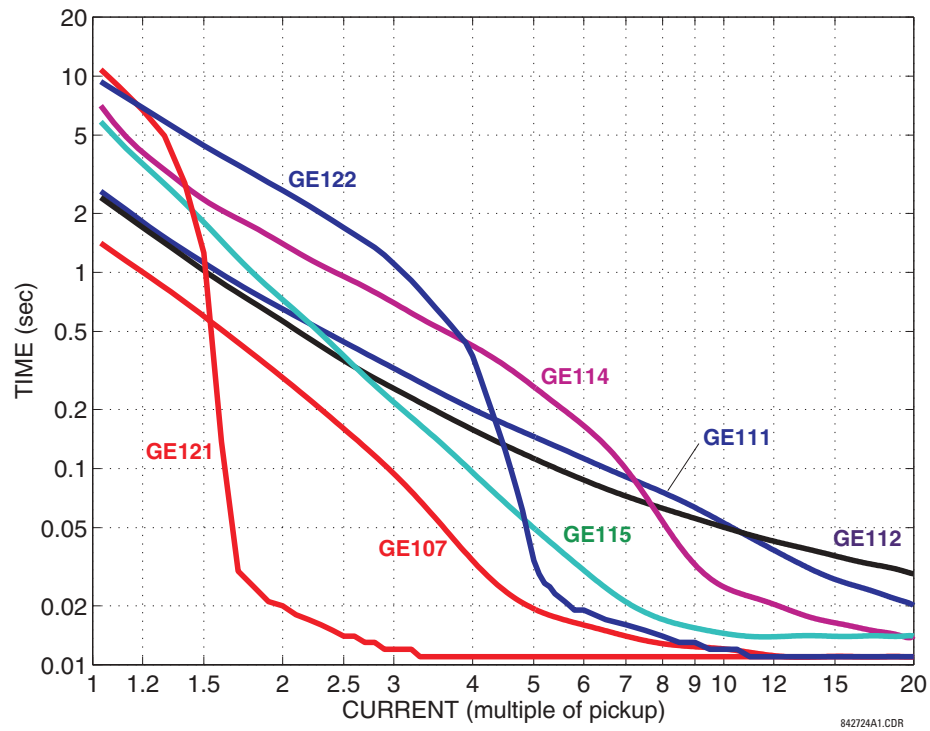


Figure 5-23: RECLOSER CURVES GE107, GE111, GE112, GE114, GE115, GE121, AND GE122

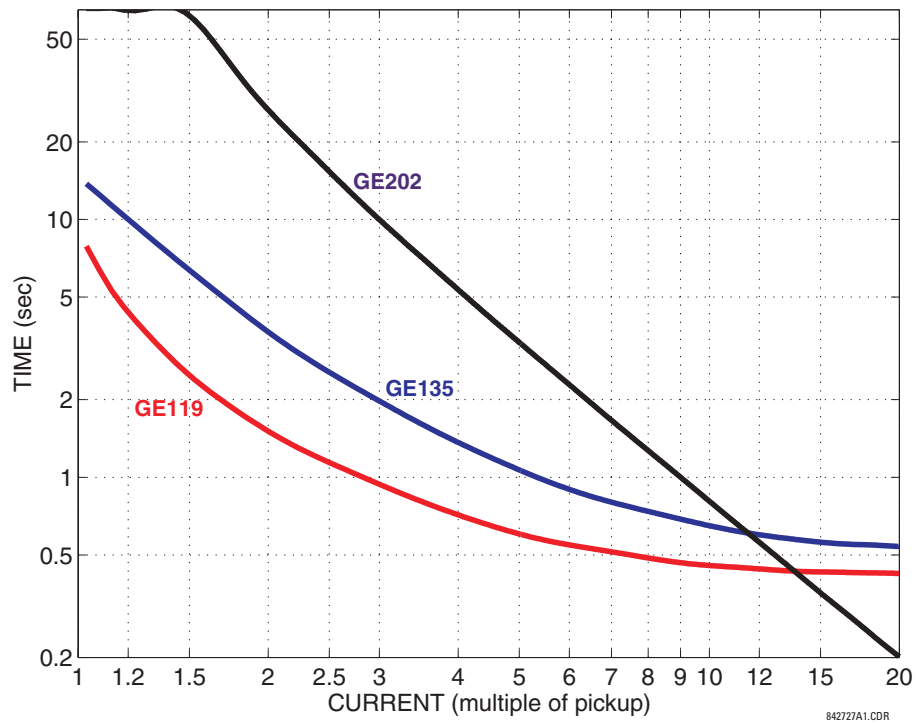


Figure 5-24: RECLOSER CURVES GE119, GE135, AND GE202

## 5.4.1 INTRODUCTION TO FLEXLOGIC™

To provide maximum flexibility to the user, the arrangement of internal digital logic combines fixed and user-programmed parameters. Logic upon which individual features are designed is fixed, and all other logic, from digital input signals through elements or combinations of elements to digital outputs, is variable. The user has complete control of all variable logic through FlexLogic™. In general, the system receives analog and digital inputs which it uses to produce analog and digital outputs. The major sub-systems of a generic UR-series relay involved in this process are shown below.

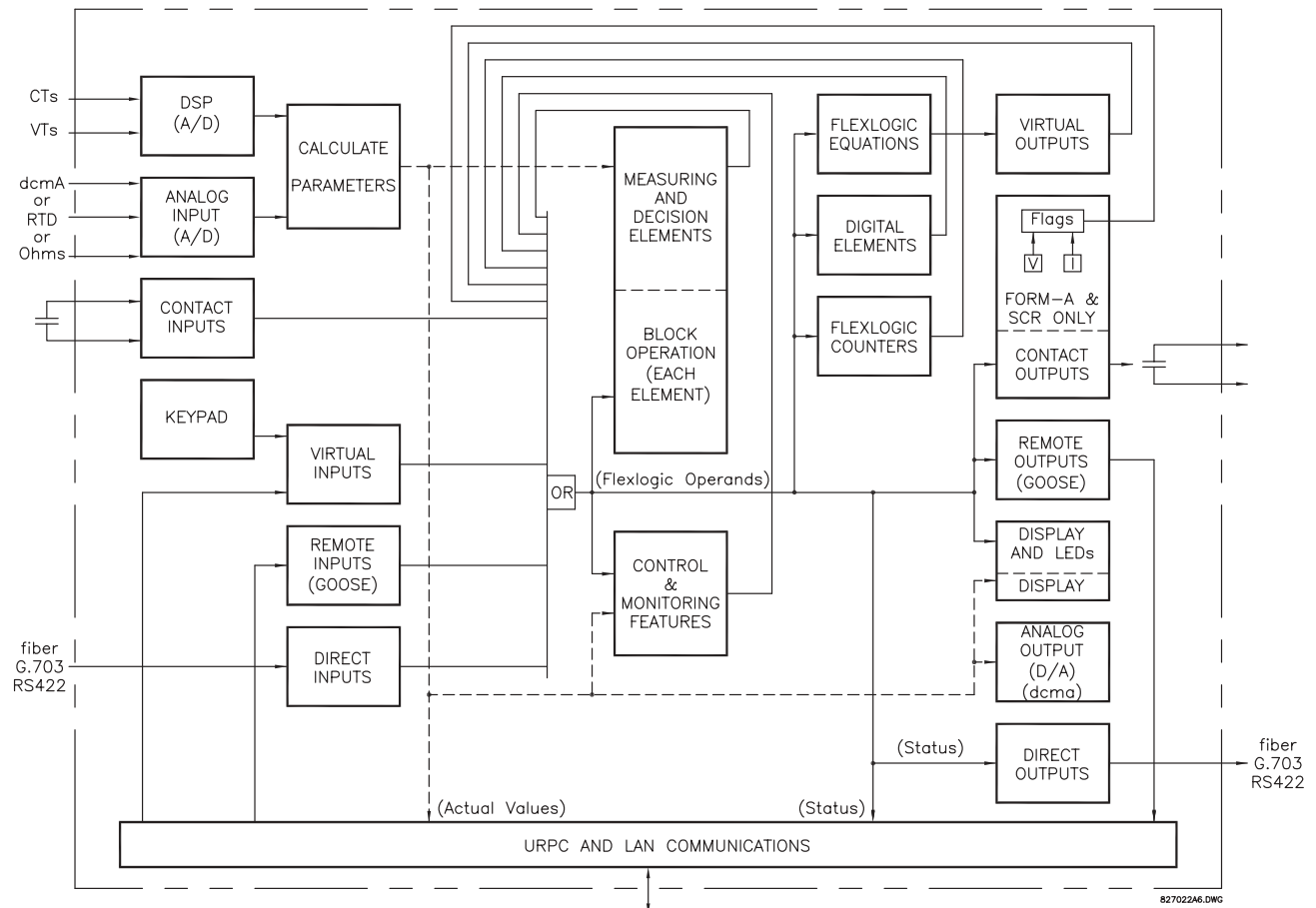


Figure 5-25: UR ARCHITECTURE OVERVIEW

The states of all digital signals used in the D30 are represented by flags (or FlexLogic™ operands, which are described later in this section). A digital “1” is represented by a ‘set’ flag. Any external contact change-of-state can be used to block an element from operating, as an input to a control feature in a FlexLogic™ equation, or to operate a contact output. The state of the contact input can be displayed locally or viewed remotely via the communications facilities provided. If a simple scheme where a contact input is used to block an element is desired, this selection is made when programming the element. This capability also applies to the other features that set flags: elements, virtual inputs, remote inputs, schemes, and human operators.

If more complex logic than presented above is required, it is implemented via FlexLogic™. For example, if it is desired to have the closed state of contact input H7a and the operated state of the phase undervoltage element block the operation of the phase time overcurrent element, the two control input states are programmed in a FlexLogic™ equation. This equation ANDs the two control inputs to produce a ‘virtual output’ which is then selected when programming the phase time overcurrent to be used as a blocking input. Virtual outputs can only be created by FlexLogic™ equations.

Traditionally, protective relay logic has been relatively limited. Any unusual applications involving interlocks, blocking, or supervisory functions had to be hard-wired using contact inputs and outputs. FlexLogic™ minimizes the requirement for auxiliary components and wiring while making more complex schemes possible.

The logic that determines the interaction of inputs, elements, schemes and outputs is field programmable through the use of logic equations that are sequentially processed. The use of virtual inputs and outputs in addition to hardware is available internally and on the communication ports for other relays to use (distributed FlexLogic™).

FlexLogic™ allows users to customize the relay through a series of equations that consist of operators and operands. The operands are the states of inputs, elements, schemes and outputs. The operators are logic gates, timers and latches (with set and reset inputs). A system of sequential operations allows any combination of specified operands to be assigned as inputs to specified operators to create an output. The final output of an equation is a numbered register called a virtual output. Virtual outputs can be used as an input operand in any equation, including the equation that generates the output, as a seal-in or other type of feedback.

A FlexLogic™ equation consists of parameters that are either operands or operators. Operands have a logic state of 1 or 0. Operators provide a defined function, such as an AND gate or a Timer. Each equation defines the combinations of parameters to be used to set a Virtual Output flag. Evaluation of an equation results in either a 1 (=ON, i.e. flag set) or 0 (=OFF, i.e. flag not set). Each equation is evaluated at least 4 times every power system cycle.

Some types of operands are present in the relay in multiple instances; e.g. contact and remote inputs. These types of operands are grouped together (for presentation purposes only) on the faceplate display. The characteristics of the different types of operands are listed in the table below.

**Table 5–4: D30 FLEXLOGIC™ OPERAND TYPES**

| OPERAND TYPE                                 | STATE       | EXAMPLE FORMAT    | CHARACTERISTICS<br>[INPUT IS '1' (= ON) IF...]   |
|--|-------------|-------------------|--|
| Contact Input                                | On          | Cont Ip On        | Voltage is presently applied to the input (external contact closed).   |
|  | Off         | Cont Ip Off       | Voltage is presently not applied to the input (external contact open).   |
| Contact Output<br>(type Form-A contact only) | Voltage On  | Cont Op 1 VOn     | Voltage exists across the contact.   |
|  | Voltage Off | Cont Op 1 VOff    | Voltage does not exist across the contact.   |
|  | Current On  | Cont Op 1 IOn     | Current is flowing through the contact.  |
|  | Current Off | Cont Op 1 IOff    | Current is not flowing through the contact.  |
| Direct Input                                 | On          | DIRECT INPUT 1 On | The direct input is presently in the ON state.   |
| Element<br>(Analog)                          | Pickup      | PHASE TOC1 PKP    | The tested parameter is presently above the pickup setting of an element which responds to rising values or below the pickup setting of an element which responds to falling values.                 |
|  | Dropout     | PHASE TOC1 DPO    | This operand is the logical inverse of the above PKP operand.  |
|  | Operate     | PHASE TOC1 OP     | The tested parameter has been above/below the pickup setting of the element for the programmed delay time, or has been at logic 1 and is now at logic 0 but the reset timer has not finished timing. |
|  | Block       | PH DIR1 BLK       | The output of the comparator is set to the block function.   |
| Element<br>(Digital)                         | Pickup      | Dig Element 1 PKP | The input operand is at logic 1.   |
|  | Dropout     | Dig Element 1 DPO | This operand is the logical inverse of the above PKP operand.  |
|  | Operate     | Dig Element 1 OP  | The input operand has been at logic 1 for the programmed pickup delay time, or has been at logic 1 for this period and is now at logic 0 but the reset timer has not finished timing.                |
| Element<br>(Digital Counter)                 | Higher than | Counter 1 HI      | The number of pulses counted is above the set number.  |
|  | Equal to    | Counter 1 EQL     | The number of pulses counted is equal to the set number.   |
|  | Lower than  | Counter 1 LO      | The number of pulses counted is below the set number.  |
| Fixed  | On          | On                | Logic 1  |
|  | Off         | Off               | Logic 0  |
| Remote Input                                 | On          | REMOTE INPUT 1 On | The remote input is presently in the ON state.   |
| Virtual Input                                | On          | Virt Ip 1 On      | The virtual input is presently in the ON state.  |
| Virtual Output                               | On          | Virt Op 1 On      | The virtual output is presently in the set state (i.e. evaluation of the equation which produces this virtual output results in a "1").  |

The operands available for this relay are listed alphabetically by types in the following table.

**Table 5–5: D30 FLEXLOGIC™ OPERANDS (Sheet 1 of 6)**

| OPERAND TYPE                                     | OPERAND SYNTAX   | OPERAND DESCRIPTION   |
|--|--|---|
| CONTROL PUSHBUTTONS                              | CONTROL PUSHBTN n ON   | Control Pushbutton $n$ ( $n = 1$ to $7$ ) is being pressed.   |
| DIRECT DEVICES                                   | DIRECT DEVICE 1On<br>↓<br>DIRECT DEVICE 16On<br>DIRECT DEVICE 1Off<br>↓<br>DIRECT DEVICE 16Off   | Flag is set, logic=1<br>↓<br>Flag is set, logic=1<br>Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
| DIRECT INPUT/<br>OUTPUT<br>CHANNEL<br>MONITORING | DIR IO CH1(2) CRC ALARM<br>DIR IO CRC ALARM<br>DIR IO CH1(2) UNRET ALM<br>DIR IO UNRET ALM   | The rate of Direct Input messages received on Channel 1(2) and failing the CRC exceeded the user-specified level.<br>The rate of Direct Input messages failing the CRC exceeded the user-specified level on Channel 1 or 2.<br>The rate of returned direct input/output messages on Channel 1(2) exceeded the user-specified level (ring configurations only).<br>The rate of returned direct input/output messages exceeded the user-specified level on Channel 1 or 2 (ring configurations only). |
| ELEMENT:<br>Autoreclose<br>(per CT bank)         | AR 1 ENABLED<br>AR 1 RIP<br>AR 1 LO<br>AR 1 BLK FROM MAN CL<br>AR 1 CLOSE<br>AR 1 SHOT CNT=0<br>↓<br>AR 1 SHOT CNT=4<br>AR 1 DISABLED  | Autoreclose 1 is enabled<br>Autoreclose 1 is in progress<br>Autoreclose 1 is locked out<br>Autoreclose 1 is temporarily disabled<br>Autoreclose 1 close command is issued<br>Autoreclose 1 shot count is 0<br><br>Autoreclose 1 shot count is 4<br>Autoreclose 1 is disabled  |
| ELEMENT:<br>Auxiliary<br>Overvoltage             | AUX OV1 PKP<br>AUX OV1 DPO<br>AUX OV1 OP   | Auxiliary Overvoltage element has picked up<br>Auxiliary Overvoltage element has dropped out<br>Auxiliary Overvoltage element has operated  |
| ELEMENT:<br>Auxiliary<br>Undervoltage            | AUX UV1 PKP<br>AUX UV1 DPO<br>AUX UV1 OP   | Auxiliary Undervoltage element has picked up<br>Auxiliary Undervoltage element has dropped out<br>Auxiliary Undervoltage element has operated   |
| ELEMENT:<br>Breaker Arcing                       | BKR ARC 1 OP<br>BKR ARC 2 OP   | Breaker Arcing Current 1 has operated<br>Breaker Arcing Current 2 has operated  |
| ELEMENT:<br>Breaker Control                      | BREAKER 1 OFF CMD<br>BREAKER 1 ON CMD<br>BREAKER 1 $\phi$ A CLSD<br>BREAKER 1 $\phi$ B CLSD<br>BREAKER 1 $\phi$ C CLSD<br>BREAKER 1 CLOSED<br>BREAKER 1 OPEN<br>BREAKER 1 DISCREP<br>BREAKER 1 TROUBLE<br>BREAKER 1 MNL CLS<br>BREAKER 1 TRIP A<br>BREAKER 1 TRIP B<br>BREAKER 1 TRIP C<br>BREAKER 1 ANY P OPEN<br>BREAKER 1 ONE P OPEN<br>BREAKER 1 OOS | Breaker 1 OFF command<br>Breaker 1 ON command<br>Breaker 1 phase A is closed<br>Breaker 1 phase B is closed<br>Breaker 1 phase C is closed<br>Breaker 1 is closed<br>Breaker 1 is open<br>Breaker 1 has discrepancy<br>Breaker 1 trouble alarm<br>Breaker 1 manual close<br>Breaker 1 trip phase A command<br>Breaker 1 trip phase B command<br>Breaker 1 trip phase C command<br>At least one pole of Breaker 1 is open<br>Only one pole of Breaker 1 is open<br>Breaker 1 is out of service       |
|  | BREAKER 2  | Same set of operands as shown for BREAKER 1   |
| ELEMENT:<br>Digital Counters                     | Counter 1 HI<br>Counter 1 EQL<br>Counter 1 LO<br>↓<br>Counter 8 HI<br>Counter 8 EQL<br>Counter 8 LO  | Digital Counter 1 output is 'more than' comparison value<br>Digital Counter 1 output is 'equal to' comparison value<br>Digital Counter 1 output is 'less than' comparison value<br>↓<br>Digital Counter 8 output is 'more than' comparison value<br>Digital Counter 8 output is 'equal to' comparison value<br>Digital Counter 8 output is 'less than' comparison value   |

Table 5–5: D30 FLEXLOGIC™ OPERANDS (Sheet 2 of 6)

| OPERAND TYPE  | OPERAND SYNTAX  | OPERAND DESCRIPTION   |
|---|---|---|
| ELEMENT:<br>Digital Elements                                  | Dig Element 1 PKP<br>Dig Element 1 OP<br>Dig Element 1 DPO<br>↓<br>Dig Element 16 PKP<br>Dig Element 16 OP<br>Dig Element 16 DPO  | Digital Element 1 is picked up<br>Digital Element 1 is operated<br>Digital Element 1 is dropped out<br>↓<br>Digital Element 16 is picked up<br>Digital Element 16 is operated<br>Digital Element 16 is dropped out  |
| ELEMENT:<br>FlexElements™                                     | FxE 1 PKP<br>FxE 1 OP<br>FxE 1 DPO<br>↓<br>FxE 8 PKP<br>FxE 8 OP<br>FxE 8 DPO   | FlexElement™ 1 has picked up<br>FlexElement™ 1 has operated<br>FlexElement™ 1 has dropped out<br>↓<br>FlexElement™ 8 has picked up<br>FlexElement™ 8 has operated<br>FlexElement™ 8 has dropped out   |
| ELEMENT:<br>Ground Distance                                   | GND DIST Z1 PKP<br>GND DIST Z1 OP<br>GND DIST Z1 OP A<br>GND DIST Z1 OP B<br>GND DIST Z1 OP C<br>GND DIST Z1 PKP A<br>GND DIST Z1 PKP B<br>GND DIST Z1 PKP C<br>GND DIST Z1 SUPN IN<br>GND DIST Z1 DPO A<br>GND DIST Z1 DPO B<br>GND DIST Z1 DPO C<br>GND DIST Z2 DIR SUPN<br>GND DIST Z2 to Z3 | Ground Distance Zone 1 has picked up<br>Ground Distance Zone 1 has operated<br>Ground Distance Zone 1 phase A has operated<br>Ground Distance Zone 1 phase B has operated<br>Ground Distance Zone 1 phase C has operated<br>Ground Distance Zone 1 phase A has picked up<br>Ground Distance Zone 1 phase B has picked up<br>Ground Distance Zone 1 phase C has picked up<br>Ground Distance Zone 1 neutral is supervising<br>Ground Distance Zone 1 phase A has dropped out<br>Ground Distance Zone 1 phase B has dropped out<br>Ground Distance Zone 1 phase C has dropped out<br>Ground Distance Zone 2 directional is supervising<br>Same set of operands as shown for GND DIST Z1 |
| ELEMENT:<br>Ground<br>Instantaneous<br>Overcurrent            | GROUND IOC1 PKP<br>GROUND IOC1 OP<br>GROUND IOC1 DPO<br>GROUND IOC2   | Ground Instantaneous Overcurrent 1 has picked up<br>Ground Instantaneous Overcurrent 1 has operated<br>Ground Instantaneous Overcurrent 1 has dropped out<br>Same set of operands as shown for GROUND IOC 1   |
| ELEMENT:<br>Ground Time<br>Overcurrent                        | GROUND TOC1 PKP<br>GROUND TOC1 OP<br>GROUND TOC1 DPO<br>GROUND TOC2   | Ground Time Overcurrent 1 has picked up<br>Ground Time Overcurrent 1 has operated<br>Ground Time Overcurrent 1 has dropped out<br>Same set of operands as shown for GROUND TOC1   |
| ELEMENT<br>Non-Volatile<br>Latches                            | LATCH 1 ON<br>LATCH 1 OFF<br>↓<br>LATCH 16 ON<br>LATCH 16 OFF   | Non-Volatile Latch 1 is ON (Logic = 1)<br>Non-Voltage Latch 1 is OFF (Logic = 0)<br>↓<br>Non-Volatile Latch 16 is ON (Logic = 1)<br>Non-Voltage Latch 16 is OFF (Logic = 0)   |
| ELEMENT:<br>Line Pickup                                       | LINE PICKUP OP<br>LINE PICKUP PKP<br>LINE PICKUP DPO<br>LINE PICKUP I<A<br>LINE PICKUP I<B<br>LINE PICKUP I<C<br>LINE PICKUP UV PKP<br>LINE PICKUP LEO PKP<br>LINE PICKUP RCL TRIP  | Line Pickup has operated<br>Line Pickup has picked up<br>Line Pickup has dropped out<br>Line Pickup detected Phase A current below 5% of nominal<br>Line Pickup detected Phase B current below 5% of nominal<br>Line Pickup detected Phase C current below 5% of nominal<br>Line Pickup Undervoltage has picked up<br>Line Pickup Line End Open has picked up<br>Line Pickup operated from overreaching Zone 2 when reclosing the line<br>(Zone 1 extension functionality)  |
| ELEMENT:<br>Load Encroachment                                 | LOAD ENCHR PKP<br>LOAD ENCHR OP<br>LOAD ENCHR DPO   | Load Encroachment has picked up<br>Load Encroachment has operated<br>Load Encroachment has dropped out  |
| ELEMENT:<br>Negative Sequence<br>Directional<br>Overcurrent   | NEG SEQ DIR OC1 FWD<br>NEG SEQ DIR OC1 REV<br>NEG SEQ DIR OC2 FWD<br>NEG SEQ DIR OC2 REV  | Negative Sequence Directional OC1 Forward has operated<br>Negative Sequence Directional OC1 Reverse has operated<br>Negative Sequence Directional OC2 Forward has operated<br>Negative Sequence Directional OC2 Reverse has operated  |
| ELEMENT:<br>Negative Sequence<br>Instantaneous<br>Overcurrent | NEG SEQ IOC1 PKP<br>NEG SEQ IOC1 OP<br>NEG SEQ IOC1 DPO<br>NEG SEQ IOC2   | Negative Sequence Instantaneous Overcurrent 1 has picked up<br>Negative Sequence Instantaneous Overcurrent 1 has operated<br>Negative Sequence Instantaneous Overcurrent 1 has dropped out<br>Same set of operands as shown for NEG SEQ IOC1  |
| ELEMENT:<br>Negative Sequence<br>Overvoltage                  | NEG SEQ OV PKP<br>NEG SEQ OV DPO<br>NEG SEQ OV OP   | Negative Sequence Overvoltage element has picked up<br>Negative Sequence Overvoltage element has dropped out<br>Negative Sequence Overvoltage element has operated  |



Table 5–5: D30 FLEXLOGIC™ OPERANDS (Sheet 3 of 6)

| OPERAND TYPE  | OPERAND SYNTAX   | OPERAND DESCRIPTION   |
|---|--|---|
| ELEMENT:<br>Negative Sequence<br>Time Overcurrent   | NEG SEQ TOC1 PKP<br>NEG SEQ TOC1 OP<br>NEG SEQ TOC1 DPO  | Negative Sequence Time Overcurrent 1 has picked up<br>Negative Sequence Time Overcurrent 1 has operated<br>Negative Sequence Time Overcurrent 1 has dropped out   |
|   | NEG SEQ TOC2   | Same set of operands as shown for NEG SEQ TOC1  |
| ELEMENT:<br>Neutral<br>Instantaneous<br>Overcurrent | NEUTRAL IOC1 PKP<br>NEUTRAL IOC1 OP<br>NEUTRAL IOC1 DPO  | Neutral Instantaneous Overcurrent 1 has picked up<br>Neutral Instantaneous Overcurrent 1 has operated<br>Neutral Instantaneous Overcurrent 1 has dropped out  |
|   | NEUTRAL IOC2   | Same set of operands as shown for NEUTRAL IOC1  |
| ELEMENT:<br>Neutral Overvoltage                     | NEUTRAL OV1 PKP<br>NEUTRAL OV1 DPO<br>NEUTRAL OV1 OP   | Neutral Overvoltage element has picked up<br>Neutral Overvoltage element has dropped out<br>Neutral Overvoltage element has operated  |
| ELEMENT:<br>Neutral Time<br>Overcurrent             | NEUTRAL TOC1 PKP<br>NEUTRAL TOC1 OP<br>NEUTRAL TOC1 DPO  | Neutral Time Overcurrent 1 has picked up<br>Neutral Time Overcurrent 1 has operated<br>Neutral Time Overcurrent 1 has dropped out   |
|   | NEUTRAL TOC2   | Same set of operands as shown for NEUTRAL TOC1  |
| ELEMENT:<br>Neutral Directional<br>Overcurrent      | NTRL DIR OC1 FWD<br>NTRL DIR OC1 REV   | Neutral Directional OC1 Forward has operated<br>Neutral Directional OC1 Reverse has operated  |
|   | NTRL DIR OC2   | Same set of operands as shown for NTRL DIR OC1  |
| ELEMENT:<br>Phase Directional<br>Overcurrent        | PH DIR1 BLK A<br>PH DIR1 BLK B<br>PH DIR1 BLK C<br>PH DIR1 BLK   | Phase A Directional 1 Block<br>Phase B Directional 1 Block<br>Phase C Directional 1 Block<br>Phase Directional 1 Block  |
|   | PH DIR2  | Same set of operands as shown for PH DIR1   |
| ELEMENT:<br>Phase Distance                          | PH DIST Z1 PKP<br>PH DIST Z1 OP<br>PH DIST Z1 OP AB<br>PH DIST Z1 OP BC<br>PH DIST Z1 OP CA<br>PH DIST Z1 PKP AB<br>PH DIST Z1 PKP BC<br>PH DIST Z1 PKP CA<br>PH DIST Z1 SUPN IAB<br>PH DIST Z1 SUPN IBC<br>PH DIST Z1 SUPN ICA<br>PH DIST Z1 DPO AB<br>PH DIST Z1 DPO BC<br>PH DIST Z1 DPO CA | Phase Distance Zone 1 has picked up<br>Phase Distance Zone 1 has operated<br>Phase Distance Zone 1 phase AB has operated<br>Phase Distance Zone 1 phase BC has operated<br>Phase Distance Zone 1 phase CA has operated<br>Phase Distance Zone 1 phase AB has picked up<br>Phase Distance Zone 1 phase BC has picked up<br>Phase Distance Zone 1 phase CA has picked up<br>Phase Distance Zone 1 phase AB IOC is supervising<br>Phase Distance Zone 1 phase BC IOC is supervising<br>Phase Distance Zone 1 phase CA IOC is supervising<br>Phase Distance Zone 1 phase AB has dropped out<br>Phase Distance Zone 1 phase BC has dropped out<br>Phase Distance Zone 1 phase CA has dropped out |
|   | PH DIST Z2 to Z3   | Same set of operands as shown for PH DIST Z1  |
| ELEMENT:<br>Phase<br>Instantaneous<br>Overcurrent   | PHASE IOC1 PKP<br>PHASE IOC1 OP<br>PHASE IOC1 DPO<br>PHASE IOC1 PKP A<br>PHASE IOC1 PKP B<br>PHASE IOC1 PKP C<br>PHASE IOC1 OP A<br>PHASE IOC1 OP B<br>PHASE IOC1 OP C<br>PHASE IOC1 DPO A<br>PHASE IOC1 DPO B<br>PHASE IOC1 DPO C   | At least one phase of PHASE IOC1 has picked up<br>At least one phase of PHASE IOC1 has operated<br>At least one phase of PHASE IOC1 has dropped out<br>Phase A of PHASE IOC1 has picked up<br>Phase B of PHASE IOC1 has picked up<br>Phase C of PHASE IOC1 has picked up<br>Phase A of PHASE IOC1 has operated<br>Phase B of PHASE IOC1 has operated<br>Phase C of PHASE IOC1 has operated<br>Phase A of PHASE IOC1 has dropped out<br>Phase B of PHASE IOC1 has dropped out<br>Phase C of PHASE IOC1 has dropped out   |
|   | PHASE IOC2   | Same set of operands as shown for PHASE IOC1  |
| ELEMENT:<br>Phase Overvoltage                       | PHASE OV1 PKP<br>PHASE OV1 OP<br>PHASE OV1 DPO<br>PHASE OV1 PKP A<br>PHASE OV1 PKP B<br>PHASE OV1 PKP C<br>PHASE OV1 OP A<br>PHASE OV1 OP B<br>PHASE OV1 OP C<br>PHASE OV1 DPO A<br>PHASE OV1 DPO B<br>PHASE OV1 DPO C   | At least one phase of Overvoltage 1 has picked up<br>At least one phase of Overvoltage 1 has operated<br>At least one phase of Overvoltage 1 has dropped out<br>Phase A of Overvoltage 1 has picked up<br>Phase B of Overvoltage 1 has picked up<br>Phase C of Overvoltage 1 has picked up<br>Phase A of Overvoltage 1 has operated<br>Phase B of Overvoltage 1 has operated<br>Phase C of Overvoltage 1 has operated<br>Phase A of Overvoltage 1 has dropped out<br>Phase B of Overvoltage 1 has dropped out<br>Phase C of Overvoltage 1 has dropped out   |

Table 5–5: D30 FLEXLOGIC™ OPERANDS (Sheet 4 of 6)

| OPERAND TYPE  | OPERAND SYNTAX   | OPERAND DESCRIPTION   |
|---|--|---|
| ELEMENT:<br>Phase Time<br>Overcurrent                     | PHASE TOC1 PKP<br>PHASE TOC1 OP<br>PHASE TOC1 DPO<br>PHASE TOC1 PKP A<br>PHASE TOC1 PKP B<br>PHASE TOC1 PKP C<br>PHASE TOC1 OP A<br>PHASE TOC1 OP B<br>PHASE TOC1 OP C<br>PHASE TOC1 DPO A<br>PHASE TOC1 DPO B<br>PHASE TOC1 DPO C | At least one phase of PHASE TOC1 has picked up<br>At least one phase of PHASE TOC1 has operated<br>At least one phase of PHASE TOC1 has dropped out<br>Phase A of PHASE TOC1 has picked up<br>Phase B of PHASE TOC1 has picked up<br>Phase C of PHASE TOC1 has picked up<br>Phase A of PHASE TOC1 has operated<br>Phase B of PHASE TOC1 has operated<br>Phase C of PHASE TOC1 has operated<br>Phase A of PHASE TOC1 has dropped out<br>Phase B of PHASE TOC1 has dropped out<br>Phase C of PHASE TOC1 has dropped out   |
|   | PHASE TOC2   | Same set of operands as shown for PHASE TOC1  |
| ELEMENT:<br>Phase Undervoltage                            | PHASE UV1 PKP<br>PHASE UV1 OP<br>PHASE UV1 DPO<br>PHASE UV1 PKP A<br>PHASE UV1 PKP B<br>PHASE UV1 PKP C<br>PHASE UV1 OP A<br>PHASE UV1 OP B<br>PHASE UV1 OP C<br>PHASE UV1 DPO A<br>PHASE UV1 DPO B<br>PHASE UV1 DPO C             | At least one phase of UV1 has picked up<br>At least one phase of UV1 has operated<br>At least one phase of UV1 has dropped out<br>Phase A of UV1 has picked up<br>Phase B of UV1 has picked up<br>Phase C of UV1 has picked up<br>Phase A of UV1 has operated<br>Phase B of UV1 has operated<br>Phase C of UV1 has operated<br>Phase A of UV1 has dropped out<br>Phase B of UV1 has dropped out<br>Phase C of UV1 has dropped out   |
|   | PHASE UV2  | Same set of operands as shown for PHASE UV1   |
| ELEMENT:<br>Power Swing Detect                            | POWER SWING OUTER<br>POWER SWING MIDDLE<br>POWER SWING INNER<br>POWER SWING BLOCK<br>POWER SWING TMRX PKP<br>POWER SWING TRIP<br>POWER SWING 50DD<br>POWER SWING INCOMING<br>POWER SWING OUTGOING<br>POWER SWING UN/BLOCK          | Positive Sequence impedance in outer characteristic.<br>Positive Sequence impedance in middle characteristic.<br>Positive Sequence impedance in inner characteristic.<br>Power Swing Blocking element operated.<br>Power Swing Timer x picked up.<br>Out-of-step Tripping operated.<br>The Power Swing element detected a disturbance other than power swing.<br>An unstable power swing has been detected (incoming locus).<br>An unstable power swing has been detected (outgoing locus).   |
| ELEMENT:<br>Selector Switch                               | SELECTOR 1 POS Y<br>SELECTOR 1 BIT 0<br>SELECTOR 1 BIT 1<br>SELECTOR 1 BIT 2<br>SELECTOR 1 STP ALARM<br><br>SELECTOR 1 BIT ALARM<br><br>SELECTOR 1 ALARM<br>SELECTOR 1 PWR ALARM   | Selector Switch 1 is in Position Y (mutually exclusive operands).<br>First bit of the 3-bit word encoding position of Selector 1.<br>Second bit of the 3-bit word encoding position of Selector 1.<br>Third bit of the 3-bit word encoding position of Selector 1.<br>Position of Selector 1 has been pre-selected with the stepping up control input but not acknowledged.<br>Position of Selector 1 has been pre-selected with the 3-bit control input but not acknowledged.<br>Position of Selector 1 has been pre-selected but not acknowledged.<br>Position of Selector Switch 1 is undetermined when the relay powers up and synchronizes to the 3-bit input. |
|   | SELECTOR 2   | Same set of operands as shown above for SELECTOR 1  |
| ELEMENT:<br>Setting Group                                 | SETTING GROUP ACT 1<br>↓<br>SETTING GROUP ACT 6  | Setting Group 1 is active<br>↓<br>Setting Group 6 is active   |
| ELEMENT:<br>Disturbance<br>Detector                       | SRCx 50DD OP   | Source x Disturbance Detector has operated  |
| ELEMENT:<br>VTFF (Voltage<br>Transformer Fuse<br>Failure) | SRCx VT FUSE FAIL OP<br>SRCx VT FUSE FAIL DPO<br>SRCx VT FUSE FAIL VOL LOSS  | Source x VT Fuse Failure detector has operated<br>Source x VT Fuse Failure detector has dropped out<br>Source x has lost voltage signals (V2 above 25% or V1 below 70% of nominal)  |
| ELEMENT:<br>Synchrocheck                                  | SYNC 1 DEAD S OP<br>SYNC 1 DEAD S DPO<br>SYNC 1 SYNC OP<br>SYNC 1 SYNC DPO<br>SYNC 1 CLS OP<br>SYNC 1 CLS DPO<br>SYNC 1 V1 ABOVE MIN<br>SYNC 1 V1 BELOW MAX<br>SYNC 1 V2 ABOVE MIN<br>SYNC 1 V2 BELOW MAX                          | Synchrocheck 1 dead source has operated<br>Synchrocheck 1 dead source has dropped out<br>Synchrocheck 1 in synchronization has operated<br>Synchrocheck 1 in synchronization has dropped out<br>Synchrocheck 1 close has operated<br>Synchrocheck 1 close has dropped out<br>Synchrocheck 1 V1 is above the minimum live voltage<br>Synchrocheck 1 V1 is below the maximum dead voltage<br>Synchrocheck 1 V2 is above the minimum live voltage<br>Synchrocheck 1 V2 is below the maximum dead voltage   |
|   | SYNC 2   | Same set of operands as shown for SYNC 1  |

Table 5–5: D30 FLEXLOGIC™ OPERANDS (Sheet 5 of 6)

| OPERAND TYPE   | OPERAND SYNTAX  | OPERAND DESCRIPTION  |
|--|---|--|
| FIXED OPERANDS   | Off   | Logic = 0. Does nothing and may be used as a delimiter in an equation list; used as 'Disable' by other features.   |
|  | On  | Logic = 1. Can be used as a test setting.  |
| INPUTS/OUTPUTS:<br>Contact Inputs  | Cont Ip 1 On<br>↓<br>Cont Ip 2 On   | (will not appear unless ordered)<br>(will not appear unless ordered)   |
|  | Cont Ip 1 Off<br>↓<br>Cont Ip 2 Off   | (will not appear unless ordered)<br>(will not appear unless ordered)   |
| INPUTS/OUTPUTS:<br>Contact Outputs,<br>Current<br>(from detector on<br>Form-A output only) | Cont Op 1 IOn<br>↓<br>Cont Op 2 IOn   | (will not appear unless ordered)<br>(will not appear unless ordered)   |
|  | Cont Op 1 IOff<br>↓<br>Cont Op 2 IOff   | (will not appear unless ordered)<br>(will not appear unless ordered)   |
| INPUTS/OUTPUTS:<br>Contact Outputs,<br>Voltage<br>(from detector on<br>Form-A output only) | Cont Op 1 VOn<br>↓<br>Cont Op 2 VOn   | (will not appear unless ordered)<br>(will not appear unless ordered)   |
|  | Cont Op 1 VOff<br>↓<br>Cont Op 2 VOff   | (will not appear unless ordered)<br>(will not appear unless ordered)   |
| INPUTS/OUTPUTS<br>Direct Inputs  | DIRECT INPUT 1 On<br>↓<br>DIRECT INPUT 32 On                                    | Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
|  | REMOTE INPUT 1 On<br>↓<br>REMOTE INPUT 32 On                                    | Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
| INPUTS/OUTPUTS:<br>Virtual Inputs  | Virt Ip 1 On<br>↓<br>Virt Ip 32 On  | Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
|  | Virt Op 1 On<br>↓<br>Virt Op 64 On  | Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
| LED TEST   | LED TEST IN PROGRESS  | An LED test has been initiated and has not finished.   |
| REMOTE DEVICES   | REMOTE DEVICE 1 On<br>↓<br>REMOTE DEVICE 16 On                                  | Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
|  | REMOTE DEVICE 1 Off<br>↓<br>REMOTE DEVICE 16 Off                                | Flag is set, logic=1<br>↓<br>Flag is set, logic=1  |
| RESETTING  | RESET OP<br>RESET OP (COMMS)<br>RESET OP (OPERAND)<br><br>RESET OP (PUSHBUTTON) | Reset command is operated (set by all 3 operands below)<br>Communications source of the reset command<br>Operand (assigned in the <b>INPUTS/OUTPUTS</b> ⇄ <b>RESETTING</b> menu) source of the reset command<br>Reset key (pushbutton) source of the reset command |

Table 5-5: D30 FLEXLOGIC™ OPERANDS (Sheet 6 of 6)

| <b>OPERAND TYPE</b>                  | <b>OPERAND SYNTAX</b>   | <b>OPERAND DESCRIPTION</b>  |
|--------------------------------------|---|---|
| <b>SELF-DIAGNOSTICS</b>              | ANY MAJOR ERROR<br>ANY MINOR ERROR<br>ANY SELF-TEST<br>BATTERY FAIL<br>DIRECT DEVICE OFF<br>DIRECT RING BREAK<br>DSP ERROR<br>EEPROM DATA ERROR<br>EQUIPMENT MISMATCH<br>FLEXLOGIC ERR TOKEN<br>IRIG-B FAILURE<br>LATCHING OUT ERROR<br>LOW ON MEMORY<br>NO DSP INTERRUPTS<br>PRI ETHERNET FAIL<br>PROGRAM MEMORY<br>PROTOTYPE FIRMWARE<br>REMOTE DEVICE OFF<br>SEC ETHERNET FAIL<br>SNTP FAILURE<br>SYSTEM EXCEPTION<br>UNIT NOT CALIBRATED<br>UNIT NOT PROGRAMMED<br>WATCHDOG ERROR | Any of the major self-test errors generated (major error)<br>Any of the minor self-test errors generated (minor error)<br>Any self-test errors generated (generic, any error)<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets.<br>See description in Chapter 7: Commands and Targets. |
| <b>UNAUTHORIZED ACCESS ALARM</b>     | UNAUTHORIZED ACCESS   | Asserted when a password entry fails while accessing a password-protected level of the relay.   |
| <b>USER-PROGRAMMABLE PUSHBUTTONS</b> | PUSHBUTTON x ON<br>PUSHBUTTON x OFF   | Pushbutton Number x is in the 'On' position<br>Pushbutton Number x is in the 'Off' position   |

Some operands can be re-named by the user. These are the names of the breakers in the breaker control feature, the ID (identification) of contact inputs, the ID of virtual inputs, and the ID of virtual outputs. If the user changes the default name/ID of any of these operands, the assigned name will appear in the relay list of operands. The default names are shown in the FlexLogic™ operands table above.

The characteristics of the logic gates are tabulated below, and the operators available in FlexLogic™ are listed in the FlexLogic™ operators table.

### Table 5–6: FLEXLOGIC™ GATE CHARACTERISTICS

| GATES | NUMBER OF INPUTS | OUTPUT IS '1' (= ON) IF... |
|-------|------------------|----------------------------|
| NOT   | 1                | input is '0'               |
| OR    | 2 to 16          | any input is '1'           |
| AND   | 2 to 16          | all inputs are '1'         |
| NOR   | 2 to 16          | all inputs are '0'         |
| NAND  | 2 to 16          | any input is '0'           |
| XOR   | 2                | only one input is '1'      |

Table 5–7: FLEXLOGIC™ OPERATORS

| TYPE                  | SYNTAX            | DESCRIPTION  | NOTES   |
|-----------------------|-------------------|--|---|
| Editor                | INSERT            | Insert a parameter in an equation list.  |   |
|                       | DELETE            | Delete a parameter from an equation list.  |   |
| End                   | END               | The first END encountered signifies the last entry in the list of processed FlexLogic™ parameters. |   |
| One Shot              | POSITIVE ONE SHOT | One shot that responds to a positive going edge.   | A 'one shot' refers to a single input gate that generates a pulse in response to an edge on the input. The output from a 'one shot' is True (positive) for only one pass through the FlexLogic™ equation. There is a maximum of 32 'one shots'. |
|                       | NEGATIVE ONE SHOT | One shot that responds to a negative going edge.   |   |
|                       | DUAL ONE SHOT     | One shot that responds to both the positive and negative going edges.                              |   |
| Logic Gate            | NOT               | Logical Not  | Operates on the previous parameter.   |
|                       | OR(2)             | 2 input OR gate  | Operates on the 2 previous parameters.  |
|                       | OR(16)            | 16 input OR gate   | Operates on the 16 previous parameters.   |
|                       | AND(2)            | 2 input AND gate   | Operates on the 2 previous parameters.  |
|                       | AND(16)           | 16 input AND gate  | Operates on the 16 previous parameters.   |
|                       | NOR(2)            | 2 input NOR gate   | Operates on the 2 previous parameters.  |
|                       | NOR(16)           | 16 input NOR gate  | Operates on the 16 previous parameters.   |
|                       | NAND(2)           | 2 input NAND gate  | Operates on the 2 previous parameters.  |
|                       | NAND(16)          | 16 input NAND gate   | Operates on the 16 previous parameters.   |
|                       | XOR(2)            | 2 input Exclusive OR gate  | Operates on the 2 previous parameters.  |
|                       | LATCH (S,R)       | Latch (Set, Reset) - reset-dominant  | The parameter preceding LATCH(S,R) is the Reset input. The parameter preceding the Reset input is the Set input.  |
| Timer                 | TIMER 1           | Timer set with FlexLogic™ Timer 1 settings.  | The timer is started by the preceding parameter. The output of the timer is TIMER #.  |
|                       | TIMER 32          | Timer set with FlexLogic™ Timer 32 settings.   |   |
| Assign Virtual Output | = Virt Op 1       | Assigns previous FlexLogic™ parameter to Virtual Output 1.   | The virtual output is set by the preceding parameter  |
|                       | = Virt Op 64      | Assigns previous FlexLogic™ parameter to Virtual Output 64.  |   |

## 5.4.2 FLEXLOGIC™ RULES

When forming a FlexLogic™ equation, the sequence in the linear array of parameters must follow these general rules:

1. Operands must precede the operator which uses the operands as inputs.
2. Operators have only one output. The output of an operator must be used to create a virtual output if it is to be used as an input to two or more operators.
3. Assigning the output of an operator to a Virtual Output terminates the equation.
4. A timer operator (e.g. "TIMER 1") or virtual output assignment (e.g. "= Virt Op 1") may only be used once. If this rule is broken, a syntax error will be declared.

## 5.4.3 FLEXLOGIC™ EVALUATION

Each equation is evaluated in the order in which the parameters have been entered.



**FlexLogic™ provides latches which by definition have a memory action, remaining in the set state after the set input has been asserted. However, they are *volatile*; i.e. they reset on the re-application of control power.**

**When making changes to settings, all FlexLogic™ equations are re-compiled whenever any new setting value is entered, so all latches are automatically reset. If it is necessary to re-initialize FlexLogic™ during testing, for example, it is suggested to power the unit down and then back up.**

## 5.4.4 FLEXLOGIC™ EXAMPLE

This section provides an example of implementing logic for a typical application. The sequence of the steps is quite important as it should minimize the work necessary to develop the relay settings. Note that the example presented in the figure below is intended to demonstrate the procedure, not to solve a specific application situation.

In the example below, it is assumed that logic has already been programmed to produce Virtual Outputs 1 and 2, and is only a part of the full set of equations used. When using FlexLogic™, it is important to make a note of each Virtual Output used – a Virtual Output designation (1 to 64) can only be properly assigned once.

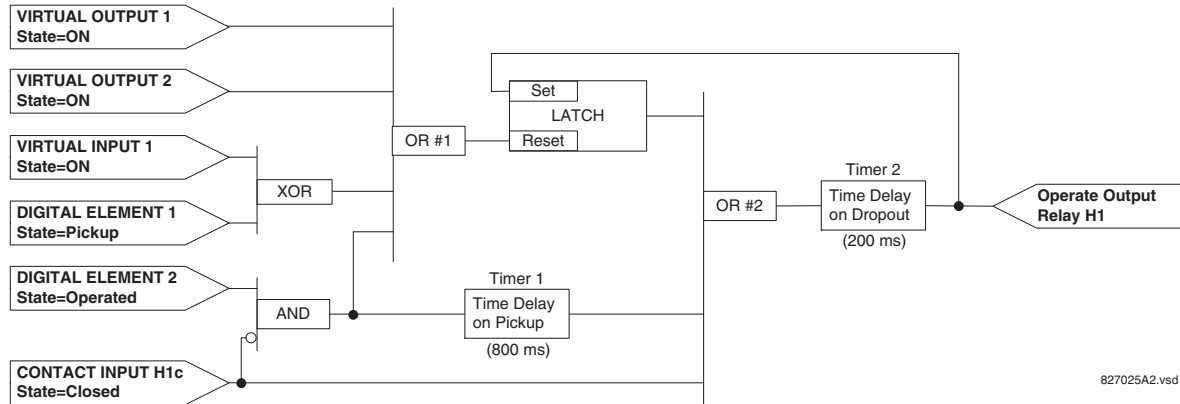


Figure 5-26: EXAMPLE LOGIC SCHEME

5

1. Inspect the example logic diagram to determine if the required logic can be implemented with the FlexLogic™ operators. If this is not possible, the logic must be altered until this condition is satisfied. Once this is done, count the inputs to each gate to verify that the number of inputs does not exceed the FlexLogic™ limits, which is unlikely but possible. If the number of inputs is too high, subdivide the inputs into multiple gates to produce an equivalent. For example, if 25 inputs to an AND gate are required, connect Inputs 1 through 16 to AND(16), 17 through 25 to AND(9), and the outputs from these two gates to AND(2).

Inspect each operator between the initial operands and final virtual outputs to determine if the output from the operator is used as an input to more than one following operator. If so, the operator output must be assigned as a Virtual Output.

For the example shown above, the output of the AND gate is used as an input to both OR#1 and Timer 1, and must therefore be made a Virtual Output and assigned the next available number (i.e. Virtual Output 3). The final output must also be assigned to a Virtual Output as Virtual Output 4, which will be programmed in the contact output section to operate relay H1 (i.e. Output Contact H1).

Therefore, the required logic can be implemented with two FlexLogic™ equations with outputs of Virtual Output 3 and Virtual Output 4 as shown below.

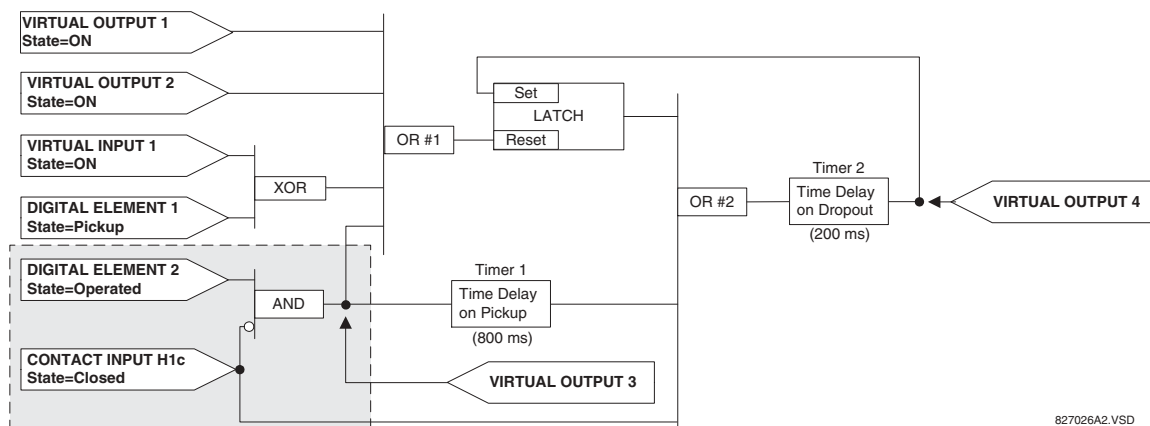


Figure 5-27: LOGIC EXAMPLE WITH VIRTUAL OUTPUTS

- Prepare a logic diagram for the equation to produce Virtual Output 3, as this output will be used as an operand in the Virtual Output 4 equation (create the equation for every output that will be used as an operand first, so that when these operands are required they will already have been evaluated and assigned to a specific Virtual Output). The logic for Virtual Output 3 is shown below with the final output assigned.

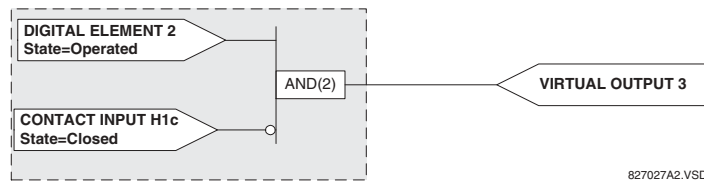


Figure 5–28: LOGIC FOR VIRTUAL OUTPUT 3

- Prepare a logic diagram for Virtual Output 4, replacing the logic ahead of Virtual Output 3 with a symbol identified as Virtual Output 3, as shown below.

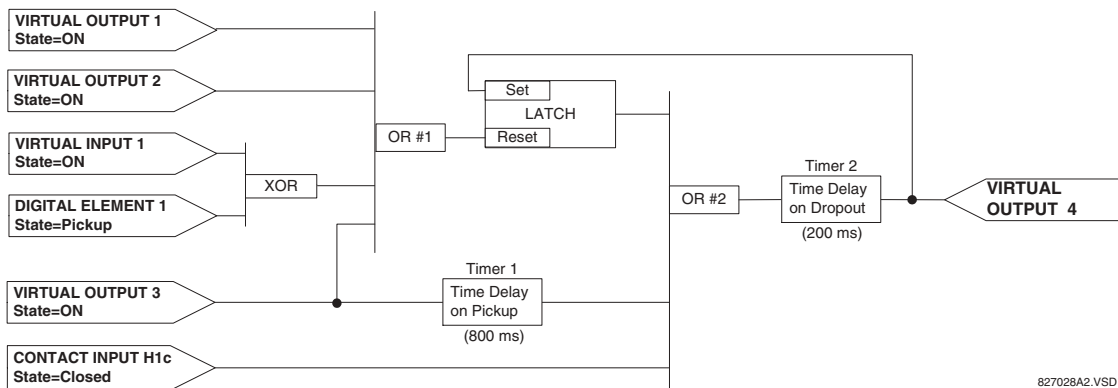


Figure 5–29: LOGIC FOR VIRTUAL OUTPUT 4

- Program the FlexLogic™ equation for Virtual Output 3 by translating the logic into available FlexLogic™ parameters. The equation is formed one parameter at a time until the required logic is complete. It is generally easier to start at the output end of the equation and work back towards the input, as shown in the following steps. It is also recommended to list operator inputs from bottom to top. For demonstration, the final output will be arbitrarily identified as parameter 99, and each preceding parameter decremented by one in turn. Until accustomed to using FlexLogic™, it is suggested that a worksheet with a series of cells marked with the arbitrary parameter numbers be prepared, as shown below.

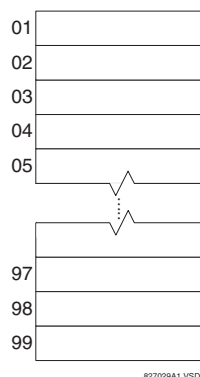


Figure 5–30: FLEXLOGIC™ WORKSHEET

- Following the procedure outlined, start with parameter 99, as follows:
 

99: The final output of the equation is Virtual Output 3, which is created by the operator "= Virt Op n". This parameter is therefore "= Virt Op 3."



- 98: The gate preceding the output is an AND, which in this case requires two inputs. The operator for this gate is a 2-input AND so the parameter is "AND(2)". Note that FlexLogic™ rules require that the number of inputs to most types of operators must be specified to identify the operands for the gate. As the 2-input AND will operate on the two operands preceding it, these inputs must be specified, starting with the lower.
- 97: This lower input to the AND gate must be passed through an inverter (the NOT operator) so the next parameter is "NOT". The NOT operator acts upon the operand immediately preceding it, so specify the inverter input next.
- 96: The input to the NOT gate is to be contact input H1c. The ON state of a contact input can be programmed to be set when the contact is either open or closed. Assume for this example the state is to be ON for a closed contact. The operand is therefore "Cont Ip H1c On".
- 95: The last step in the procedure is to specify the upper input to the AND gate, the operated state of digital element 2. This operand is "DIG ELEM 2 OP".

Writing the parameters in numerical order can now form the equation for VIRTUAL OUTPUT 3:

```
[95] DIG ELEM 2 OP
[96] Cont Ip H1c On
[97] NOT
[98] AND(2)
[99] = Virt Op 3
```

It is now possible to check that this selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to the Logic for Virtual Output 3 diagram as a check.

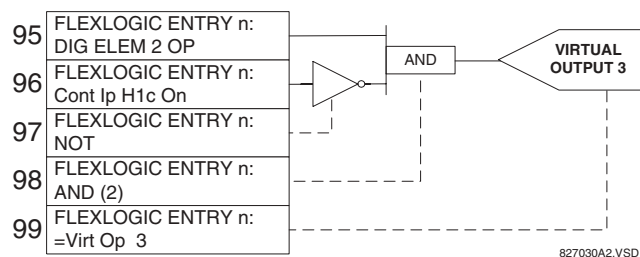


Figure 5–31: FLEXLOGIC™ EQUATION FOR VIRTUAL OUTPUT 3

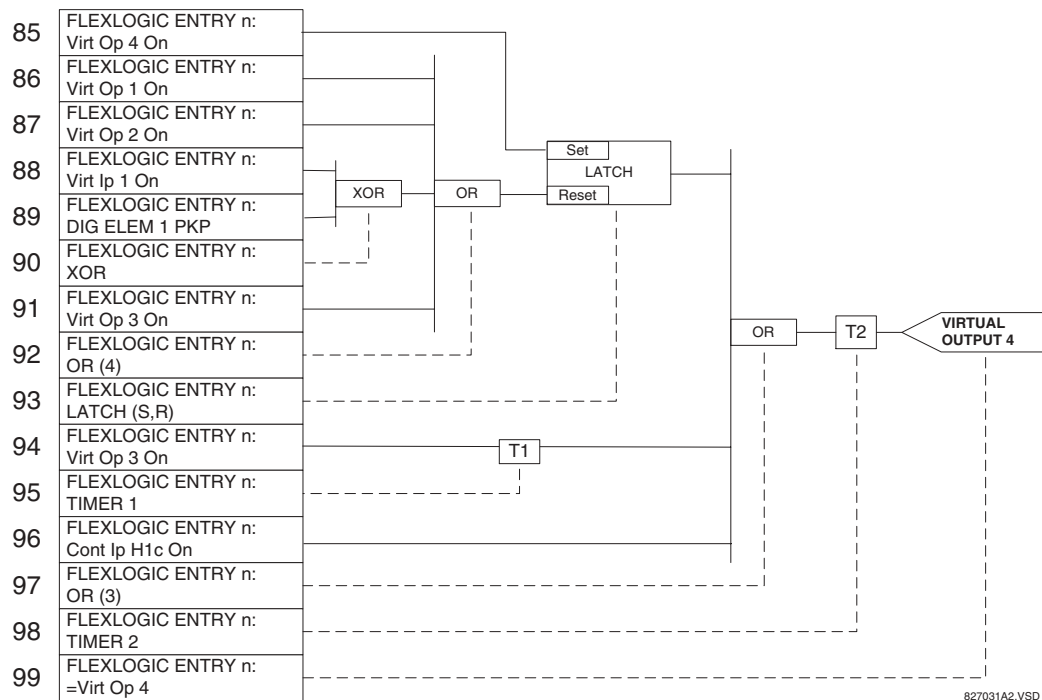
6. Repeating the process described for VIRTUAL OUTPUT 3, select the FlexLogic™ parameters for Virtual Output 4.
- 99: The final output of the equation is VIRTUAL OUTPUT 4 which is parameter "= Virt Op 4".
- 98: The operator preceding the output is Timer 2, which is operand "TIMER 2". Note that the settings required for the timer are established in the timer programming section.
- 97: The operator preceding Timer 2 is OR #2, a 3-input OR, which is parameter "OR(3)".
- 96: The lowest input to OR #2 is operand "Cont Ip H1c On".
- 95: The center input to OR #2 is operand "TIMER 1".
- 94: The input to Timer 1 is operand "Virt Op 3 On".
- 93: The upper input to OR #2 is operand "LATCH (S,R)".
- 92: There are two inputs to a latch, and the input immediately preceding the latch reset is OR #1, a 4-input OR, which is parameter "OR(4)".
- 91: The lowest input to OR #1 is operand "Virt Op 3 On".
- 90: The input just above the lowest input to OR #1 is operand "XOR(2)".
- 89: The lower input to the XOR is operand "DIG ELEM 1 PKP".
- 88: The upper input to the XOR is operand "Virt Ip 1 On".
- 87: The input just below the upper input to OR #1 is operand "Virt Op 2 On".
- 86: The upper input to OR #1 is operand "Virt Op 1 On".
- 85: The last parameter is used to set the latch, and is operand "Virt Op 4 On".



The equation for VIRTUAL OUTPUT 4 is:

```
[85] Virt Op 4 On
[86] Virt Op 1 On
[87] Virt Op 2 On
[88] Virt Ip 1 On
[89] DIG ELEM 1 PKP
[90] XOR(2)
[91] Virt Op 3 On
[92] OR(4)
[93] LATCH (S,R)
[94] Virt Op 3 On
[95] TIMER 1
[96] Cont Ip H1c On
[97] OR(3)
[98] TIMER 2
[99] = Virt Op 4
```

It is now possible to check that the selection of parameters will produce the required logic by converting the set of parameters into a logic diagram. The result of this process is shown below, which is compared to the Logic for Virtual Output 4 diagram as a check.



**Figure 5–32: FLEXLOGIC™ EQUATION FOR VIRTUAL OUTPUT 4**

- Now write the complete FlexLogic™ expression required to implement the logic, making an effort to assemble the equation in an order where Virtual Outputs that will be used as inputs to operators are created before needed. In cases where a lot of processing is required to perform logic, this may be difficult to achieve, but in most cases will not cause problems as all logic is calculated at least 4 times per power frequency cycle. The possibility of a problem caused by sequential processing emphasizes the necessity to test the performance of FlexLogic™ before it is placed in service.

In the following equation, Virtual Output 3 is used as an input to both Latch 1 and Timer 1 as arranged in the order shown below:

```
DIG ELEM 2 OP
Cont Ip H1c On
NOT
AND(2)
```

```

= Virt Op 3
Virt Op 4 On
Virt Op 1 On
Virt Op 2 On
Virt Ip 1 On
DIG ELEM 1 PKP
XOR(2)
Virt Op 3 On
OR(4)
LATCH (S,R)
Virt Op 3 On
TIMER 1
Cont Ip H1c On
OR(3)
TIMER 2
= Virt Op 4
END

```

In the expression above, the Virtual Output 4 input to the 4-input OR is listed before it is created. This is typical of a form of feedback, in this case, used to create a seal-in effect with the latch, and is correct.

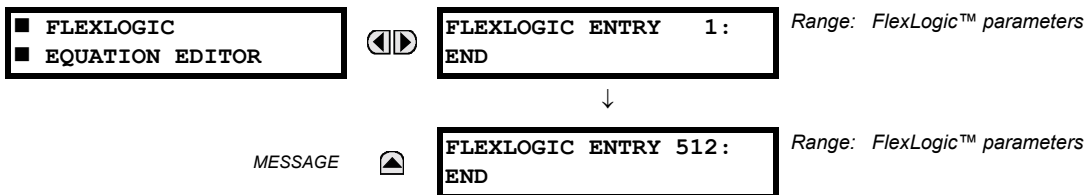
8. The logic should always be tested after it is loaded into the relay, in the same fashion as has been used in the past. Testing can be simplified by placing an "END" operator within the overall set of FlexLogic™ equations. The equations will then only be evaluated up to the first "END" operator.

The "On" and "Off" operands can be placed in an equation to establish a known set of conditions for test purposes, and the "INSERT" and "DELETE" commands can be used to modify equations.

## 5

## 5.4.5 FLEXLOGIC™ EQUATION EDITOR

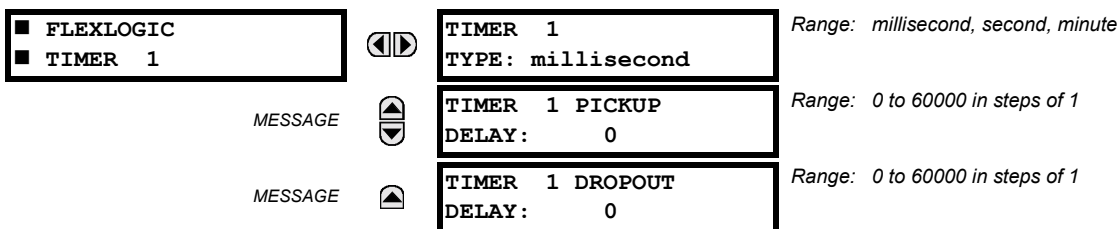
PATH: SETTINGS ⇒ FLEXLOGIC ⇒ FLEXLOGIC EQUATION EDITOR



There are 512 FlexLogic™ entries available, numbered from 1 to 512, with default 'END' entry settings. If a "Disabled" Element is selected as a FlexLogic™ entry, the associated state flag will never be set to '1'. The '+/-' key may be used when editing FlexLogic™ equations from the keypad to quickly scan through the major parameter types.

## 5.4.6 FLEXLOGIC™ TIMERS

PATH: SETTINGS ⇒ FLEXLOGIC ⇒ FLEXLOGIC TIMERS ⇒ FLEXLOGIC TIMER 1(32)



There are 32 identical FlexLogic™ timers available. These timers can be used as operators for FlexLogic™ equations.

- **TIMER 1 TYPE:** This setting is used to select the time measuring unit.
- **TIMER 1 PICKUP DELAY:** Sets the time delay to pickup. If a pickup delay is not required, set this function to "0".
- **TIMER 1 DROPOUT DELAY:** Sets the time delay to dropout. If a dropout delay is not required, set this function to "0".

## 5.4.7 FLEXELEMENTS™

PATH: SETTING ⇒ FLEXLOGIC ⇒ FLEXELEMENTS ⇒ FLEXELEMENT 1(8)

|  |  |  |   |
|--|--|--|---|
| <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div></div> |  | <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div><div>FUNCTION: Disabled</div></div>    | Range: Disabled, Enabled                      |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 NAME:</div><div>FxE1</div></div>            | Range: up to 6 alphanumeric characters        |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 +IN:</div><div>Off</div></div>              | Range: Off, any analog actual value parameter |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 -IN:</div><div>Off</div></div>              | Range: Off, any analog actual value parameter |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 INPUT</div><div>MODE: Signed</div></div>    | Range: Signed, Absolute                       |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 COMP</div><div>MODE: Level</div></div>      | Range: Level, Delta                           |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div><div>DIRECTION: Over</div></div>       | Range: Over, Under                            |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div><div>PICKUP: 1.000 pu</div></div>      | Range: −90.000 to 90.000 pu in steps of 0.001 |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div><div>HYSTERESIS: 3.0%</div></div>      | Range: 0.1 to 50.0% in steps of 0.1           |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 dt</div><div>UNIT: milliseconds</div></div> | Range: milliseconds, seconds, minutes         |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 dt:</div><div>20</div></div>                | Range: 20 to 86400 in steps of 1              |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 PKP</div><div>DELAY: 0.000 s</div></div>    | Range: 0.000 to 65.535 s in steps of 0.001    |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 RST</div><div>DELAY: 0.000 s</div></div>    | Range: 0.000 to 65.535 s in steps of 0.001    |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1 BLK:</div><div>Off</div></div>              | Range: FlexLogic™ operand                     |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div><div>TARGET: Self-reset</div></div>    | Range: Self-reset, Latched, Disabled          |
| MESSAGE  | <div><div><div></div><div></div></div></div> | <div><div><div></div><div></div></div><div>FLEXELEMENT 1</div><div>EVENTS: Disabled</div></div>      | Range: Disabled, Enabled                      |

A FlexElement™ is a universal comparator that can be used to monitor any analog actual value calculated by the relay or a net difference of any two analog actual values of the same type. The effective operating signal could be treated as a signed number or its absolute value could be used as per user's choice.

The element can be programmed to respond either to a signal level or to a rate-of-change (delta) over a pre-defined period of time. The output operand is asserted when the operating signal is higher than a threshold or lower than a threshold as per user's choice.

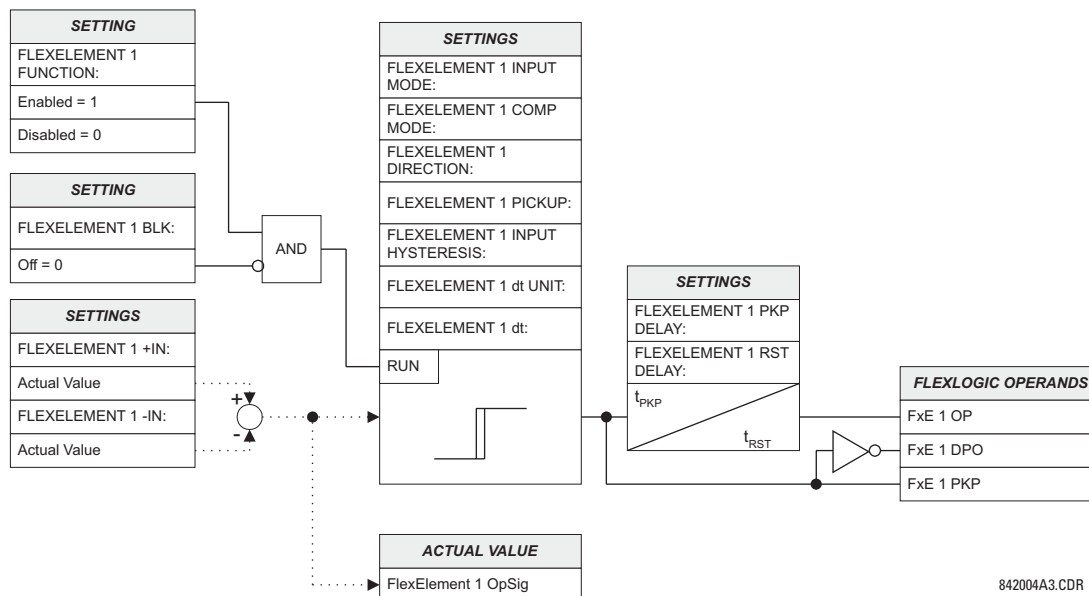


Figure 5-33: FLEXELEMENT™ SCHEME LOGIC

5

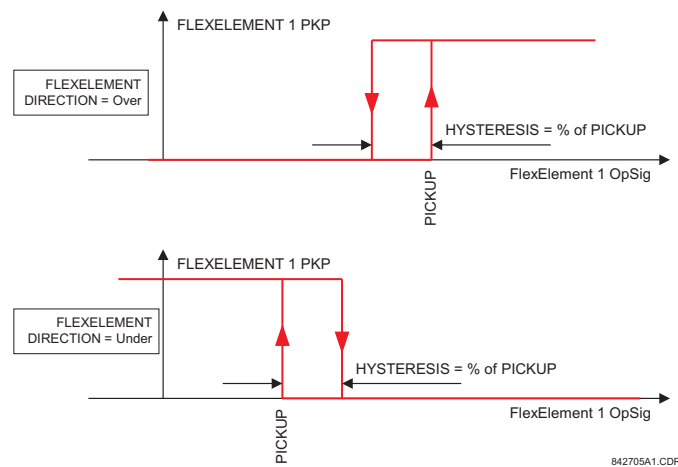
The **FLEXELEMENT 1 +IN** setting specifies the first (non-inverted) input to the FlexElement™. Zero is assumed as the input if this setting is set to “Off”. For proper operation of the element at least one input must be selected. Otherwise, the element will not assert its output operands.

This **FLEXELEMENT 1 –IN** setting specifies the second (inverted) input to the FlexElement™. Zero is assumed as the input if this setting is set to “Off”. For proper operation of the element at least one input must be selected. Otherwise, the element will not assert its output operands. This input should be used to invert the signal if needed for convenience, or to make the element respond to a differential signal such as for a top-bottom oil temperature differential alarm. The element will not operate if the two input signals are of different types, for example if one tries to use active power and phase angle to build the effective operating signal.

The element responds directly to the differential signal if the **FLEXELEMENT 1 INPUT MODE** setting is set to “Signed”. The element responds to the absolute value of the differential signal if this setting is set to “Absolute”. Sample applications for the “Absolute” setting include monitoring the angular difference between two phasors with a symmetrical limit angle in both directions; monitoring power regardless of its direction, or monitoring a trend regardless of whether the signal increases or decreases.

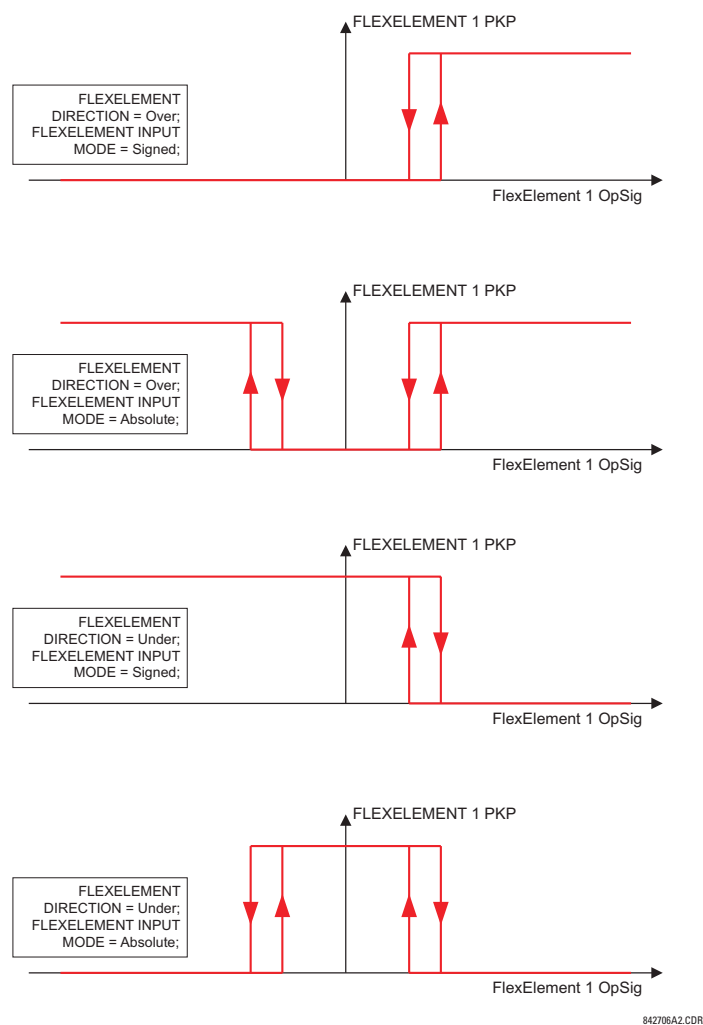
The element responds directly to its operating signal – as defined by the **FLEXELEMENT 1 +IN**, **FLEXELEMENT 1 –IN** and **FLEXELEMENT 1 INPUT MODE** settings – if the **FLEXELEMENT 1 COMP MODE** setting is set to “Threshold”. The element responds to the rate of change of its operating signal if the **FLEXELEMENT 1 COMP MODE** setting is set to “Delta”. In this case the **FLEXELEMENT 1 dt UNIT** and **FLEXELEMENT 1 dt** settings specify how the rate of change is derived.

The **FLEXELEMENT 1 DIRECTION** setting enables the relay to respond to either high or low values of the operating signal. The following figure explains the application of the **FLEXELEMENT 1 DIRECTION**, **FLEXELEMENT 1 PICKUP** and **FLEXELEMENT 1 HYSTERESIS** settings.



**Figure 5-34: FLEXELEMENT™ DIRECTION, PICKUP, AND HYSTERESIS**

In conjunction with the **FLEXELEMENT 1 INPUT MODE** setting the element could be programmed to provide two extra characteristics as shown in the figure below.



**Figure 5-35: FLEXELEMENT™ INPUT MODE SETTING**

The **FLEXELEMENT 1 PICKUP** setting specifies the operating threshold for the effective operating signal of the element. If set to “Over”, the element picks up when the operating signal exceeds the **FLEXELEMENT 1 PICKUP** value. If set to “Under”, the element picks up when the operating signal falls below the **FLEXELEMENT 1 PICKUP** value.

The **FLEXELEMENT 1 HYSTERESIS** setting controls the element dropout. It should be noticed that both the operating signal and the pickup threshold can be negative facilitating applications such as reverse power alarm protection. The FlexElement™ can be programmed to work with all analog actual values measured by the relay. The **FLEXELEMENT 1 PICKUP** setting is entered in per-unit values using the following definitions of the base units:

**Table 5–8: FLEXELEMENT™ BASE UNITS**

|   |  |
|---|--|
| BREAKER ARCING AMPS<br>(Brk X Arc Amp A, B, and C)                                    | BASE = $2000 \text{ kA}^2 \times \text{cycle}$   |
| dcmA  | BASE = maximum value of the <b>DCMA INPUT MAX</b> setting for the two transducers configured under the +IN and –IN inputs. |
| FREQUENCY   | $f_{\text{BASE}} = 1 \text{ Hz}$   |
| PHASE ANGLE   | $\phi_{\text{BASE}} = 360 \text{ degrees}$ (see the UR angle referencing convention)                                       |
| POWER FACTOR  | $\text{PF}_{\text{BASE}} = 1.00$   |
| RTDs  | BASE = $100^\circ\text{C}$   |
| SOURCE CURRENT  | $I_{\text{BASE}} = \text{maximum nominal primary RMS value of the +IN and –IN inputs}$                                     |
| SOURCE ENERGY<br>(Positive and Negative Watthours,<br>Positive and Negative Varhours) | $E_{\text{BASE}} = 10000 \text{ MWh or MVAh, respectively}$  |
| SOURCE POWER  | $P_{\text{BASE}} = \text{maximum value of } V_{\text{BASE}} \times I_{\text{BASE}} \text{ for the +IN and –IN inputs}$     |
| SOURCE VOLTAGE  | $V_{\text{BASE}} = \text{maximum nominal primary RMS value of the +IN and –IN inputs}$                                     |
| SYNCHROCHECK<br>(Max Delta Volts)   | $V_{\text{BASE}} = \text{maximum primary RMS value of all the sources related to the +IN and –IN inputs}$                  |

The **FLEXELEMENT 1 HYSTERESIS** setting defines the pickup–dropout relation of the element by specifying the width of the hysteresis loop as a percentage of the pickup value as shown in the FlexElement™ Direction, Pickup, and Hysteresis diagram.

The **FLEXELEMENT 1 DT UNIT** setting specifies the time unit for the setting **FLEXELEMENT 1 dt**. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to “Delta”. The **FLEXELEMENT 1 DT** setting specifies duration of the time interval for the rate of change mode of operation. This setting is applicable only if **FLEXELEMENT 1 COMP MODE** is set to “Delta”.

This **FLEXELEMENT 1 PKP DELAY** setting specifies the pickup delay of the element. The **FLEXELEMENT 1 RST DELAY** setting specifies the reset delay of the element.

## 5.4.8 NON-VOLATILE LATCHES

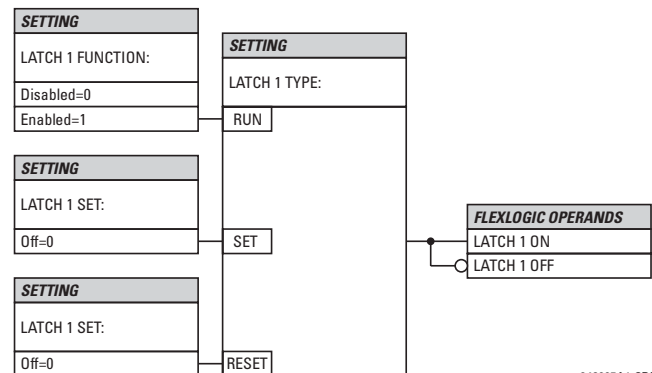
PATH: SETTINGS ⇒ FLEXLOGIC ⇒ NON-VOLATILE LATCHES ⇒ LATCH 1(16)

|                |    |   |                                      |
|----------------|----|---|--------------------------------------|
| <b>LATCH 1</b> | ◀▶ | <b>LATCH 1</b><br><b>FUNCTION: Disabled</b>   | Range: Disabled, Enabled             |
| MESSAGE ▲▼     | ▲▼ | <b>LATCH 1 TYPE:</b><br><b>Reset Dominant</b> | Range: Reset Dominant, Set Dominant  |
| MESSAGE ▲▼     | ▲▼ | <b>LATCH 1 SET:</b><br><b>Off</b>             | Range: FlexLogic™ operand            |
| MESSAGE ▲▼     | ▲▼ | <b>LATCH 1 RESET:</b><br><b>Off</b>           | Range: FlexLogic™ operand            |
| MESSAGE ▲▼     | ▲▼ | <b>LATCH 1</b><br><b>TARGET: Self-reset</b>   | Range: Self-reset, Latched, Disabled |
| MESSAGE ▲▼     | ▲▼ | <b>LATCH 1</b><br><b>EVENTS: Disabled</b>     | Range: Disabled, Enabled             |

The non-volatile latches provide a permanent logical flag that is stored safely and will not reset upon reboot after the relay is powered down. Typical applications include sustaining operator commands or permanently block relay functions, such as Autorecloser, until a deliberate HMI action resets the latch. The settings, logic, and element operation are described below:

- **LATCH 1 TYPE:** This setting characterizes Latch 1 to be Set- or Reset-dominant.
- **LATCH 1 SET:** If asserted, the specified FlexLogic™ operands 'sets' Latch 1.
- **LATCH 1 RESET:** If asserted, the specified FlexLogic™ operand 'resets' Latch 1.

| LATCH N TYPE   | LATCH N SET | LATCH N RESET | LATCH N ON     | LATCH N OFF    |
|----------------|-------------|---------------|----------------|----------------|
| Reset Dominant | ON          | OFF           | ON             | OFF            |
|                | OFF         | OFF           | Previous State | Previous State |
|                | ON          | ON            | OFF            | ON             |
|                | OFF         | ON            | OFF            | ON             |
| Set Dominant   | ON          | OFF           | ON             | OFF            |
|                | ON          | ON            | ON             | OFF            |
|                | OFF         | OFF           | Previous State | Previous State |
|                | OFF         | ON            | OFF            | ON             |



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Figure 5-36: NON-VOLATILE LATCH OPERATION TABLE (N=1 to 16) AND LOGIC

## 5.5.1 OVERVIEW

Each protection element can be assigned up to six different sets of settings according to Setting Group designations 1 to 6. The performance of these elements is defined by the active Setting Group at a given time. Multiple setting groups allow the user to conveniently change protection settings for different operating situations (e.g. altered power system configuration, season of the year). The active setting group can be preset or selected via the **SETTING GROUPS** menu (see the *Control Elements* section later in this chapter). See also the *Introduction to Elements* section at the beginning of this chapter.

## 5.5.2 SETTING GROUP

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6)

|   |  |  |                 |
|---|--|--|-----------------|
| <div> <div>SETTING GROUP 1</div> <div></div> </div> |  | <div> <div>LINE PICKUP</div> <div></div> </div>              | See page 5-71.  |
| MESSAGE   |  | <div> <div>DISTANCE</div> <div></div> </div>                 | See page 5-73.  |
| MESSAGE   |  | <div> <div>POWER SWING</div> <div>DETECT</div> </div>        | See page 5-88.  |
| MESSAGE   |  | <div> <div>LOAD ENCROACHMENT</div> <div></div> </div>        | See page 5-88.  |
| MESSAGE   |  | <div> <div>PHASE CURRENT</div> <div></div> </div>            | See page 5-98.  |
| MESSAGE   |  | <div> <div>NEUTRAL CURRENT</div> <div></div> </div>          | See page 5-108. |
| MESSAGE   |  | <div> <div>GROUND CURRENT</div> <div></div> </div>           | See page 5-116. |
| MESSAGE   |  | <div> <div>NEGATIVE SEQUENCE</div> <div>CURRENT</div> </div> | See page 5-119. |
| MESSAGE   |  | <div> <div>VOLTAGE ELEMENTS</div> <div></div> </div>         | See page 5-124. |

Each of the six Setting Group menus is identical. **SETTING GROUP 1** (the default active group) automatically becomes active if no other group is active (see the *Control Elements* section for additional details).



### 5.5.3 LINE PICKUP

**PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ LINE PICKUP**

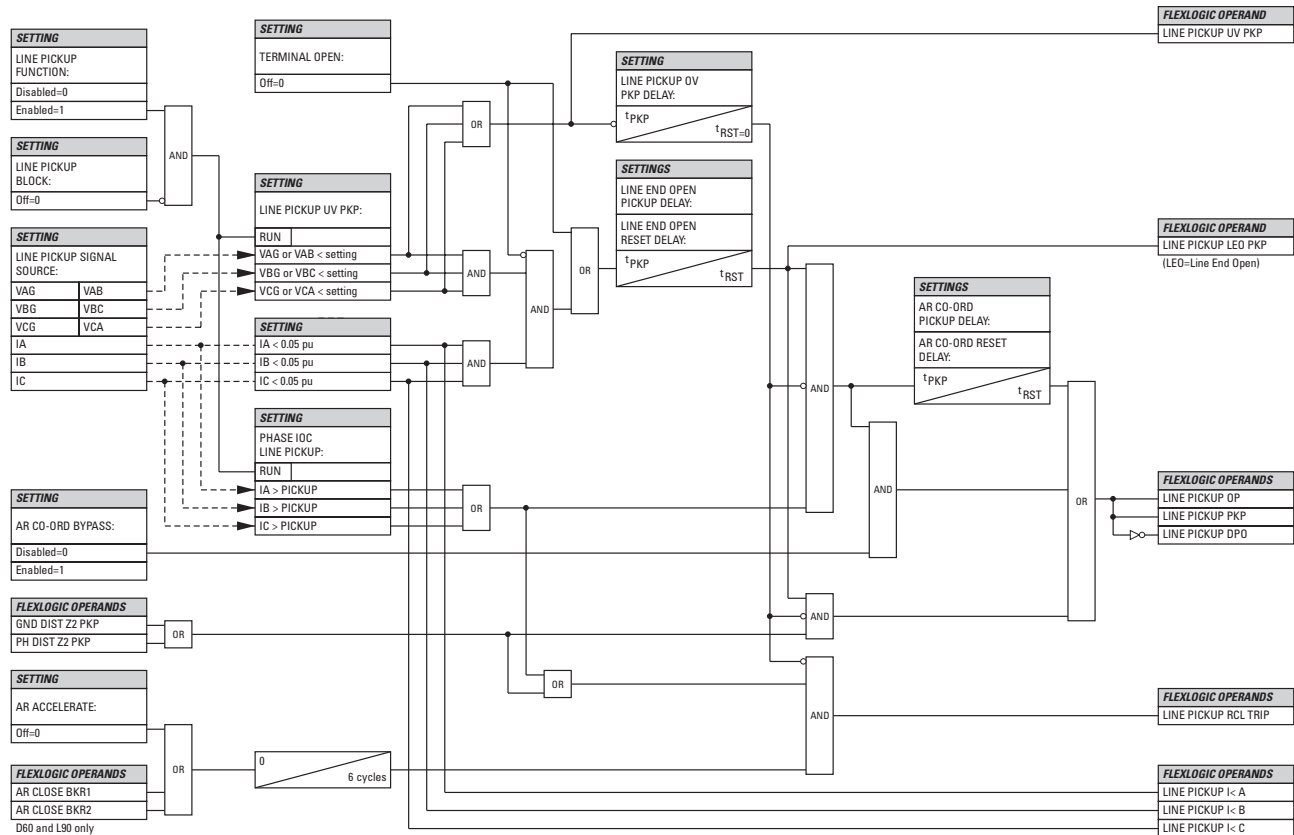
| LINE PICKUP |  | LINE PICKUP<br>FUNCTION: Disabled      | Range: Disabled, Enabled                    |
|-------------|--|--|---|
| MESSAGE     |  | LINE PICKUP SIGNAL<br>SOURCE: SRC 1    | Range: SRC 1, SRC 2                         |
| MESSAGE     |  | PHASE IOC LINE<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE     |  | LINE PICKUP UV PKP:<br>0.700 pu        | Range: 0.000 to 3.000 pu in steps of 0.001  |
| MESSAGE     |  | LINE END OPEN PICKUP<br>DELAY: 0.150 s | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE     |  | LINE END OPEN RESET<br>DELAY: 0.090 s  | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE     |  | LINE PICKUP OV PKP<br>DELAY: 0.040 s   | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE     |  | AR CO-ORD BYPASS:<br>Enabled           | Range: Disabled, Enabled                    |
| MESSAGE     |  | AR CO-ORD PICKUP<br>DELAY: 0.045 s     | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE     |  | AR CO-ORD RESET<br>DELAY: 0.005 s      | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE     |  | TERMINAL OPEN:<br>Off                  | Range: FlexLogic™ operand                   |
| MESSAGE     |  | AR ACCELERATE:<br>Off                  | Range: FlexLogic™ operand                   |
| MESSAGE     |  | LINE PICKUP BLOCK:<br>Off              | Range: FlexLogic™ operand                   |
| MESSAGE     |  | LINE PICKUP<br>TARGET: Self-reset      | Range: Self-reset, Latched, Disabled        |
| MESSAGE     |  | LINE PICKUP<br>EVENTS: Disabled        | Range: Disabled, Enabled                    |

The Line Pickup feature uses a combination of undercurrent and undervoltage to identify a line that has been de-energized (line end open). Alternately, the user may assign a FlexLogic™ operand to the **TERMINAL OPEN** setting that specifies the terminal status. Three instantaneous overcurrent elements are used to identify a previously de-energized line that has been closed onto a fault. Faults other than close-in faults can be identified satisfactorily with the Distance elements.

Co-ordination features are included to ensure satisfactory operation when high speed 'automatic reclosure (AR)' is employed. The **AR CO-ORD DELAY** setting allows the overcurrent setting to be below the expected load current seen after reclose. Co-ordination is achieved by all of the **LINE PICKP UV** elements resetting and blocking the trip path before the **AR CO-ORD DELAY** times out. The **AR CO-ORD BYPASS** setting is normally enabled. It is disabled if high speed autoreclosure is implemented.

The line pickup protection incorporates Zone 1 extension capability. When the line is being re-energized from the local terminal, pickup of an overreaching Zone 2 or excessive phase current within six power cycles after the autorecloser issues a close command results in the LINE PICKUP RCL TRIP FlexLogic™ operand. Configure the LINE PICKUP RCL TRIP operand to perform a trip action if the intent is apply Zone 1 extension.

The Zone 1 extension philosophy used here normally operates from an under-reaching zone, and uses an overreaching distance zone when reclosing the line with the other line end open. The **AR ACCELERATE** setting is provided to achieve Zone 1 extension functionality if external autoreclosure is employed. Another Zone 1 extension approach is to permanently apply an overreaching zone, and reduce the reach when reclosing. This philosophy can be programmed via the Autoreclose scheme.



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Figure 5-37: LINE PICKUP SCHEME LOGIC

## 5.5.4 DISTANCE

## a) MAIN MENU

PATH: SETTINGS ⇨ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ DISTANCE

|            |    |                               |                                     |
|------------|----|-------------------------------|-------------------------------------|
| ■ DISTANCE | ◀▶ | DISTANCE<br>SOURCE: SRC 1     | Range: SRC 1, SRC 2                 |
| MESSAGE    | ▲▼ | MEMORY<br>DURATION: 10 cycles | Range: 5 to 25 cycles in steps of 1 |
| MESSAGE    | ▲▼ | FORCE SELF-POLAR:<br>Off      | Range: FlexLogic™ operand           |
| MESSAGE    | ▲▼ | ■ PHASE DISTANCE Z1<br>■      | See page 5-74.                      |
| MESSAGE    | ▲▼ | ■ PHASE DISTANCE Z2<br>■      | See page 5-74.                      |
| MESSAGE    | ▲▼ | ■ PHASE DISTANCE Z3<br>■      | See page 5-74.                      |
| MESSAGE    | ▲▼ | ■ GROUND DISTANCE Z1<br>■     | See page 5-82.                      |
| MESSAGE    | ▲▼ | ■ GROUND DISTANCE Z2<br>■     | See page 5-82.                      |
| MESSAGE    | ▲▼ | ■ GROUND DISTANCE Z3<br>■     | See page 5-82.                      |

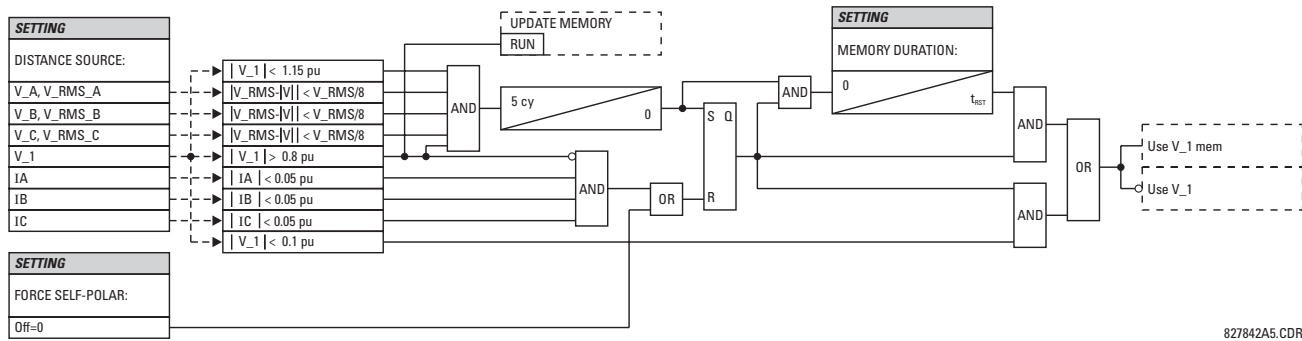
Three common settings (**DISTANCE SOURCE**, **MEMORY DURATION**, and **FORCE SELF-POLAR**) and six menus for three zone of phase and ground distance protection are available. The **DISTANCE SOURCE** identifies the Signal Source for all distance functions. The Mho distance functions use a dynamic characteristic: the positive-sequence voltage – either memorized or actual – is used as a polarizing signal. The memory voltage is also used by the built-in directional supervising functions applied for both the Mho and Quad characteristics.

The **MEMORY DURATION** setting specifies the length of time a memorized positive-sequence voltage should be used in the distance calculations. After this interval expires, the relay checks the magnitude of the actual positive-sequence voltage. If it is higher than 10% of the nominal, the actual voltage is used, if lower – the memory voltage continues to be used.

The memory is established when the positive-sequence voltage stays above 80% of its nominal value for five power system cycles. For this reason it is important to ensure that the nominal secondary voltage of the VT is entered correctly under the **SETTINGS** ⇨ **SYSTEM SETUP** ⇨ **AC INPUTS** ⇨ **VOLTAGE BANK** menu.

Set **MEMORY DURATION** long enough to ensure stability on close-in reverse three-phase faults. For this purpose, the maximum fault clearing time (breaker fail time) in the substation should be considered. On the other hand, the **MEMORY DURATION** cannot be too long as the power system may experience power swing conditions rotating the voltage and current phasors slowly while the memory voltage is static, as frozen at the beginning of the fault. Keeping the memory in effect for too long may eventually lead to incorrect operation of the distance functions.

The distance zones can be forced to become self-polarized through the **FORCE SELF-POLAR** setting. Any user-selected condition (FlexLogic™ operand) can be configured to force self-polarization. When the selected operand is asserted (logic 1), the distance functions become self-polarized regardless of other memory voltage logic conditions. When the selected operand is de-asserted (logic 0), the distance functions follow other conditions of the memory voltage logic as shown below.



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Figure 5-38: MEMORY VOLTAGE LOGIC

## b) PHASE DISTANCE

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ DISTANCE ⇒ PHASE DISTANCE Z1(Z3)

|   |                          |                                  |                    |   |
|---|--------------------------|----------------------------------|--------------------|---|
| 5 | <b>PHASE DISTANCE Z1</b> |                                  | PHS DIST Z1        | Range: Disabled, Enabled  |
|   |                          |                                  | FUNCTION: Disabled |   |
|   | MESSAGE                  | PHS DIST Z1 DIR:                 | Forward            | Range: Forward, Reverse, Non-directional                                  |
|   | MESSAGE                  | PHS DIST Z1 SHAPE:               | Mho                | Range: Mho, Quad  |
|   | MESSAGE                  | PHS DIST Z1 XFMR VOL CONNECTION: | None               | Range: None, Dy1, Dy3, Dy5, Dy7, Dy9, Dy11, Yd1, Yd3, Yd5, Yd7, Yd9, Yd11 |
|   | MESSAGE                  | PHS DIST Z1 XFMR CUR CONNECTION: | None               | Range: None, Dy1, Dy3, Dy5, Dy7, Dy9, Dy11, Yd1, Yd3, Yd5, Yd7, Yd9, Yd11 |
|   | MESSAGE                  | PHS DIST Z1 REACH:               | 2.00 ohms          | Range: 0.02 to 250.00 ohms in steps of 0.01                               |
|   | MESSAGE                  | PHS DIST Z1 RCA:                 | 85°                | Range: 30 to 90° in steps of 1  |
|   | MESSAGE                  | PHS DIST Z1 REV REACH:           | 2.00 ohms          | Range: 0.02 to 250.00 ohms in steps of 0.01                               |
|   | MESSAGE                  | PHS DIST Z1 REV REACH RCA:       | 85°                | Range: 30 to 90° in steps of 1  |
|   | MESSAGE                  | PHS DIST Z1 COMP LIMIT:          | 90°                | Range: 30 to 90° in steps of 1  |
|   | MESSAGE                  | PHS DIST Z1 DIR RCA:             | 85°                | Range: 30 to 90° in steps of 1  |
|   | MESSAGE                  | PHS DIST Z1 DIR COMP LIMIT:      | 90°                | Range: 30 to 90° in steps of 1  |
|   | MESSAGE                  | PHS DIST Z1 QUAD RGT BLD:        | 10.00 ohms         | Range: 0.02 to 500.00 ohms in steps of 0.01                               |
|   | MESSAGE                  | PHS DIST Z1 QUAD RGT BLD RCA:    | 85°                | Range: 60 to 90° in steps of 1  |
|   | MESSAGE                  | PHS DIST Z1 QUAD LFT BLD:        | 10.00 ohms         | Range: 0.02 to 500.00 ohms in steps of 0.01                               |

|         |  |                                      |   |
|---------|--|--------------------------------------|---|
| MESSAGE |  | PHS DIST Z1 QUAD<br>LFT BLD RCA: 85° | Range: 60 to 90° in steps of 1              |
| MESSAGE |  | PHS DIST Z1<br>SUPV: 0.200 pu        | Range: 0.050 to 30.000 pu in steps of 0.001 |
| MESSAGE |  | PHS DIST Z1 VOLT<br>LEVEL: 0.000 pu  | Range: 0.000 to 5.000 pu in steps of 0.001  |
| MESSAGE |  | PHS DIST Z1<br>DELAY: 0.000 s        | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE |  | PHS DIST Z1 BLK:<br>Off              | Range: FlexLogic™ operand                   |
| MESSAGE |  | PHS DIST Z1<br>TARGET: Self-reset    | Range: Self-reset, Latched, Disabled        |
| MESSAGE |  | PHS DIST Z1<br>EVENTS: Disabled      | Range: Disabled, Enabled                    |

The phase mho distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, and overcurrent supervising characteristics. The phase quadrilateral distance function is comprised of a reactance characteristic, right and left blinders, and 100% memory-polarized directional and current supervising characteristics. When set to “Non-directional”, the mho function becomes an offset mho with the reverse reach controlled independently from the forward reach, and all the directional characteristics removed. When set to “Non-directional”, the quadrilateral function applies a reactance line in the reverse direction instead of the directional comparators. Refer to Chapter 8 for additional information.

Three zones of phase distance protection are provided. Each zone is configured individually through its own setting menu. All of the settings can be independently modified for each of the zones except:

1. The **SIGNAL SOURCE** setting (common for the phase distance elements of all zones as entered under **SETTINGS** ⇒ **GROUPED ELEMENTS** ⇒ **SETTING GROUP 1(6)** ⇒ **DISTANCE**).
2. The **MEMORY DURATION** setting (common for the phase distance elements of all zones as entered under **SETTINGS** ⇒ **GROUPED ELEMENTS** ⇒ **SETTING GROUP 1(6)** ⇒ **DISTANCE**).

The common distance settings described earlier must be properly chosen for correct operation of the phase distance elements. Although all three zones can be used as either instantaneous elements (pickup [PKP] and dropout [DPO] FlexLogic™ operands) or time-delayed elements (operate [OP] FlexLogic™ operands), only Zone 1 is intended for the instantaneous under-reaching tripping mode. Additional details may be found in Chapter 8: Theory of Operation.



**Ensure that the PHASE VT SECONDARY VOLTAGE setting (see the **SETTINGS** ⇒ **SYSTEM SETUP** ⇒ **AC INPUTS** ⇒ **VOLTAGE BANK** menu) is set correctly to prevent improper operation of associated memory action.**

- **PHS DIST Z1 DIR:** All three zones are reversible. The forward direction is defined by the **PHS DIST Z1 RCA** setting, whereas the reverse direction is shifted 180° from that angle. The non-directional zone spans between the forward reach impedance defined by the **PHS DIST Z1 REACH** and **PHS DIST Z1 RCA** settings, and the reverse reach impedance defined by **PHS DIST Z1 REV REACH** and **PHS DIST Z1 REV REACH RCA** as illustrated below.
- **PHS DIST Z1 SHAPE:** This setting selects the shape of the phase distance function between the mho and quadrilateral characteristics. The selection is available on a per-zone basis. The two characteristics and their possible variations are shown in the following figures.

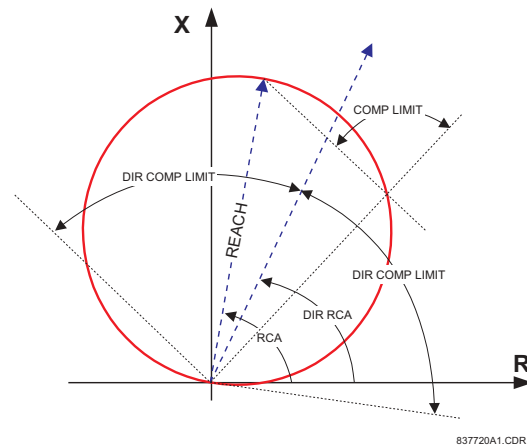


Figure 5-39: DIRECTIONAL MHO DISTANCE CHARACTERISTIC

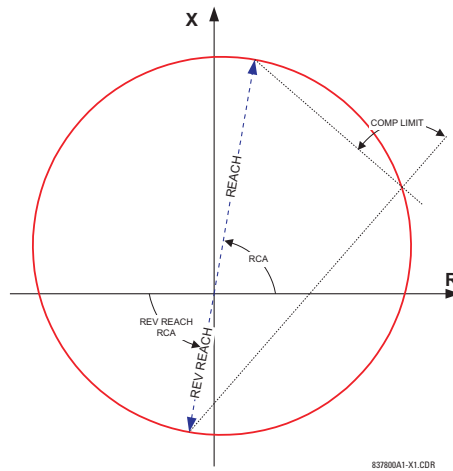


Figure 5-40: NON-DIRECTIONAL MHO DISTANCE CHARACTERISTIC

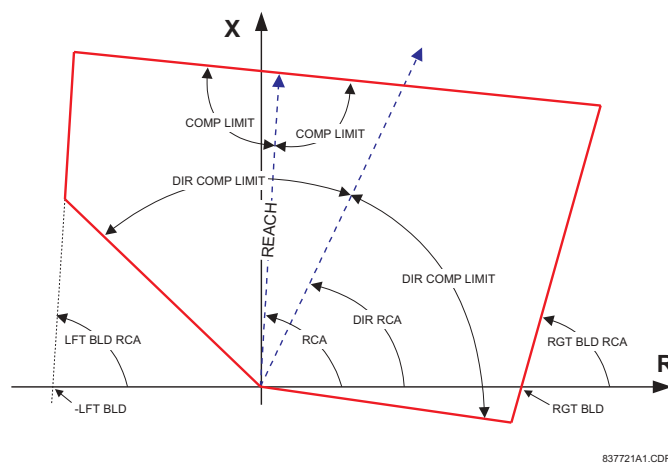


Figure 5-41: DIRECTIONAL QUADRILATERAL PHASE DISTANCE CHARACTERISTIC

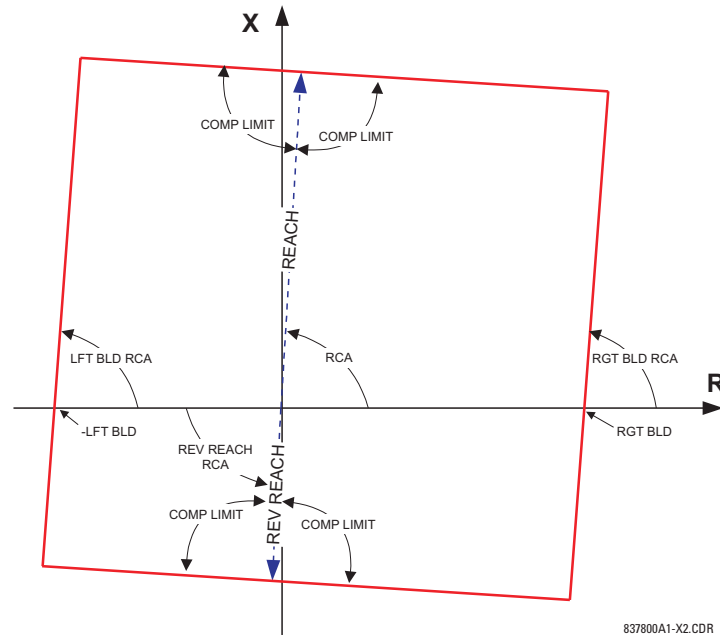


Figure 5-42: NON-DIRECTIONAL QUADRILATERAL PHASE DISTANCE CHARACTERISTIC

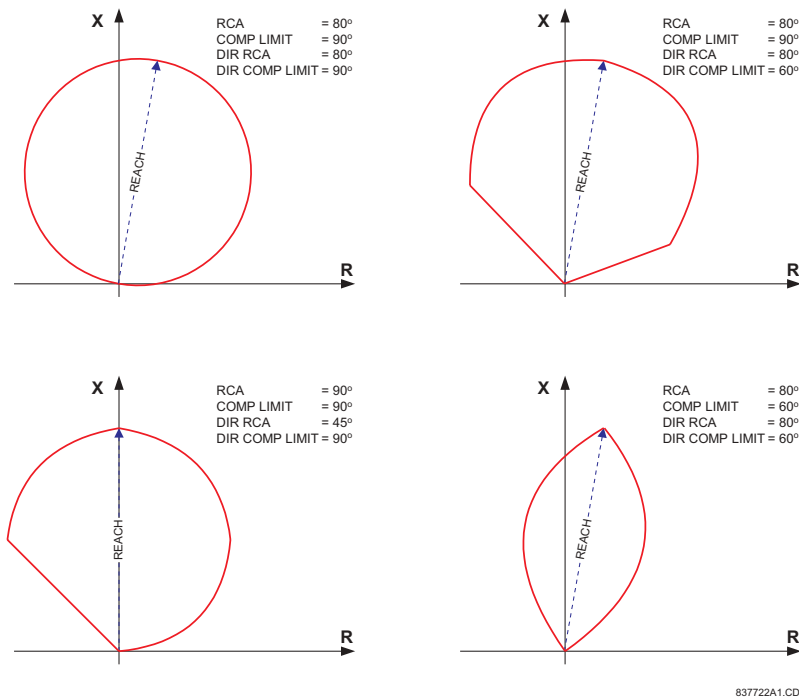


Figure 5-43: MHO DISTANCE CHARACTERISTIC SAMPLE SHAPES

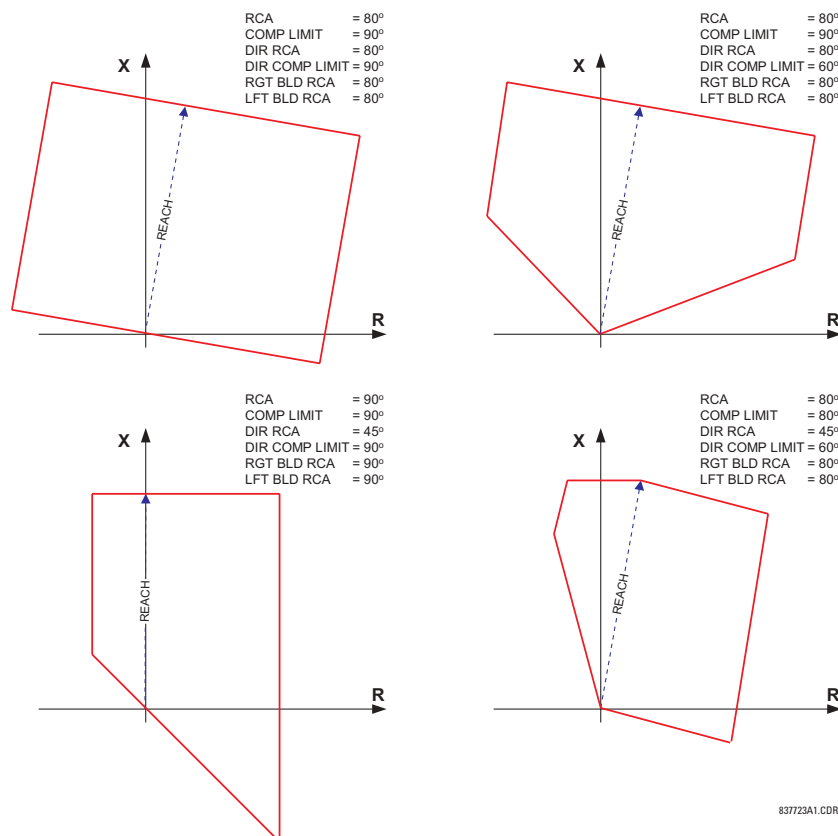


Figure 5-44: QUADRILATERAL DISTANCE CHARACTERISTIC SAMPLE SHAPES

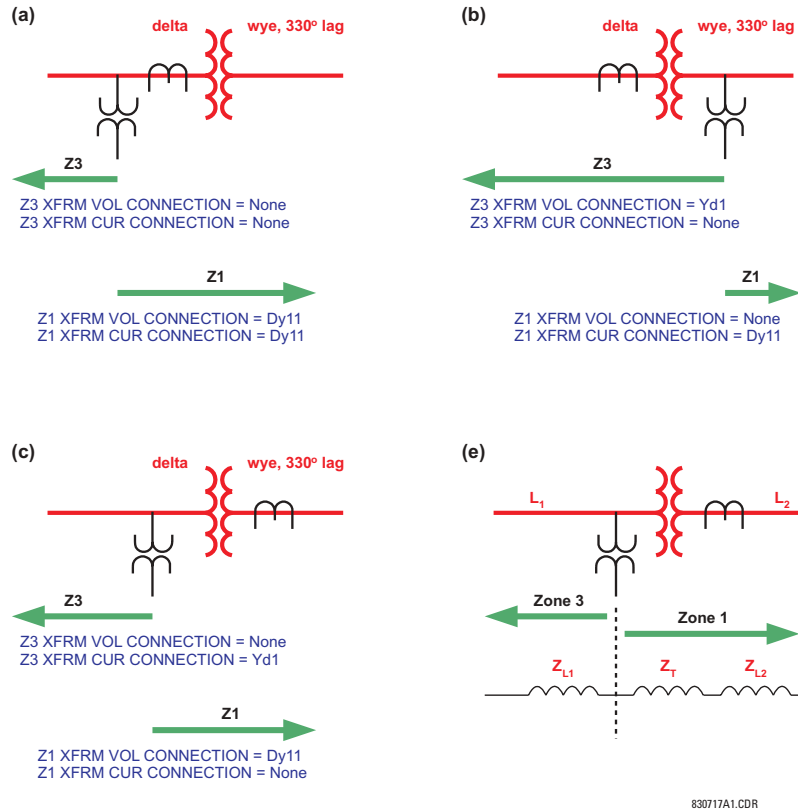
- PHS DIST Z1 XFMR VOL CONNECTION:** The phase distance elements can be applied to look through a three-phase delta-wye or wye-delta power transformer. In addition, VTs and CTs could be located independently from one another at different windings of the transformer. If the potential source is located at the correct side of the transformer, this setting shall be set to "None".

This setting specifies the location of the voltage source with respect to the involved power transformer in the direction of the zone. The following figure illustrates the usage of this setting. In section (a), Zone 1 is looking through a transformer from the delta into the wye winding. Therefore, the Z1 setting shall be set to "Dy11". In section (b), Zone 3 is looking through a transformer from the wye into the delta winding. Therefore, the Z3 setting shall be set to "Yd1". The zone is restricted by the potential point (location of the VTs) as illustrated in Figure (e).

- PHS DIST Z1 XFMR CUR CONNECTION:** This setting specifies the location of the current source with respect to the involved power transformer in the direction of the zone. In section (a) of the following figure, Zone 1 is looking through a transformer from the delta into the wye winding. Therefore, the Z1 setting shall be set to "Dy11". In section (b), the CTs are located at the same side as the read point. Therefore, the Z3 setting shall be set to "None".

See Chapter 8: Theory of Operation for more details, and Chapter 9: Application of Settings for information on how to calculate distance reach settings in applications involving power transformers.





**Figure 5-45: APPLICATIONS OF THE PH DIST XFMR VOL/CUR CONNECTION SETTINGS**

- **PHS DIST Z1 REACH:** This setting defines the zone reach for the forward and reverse applications. In the non-directional applications, this setting defines the forward reach of the zone. The reverse reach impedance in non-directional applications is set independently. The reach impedance is entered in secondary ohms. The reach impedance angle is entered as the **PHS DIST Z1 RCA** setting.
- **PHS DIST Z1 RCA:** This setting specifies the characteristic angle (similar to the 'maximum torque angle' in previous technologies) of the phase distance characteristic for the forward and reverse applications. In the non-directional applications, this setting defines the angle of the forward reach impedance. The reverse reach impedance in the non-directional applications is set independently. The setting is an angle of reach impedance as shown in Mho and Quadrilateral Distance Characteristic figures. This setting is independent from **PHS DIST Z1 DIR RCA**, the characteristic angle of an extra directional supervising function.
- **PHS DIST Z1 REV REACH:** This setting defines the reverse reach of the zone set to non-directional (**PHS DIST Z1 DIR** setting). The value must be entered in secondary ohms. This setting does not apply when the zone direction is set to "Forward" or "Reverse".
- **PHS DIST Z1 REV REACH RCA:** This setting defines the angle of the reverse reach impedance if the zone is set to non-directional (**PHS DIST Z1 DIR** setting). This setting does not apply when the zone direction is set to "Forward" or "Reverse".
- **PHS DIST Z1 COMP LIMIT:** This setting shapes the operating characteristic. In particular, it produces the lens-type characteristic of the mho function and a tent-shaped characteristic of the reactance boundary of the quadrilateral function. If the mho shape is selected, the same limit angle applies to both the mho and supervising reactance comparators. In conjunction with the mho shape selection, the setting improves loadability of the protected line. In conjunction with the quadrilateral characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.
- **PHS DIST Z1 DIR RCA:** This setting selects the characteristic angle (or 'maximum torque angle') of the directional supervising function. If the mho shape is applied, the directional function is an extra supervising function as the dynamic mho characteristic is itself directional. In conjunction with the quadrilateral shape, this setting defines the only

directional function built into the phase distance element. The directional function uses the memory voltage for polarization. This setting typically equals the distance characteristic angle **PHS DIST Z1 RCA**.

- **PHS DIST Z1 DIR COMP LIMIT:** Selects the comparator limit angle for the directional supervising function.
- **PHS DIST Z1 QUAD RGT BLD:** This setting defines the right blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane (see the Quadrilateral Distance Characteristic figures). The angular position of the blinder is adjustable with the use of the **PHS DIST Z1 QUAD RGT BLD RCA** setting. This setting applies only to the quadrilateral characteristic and should be set giving consideration to the maximum load current and required resistive coverage.
- **PHS DIST Z1 QUAD RGT BLD RCA:** This setting defines the angular position of the right blinder of the quadrilateral characteristic (see the Quadrilateral Distance Characteristic figures).
- **PHS DIST Z1 QUAD LFT BLD:** This setting defines the left blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane (see the Quadrilateral Distance Characteristic figure). The angular position of the blinder is adjustable with the use of the **PHS DIST Z1 QUAD LFT BLD RCA** setting. This setting applies only to the quadrilateral characteristic and should be set with consideration to the maximum load current.
- **PHS DIST Z1 QUAD LFT BLD RCA:** This setting defines the angular position of the left blinder of the quadrilateral characteristic (see the Quadrilateral Distance Characteristic figures).
- **PHS DIST Z1 SUPV:** The phase distance elements are supervised by the magnitude of the line-to-line current (fault loop current used for the distance calculations). For convenience,  $\sqrt{3}$  is accommodated by the pickup (i.e., before being used, the entered value of the threshold setting is multiplied by  $\sqrt{3}$ ).

If the minimum fault current level is sufficient, the current supervision pickup should be set above maximum full load current preventing maloperation under VT fuse fail conditions. This requirement may be difficult to meet for remote faults at the end of Zones 2 through 3. If this is the case, the current supervision pickup would be set below the full load current, but this may result in maloperation during fuse fail conditions.

- **PHS DIST Z1 VOLT LEVEL:** This setting is relevant for applications on series-compensated lines, or in general, if series capacitors are located between the relaying point and a point where the zone shall not overreach. For plain (non-compensated) lines, set to zero. Otherwise, the setting is entered in per unit of the phase VT bank configured under the **DISTANCE SOURCE**. Effectively, this setting facilitates dynamic current-based reach reduction. In non-directional applications (**PHS DIST Z1 DIR** set to “Non-directional”), this setting applies only to the forward reach of the non-directional zone. See Chapters 8 and 9 for information on calculating this setting for series compensated lines.
- **PHS DIST Z1 DELAY:** This setting allows the user to delay operation of the distance elements and implement stepped distance protection. The distance element timers for Zones 2 through 3 apply a short dropout delay to cope with faults located close to the zone boundary when small oscillations in the voltages and/or currents could inadvertently reset the timer. Zone 1 does not need any drop out delay since it is sealed-in by the presence of current.
- **PHS DIST Z1 BLK:** This setting enables the user to select a FlexLogic™ operand to block a given distance element. VT fuse fail detection is one of the applications for this setting.

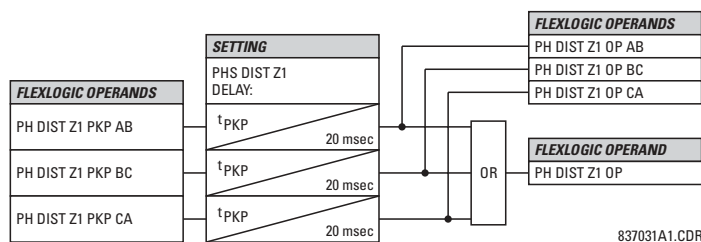


Figure 5-46: PHASE DISTANCE ZONE 1 TO 3 OP SCHEME

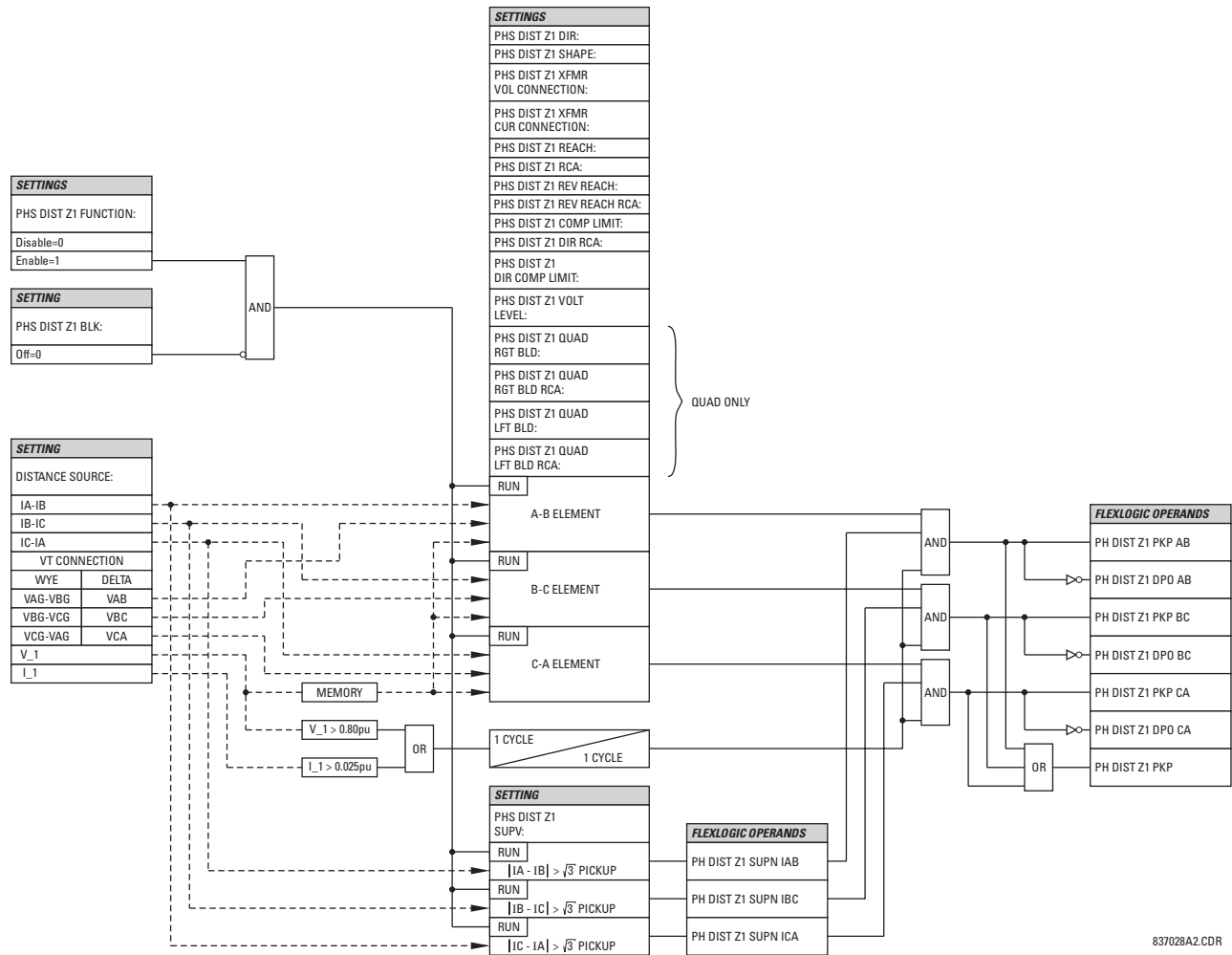


Figure 5-47: PHASE DISTANCE ZONE 1 TO 3 SCHEME LOGIC

## c) GROUND DISTANCE

PATH: SETTINGS ⇒ ↓ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ ↓ DISTANCE ⇒ ↓ GROUND DISTANCE Z1(Z3)

|                      |  |                                       |   |
|----------------------|--|---------------------------------------|---|
| ■ GROUND DISTANCE Z1 |  | GND DIST Z1                           | Range: Disabled, Enabled                    |
|                      |  | FUNCTION: Disabled                    |   |
| MESSAGE              |  | GND DIST Z1 DIR:<br>Forward           | Range: Forward, Reverse, Non-directional    |
| MESSAGE              |  | GND DIST Z1<br>SHAPE: Mho             | Range: Mho, Quad                            |
| MESSAGE              |  | GND DIST Z1<br>Z0/Z1 MAG: 2.70        | Range: 0.00 to 10.00 in steps of 0.01       |
| MESSAGE              |  | GND DIST Z1<br>Z0/Z1 ANG: 0°          | Range: -90 to 90° in steps of 1             |
| MESSAGE              |  | GND DIST Z1<br>ZOM/Z1 MAG: 0.00       | Range: 0.00 to 7.00 in steps of 0.01        |
| MESSAGE              |  | GND DIST Z1<br>ZOM/Z1 ANG: 0°         | Range: -90 to 90° in steps of 1             |
| MESSAGE              |  | GND DIST Z1<br>REACH: 2.00 Ω          | Range: 0.02 to 250.00 Ω in steps of 0.01    |
| MESSAGE              |  | GND DIST Z1<br>RCA: 85°               | Range: 30 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1 REV<br>REACH: 2.00 Ω      | Range: 0.02 to 250.00 Ω in steps of 0.01    |
| MESSAGE              |  | GND DIST Z1 REV<br>REACH RCA: 85°     | Range: 30 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1 POL<br>CURRENT: Zero-seq  | Range: Zero-seq, Neg-seq                    |
| MESSAGE              |  | GND DIST Z1 NON-<br>HOMOGEN ANG: 0.0° | Range: -40.0 to 40.0° in steps of 0.1       |
| MESSAGE              |  | GND DIST Z1<br>COMP LIMIT: 90°        | Range: 30 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1<br>DIR RCA: 85°           | Range: 30 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1<br>DIR COMP LIMIT: 90°    | Range: 30 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1 QUAD<br>RGT BLD: 10.00 Ω  | Range: 0.02 to 500.00 Ω in steps of 0.01    |
| MESSAGE              |  | GND DIST Z1 QUAD<br>RGT BLD RCA: 85°  | Range: 60 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1 QUAD<br>LFT BLD: 10.00 Ω  | Range: 0.02 to 500.00 Ω in steps of 0.01    |
| MESSAGE              |  | GND DIST Z1 QUAD<br>LFT BLD RCA: 85°  | Range: 60 to 90° in steps of 1              |
| MESSAGE              |  | GND DIST Z1<br>SUPV: 0.200 pu         | Range: 0.050 to 30.000 pu in steps of 0.001 |

|         |  |                                     |  |
|---------|--|-------------------------------------|--|
| MESSAGE |  | GND DIST Z1 VOLT<br>LEVEL: 0.000 pu | Range: 0.000 to 5.000 pu in steps of 0.001 |
| MESSAGE |  | GND DIST Z1<br>DELAY: 0.000 s       | Range: 0.000 to 65.535 s in steps of 0.001 |
| MESSAGE |  | GND DIST Z1 BLK:<br>Off             | Range: FlexLogic™ operand                  |
| MESSAGE |  | GND DIST Z1<br>TARGET: Self-Reset   | Range: Self-Reset, Latched, Disabled       |
| MESSAGE |  | GND DIST Z1<br>EVENTS: Disabled     | Range: Disabled, Enabled                   |

The ground mho distance function uses a dynamic 100% memory-polarized mho characteristic with additional reactance, directional, current, and phase selection supervising characteristics. The ground quadrilateral distance function is composed of a reactance characteristic, right and left blinders, and 100% memory-polarized directional, overcurrent, and phase selection supervising characteristics.

When set to non-directional, the mho function becomes an offset mho with the reverse reach controlled independently from the forward reach, and all the directional characteristics removed. When set to non-directional, the quadrilateral function applies a reactance line in the reverse direction instead of the directional comparators.

The reactance supervision for the mho function uses the zero-sequence current for polarization. The reactance line of the quadrilateral function uses either zero-sequence or negative-sequence current as a polarizing quantity. The selection is controlled by a user setting and depends on the degree of non-homogeneity of the zero-sequence and negative-sequence equivalent networks.

The directional supervision uses memory voltage as polarizing quantity and both zero- and negative-sequence currents as operating quantities.

The phase selection supervision restrains the ground elements during double-line-to-ground faults as they – by principles of distance relaying – may be inaccurate in such conditions. Ground distance Zones 1 through 3 apply additional zero-sequence directional supervision. See Chapter 8 for additional details.

Three zones of ground distance protection are provided. Each zone is configured individually through its own setting menu. All of the settings can be independently modified for each of the zones except:

1. The **SIGNAL SOURCE** setting (common for both phase and ground elements for all three zones as entered under the **SETTINGS** ⇒ **GROUPED ELEMENTS** ⇒ **SETTING GROUP 1(6)** ⇒ **DISTANCE** menu).
2. The **MEMORY DURATION** setting (common for both phase and ground elements for all three zones as entered under the **SETTINGS** ⇒ **GROUPED ELEMENTS** ⇒ **SETTING GROUP 1(6)** ⇒ **DISTANCE** menu).

The common distance settings noted at the start of the Distance section must be properly chosen for correct operation of the ground distance elements.

Although all three zones can be used as either instantaneous elements (pickup [PKP] and dropout [DPO] FlexLogic™ signals) or time-delayed elements (operate [OP] FlexLogic™ signals), only Zone 1 is intended for the instantaneous under-reaching tripping mode.



**Ensure that the PHASE VT SECONDARY VOLTAGE (see the SETTINGS ⇒ SYSTEM SETUP ⇒ AC INPUTS ⇒ VOLTAGE BANK menu) is set correctly to prevent improper operation of associated memory action.**

- **GND DIST Z1 DIR:** All three zones are reversible. The forward direction is defined by the **GND DIST Z1 RCA** setting and the reverse direction is shifted by 180° from that angle. The non-directional zone spans between the forward reach impedance defined by the **GND DIST Z1 REACH** and **GND DIST Z1 RCA** settings, and the reverse reach impedance defined by the **GND DIST Z1 REV REACH** and **GND DIST Z1 REV REACH RCA** settings.
- **GND DIST Z1 SHAPE:** This setting selects the shape of the ground distance characteristic between the mho and quadrilateral characteristics. The selection is available on a per-zone basis.

The directional and non-directional quadrilateral ground distance characteristics are shown below. The directional and non-directional mho ground distance characteristics are the same as those shown for the phase distance element in the previous sub-section.

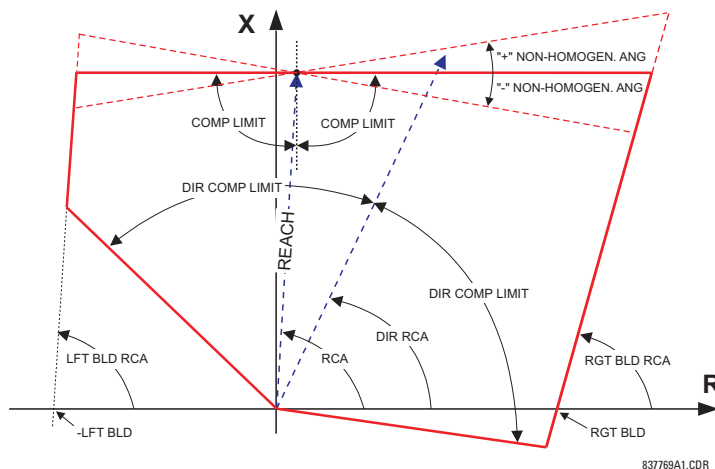


Figure 5-48: DIRECTIONAL QUADRILATERAL GROUND DISTANCE CHARACTERISTIC

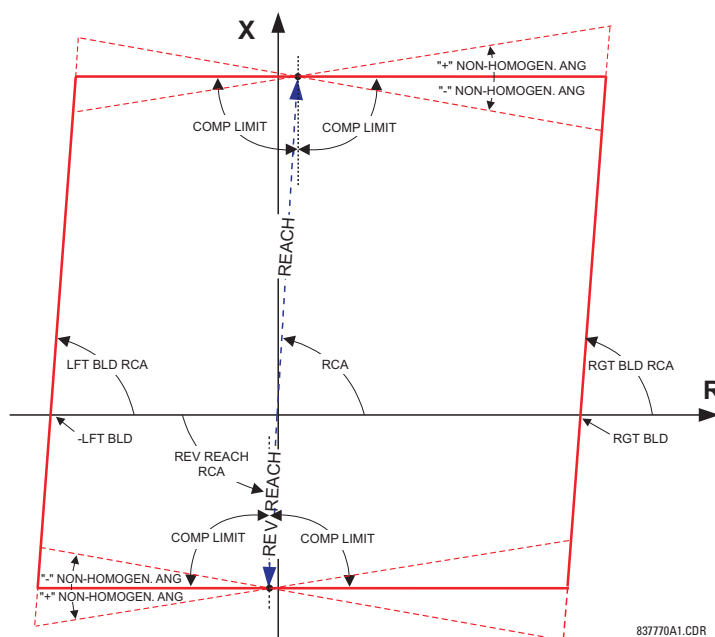


Figure 5-49: NON-DIRECTIONAL QUADRILATERAL GROUND DISTANCE CHARACTERISTIC

- **GND DIST Z1 Z0/Z1 MAG:** This setting specifies the ratio between the zero-sequence and positive-sequence impedance required for zero-sequence compensation of the ground distance elements. This setting is available on a per-zone basis, enabling precise settings for tapped, non-homogeneous, and series compensated lines.
- **GND DIST Z1 Z0/Z1 ANG:** This setting specifies the angle difference between the zero-sequence and positive-sequence impedance required for zero-sequence compensation of the ground distance elements. The entered value is the zero-sequence impedance angle minus the positive-sequence impedance angle. This setting is available on a per-zone basis, enabling precise values for tapped, non-homologous, and series-compensated lines.
- **GND DIST Z1 ZOM/Z1 MAG:** The ground distance elements can be programmed to apply compensation for the zero-sequence mutual coupling between parallel lines. If this compensation is required, the ground current from the parallel line (3I<sub>0</sub>) measured in the direction of the zone being compensated must be connected to the ground input CT of the CT bank configured under the **DISTANCE SOURCE**. This setting specifies the ratio between the magnitudes of the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line. It is imperative to set this setting to zero if the compensation is not to be performed.

- **GND DIST Z1 ZOM/Z1 ANG:** This setting specifies the angle difference between the mutual zero-sequence impedance between the lines and the positive-sequence impedance of the protected line.
- **GND DIST Z1 REACH:** This setting defines the reach of the zone for the forward and reverse applications. In non-directional applications, this setting defines the forward reach of the zone. The reverse reach impedance in non-directional applications is set independently. The angle of the reach impedance is entered as the **GND DIST Z1 RCA** setting. The reach impedance is entered in secondary ohms.
- **GND DIST Z1 RCA:** This setting specifies the characteristic angle (similar to the 'maximum torque angle' in previous technologies) of the ground distance characteristic for the forward and reverse applications. In the non-directional applications this setting defines the forward reach of the zone. The reverse reach impedance in the non-directional applications is set independently. This setting is independent from the **GND DIST Z1 DIR RCA** setting (the characteristic angle of an extra directional supervising function).



The relay internally performs zero-sequence compensation for the protected circuit based on the values entered for **GND DIST Z1 Z0/Z1 MAG** and **GND DIST Z1 Z0/Z1 ANG**, and if configured to do so, zero-sequence compensation for mutual coupling based on the values entered for **GND DIST Z1 Z0M/Z1 MAG** and **GND DIST Z1 Z0M/Z1 ANG** (see Chapter 8 for details). The **GND DIST Z1 REACH** and **GND DIST Z1 RCA** should, therefore, be entered in terms of positive sequence quantities.

- **GND DIST Z1 REV REACH:** This setting defines the reverse reach of the zone set to non-directional (**GND DIST Z1 DIR** setting). The value must be entered in secondary ohms. This setting does not apply when the zone direction is set to "Forward" or "Reverse".
- **GND DIST Z1 REV REACH RCA:** This setting defines the angle of the reverse reach impedance if the zone is set to non-directional (**GND DIST Z1 DIR** setting). This setting does not apply when the zone direction is set to "Forward" or "Reverse".
- **GND DIST Z1 POL CURRENT:** This setting applies only if the **GND DIST Z1 SHAPE** is set to "Quad" and controls the polarizing current used by the reactance comparator of the quadrilateral characteristic. Either the zero-sequence or negative-sequence current could be used. Refer to Chapters 8 and 9 for additional information. In general, a variety of system conditions must be examined to select an optimum polarizing current. This setting becomes less relevant when the resistive coverage and zone reach are set conservatively. Also, this setting is more relevant in lower voltage applications such as on distribution lines or cables, as compared with high-voltage transmission lines. This setting applies to both the **Z1** and reverse reactance lines if the zone is set to non-directional.
- **GND DIST Z1 NON-HOMOGEN ANG:** This setting applies only if the **GND DIST Z1 SHAPE** is set to "Quad" and provides a method to correct the angle of the polarizing current of the reactance comparator for non-homogeneity of the zero-sequence or negative-sequence networks. Refer to Chapters 8 and 9 for additional information. In general, a variety of system conditions must be examined to select this setting. In many applications this angle is used to reduce the reach at high resistances in order to avoid overreaching under far-out reach settings and/or when the sequence networks are greatly non-homogeneous. This setting applies to both the forward and reverse reactance lines if the zone is set to non-directional.
- **GND DIST Z1 COMP LIMIT:** This setting shapes the operating characteristic. In particular, it enables a lens-shaped characteristic of the mho function and a tent-shaped characteristic of the quadrilateral function reactance boundary. If the mho shape is selected, the same limit angle applies to mho and supervising reactance comparators. In conjunction with the mho shape selection, this setting improves loadability of the protected line. In conjunction with the quadrilateral characteristic, this setting improves security for faults close to the reach point by adjusting the reactance boundary into a tent-shape.
- **GND DIST Z1 DIR RCA:** Selects the characteristic angle (or 'maximum torque angle') of the directional supervising function. If the mho shape is applied, the directional function is an extra supervising function, as the dynamic mho characteristic itself is a directional one. In conjunction with the quadrilateral shape selection, this setting defines the only directional function built into the ground distance element. The directional function uses memory voltage for polarization.
- **GND DIST Z1 DIR COMP LIMIT:** This setting selects the comparator limit angle for the directional supervising function.
- **GND DIST Z1 QUAD RGT BLD:** This setting defines the right blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane (see the Quadrilateral Distance Characteristic figure). The angular position of the blinder is adjustable with the use of the **GND DIST Z1 QUAD RGT BLD RCA** setting. This setting applies only to the quadrilateral characteristic and should be set with consideration to the maximum load current and required resistive coverage.

- **GND DIST Z1 QUAD RGT BLD RCA:** This setting defines the angular position of the right blinder of the quadrilateral characteristic (see the Quadrilateral Distance Characteristic figure).
- **GND DIST Z1 QUAD LFT BLD:** This setting defines the left blinder position of the quadrilateral characteristic along the resistive axis of the impedance plane (see the Quadrilateral Distance Characteristic figure). The angular position of the blinder is adjustable with the use of the **GND DIST Z1 QUAD LFT BLD RCA** setting. This setting applies only to the quadrilateral characteristic and should be set with consideration to the maximum load current.
- **GND DIST Z1 QUAD LFT BLD RCA:** This setting defines the angular position of the left blinder of the quadrilateral characteristic (see the Quadrilateral Distance Characteristic figure).
- **GND DIST Z1 SUPV:** The ground distance elements are supervised by the magnitude of the neutral (3I<sub>0</sub>) current. The current supervision pickup should be set above the maximum unbalance current under maximum load conditions preventing maloperation due to VT fuse failure.
- **GND DIST Z1 VOLT LEVEL:** This setting is relevant for applications on series-compensated lines, or in general, if series capacitors are located between the relaying point and a point for which the zone shall not overreach. For plain (non-compensated) lines, this setting shall be set to zero. Otherwise, the setting is entered in per unit of the VT bank configured under the **DISTANCE SOURCE**. Effectively, this setting facilitates dynamic current-based reach reduction. In non-directional applications (**GND DIST Z1 DIR** set to “Non-directional”), this setting applies only to the forward reach of the non-directional zone. See Chapter 8 and 9 for additional details and information on calculating this setting value for applications on series compensated lines.
- **GND DIST Z1 DELAY:** This setting enables the user to delay operation of the distance elements and implement a stepped distance backup protection. The distance element timer applies a short drop out delay to cope with faults located close to the boundary of the zone when small oscillations in the voltages and/or currents could inadvertently reset the timer.
- **GND DIST Z1 BLK:** This setting enables the user to select a FlexLogic™ operand to block the given distance element. VT fuse fail detection is one of the applications for this setting.

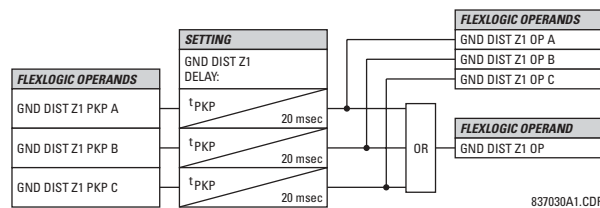


Figure 5–50: GROUND DISTANCE Z1 TO Z3 OP SCHEME



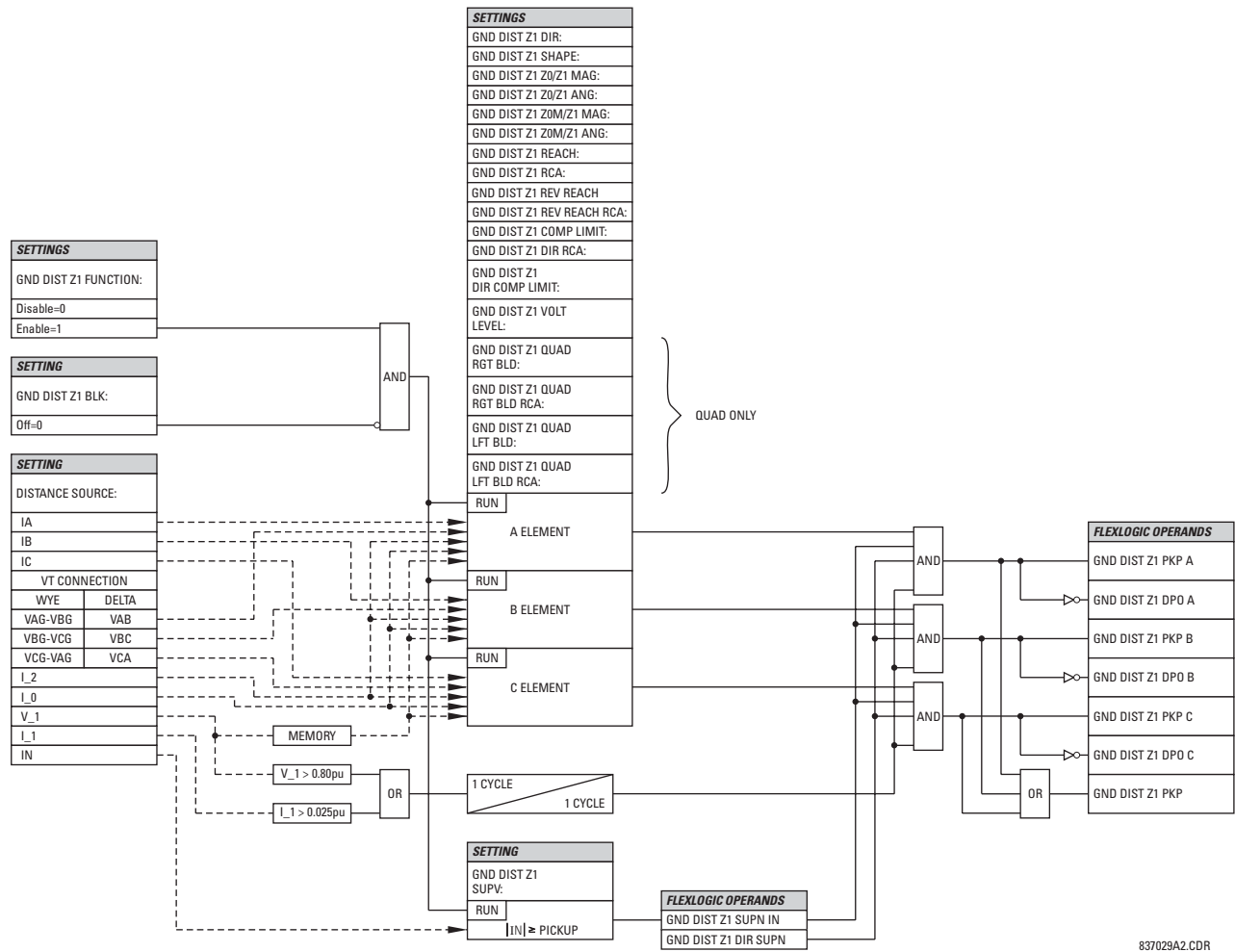


Figure 5-51: GROUND DISTANCE ZONE 1 TO ZONE 3 SCHEME LOGIC

**GROUND DIRECTIONAL SUPERVISION:**

A dual (zero- and negative-sequence) memory-polarized directional supervision applied to the ground distance protection elements has been shown to give good directional integrity. However, a reverse double-line-to-ground fault can lead to a maloperation of the ground element in a sound phase if the zone reach setting is increased to cover high resistance faults.

Ground distance Zones 2 through 3 use an additional ground directional supervision to enhance directional integrity. The element's directional characteristic angle is used as a 'maximum torque angle' together with a 90° limit angle.

The supervision is biased toward operation in order to avoid compromising the sensitivity of ground distance elements at low signal levels. Otherwise, the reverse fault condition that generates concern will have high polarizing levels so that a correct reverse fault decision can be reliably made.

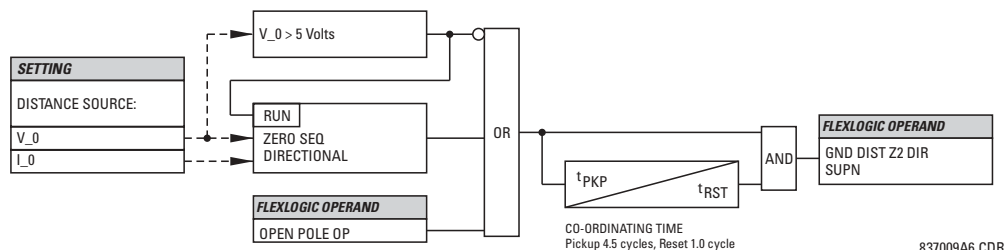


Figure 5-52: GROUND DIRECTIONAL SUPERVISION SCHEME LOGIC

## 5.5.5 POWER SWING DETECT

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ POWER SWING DETECT

|                           |         |  |   |
|---------------------------|---------|--|---|
| ■ POWER SWING<br>■ DETECT |         | POWER SWING<br>FUNCTION: Disabled          | Range: Disabled, Enabled                    |
|                           | MESSAGE | POWER SWING<br>SOURCE: SRC 1               | Range: SRC 1, SRC 2                         |
|                           | MESSAGE | POWER SWING<br>SHAPE: Mho Shape            | Range: Mho Shape, Quad Shape                |
|                           | MESSAGE | POWER SWING<br>MODE: Two Step              | Range: Two Step, Three Step                 |
|                           | MESSAGE | POWER SWING<br>SUPV: 0.600 pu              | Range: 0.050 to 30.000 pu in steps of 0.001 |
|                           | MESSAGE | POWER SWING FWD<br>REACH: 50.00 Ω          | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING QUAD FWD<br>REACH MID: 60.00 Ω | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING QUAD FWD<br>REACH OUT: 70.00 Ω | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING FWD<br>RCA: 75°                | Range: 40 to 90° in steps of 1              |
|                           | MESSAGE | POWER SWING REV<br>REACH: 50.00 Ω          | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING QUAD REV<br>REACH MID: 60.00 Ω | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING QUAD REV<br>REACH OUT: 70.00 Ω | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING REV<br>RCA: 75°                | Range: 40 to 90° in steps of 1              |
|                           | MESSAGE | POWER SWING OUTER<br>LIMIT ANGLE: 120°     | Range: 40 to 140° in steps of 1             |
|                           | MESSAGE | POWER SWING MIDDLE<br>LIMIT ANGLE: 90°     | Range: 40 to 140° in steps of 1             |
|                           | MESSAGE | POWER SWING INNER<br>LIMIT ANGLE: 60°      | Range: 40 to 140° in steps of 1             |
|                           | MESSAGE | POWER SWING OUTER<br>RGT BLD: 100.00 Ω     | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING OUTER<br>LFT BLD: 100.00 Ω     | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING MIDDLE<br>RGT BLD: 100.00 Ω    | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING MIDDLE<br>LFT BLD: 100.00 Ω    | Range: 0.10 to 500.00 Ω in steps of 0.01    |
|                           | MESSAGE | POWER SWING INNER<br>RGT BLD: 100.00 Ω     | Range: 0.10 to 500.00 Ω in steps of 0.01    |

|         |  |   |   |
|---------|--|---|---|
| MESSAGE |  | POWER SWING INNER<br>LFT BLD: 100.00 $\Omega$ | Range: 0.10 to 500.00 $\Omega$ in steps of 0.01 |
| MESSAGE |  | POWER SWING PICKUP<br>DELAY 1: 0.030 s        | Range: 0.000 to 65.535 s in steps of 0.001      |
| MESSAGE |  | POWER SWING RESET<br>DELAY 1: 0.050 s         | Range: 0.000 to 65.535 s in steps of 0.001      |
| MESSAGE |  | POWER SWING PICKUP<br>DELAY 2: 0.017 s        | Range: 0.000 to 65.535 s in steps of 0.001      |
| MESSAGE |  | POWER SWING PICKUP<br>DELAY 3: 0.009 s        | Range: 0.000 to 65.535 s in steps of 0.001      |
| MESSAGE |  | POWER SWING PICKUP<br>DELAY 4: 0.017 s        | Range: 0.000 to 65.535 s in steps of 0.001      |
| MESSAGE |  | POWER SWING SEAL-IN<br>DELAY: 0.400 s         | Range: 0.000 to 65.535 s in steps of 0.001      |
| MESSAGE |  | POWER SWING TRIP<br>MODE: Delayed             | Range: Early, Delayed                           |
| MESSAGE |  | POWER SWING BLK:<br>Off                       | Range: Flexlogic™ operand                       |
| MESSAGE |  | POWER SWING<br>TARGET: Self-Reset             | Range: Self-Reset, Latched, Disabled            |
| MESSAGE |  | POWER SWING<br>EVENTS: Disabled               | Range: Disabled, Enabled                        |

The Power Swing Detect element provides both power swing blocking and out-of-step tripping functions. The element measures the positive-sequence apparent impedance and traces its locus with respect to either two or three user-selectable operating characteristic boundaries. Upon detecting appropriate timing relations, the blocking and/or tripping indication is given through FlexLogic™ operands. The element incorporates an adaptive disturbance detector. This function does not trigger on power swings, but is capable of detecting faster disturbances – faults in particular – that may occur during power swings. Operation of this dedicated disturbance detector is signaled via the POWER SWING 50DD operand.

The Power Swing Detect element asserts two outputs intended for blocking selected protection elements on power swings: POWER SWING BLOCK is a traditional signal that is safely asserted for the entire duration of the power swing, and POWER SWING UN/BLOCK is established in the same way, but resets when an extra disturbance is detected during the power swing. The POWER SWING UN/BLOCK operand may be used for blocking selected protection elements if the intent is to respond to faults during power swing conditions.

Different protection elements respond differently to power swings. If tripping is required for faults during power swing conditions, some elements may be blocked permanently (using the POWER SWING BLOCK operand), and others may be blocked and dynamically unblocked upon fault detection (using the POWER SWING UN/BLOCK operand).

The operating characteristic and logic figures should be viewed along with the following discussion to develop an understanding of the operation of the element.

The Power Swing Detect element operates in three-step or two-step mode:

- **Three-step operation:** The power swing blocking sequence essentially times the passage of the locus of the positive-sequence impedance between the outer and the middle characteristic boundaries. If the locus enters the outer characteristic (indicated by the POWER SWING OUTER FlexLogic™ operand) but stays outside the middle characteristic (indicated by the POWER SWING MIDDLE FlexLogic™ operand) for an interval longer than **POWER SWING PICKUP DELAY 1**, the power swing blocking signal (POWER SWING BLOCK FlexLogic™ operand) is established and sealed-in. The blocking signal resets when the locus leaves the outer characteristic, but not sooner than the **POWER SWING RESET DELAY 1** time.
- **Two-step operation:** If the 2-step mode is selected, the sequence is identical, but it is the outer and inner characteristics that are used to time the power swing locus.

The Out-of-Step Tripping feature operates as follows for three-step and two-step Power Swing Detection modes:

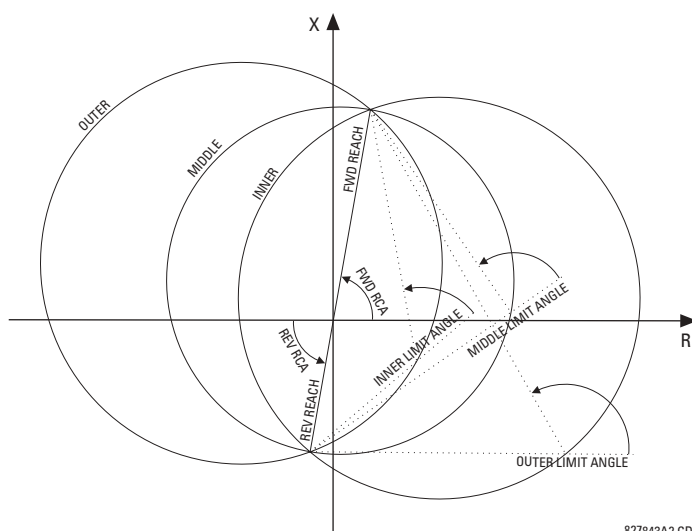
- **Three-step operation:** The out-of-step trip sequence identifies unstable power swings by determining if the impedance locus spends a finite time between the outer and middle characteristics and then a finite time between the middle and inner characteristics. The first step is similar to the power swing blocking sequence. After timer **POWER SWING PICKUP DELAY 1** times out, Latch 1 is set as long as the impedance stays within the outer characteristic.

If afterwards, at any time (given the impedance stays within the outer characteristic), the locus enters the middle characteristic but stays outside the inner characteristic for a period of time defined as **POWER SWING PICKUP DELAY 2**, Latch 2 is set as long as the impedance stays inside the outer characteristic. If afterwards, at any time (given the impedance stays within the outer characteristic), the locus enters the inner characteristic and stays there for a period of time defined as **POWER SWING PICKUP DELAY 3**, Latch 2 is set as long as the impedance stays inside the outer characteristic; the element is now ready to trip.

If the "Early" trip mode is selected, the **POWER SWING TRIP** operand is set immediately and sealed-in for the interval set by the **POWER SWING SEAL-IN DELAY**. If the "Delayed" trip mode is selected, the element waits until the impedance locus leaves the inner characteristic, then times out the **POWER SWING PICKUP DELAY 2** and sets Latch 4; the element is now ready to trip. The trip operand is set later, when the impedance locus leaves the outer characteristic.

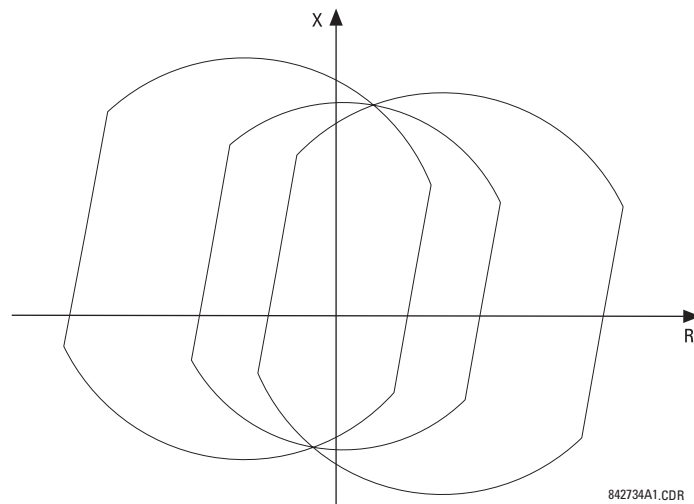
- **Two-step operation:** The 2-step mode of operation is similar to the 3-step mode with two exceptions. First, the initial stage monitors the time spent by the impedance locus between the outer and inner characteristics. Second, the stage involving the **POWER SWING PICKUP DELAY 2** timer is bypassed. It is up to the user to integrate the blocking (**POWER SWING BLOCK**) and tripping (**POWER SWING TRIP**) FlexLogic™ operands with other protection functions and output contacts in order to make this element fully operational.

The element can be set to use either lens (mho) or rectangular (quad) characteristics as illustrated below. When set to "Mho", the element applies the right and left blinders as well. If the blinders are not required, their settings should be set high enough to effectively disable the blinders.

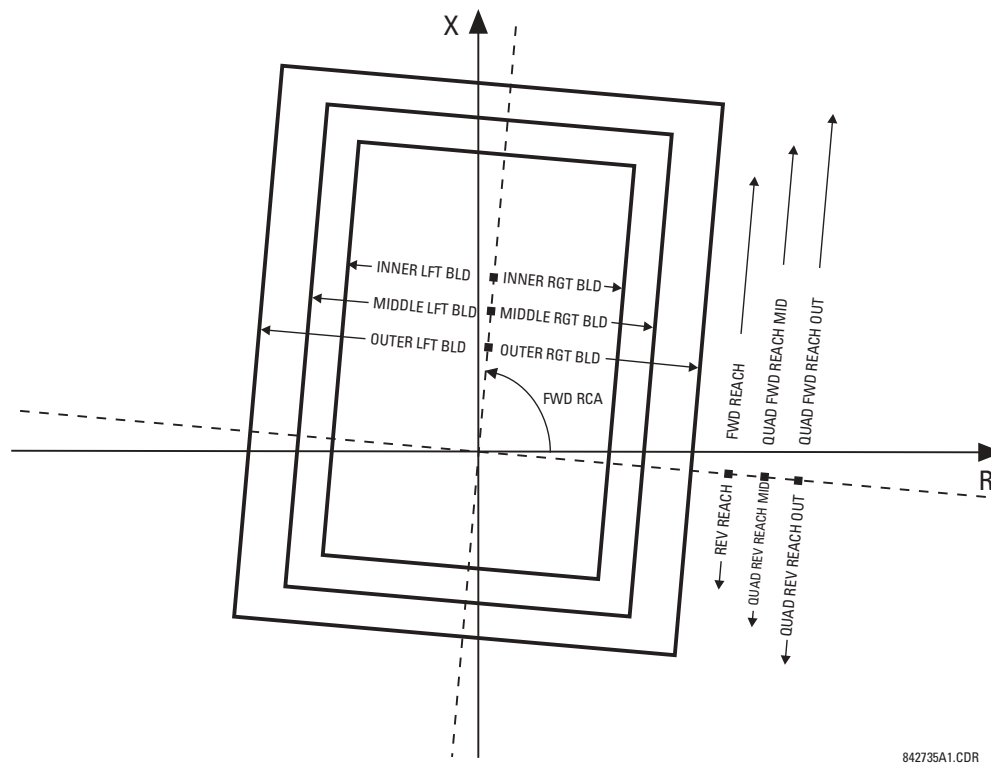


827843A2.CDR

Figure 5-53: POWER SWING DETECT MHO OPERATING CHARACTERISTICS



**Figure 5-54: EFFECTS OF BLINDERS ON THE MHO CHARACTERISTICS**



**Figure 5-55: POWER SWING DETECT QUAD OPERATING CHARACTERISTICS**

The FlexLogic™ output operands for the Power Swing Detect element are described below:

- The POWER SWING OUTER, POWER SWING MIDDLE, POWER SWING INNER, POWER SWING TMR2 PKP, POWER SWING TMR3 PKP, and POWER SWING TMR4 PKP FlexLogic™ operands are auxiliary operands that could be used to facilitate testing and special applications.
- The POWER SWING BLOCK FlexLogic™ operand shall be used to block selected protection elements such as distance functions.

- The POWER SWING UN/BLOCK FlexLogic™ operand shall be used to block those protection elements that are intended to be blocked under power swings, but subsequently unblocked should a fault occur after the power swing blocking condition has been established.
- The POWER SWING 50DD FlexLogic™ operand indicates that an adaptive disturbance detector integrated with the element has picked up. This operand will trigger on faults occurring during power swing conditions. This includes both three-phase and single-pole-open conditions.
- The POWER SWING INCOMING FlexLogic™ operand indicates an unstable power swing with an incoming locus (the locus enters the inner characteristic).
- The POWER SWING OUTGOING FlexLogic™ operand indicates an unstable power swing with an outgoing locus (the locus leaving the outer characteristic). This operand can be used to count unstable swings and take certain action only after pre-defined number of unstable power swings.
- The POWER SWING TRIP FlexLogic™ operand is a trip command.

The settings for the Power Swing Detect element are described below:

- **POWER SWING FUNCTION:** This setting enables/disables the entire Power Swing Detection element. The setting applies to both power swing blocking and out-of-step tripping functions.
- **POWER SWING SOURCE:** The source setting identifies the Signal Source for both blocking and tripping functions.
- **POWER SWING SHAPE:** This setting selects the shapes (either “Mho” or “Quad”) of the outer, middle and, inner characteristics of the power swing detect element. The operating principle is not affected. The “Mho” characteristics use the left and right blinders.
- **POWER SWING MODE:** This setting selects between the 2-step and 3-step operating modes and applies to both power swing blocking and out-of-step tripping functions. The 3-step mode applies if there is enough space between the maximum load impedances and distance characteristics of the relay that all three (outer, middle, and inner) characteristics can be placed between the load and the distance characteristics. Whether the spans between the outer and middle as well as the middle and inner characteristics are sufficient should be determined by analysis of the fastest power swings expected in correlation with settings of the power swing timers.

The 2-step mode uses only the outer and inner characteristics for both blocking and tripping functions. This leaves more space in heavily loaded systems to place two power swing characteristics between the distance characteristics and the maximum load, but allows for only one determination of the impedance trajectory.

- **POWER SWING SUPV:** A common overcurrent pickup level supervises all three power swing characteristics. The supervision responds to the positive sequence current.
- **POWER SWING FWD REACH:** This setting specifies the forward reach of all three mho characteristics and the inner quad characteristic. For a simple system consisting of a line and two equivalent sources, this reach should be higher than the sum of the line and remote source positive-sequence impedances. Detailed transient stability studies may be needed for complex systems in order to determine this setting. The angle of this reach impedance is specified by the **POWER SWING FWD RCA** setting.
- **POWER SWING QUAD FWD REACH MID:** This setting specifies the forward reach of the middle quad characteristic. The angle of this reach impedance is specified by the **POWER SWING FWD RCA** setting. The setting is not used if the shape setting is “Mho”.
- **POWER SWING QUAD FWD REACH OUT:** This setting specifies the forward reach of the outer quad characteristic. The angle of this reach impedance is specified by the **POWER SWING FWD RCA** setting. The setting is not used if the shape setting is “Mho”.
- **POWER SWING FWD RCA:** This setting specifies the angle of the forward reach impedance for the mho characteristics, angles of all the blinders, and both forward and reverse reach impedances of the quad characteristics.
- **POWER SWING REV REACH:** This setting specifies the reverse reach of all three mho characteristics and the inner quad characteristic. For a simple system of a line and two equivalent sources, this reach should be higher than the positive-sequence impedance of the local source. Detailed transient stability studies may be needed for complex systems to determine this setting. The angle of this reach impedance is specified by the **POWER SWING REV RCA** setting for “Mho”, and the **POWER SWING FWD RCA** setting for “Quad”.
- **POWER SWING QUAD REV REACH MID:** This setting specifies the reverse reach of the middle quad characteristic. The angle of this reach impedance is specified by the **POWER SWING FWD RCA** setting. The setting is not used if the shape setting is “Mho”.

- **POWER SWING QUAD REV REACH OUT:** This setting specifies the reverse reach of the outer quad characteristic. The angle of this reach impedance is specified by the **POWER SWING FWD RCA** setting. The setting is not used if the shape setting is “Mho”.
- **POWER SWING REV RCA:** This setting specifies the angle of the reverse reach impedance for the mho characteristics. This setting applies to mho shapes only.
- **POWER SWING OUTER LIMIT ANGLE:** This setting defines the outer power swing characteristic. The convention depicted in the Power Swing Detect Characteristic diagram should be observed: values greater than 90° result in an ‘apple’ shaped characteristic; values less than 90° result in a lens shaped characteristic. This angle must be selected in consideration of the maximum expected load. If the maximum load angle is known, the outer limit angle should be coordinated with a 20° security margin. Detailed studies may be needed for complex systems to determine this setting. This setting applies to mho shapes only.
- **POWER SWING MIDDLE LIMIT ANGLE:** This setting defines the middle power swing detect characteristic. It is relevant only for the 3-step mode. A typical value would be close to the average of the outer and inner limit angles. This setting applies to mho shapes only.
- **POWER SWING INNER LIMIT ANGLE:** This setting defines the inner power swing detect characteristic. The inner characteristic is used by the out-of-step tripping function: beyond the inner characteristic out-of-step trip action is definite (the actual trip may be delayed as per the **TRIP MODE** setting). Therefore, this angle must be selected in consideration to the power swing angle beyond which the system becomes unstable and cannot recover.  
  
The inner characteristic is also used by the power swing blocking function in the 2-step mode. In this case, set this angle large enough so that the characteristics of the distance elements are safely enclosed by the inner characteristic. This setting applies to mho shapes only.
- **POWER SWING OUTER, MIDDLE, and INNER RGT BLD:** These settings specify the resistive reach of the right blinder. The blinder applies to both “Mho” and “Quad” characteristics. Set these value high if no blinder is required for the “Mho” characteristic.
- **POWER SWING OUTER, MIDDLE, and INNER LFT BLD:** These settings specify the resistive reach of the left blinder. Enter a positive value; the relay automatically uses a negative value. The blinder applies to both “Mho” and “Quad” characteristics. Set this value high if no blinder is required for the “Mho” characteristic.
- **POWER SWING PICKUP DELAY 1:** All the coordinating timers are related to each other and should be set to detect the fastest expected power swing and produce out-of-step tripping in a secure manner. The timers should be set in consideration to the power swing detect characteristics, mode of power swing detect operation and mode of out-of-step tripping. This timer defines the interval that the impedance locus must spend between the outer and inner characteristics (2-step operating mode), or between the outer and middle characteristics (3-step operating mode) before the power swing blocking signal is established. This time delay must be set shorter than the time required for the impedance locus to travel between the two selected characteristics during the fastest expected power swing. This setting is relevant for both power swing blocking and out-of-step tripping.
- **POWER SWING RESET DELAY 1:** This setting defines the dropout delay for the power swing blocking signal. Detection of a condition requiring a Block output sets Latch 1 after **PICKUP DELAY 1** time. When the impedance locus leaves the outer characteristic, timer **POWER SWING RESET DELAY 1** is started. When the timer times-out the latch is reset. This setting should be selected to give extra security for the power swing blocking action.
- **POWER SWING PICKUP DELAY 2:** Controls the out-of-step tripping function in the 3-step mode only. This timer defines the interval the impedance locus must spend between the middle and inner characteristics before the second step of the out-of-step tripping sequence is completed. This time delay must be set shorter than the time required for the impedance locus to travel between the two characteristics during the fastest expected power swing.
- **POWER SWING PICKUP DELAY 3:** Controls the out-of-step tripping function only. It defines the interval the impedance locus must spend within the inner characteristic before the last step of the out-of-step tripping sequence is completed and the element is armed to trip. The actual moment of tripping is controlled by the **TRIP MODE** setting. This time delay is provided for extra security before the out-of-step trip action is executed.
- **POWER SWING PICKUP DELAY 4:** Controls the out-of-step tripping function in “Delayed” trip mode only. This timer defines the interval the impedance locus must spend outside the inner characteristic but within the outer characteristic before the element is armed for the delayed trip. The delayed trip occurs when the impedance leaves the outer characteristic. This time delay is provided for extra security and should be set considering the fastest expected power swing.



- **POWER SWING SEAL-IN DELAY:** The out-of-step trip FlexLogic™ operand (POWER SWING TRIP) is sealed-in for the specified period of time. The sealing-in is crucial in the delayed trip mode, as the original trip signal is a very short pulse occurring when the impedance locus leaves the outer characteristic after the out-of-step sequence is completed.
- **POWER SWING TRIP MODE:** Selection of the “Early” trip mode results in an instantaneous trip after the last step in the out-of-step tripping sequence is completed. The Early trip mode will stress the circuit breakers as the currents at that moment are high (the electromotive forces of the two equivalent systems are approximately 180° apart). Selection of the “Delayed” trip mode results in a trip at the moment when the impedance locus leaves the outer characteristic. Delayed trip mode will relax the operating conditions for the breakers as the currents at that moment are low. The selection should be made considering the capability of the breakers in the system.
- **POWER SWING BLK:** This setting specifies the FlexLogic™ operand used for blocking the out-of-step function only. The power swing blocking function is operational all the time as long as the element is enabled. The blocking signal resets the output POWER SWING TRIP operand but does not stop the out-of-step tripping sequence.

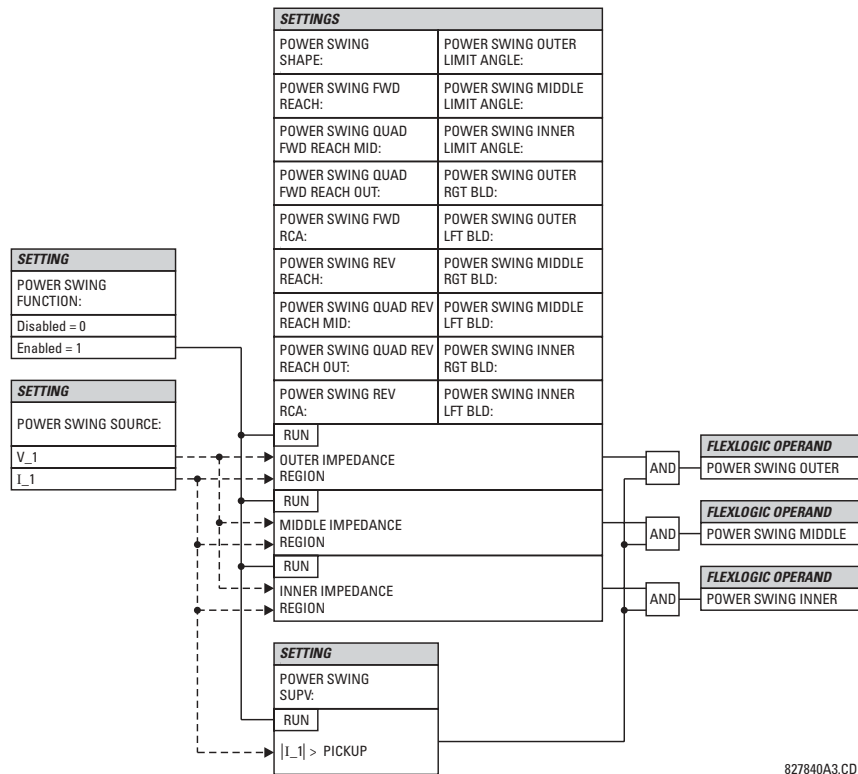


Figure 5-56: POWER SWING DETECT SCHEME LOGIC (1 of 3)

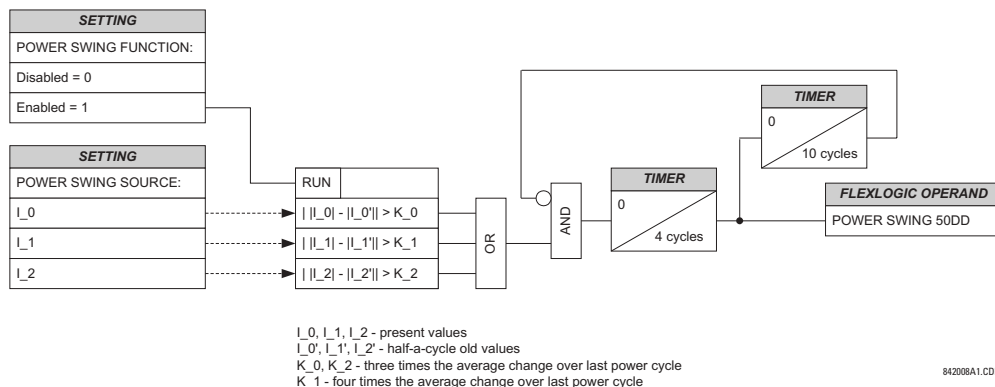


Figure 5-57: POWER SWING DETECT SCHEME LOGIC (2 of 3)



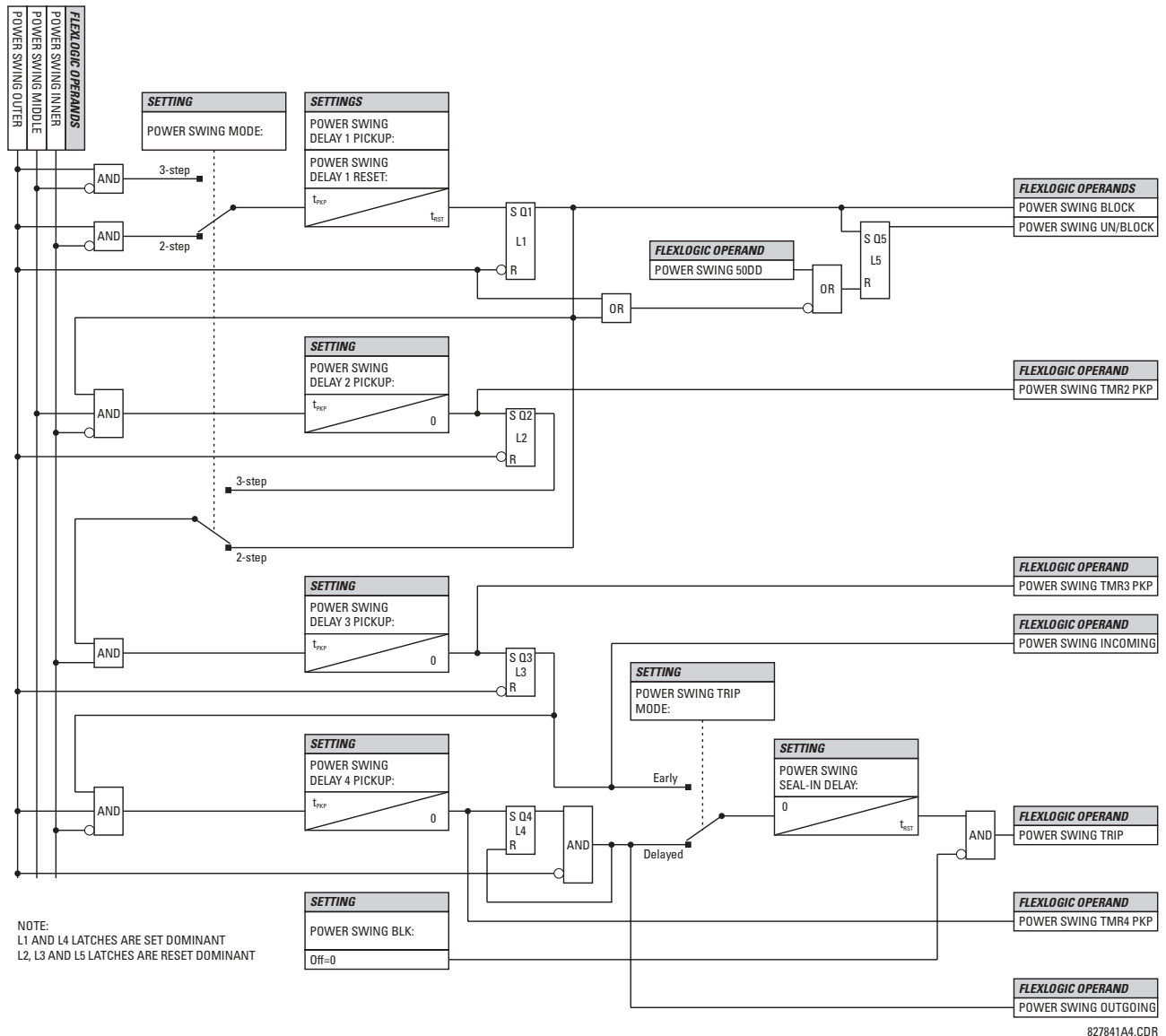


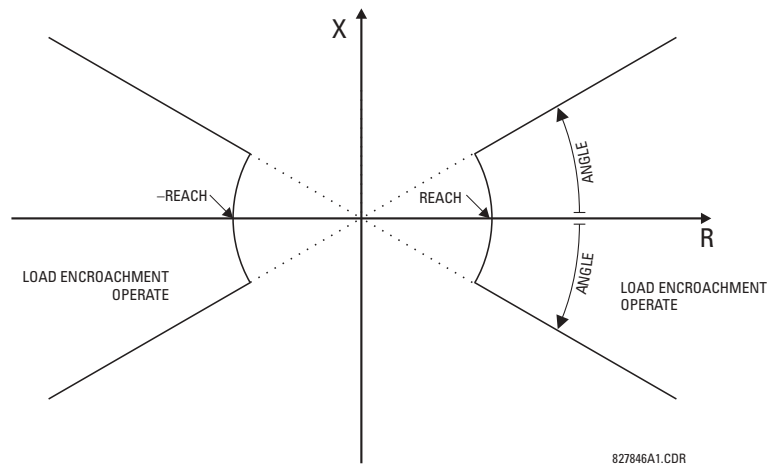
Figure 5–58: POWER SWING DETECT SCHEME LOGIC (3 of 3)

## 5.5.6 LOAD ENCROACHMENT

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ LOAD ENCROACHMENT

|                     |    |   |   |
|---------------------|----|---|---|
| ■ LOAD ENCROACHMENT | ◀▶ | LOAD ENCROACHMENT<br>FUNCTION: Disabled | Range: Disabled, Enabled                    |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>SOURCE: SRC 1      | Range: SRC 1, SRC 2                         |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>MIN VOLT: 0.250 pu | Range: 0.000 to 3.000 pu in steps of 0.001  |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>REACH: 1.00 Ω      | Range: 0.02 to 250.00 ohms in steps of 0.01 |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>ANGLE: 30°         | Range: 5 to 50° in steps of 1               |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>PKP DELAY: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>RST DELAY: 0.000 s | Range: 0.000 to 65.535 s in steps of 0.001  |
| MESSAGE             | ▲▼ | LOAD ENCRMNT BLK:<br>Off                | Range: Flexlogic™ operand                   |
| MESSAGE             | ▲▼ | LOAD ENCROACHMENT<br>TARGET: Self-reset | Range: Self-reset, Latched, Disabled        |
| MESSAGE             | ▲  | LOAD ENCROACHMENT<br>EVENTS: Disabled   | Range: Disabled, Enabled                    |

The Load Encroachment element responds to the positive-sequence voltage and current and applies a characteristic shown in the figure below.



827846A1.CDR

Figure 5-59: LOAD ENCROACHMENT CHARACTERISTIC

The element operates if the positive-sequence voltage is above a settable level and asserts its output signal that can be used to block selected protection elements such as distance or phase overcurrent. The following figure shows an effect of the Load Encroachment characteristics used to block the Quad distance element.

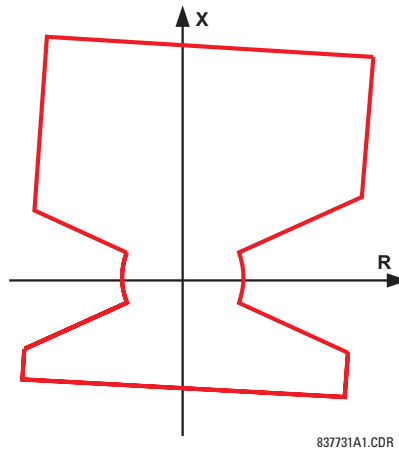


Figure 5-60: LOAD ENCROACHMENT APPLIED TO DISTANCE ELEMENT

- LOAD ENCROACHMENT MIN VOLT:** This setting specifies the minimum positive-sequence voltage required for operation of the element. If the voltage is below this threshold a blocking signal will not be asserted by the element. When selecting this setting one must remember that the D30 measures the phase-to-ground sequence voltages regardless of the VT connection.  
 The nominal VT secondary voltage as specified under **PATH: SYSTEM SETUP** ⇒ **AC INPUTS** ⇒ **VOLTAGE BANK X1** ⇒ **PHASE VT SECONDARY** is the p.u. base for this setting.
- LOAD ENCROACHMENT REACH:** This setting specifies the resistive reach of the element as shown in the Load Encroachment Characteristic diagram. This setting should be entered in secondary ohms and be calculated as the positive-sequence resistance seen by the relay under maximum load conditions and unity power factor.
- LOAD ENCROACHMENT ANGLE:** This setting specifies the size of the blocking region as shown on the Load Encroachment Characteristic diagram and applies to the positive sequence impedance.

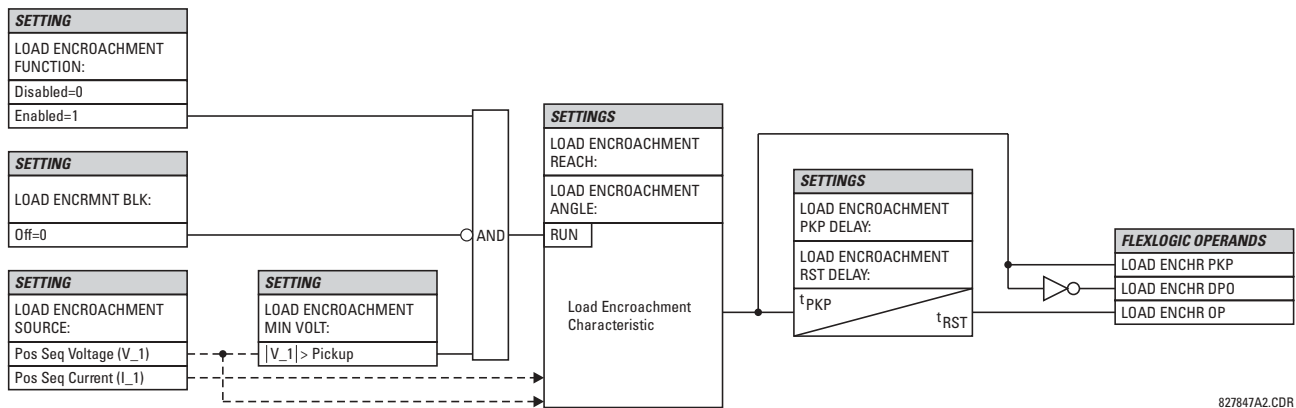


Figure 5-61: LOAD ENCROACHMENT SCHEME LOGIC

## 5.5.7 PHASE CURRENT

## a) MAIN MENU

PATH: SETTINGS ⇒ ↓ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ ↓ PHASE CURRENT

|                 |    |                            |                 |
|-----------------|----|----------------------------|-----------------|
| ■ PHASE CURRENT | ◀▶ | ■ PHASE TOC1               | See page 5-103. |
| MESSAGE         | ▲▼ | ■ PHASE TOC2               | See page 5-103. |
| MESSAGE         | ▲▼ | ■ PHASE IOC1               | See page 5-105. |
| MESSAGE         | ▲▼ | ■ PHASE IOC2               | See page 5-105. |
| MESSAGE         | ▲▼ | ■ PHASE<br>■ DIRECTIONAL 1 | See page 5-106. |
| MESSAGE         | ▲  | ■ PHASE<br>■ DIRECTIONAL 2 | See page 5-106. |

## b) INVERSE TOC CURVE CHARACTERISTICS

The inverse time overcurrent curves used by the time overcurrent elements are the IEEE, IEC, GE Type IAC, and  $I^2t$  standard curve shapes. This allows for simplified coordination with downstream devices. If however, none of these curve shapes is adequate, FlexCurves™ may be used to customize the inverse time curve characteristics. The Definite Time curve is also an option that may be appropriate if only simple protection is required.

Table 5-9: OVERCURRENT CURVE TYPES

| IEEE                 | IEC                 | GE TYPE IAC        | OTHER                      |
|----------------------|---------------------|--------------------|----------------------------|
| IEEE Extremely Inv.  | IEC Curve A (BS142) | IAC Extremely Inv. | $I^2t$                     |
| IEEE Very Inverse    | IEC Curve B (BS142) | IAC Very Inverse   | FlexCurves™ A, B, C, and D |
| IEEE Moderately Inv. | IEC Curve C (BS142) | IAC Inverse        | Recloser Curves            |
|                      | IEC Short Inverse   | IAC Short Inverse  | Definite Time              |

A time dial multiplier setting allows selection of a multiple of the base curve shape (where the time dial multiplier = 1) with the curve shape (CURVE) setting. Unlike the electromechanical time dial equivalent, operate times are directly proportional to the time multiplier (TD MULTIPLIER) setting value. For example, all times for a multiplier of 10 are 10 times the multiplier 1 or base curve values. Setting the multiplier to zero results in an instantaneous response to all current levels above pickup.

Time overcurrent time calculations are made with an internal 'energy capacity' memory variable. When this variable indicates that the energy capacity has reached 100%, a time overcurrent element will operate. If less than 100% energy capacity is accumulated in this variable and the current falls below the dropout threshold of 97 to 98% of the pickup value, the variable must be reduced. Two methods of this resetting operation are available: "Instantaneous" and "Timed". The "Instantaneous" selection is intended for applications with other relays, such as most static relays, which set the energy capacity directly to zero when the current falls below the reset threshold. The "Timed" selection can be used where the relay must coordinate with electromechanical relays.



Graphs of standard time-current curves on 11" × 17" log-log graph paper are available upon request from the GE Multilin literature department. The original files are also available in PDF format on the enerVista CD and the GE Multilin website at <http://www.GEindustrial.com/multilin>.

**IEEE CURVES:**

The IEEE time overcurrent curve shapes conform to industry standards and the IEEE C37.112-1996 curve classifications for extremely, very, and moderately inverse. The IEEE curves are derived from the formulae:

$$T = TDM \times \left[ \frac{A}{\left( \frac{I}{I_{pickup}} \right)^p - 1} + B \right], T_{RESET} = TDM \times \left[ \frac{t_r}{\left( \frac{I}{I_{pickup}} \right)^2 - 1} \right] \quad (\text{EQ 5.5})$$

where:  $T$  = operate time (in seconds),  $TDM$  = Multiplier setting,  $I$  = input current,  $I_{pickup}$  = Pickup Current setting  
 $A, B, p$  = constants,  $T_{RESET}$  = reset time in seconds (assuming energy capacity is 100% and RESET is "Timed"),  
 $t_r$  = characteristic constant

**Table 5–10: IEEE INVERSE TIME CURVE CONSTANTS**

| IEEE CURVE SHAPE        | A      | B      | P       | T <sub>R</sub> |
|-------------------------|--------|--------|---------|----------------|
| IEEE Extremely Inverse  | 28.2   | 0.1217 | 2.0000  | 29.1           |
| IEEE Very Inverse       | 19.61  | 0.491  | 2.0000  | 21.6           |
| IEEE Moderately Inverse | 0.0515 | 0.1140 | 0.02000 | 4.85           |

**Table 5–11: IEEE CURVE TRIP TIMES (IN SECONDS)**

| MULTIPLIER<br>(TDM)            | CURRENT ( $I / I_{pickup}$ ) |        |        |        |        |        |        |        |        |        |
|--------------------------------|------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                | 1.5                          | 2.0    | 3.0    | 4.0    | 5.0    | 6.0    | 7.0    | 8.0    | 9.0    | 10.0   |
| <b>IEEE EXTREMELY INVERSE</b>  |                              |        |        |        |        |        |        |        |        |        |
| 0.5                            | 11.341                       | 4.761  | 1.823  | 1.001  | 0.648  | 0.464  | 0.355  | 0.285  | 0.237  | 0.203  |
| 1.0                            | 22.682                       | 9.522  | 3.647  | 2.002  | 1.297  | 0.927  | 0.709  | 0.569  | 0.474  | 0.407  |
| 2.0                            | 45.363                       | 19.043 | 7.293  | 4.003  | 2.593  | 1.855  | 1.418  | 1.139  | 0.948  | 0.813  |
| 4.0                            | 90.727                       | 38.087 | 14.587 | 8.007  | 5.187  | 3.710  | 2.837  | 2.277  | 1.897  | 1.626  |
| 6.0                            | 136.090                      | 57.130 | 21.880 | 12.010 | 7.780  | 5.564  | 4.255  | 3.416  | 2.845  | 2.439  |
| 8.0                            | 181.454                      | 76.174 | 29.174 | 16.014 | 10.374 | 7.419  | 5.674  | 4.555  | 3.794  | 3.252  |
| 10.0                           | 226.817                      | 95.217 | 36.467 | 20.017 | 12.967 | 9.274  | 7.092  | 5.693  | 4.742  | 4.065  |
| <b>IEEE VERY INVERSE</b>       |                              |        |        |        |        |        |        |        |        |        |
| 0.5                            | 8.090                        | 3.514  | 1.471  | 0.899  | 0.654  | 0.526  | 0.450  | 0.401  | 0.368  | 0.345  |
| 1.0                            | 16.179                       | 7.028  | 2.942  | 1.798  | 1.308  | 1.051  | 0.900  | 0.802  | 0.736  | 0.689  |
| 2.0                            | 32.358                       | 14.055 | 5.885  | 3.597  | 2.616  | 2.103  | 1.799  | 1.605  | 1.472  | 1.378  |
| 4.0                            | 64.716                       | 28.111 | 11.769 | 7.193  | 5.232  | 4.205  | 3.598  | 3.209  | 2.945  | 2.756  |
| 6.0                            | 97.074                       | 42.166 | 17.654 | 10.790 | 7.849  | 6.308  | 5.397  | 4.814  | 4.417  | 4.134  |
| 8.0                            | 129.432                      | 56.221 | 23.538 | 14.387 | 10.465 | 8.410  | 7.196  | 6.418  | 5.889  | 5.513  |
| 10.0                           | 161.790                      | 70.277 | 29.423 | 17.983 | 13.081 | 10.513 | 8.995  | 8.023  | 7.361  | 6.891  |
| <b>IEEE MODERATELY INVERSE</b> |                              |        |        |        |        |        |        |        |        |        |
| 0.5                            | 3.220                        | 1.902  | 1.216  | 0.973  | 0.844  | 0.763  | 0.706  | 0.663  | 0.630  | 0.603  |
| 1.0                            | 6.439                        | 3.803  | 2.432  | 1.946  | 1.688  | 1.526  | 1.412  | 1.327  | 1.260  | 1.207  |
| 2.0                            | 12.878                       | 7.606  | 4.864  | 3.892  | 3.377  | 3.051  | 2.823  | 2.653  | 2.521  | 2.414  |
| 4.0                            | 25.756                       | 15.213 | 9.729  | 7.783  | 6.753  | 6.102  | 5.647  | 5.307  | 5.041  | 4.827  |
| 6.0                            | 38.634                       | 22.819 | 14.593 | 11.675 | 10.130 | 9.153  | 8.470  | 7.960  | 7.562  | 7.241  |
| 8.0                            | 51.512                       | 30.426 | 19.458 | 15.567 | 13.507 | 12.204 | 11.294 | 10.614 | 10.083 | 9.654  |
| 10.0                           | 64.390                       | 38.032 | 24.322 | 19.458 | 16.883 | 15.255 | 14.117 | 13.267 | 12.604 | 12.068 |

## IEC CURVES

For European applications, the relay offers three standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC Curve A, IEC Curve B, and IEC Curve C. The formulae for these curves are:

$$T = TDM \times \left[ \frac{K}{(I/I_{pickup})^E - 1} \right], T_{RESET} = TDM \times \left[ \frac{t_r}{(I/I_{pickup})^2 - 1} \right] \quad (\text{EQ 5.6})$$

where:  $T$  = operate time (in seconds),  $TDM$  = Multiplier setting,  $I$  = input current,  $I_{pickup}$  = Pickup Current setting,  $K$ ,  $E$  = constants,  $t_r$  = characteristic constant, and  $T_{RESET}$  = reset time in seconds (assuming energy capacity is 100% and RESET is "Timed")

Table 5-12: IEC (BS) INVERSE TIME CURVE CONSTANTS

| IEC (BS) CURVE SHAPE | K      | E     | T <sub>R</sub> |
|----------------------|--------|-------|----------------|
| IEC Curve A (BS142)  | 0.140  | 0.020 | 9.7            |
| IEC Curve B (BS142)  | 13.500 | 1.000 | 43.2           |
| IEC Curve C (BS142)  | 80.000 | 2.000 | 58.2           |
| IEC Short Inverse    | 0.050  | 0.040 | 0.500          |

Table 5-13: IEC CURVE TRIP TIMES (IN SECONDS)

| MULTIPLIER<br>(TDM)   | CURRENT ( $I/I_{pickup}$ ) |        |        |       |       |       |       |       |       |       |
|-----------------------|----------------------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
|                       | 1.5                        | 2.0    | 3.0    | 4.0   | 5.0   | 6.0   | 7.0   | 8.0   | 9.0   | 10.0  |
| <b>IEC CURVE A</b>    |                            |        |        |       |       |       |       |       |       |       |
| 0.05                  | 0.860                      | 0.501  | 0.315  | 0.249 | 0.214 | 0.192 | 0.176 | 0.165 | 0.156 | 0.149 |
| 0.10                  | 1.719                      | 1.003  | 0.630  | 0.498 | 0.428 | 0.384 | 0.353 | 0.330 | 0.312 | 0.297 |
| 0.20                  | 3.439                      | 2.006  | 1.260  | 0.996 | 0.856 | 0.767 | 0.706 | 0.659 | 0.623 | 0.594 |
| 0.40                  | 6.878                      | 4.012  | 2.521  | 1.992 | 1.712 | 1.535 | 1.411 | 1.319 | 1.247 | 1.188 |
| 0.60                  | 10.317                     | 6.017  | 3.781  | 2.988 | 2.568 | 2.302 | 2.117 | 1.978 | 1.870 | 1.782 |
| 0.80                  | 13.755                     | 8.023  | 5.042  | 3.984 | 3.424 | 3.070 | 2.822 | 2.637 | 2.493 | 2.376 |
| 1.00                  | 17.194                     | 10.029 | 6.302  | 4.980 | 4.280 | 3.837 | 3.528 | 3.297 | 3.116 | 2.971 |
| <b>IEC CURVE B</b>    |                            |        |        |       |       |       |       |       |       |       |
| 0.05                  | 1.350                      | 0.675  | 0.338  | 0.225 | 0.169 | 0.135 | 0.113 | 0.096 | 0.084 | 0.075 |
| 0.10                  | 2.700                      | 1.350  | 0.675  | 0.450 | 0.338 | 0.270 | 0.225 | 0.193 | 0.169 | 0.150 |
| 0.20                  | 5.400                      | 2.700  | 1.350  | 0.900 | 0.675 | 0.540 | 0.450 | 0.386 | 0.338 | 0.300 |
| 0.40                  | 10.800                     | 5.400  | 2.700  | 1.800 | 1.350 | 1.080 | 0.900 | 0.771 | 0.675 | 0.600 |
| 0.60                  | 16.200                     | 8.100  | 4.050  | 2.700 | 2.025 | 1.620 | 1.350 | 1.157 | 1.013 | 0.900 |
| 0.80                  | 21.600                     | 10.800 | 5.400  | 3.600 | 2.700 | 2.160 | 1.800 | 1.543 | 1.350 | 1.200 |
| 1.00                  | 27.000                     | 13.500 | 6.750  | 4.500 | 3.375 | 2.700 | 2.250 | 1.929 | 1.688 | 1.500 |
| <b>IEC CURVE C</b>    |                            |        |        |       |       |       |       |       |       |       |
| 0.05                  | 3.200                      | 1.333  | 0.500  | 0.267 | 0.167 | 0.114 | 0.083 | 0.063 | 0.050 | 0.040 |
| 0.10                  | 6.400                      | 2.667  | 1.000  | 0.533 | 0.333 | 0.229 | 0.167 | 0.127 | 0.100 | 0.081 |
| 0.20                  | 12.800                     | 5.333  | 2.000  | 1.067 | 0.667 | 0.457 | 0.333 | 0.254 | 0.200 | 0.162 |
| 0.40                  | 25.600                     | 10.667 | 4.000  | 2.133 | 1.333 | 0.914 | 0.667 | 0.508 | 0.400 | 0.323 |
| 0.60                  | 38.400                     | 16.000 | 6.000  | 3.200 | 2.000 | 1.371 | 1.000 | 0.762 | 0.600 | 0.485 |
| 0.80                  | 51.200                     | 21.333 | 8.000  | 4.267 | 2.667 | 1.829 | 1.333 | 1.016 | 0.800 | 0.646 |
| 1.00                  | 64.000                     | 26.667 | 10.000 | 5.333 | 3.333 | 2.286 | 1.667 | 1.270 | 1.000 | 0.808 |
| <b>IEC SHORT TIME</b> |                            |        |        |       |       |       |       |       |       |       |
| 0.05                  | 0.153                      | 0.089  | 0.056  | 0.044 | 0.038 | 0.034 | 0.031 | 0.029 | 0.027 | 0.026 |
| 0.10                  | 0.306                      | 0.178  | 0.111  | 0.088 | 0.075 | 0.067 | 0.062 | 0.058 | 0.054 | 0.052 |
| 0.20                  | 0.612                      | 0.356  | 0.223  | 0.175 | 0.150 | 0.135 | 0.124 | 0.115 | 0.109 | 0.104 |
| 0.40                  | 1.223                      | 0.711  | 0.445  | 0.351 | 0.301 | 0.269 | 0.247 | 0.231 | 0.218 | 0.207 |
| 0.60                  | 1.835                      | 1.067  | 0.668  | 0.526 | 0.451 | 0.404 | 0.371 | 0.346 | 0.327 | 0.311 |
| 0.80                  | 2.446                      | 1.423  | 0.890  | 0.702 | 0.602 | 0.538 | 0.494 | 0.461 | 0.435 | 0.415 |
| 1.00                  | 3.058                      | 1.778  | 1.113  | 0.877 | 0.752 | 0.673 | 0.618 | 0.576 | 0.544 | 0.518 |

**IAC CURVES:**

The curves for the General Electric type IAC relay family are derived from the formulae:

$$T = TDM \times \left( A + \frac{B}{(I/I_{pkp}) - C} + \frac{D}{((I/I_{pkp}) - C)^2} + \frac{E}{((I/I_{pkp}) - C)^3} \right), T_{RESET} = TDM \times \left[ \frac{t_r}{(I/I_{pkp})^2 - 1} \right] \quad (\text{EQ 5.7})$$

where:  $T$  = operate time (in seconds),  $TDM$  = Multiplier setting,  $I$  = Input current,  $I_{pkp}$  = Pickup Current setting,  $A$  to  $E$  = constants,  $t_r$  = characteristic constant, and  $T_{RESET}$  = reset time in seconds (assuming energy capacity is 100% and RESET is "Timed")

**Table 5-14: GE TYPE IAC INVERSE TIME CURVE CONSTANTS**

| IAC CURVE SHAPE     | A      | B      | C      | D       | E      | T <sub>R</sub> |
|---------------------|--------|--------|--------|---------|--------|----------------|
| IAC Extreme Inverse | 0.0040 | 0.6379 | 0.6200 | 1.7872  | 0.2461 | 6.008          |
| IAC Very Inverse    | 0.0900 | 0.7955 | 0.1000 | -1.2885 | 7.9586 | 4.678          |
| IAC Inverse         | 0.2078 | 0.8630 | 0.8000 | -0.4180 | 0.1947 | 0.990          |
| IAC Short Inverse   | 0.0428 | 0.0609 | 0.6200 | -0.0010 | 0.0221 | 0.222          |

**Table 5-15: IAC CURVE TRIP TIMES**

| MULTIPLIER<br>(TDM)          | CURRENT ( $I/I_{pickup}$ ) |        |       |       |       |       |       |       |       |       |
|------------------------------|----------------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
|                              | 1.5                        | 2.0    | 3.0   | 4.0   | 5.0   | 6.0   | 7.0   | 8.0   | 9.0   | 10.0  |
| <b>IAC EXTREMELY INVERSE</b> |                            |        |       |       |       |       |       |       |       |       |
| 0.5                          | 1.699                      | 0.749  | 0.303 | 0.178 | 0.123 | 0.093 | 0.074 | 0.062 | 0.053 | 0.046 |
| 1.0                          | 3.398                      | 1.498  | 0.606 | 0.356 | 0.246 | 0.186 | 0.149 | 0.124 | 0.106 | 0.093 |
| 2.0                          | 6.796                      | 2.997  | 1.212 | 0.711 | 0.491 | 0.372 | 0.298 | 0.248 | 0.212 | 0.185 |
| 4.0                          | 13.591                     | 5.993  | 2.423 | 1.422 | 0.983 | 0.744 | 0.595 | 0.495 | 0.424 | 0.370 |
| 6.0                          | 20.387                     | 8.990  | 3.635 | 2.133 | 1.474 | 1.115 | 0.893 | 0.743 | 0.636 | 0.556 |
| 8.0                          | 27.183                     | 11.987 | 4.846 | 2.844 | 1.966 | 1.487 | 1.191 | 0.991 | 0.848 | 0.741 |
| 10.0                         | 33.979                     | 14.983 | 6.058 | 3.555 | 2.457 | 1.859 | 1.488 | 1.239 | 1.060 | 0.926 |
| <b>IAC VERY INVERSE</b>      |                            |        |       |       |       |       |       |       |       |       |
| 0.5                          | 1.451                      | 0.656  | 0.269 | 0.172 | 0.133 | 0.113 | 0.101 | 0.093 | 0.087 | 0.083 |
| 1.0                          | 2.901                      | 1.312  | 0.537 | 0.343 | 0.266 | 0.227 | 0.202 | 0.186 | 0.174 | 0.165 |
| 2.0                          | 5.802                      | 2.624  | 1.075 | 0.687 | 0.533 | 0.453 | 0.405 | 0.372 | 0.349 | 0.331 |
| 4.0                          | 11.605                     | 5.248  | 2.150 | 1.374 | 1.065 | 0.906 | 0.810 | 0.745 | 0.698 | 0.662 |
| 6.0                          | 17.407                     | 7.872  | 3.225 | 2.061 | 1.598 | 1.359 | 1.215 | 1.117 | 1.046 | 0.992 |
| 8.0                          | 23.209                     | 10.497 | 4.299 | 2.747 | 2.131 | 1.813 | 1.620 | 1.490 | 1.395 | 1.323 |
| 10.0                         | 29.012                     | 13.121 | 5.374 | 3.434 | 2.663 | 2.266 | 2.025 | 1.862 | 1.744 | 1.654 |
| <b>IAC INVERSE</b>           |                            |        |       |       |       |       |       |       |       |       |
| 0.5                          | 0.578                      | 0.375  | 0.266 | 0.221 | 0.196 | 0.180 | 0.168 | 0.160 | 0.154 | 0.148 |
| 1.0                          | 1.155                      | 0.749  | 0.532 | 0.443 | 0.392 | 0.360 | 0.337 | 0.320 | 0.307 | 0.297 |
| 2.0                          | 2.310                      | 1.499  | 1.064 | 0.885 | 0.784 | 0.719 | 0.674 | 0.640 | 0.614 | 0.594 |
| 4.0                          | 4.621                      | 2.997  | 2.128 | 1.770 | 1.569 | 1.439 | 1.348 | 1.280 | 1.229 | 1.188 |
| 6.0                          | 6.931                      | 4.496  | 3.192 | 2.656 | 2.353 | 2.158 | 2.022 | 1.921 | 1.843 | 1.781 |
| 8.0                          | 9.242                      | 5.995  | 4.256 | 3.541 | 3.138 | 2.878 | 2.695 | 2.561 | 2.457 | 2.375 |
| 10.0                         | 11.552                     | 7.494  | 5.320 | 4.426 | 3.922 | 3.597 | 3.369 | 3.201 | 3.072 | 2.969 |
| <b>IAC SHORT INVERSE</b>     |                            |        |       |       |       |       |       |       |       |       |
| 0.5                          | 0.072                      | 0.047  | 0.035 | 0.031 | 0.028 | 0.027 | 0.026 | 0.026 | 0.025 | 0.025 |
| 1.0                          | 0.143                      | 0.095  | 0.070 | 0.061 | 0.057 | 0.054 | 0.052 | 0.051 | 0.050 | 0.049 |
| 2.0                          | 0.286                      | 0.190  | 0.140 | 0.123 | 0.114 | 0.108 | 0.105 | 0.102 | 0.100 | 0.099 |
| 4.0                          | 0.573                      | 0.379  | 0.279 | 0.245 | 0.228 | 0.217 | 0.210 | 0.204 | 0.200 | 0.197 |
| 6.0                          | 0.859                      | 0.569  | 0.419 | 0.368 | 0.341 | 0.325 | 0.314 | 0.307 | 0.301 | 0.296 |
| 8.0                          | 1.145                      | 0.759  | 0.559 | 0.490 | 0.455 | 0.434 | 0.419 | 0.409 | 0.401 | 0.394 |
| 10.0                         | 1.431                      | 0.948  | 0.699 | 0.613 | 0.569 | 0.542 | 0.524 | 0.511 | 0.501 | 0.493 |

**I<sup>2</sup>t CURVES:**

The curves for the I<sup>2</sup>t are derived from the formulae:

$$T = \text{TDM} \times \left[ \frac{100}{\left( \frac{I}{I_{pickup}} \right)^2} \right], \quad T_{RESET} = \text{TDM} \times \left[ \frac{100}{\left( \frac{I}{I_{pickup}} \right)^{-2}} \right] \quad (\text{EQ 5.8})$$

where:  $T$  = Operate Time (sec.); TDM = Multiplier Setting;  $I$  = Input Current;  $I_{pickup}$  = Pickup Current Setting;  
 $T_{RESET}$  = Reset Time in sec. (assuming energy capacity is 100% and RESET: Timed)

**Table 5–16: I<sup>2</sup>T CURVE TRIP TIMES**

| MULTIPLIER<br>(TDM) | CURRENT ( $I / I_{pickup}$ ) |         |        |        |        |        |        |        |        |        |
|---------------------|------------------------------|---------|--------|--------|--------|--------|--------|--------|--------|--------|
|                     | 1.5                          | 2.0     | 3.0    | 4.0    | 5.0    | 6.0    | 7.0    | 8.0    | 9.0    | 10.0   |
| 0.01                | 0.44                         | 0.25    | 0.11   | 0.06   | 0.04   | 0.03   | 0.02   | 0.02   | 0.01   | 0.01   |
| 0.10                | 4.44                         | 2.50    | 1.11   | 0.63   | 0.40   | 0.28   | 0.20   | 0.16   | 0.12   | 0.10   |
| 1.00                | 44.44                        | 25.00   | 11.11  | 6.25   | 4.00   | 2.78   | 2.04   | 1.56   | 1.23   | 1.00   |
| 10.00               | 444.44                       | 250.00  | 111.11 | 62.50  | 40.00  | 27.78  | 20.41  | 15.63  | 12.35  | 10.00  |
| 100.00              | 4444.4                       | 2500.0  | 1111.1 | 625.00 | 400.00 | 277.78 | 204.08 | 156.25 | 123.46 | 100.00 |
| 600.00              | 26666.7                      | 15000.0 | 6666.7 | 3750.0 | 2400.0 | 1666.7 | 1224.5 | 937.50 | 740.74 | 600.00 |

**FLEXCURVES™:**

The custom FlexCurves™ are described in detail in the FlexCurves™ section of this chapter. The curve shapes for the FlexCurves™ are derived from the formulae:

$$T = \text{TDM} \times \left[ \text{FlexCurve Time at } \left( \frac{I}{I_{pickup}} \right) \right] \quad \text{when } \left( \frac{I}{I_{pickup}} \right) \geq 1.00 \quad (\text{EQ 5.9})$$

$$T_{RESET} = \text{TDM} \times \left[ \text{FlexCurve Time at } \left( \frac{I}{I_{pickup}} \right) \right] \quad \text{when } \left( \frac{I}{I_{pickup}} \right) \leq 0.98 \quad (\text{EQ 5.10})$$

where:  $T$  = Operate Time (sec.), TDM = Multiplier setting  
 $I$  = Input Current,  $I_{pickup}$  = Pickup Current setting  
 $T_{RESET}$  = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

**DEFINITE TIME CURVE:**

The Definite Time curve shape operates as soon as the pickup level is exceeded for a specified period of time. The base definite time curve delay is in seconds. The curve multiplier of 0.00 to 600.00 makes this delay adjustable from instantaneous to 600.00 seconds in steps of 10 ms.

$$T = \text{TDM} \text{ in seconds, when } I > I_{pickup} \quad (\text{EQ 5.11})$$

$$T_{RESET} = -\text{TDM} \text{ in seconds} \quad (\text{EQ 5.12})$$

where:  $T$  = Operate Time (sec.), TDM = Multiplier setting  
 $I$  = Input Current,  $I_{pickup}$  = Pickup Current setting  
 $T_{RESET}$  = Reset Time in seconds (assuming energy capacity is 100% and RESET: Timed)

**RECLOSER CURVES:**

The D30 uses the FlexCurve™ feature to facilitate programming of 41 recloser curves. Please refer to the FlexCurve™ section in this chapter for additional details.



## c) PHASE TIME OVERCURRENT (ANSI 51P)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ PHASE CURRENT ⇒ PHASE TOC1(2)

|              |    |                      |   |
|--------------|----|----------------------|---|
| ■ PHASE TOC1 |    | PHASE TOC1           | Range: Disabled, Enabled                    |
| ■            |    | FUNCTION: Disabled   |   |
| MESSAGE      | ▲▼ | PHASE TOC1 SIGNAL    | Range: SRC 1, SRC 2                         |
|              |    | SOURCE: SRC 1        |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: Phasor, RMS                          |
|              |    | INPUT: Phasor        |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: 0.000 to 30.000 pu in steps of 0.001 |
|              |    | PICKUP: 1.000 pu     |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: See Overcurrent Curve Types table    |
|              |    | CURVE: IEEE Mod Inv  |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: 0.00 to 600.00 in steps of 0.01      |
|              |    | TD MULTIPLIER: 1.00  |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: Instantaneous, Timed                 |
|              |    | RESET: Instantaneous |   |
| MESSAGE      | ▲▼ | PHASE TOC1 VOLTAGE   | Range: Disabled, Enabled                    |
|              |    | RESTRAINT: Disabled  |   |
| MESSAGE      | ▲▼ | PHASE TOC1 BLOCK A:  | Range: FlexLogic™ operand                   |
|              |    | Off                  |   |
| MESSAGE      | ▲▼ | PHASE TOC1 BLOCK B:  | Range: FlexLogic™ operand                   |
|              |    | Off                  |   |
| MESSAGE      | ▲▼ | PHASE TOC1 BLOCK C:  | Range: FlexLogic™ operand                   |
|              |    | Off                  |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: Self-reset, Latched, Disabled        |
|              |    | TARGET: Self-reset   |   |
| MESSAGE      | ▲▼ | PHASE TOC1           | Range: Disabled, Enabled                    |
|              |    | EVENTS: Disabled     |   |

The phase time overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple Definite Time element. The phase current input quantities may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: “Timed” and “Instantaneous” (refer to the *Inverse TOC Curves Characteristic* sub-section earlier for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.

The **PHASE TOC1 PICKUP** setting can be dynamically reduced by a voltage restraint feature (when enabled). This is accomplished via the multipliers (Mvr) corresponding to the phase-phase voltages of the voltage restraint characteristic curve (see the figure below); the pickup level is calculated as ‘Mvr’ times the **PHASE TOC1 PICKUP** setting. If the voltage restraint feature is disabled, the pickup level always remains at the setting value.

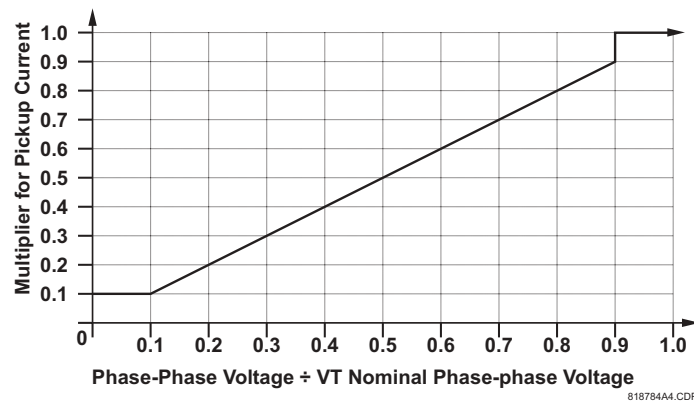


Figure 5-62: PHASE TOC VOLTAGE RESTRAINT CHARACTERISTIC

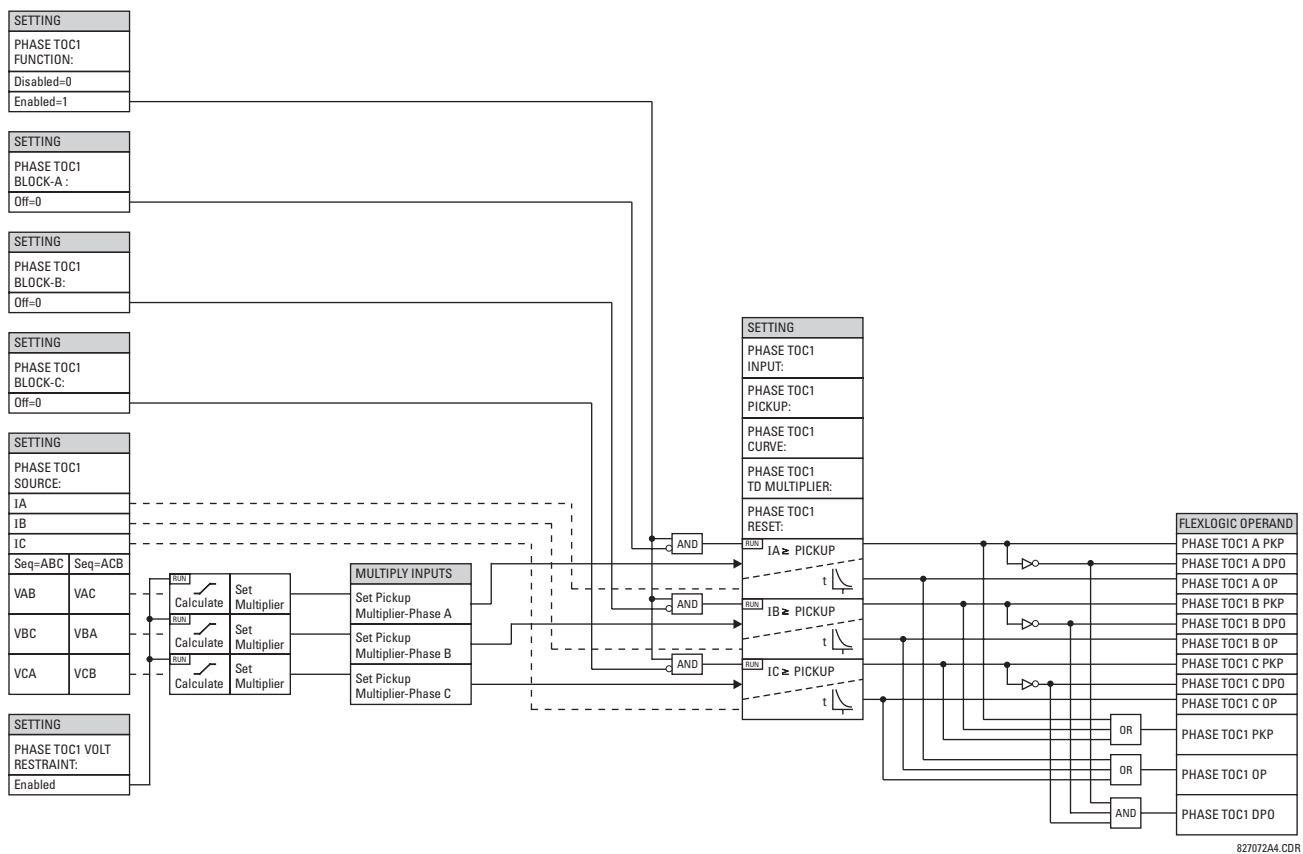


Figure 5-63: PHASE TOC1 SCHEME LOGIC

## d) PHASE INSTANTANEOUS OVERCURRENT (ANSI 50P)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ PHASE CURRENT ⇒ PHASE IOC 1(2)

|              |    |                                    |   |
|--------------|----|------------------------------------|---|
| ■ PHASE IOC1 |    | PHASE IOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                    |
| MESSAGE      | ▲▼ | PHASE IOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                         |
| MESSAGE      | ▲▼ | PHASE IOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE      | ▲▼ | PHASE IOC1 PICKUP<br>DELAY: 0.00 s | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE      | ▲▼ | PHASE IOC1 RESET<br>DELAY: 0.00 s  | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE      | ▲▼ | PHASE IOC1 BLOCK A:<br>Off         | Range: FlexLogic™ operand                   |
| MESSAGE      | ▲▼ | PHASE IOC1 BLOCK B:<br>Off         | Range: FlexLogic™ operand                   |
| MESSAGE      | ▲▼ | PHASE IOC1 BLOCK C:<br>Off         | Range: FlexLogic™ operand                   |
| MESSAGE      | ▲▼ | PHASE IOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled        |
| MESSAGE      | ▲  | PHASE IOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                    |

The phase instantaneous overcurrent element may be used as an instantaneous element with no intentional delay or as a Definite Time element. The input current is the fundamental phasor magnitude.

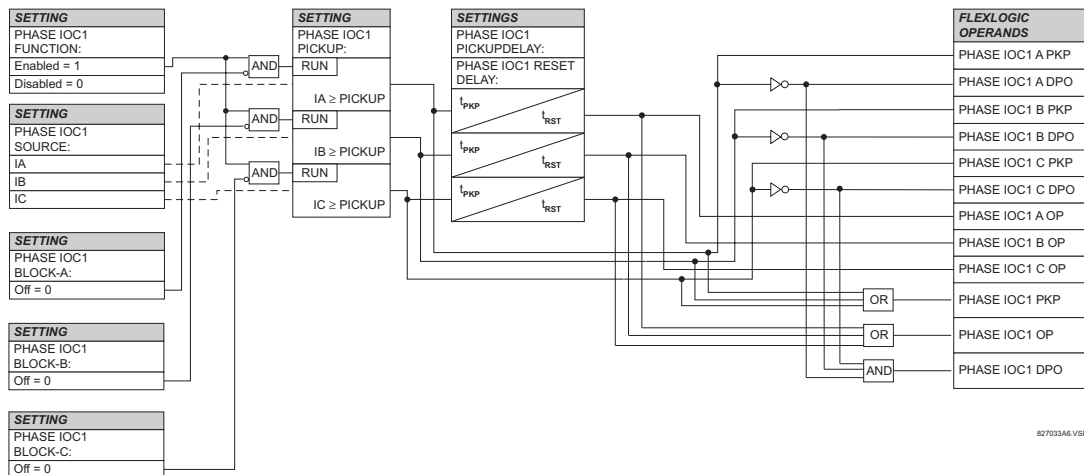


Figure 5-64: PHASE IOC1 SCHEME LOGIC

## e) PHASE DIRECTIONAL OVERCURRENT (ANSI 67P)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ PHASE CURRENT ⇒ PHASE DIRECTIONAL 1(2)

|                 |    |                     |  |
|-----------------|----|---------------------|--|
| ■ PHASE         |    | PHASE DIR 1         | Range: Disabled, Enabled                   |
| ■ DIRECTIONAL 1 |    | FUNCTION: Disabled  |  |
| MESSAGE         | ▲▼ | PHASE DIR 1 SIGNAL  | Range: SRC 1, SRC 2                        |
|                 |    | SOURCE: SRC 1       |  |
| MESSAGE         | ▲▼ | PHASE DIR 1 BLOCK:  | Range: FlexLogic™ operand                  |
|                 |    | Off                 |  |
| MESSAGE         | ▲▼ | PHASE DIR 1         | Range: 0 to 359° in steps of 1             |
|                 |    | ECA: 30             |  |
| MESSAGE         | ▲▼ | PHASE DIR POL V1    | Range: 0.000 to 3.000 pu in steps of 0.001 |
|                 |    | THRESHOLD: 0.700 pu |  |
| MESSAGE         | ▲▼ | PHASE DIR 1 BLOCK   | Range: No, Yes                             |
|                 |    | WHEN V MEM EXP: No  |  |
| MESSAGE         | ▲▼ | PHASE DIR 1         | Range: Self-reset, Latched, Disabled       |
|                 |    | TARGET: Self-reset  |  |
| MESSAGE         | ▲▼ | PHASE DIR 1         | Range: Disabled, Enabled                   |
|                 |    | EVENTS: Disabled    |  |

The phase directional elements (one for each of phases A, B, and C) determine the phase current flow direction for steady state and fault conditions and can be used to control the operation of the phase overcurrent elements via the **BLOCK** inputs of these elements.

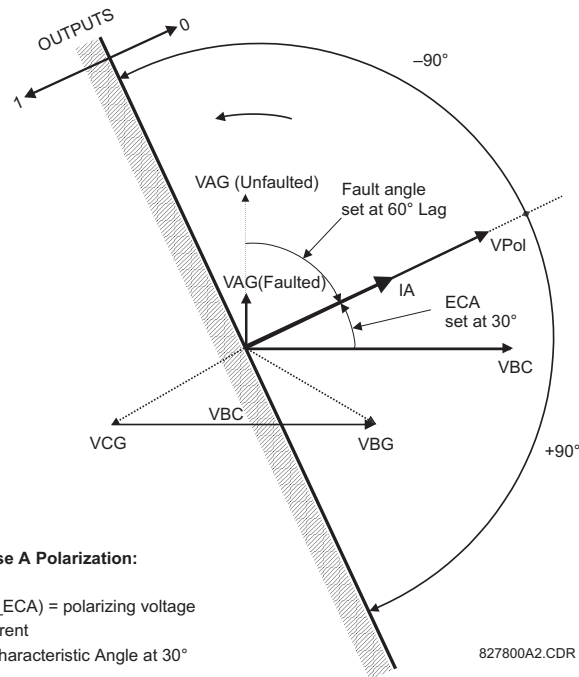


Figure 5-65: PHASE A DIRECTIONAL POLARIZATION

This element is intended to apply a block signal to an overcurrent element to prevent an operation when current is flowing in a particular direction. The direction of current flow is determined by measuring the phase angle between the current from the phase CTs and the line-line voltage from the VTs, based on the 90° or 'quadrature' connection. If there is a requirement to supervise overcurrent elements for flows in opposite directions, such as can happen through a bus-tie breaker, two phase directional elements should be programmed with opposite ECA settings.

To increase security for three phase faults very close to the VTs used to measure the polarizing voltage, a 'voltage memory' feature is incorporated. This feature stores the polarizing voltage the moment before the voltage collapses, and uses it to determine direction. The voltage memory remains valid for one second after the voltage has collapsed.

The main component of the phase directional element is the phase angle comparator with two inputs: the operating signal (phase current) and the polarizing signal (the line voltage, shifted in the leading direction by the characteristic angle, ECA).

The following table shows the operating and polarizing signals used for phase directional control:

| PHASE | OPERATING SIGNAL | POLARIZING SIGNAL $V_{pol}$         |                                     |
|-------|------------------|-------------------------------------|-------------------------------------|
|       |                  | ABC PHASE SEQUENCE                  | ACB PHASE SEQUENCE                  |
| A     | Angle of IA      | Angle of VBC $\times (1\angle ECA)$ | Angle of VCB $\times (1\angle ECA)$ |
| B     | Angle of IB      | Angle of VCA $\times (1\angle ECA)$ | Angle of VAC $\times 1\angle ECA)$  |
| C     | Angle of IC      | Angle of VAB $\times (1\angle ECA)$ | Angle of VBA $\times (1\angle ECA)$ |

#### MODE OF OPERATION:

- When the function is "Disabled", or the operating current is below  $5\% \times CT$  nominal, the element output is "0".
- When the function is "Enabled", the operating current is above  $5\% \times CT$  nominal, and the polarizing voltage is above the set threshold, the element output is dependent on the phase angle between the operating and polarizing signals:
  - The element output is logic "0" when the operating current is within polarizing voltage  $\pm 90^\circ$ .
  - For all other angles, the element output is logic "1".
- Once the voltage memory has expired, the phase overcurrent elements under directional control can be set to block or trip on overcurrent as follows:
  - When **BLOCK WHEN V MEM EXP** is set to "Yes", the directional element will block the operation of any phase overcurrent element under directional control when voltage memory expires.
  - When **BLOCK WHEN V MEM EXP** is set to "No", the directional element allows tripping of phase overcurrent elements under directional control when voltage memory expires.

In all cases, directional blocking will be permitted to resume when the polarizing voltage becomes greater than the 'polarizing voltage threshold'.

#### SETTINGS:

- PHASE DIR 1 SIGNAL SOURCE:** This setting is used to select the source for the operating and polarizing signals. The operating current for the phase directional element is the phase current for the selected current source. The polarizing voltage is the line voltage from the phase VTs, based on the  $90^\circ$  or 'quadrature' connection and shifted in the leading direction by the element characteristic angle (ECA).
- PHASE DIR 1 ECA:** This setting is used to select the element characteristic angle, i.e. the angle by which the polarizing voltage is shifted in the leading direction to achieve dependable operation. In the design of the UR-series elements, a block is applied to an element by asserting logic 1 at the blocking input. This element should be programmed via the ECA setting so that the output is **logic 1 for current in the non-tripping direction**.
- PHASE DIR 1 POL V THRESHOLD:** This setting is used to establish the minimum level of voltage for which the phase angle measurement is reliable. The setting is based on VT accuracy. The default value is "0.05 pu".
- PHASE DIR 1 BLOCK WHEN V MEM EXP:** This setting is used to select the required operation upon expiration of voltage memory. When set to "Yes", the directional element blocks the operation of any phase overcurrent element under directional control, when voltage memory expires; when set to "No", the directional element allows tripping of phase overcurrent elements under directional control.



**The Phase Directional element responds to the forward load current. In the case of a following reverse fault, the element needs some time – in the order of 8 ms – to establish a blocking signal. Some protection elements such as instantaneous overcurrent may respond to reverse faults before the blocking signal is established. Therefore, a coordination time of at least 10 ms must be added to all the instantaneous protection elements under the supervision of the Phase Directional element. If current reversal is of a concern, a longer delay – in the order of 20 ms – may be needed.**

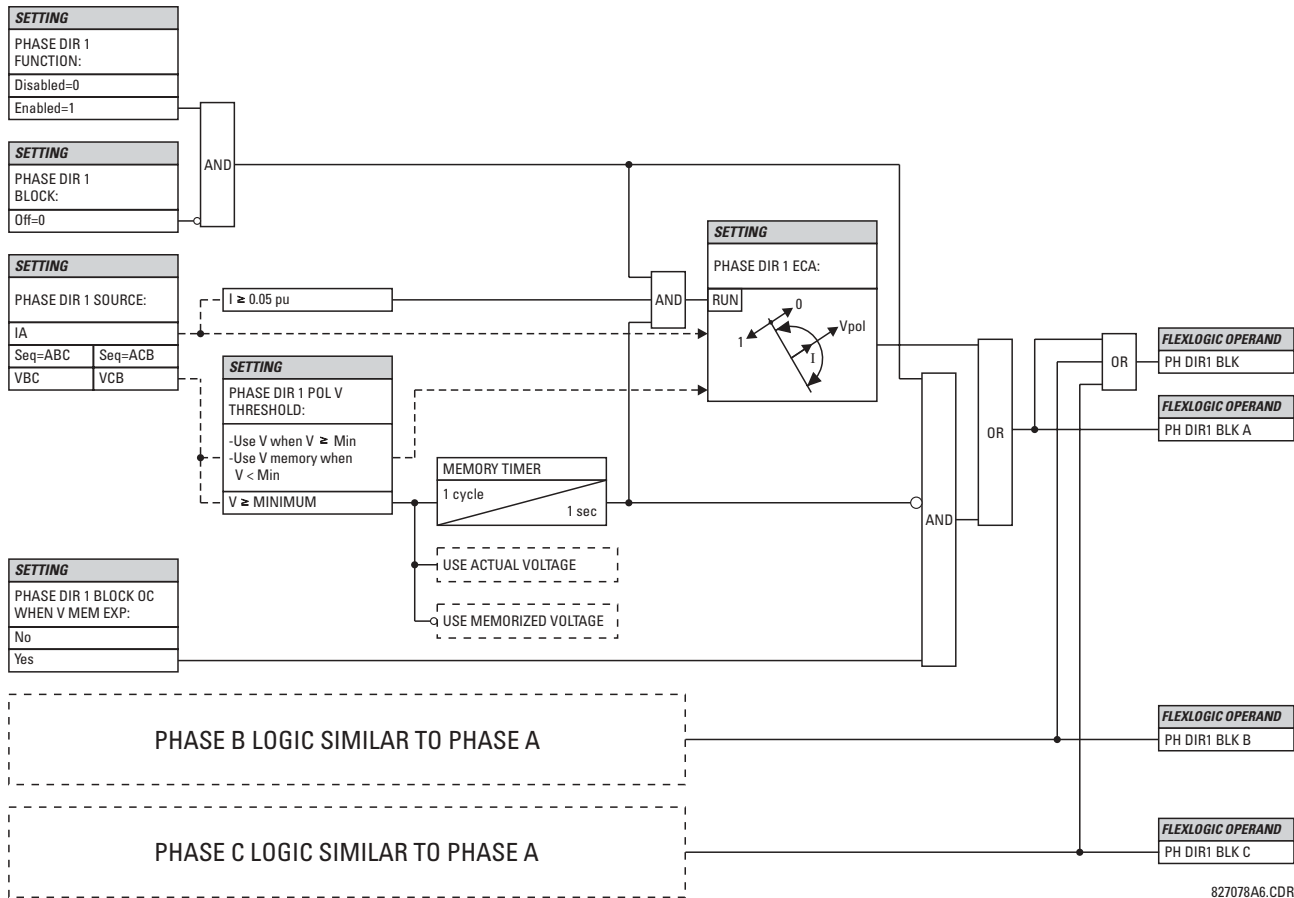


Figure 5-66: PHASE DIRECTIONAL SCHEME LOGIC

## 5.5.8 NEUTRAL CURRENT

## a) MAIN MENU

PATH: SETTINGS ⇨ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ NEUTRAL CURRENT

|                   |     |                              |                 |
|-------------------|-----|------------------------------|-----------------|
| ■ NEUTRAL CURRENT | ⏮ ⏭ | ■ NEUTRAL TOC1               | See page 5-109. |
| ■                 | ⏮ ⏭ | ■ NEUTRAL TOC2               | See page 5-109. |
| MESSAGE           | ⏮ ⏭ | ■ NEUTRAL IOC1               | See page 5-110. |
| MESSAGE           | ⏮ ⏭ | ■ NEUTRAL IOC2               | See page 5-110. |
| MESSAGE           | ⏮ ⏭ | ■ NEUTRAL<br>■ DIRECTIONAL 1 | See page 5-111. |
| MESSAGE           | ⏮ ⏭ | ■ NEUTRAL<br>■ DIRECTIONAL 2 | See page 5-111. |

## b) NEUTRAL TIME OVERCURRENT (ANSI 51N)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ NEUTRAL CURRENT ⇒ NEUTRAL TOC1(2)

|                |    |                                      |   |
|----------------|----|--------------------------------------|---|
| ■ NEUTRAL TOC1 | ◀▶ | NEUTRAL TOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                    |
| MESSAGE        | ▲▼ | NEUTRAL TOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                         |
| MESSAGE        | ▲▼ | NEUTRAL TOC1<br>INPUT: Phasor        | Range: Phasor, RMS                          |
| MESSAGE        | ▲▼ | NEUTRAL TOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE        | ▲▼ | NEUTRAL TOC1<br>CURVE: IEEE Mod Inv  | Range: See OVERCURRENT CURVE TYPES table    |
| MESSAGE        | ▲▼ | NEUTRAL TOC1<br>TD MULTIPLIER: 1.00  | Range: 0.00 to 600.00 in steps of 0.01      |
| MESSAGE        | ▲▼ | NEUTRAL TOC1<br>RESET: Instantaneous | Range: Instantaneous, Timed                 |
| MESSAGE        | ▲▼ | NEUTRAL TOC1 BLOCK:<br>Off           | Range: FlexLogic™ operand                   |
| MESSAGE        | ▲▼ | NEUTRAL TOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled        |
| MESSAGE        | ▲  | NEUTRAL TOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                    |

The Neutral Time Overcurrent element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple Definite Time element. The neutral current input value is a quantity calculated as  $3I_0$  from the phase currents and may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application.

Two methods of resetting operation are available: “Timed” and “Instantaneous” (refer to the *Inverse TOC Curve Characteristics* section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.

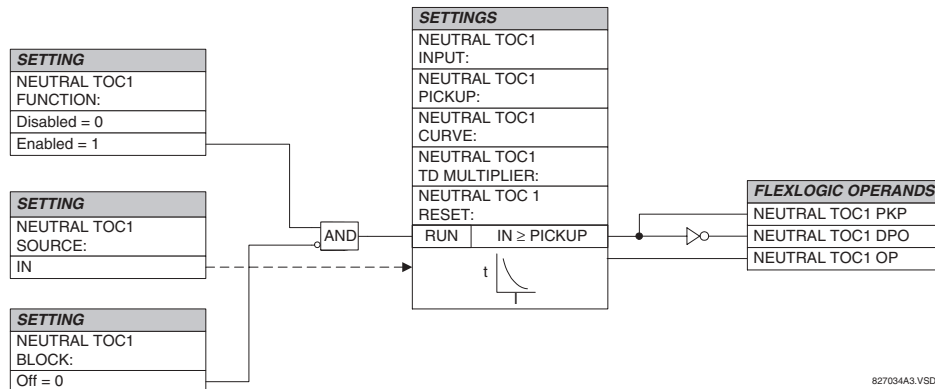


Figure 5-67: NEUTRAL TOC1 SCHEME LOGIC

## c) NEUTRAL INSTANTANEOUS OVERCURRENT (ANSI 50N)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ NEUTRAL CURRENT ⇒ NEUTRAL IOC1(2)

|                |    |                                      |   |
|----------------|----|--------------------------------------|---|
| ■ NEUTRAL IOC1 | ◀▶ | NEUTRAL IOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                    |
| MESSAGE        | ▲▼ | NEUTRAL IOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                         |
| MESSAGE        | ▲▼ | NEUTRAL IOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE        | ▲▼ | NEUTRAL IOC1 PICKUP<br>DELAY: 0.00 s | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE        | ▲▼ | NEUTRAL IOC1 RESET<br>DELAY: 0.00 s  | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE        | ▲▼ | NEUTRAL IOC1 BLOCK:<br>Off           | Range: FlexLogic™ operand                   |
| MESSAGE        | ▲▼ | NEUTRAL IOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled        |
| MESSAGE        | ▲  | NEUTRAL IOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                    |

The Neutral Instantaneous Overcurrent element may be used as an instantaneous function with no intentional delay or as a Definite Time function. The element essentially responds to the magnitude of a neutral current fundamental frequency phasor calculated from the phase currents. A “positive-sequence restraint” is applied for better performance. A small portion (6.25%) of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity of the element as follows:

$$I_{op} = 3 \times (|I_0| - K \cdot |I_1|) \quad \text{where } K = 1/16 \quad (\text{EQ 5.13})$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- system unbalances under heavy load conditions
- transformation errors of current transformers (CTs) during double-line and three-phase faults
- switch-off transients during double-line and three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on how test currents are injected into the relay (single-phase injection:  $I_{op} = 0.9375 \cdot I_{injected}$ ; three-phase pure zero-sequence injection:  $I_{op} = 3 \times I_{injected}$ ).

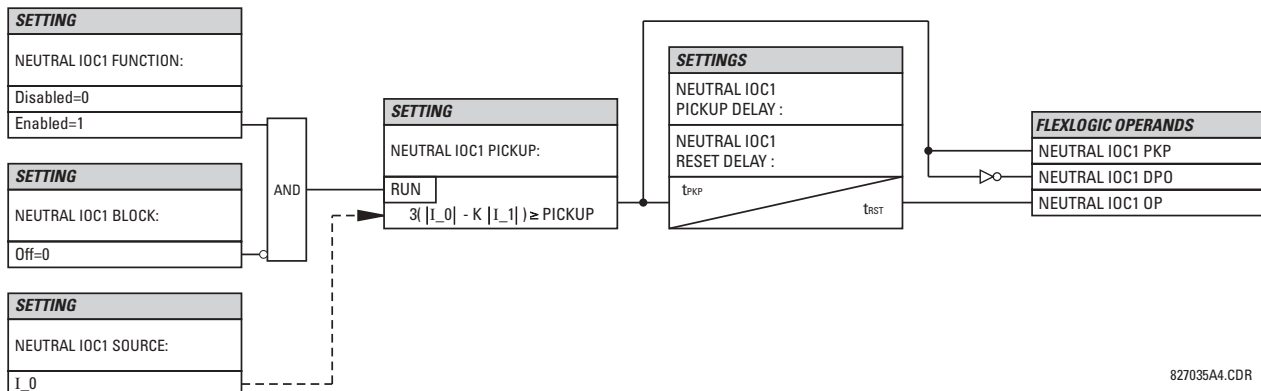


Figure 5-68: NEUTRAL IOC1 SCHEME LOGIC



## d) NEUTRAL DIRECTIONAL OVERCURRENT (ANSI 67N)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ NEUTRAL CURRENT ⇒ NEUTRAL DIRECTIONAL OC1(2)

|                                |         |  |   |
|--------------------------------|---------|--|---|
| ■ NEUTRAL<br>■ DIRECTIONAL OC1 |         | NEUTRAL DIR OC1<br>FUNCTION: Disabled        | Range: Disabled, Enabled                    |
|                                | MESSAGE | NEUTRAL DIR OC1<br>SOURCE: SRC 1             | Range: SRC 1, SRC 2                         |
|                                | MESSAGE | NEUTRAL DIR OC1<br>POLARIZING: Voltage       | Range: Voltage, Current, Dual               |
|                                | MESSAGE | NEUTRAL DIR OC1 POL<br>VOLT: Calculated V0   | Range: Calculated V0, Measured VX           |
|                                | MESSAGE | NEUTRAL DIR OC1 OP<br>CURR: Calculated 3I0   | Range: Calculated 3I0, Measured IG          |
|                                | MESSAGE | NEUTRAL DIR OC1 POS-<br>SEQ RESTRAINT: 0.063 | Range: 0.000 to 0.500 in steps of 0.001     |
|                                | MESSAGE | NEUTRAL DIR OC1<br>OFFSET: 0.00 Ω            | Range: 0.00 to 250.00 Ω in steps of 0.01    |
|                                | MESSAGE | NEUTRAL DIR OC1 FWD<br>ECA: 75° Lag          | Range: -90 to 90° in steps of 1             |
|                                | MESSAGE | NEUTRAL DIR OC1 FWD<br>LIMIT ANGLE: 90°      | Range: 40 to 90° in steps of 1              |
|                                | MESSAGE | NEUTRAL DIR OC1 FWD<br>PICKUP: 0.050 pu      | Range: 0.002 to 30.000 pu in steps of 0.001 |
|                                | MESSAGE | NEUTRAL DIR OC1 REV<br>LIMIT ANGLE: 90°      | Range: 40 to 90° in steps of 1              |
|                                | MESSAGE | NEUTRAL DIR OC1 REV<br>PICKUP: 0.050 pu      | Range: 0.002 to 30.000 pu in steps of 0.001 |
|                                | MESSAGE | NEUTRAL DIR OC1 BLK:<br>Off                  | Range: FlexLogic™ operand                   |
|                                | MESSAGE | NEUTRAL DIR OC1<br>TARGET: Self-reset        | Range: Self-reset, Latched, Disabled        |
|                                | MESSAGE | NEUTRAL DIR OC1<br>EVENTS: Disabled          | Range: Disabled, Enabled                    |

There are two Neutral Directional Overcurrent protection elements available. The element provides both forward and reverse fault direction indications the NEUTRAL DIR OC1 FWD and NEUTRAL DIR OC1 REV operands, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as “forward or “reverse”, respectively (directional unit).

The **overcurrent unit** responds to the magnitude of a fundamental frequency phasor of the either the neutral current calculated from the phase currents or the ground current. There are two separate pickup settings for the forward- and reverse-looking functions, respectively. If set to use the calculated 3I<sub>0</sub>, the element applies a “positive-sequence restraint” for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the zero-sequence current magnitude when forming the operating quantity.

$$I_{op} = 3 \times (|I_0| - K \times |I_1|) \quad (\text{EQ 5.14})$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious zero-sequence currents resulting from:

- System unbalances under heavy load conditions.

- Transformation errors of current transformers (CTs) during double-line and three-phase faults.
- Switch-off transients during double-line and three-phase faults.

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay (single-phase injection:  $I_{op} = (1 - K) \times I_{injected}$ ; three-phase pure zero-sequence injection:  $I_{op} = 3 \times I_{injected}$ ).

The positive-sequence restraint is removed for low currents. If the positive-sequence current is below 0.8 pu, the restraint is removed by changing the constant  $K$  to zero. This facilitates better response to high-resistance faults when the unbalance is very small and there is no danger of excessive CT errors as the current is low.

The **directional unit** uses the zero-sequence current ( $I_0$ ) or ground current (IG) for fault direction discrimination and may be programmed to use either zero-sequence voltage ("Calculated V0" or "Measured VX"), ground current (IG), or both for polarizing. The following tables define the neutral directional overcurrent element.

**Table 5–17: QUANTITIES FOR "CALCULATED 3I0" CONFIGURATION**

| DIRECTIONAL UNIT |           |                                 |                            | OVERCURRENT UNIT  |
|------------------|-----------|---------------------------------|----------------------------|---|
| POLARIZING MODE  | DIRECTION | COMPARED PHASORS                |                            |   |
| Voltage          | Forward   | $-V\_0 + Z\_offset \times I\_0$ | $I\_0 \times 1\angle ECA$  | $I_{op} = 3 \times ( I\_0  - K \times  I\_1 )$ if $ I_1  > 0.8$ pu<br>$I_{op} = 3 \times ( I\_0 )$ if $ I_1  \leq 0.8$ pu |
|                  | Reverse   | $-V\_0 + Z\_offset \times I\_0$ | $-I\_0 \times 1\angle ECA$ |   |
| Current          | Forward   | IG                              | $I\_0$                     |   |
|                  | Reverse   | IG                              | $-I\_0$                    |   |
| Dual             | Forward   | $-V\_0 + Z\_offset \times I\_0$ | $I\_0 \times 1\angle ECA$  |   |
|                  |           | or                              |                            |   |
|                  |           | IG                              | $I\_0$                     |   |
|                  | Reverse   | $-V\_0 + Z\_offset \times I\_0$ | $-I\_0 \times 1\angle ECA$ |   |
|                  |           | or                              |                            |   |
|                  |           | IG                              | $-I\_0$                    |   |

**Table 5–18: QUANTITIES FOR "MEASURED IG" CONFIGURATION**

| DIRECTIONAL UNIT |           |                                 |                           | OVERCURRENT UNIT |
|------------------|-----------|---------------------------------|---------------------------|------------------|
| POLARIZING MODE  | DIRECTION | COMPARED PHASORS                |                           |                  |
| Voltage          | Forward   | $-V\_0 + Z\_offset \times IG/3$ | $IG \times 1 \angle ECA$  | $I_{op} =  IG $  |
|                  | Reverse   | $-V\_0 + Z\_offset \times IG/3$ | $-IG \times 1 \angle ECA$ |                  |

where:  $V_0 = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$  = zero sequence voltage ,

$I_0 = \frac{1}{3}I_N = \frac{1}{3}(I_A + I_B + I_C)$  = zero sequence current ,

ECA = element characteristic angle and IG = ground current

When **NEUTRAL DIR OC1 POL VOLT** is set to "Measured VX", one-third of this voltage is used in place of  $V_0$ . The following figure explains the usage of the voltage polarized directional unit of the element.

The figure below shows the voltage-polarized phase angle comparator characteristics for a phase A to ground fault, with:

ECA = 90° (element characteristic angle = centerline of operating characteristic)

FWD LA = 80° (forward limit angle = the ± angular limit with the ECA for operation)

REV LA = 80° (reverse limit angle = the ± angular limit with the ECA for operation)

The element incorporates a current reversal logic: if the reverse direction is indicated for at least 1.25 of a power system cycle, the prospective forward indication will be delayed by 1.5 of a power system cycle. The element is designed to emulate an electromechanical directional device. Larger operating and polarizing signals will result in faster directional discrimination bringing more security to the element operation.

The forward-looking function is designed to be more secure as compared to the reverse-looking function, and therefore, should be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and should be used for the blocking direction. This allows for better protection coordination.

The above bias should be taken into account when using the neutral directional overcurrent element to directionalize other protection elements.

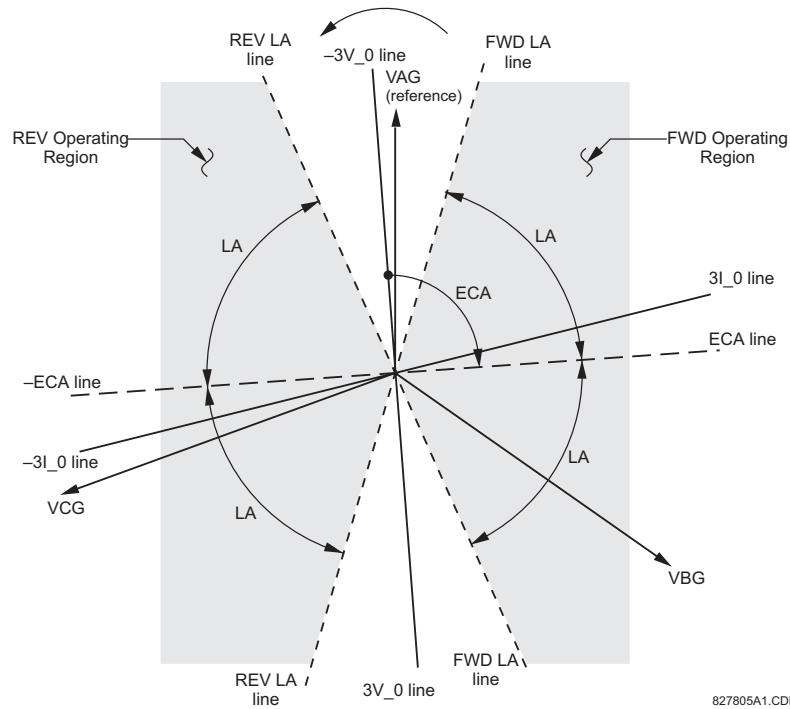


Figure 5-69: NEUTRAL DIRECTIONAL VOLTAGE-POLARIZED CHARACTERISTICS

- **NEUTRAL DIR OC1 POLARIZING:** This setting selects the polarizing mode for the directional unit.
  - If “Voltage” polarizing is selected, the element uses the zero-sequence voltage angle for polarization. The user can use either the zero-sequence voltage  $V_0$  calculated from the phase voltages, or the zero-sequence voltage supplied externally as the auxiliary voltage  $V_x$ , both from the **NEUTRAL DIR OC1 SOURCE**.  
 The calculated  $V_0$  can be used as polarizing voltage only if the voltage transformers are connected in Wye. The auxiliary voltage can be used as the polarizing voltage provided **SYSTEM SETUP** ⇒ **AC INPUTS** ⇒ **VOLTAGE BANK** ⇒ **AUXILIARY VT CONNECTION** is set to “Vn” and the auxiliary voltage is connected to a zero-sequence voltage source (such as open delta connected secondary of VTs).  
 The zero-sequence ( $V_0$ ) or auxiliary voltage ( $V_x$ ), accordingly, must be higher than 0.02 pu nominal voltage to be validated as a polarizing signal. If the polarizing signal is invalid, neither forward nor reverse indication is given.
  - If “Current” polarizing is selected, the element uses the ground current angle connected externally and configured under **NEUTRAL OC1 SOURCE** for polarization. The Ground CT must be connected between the ground and neutral point of an adequate local source of ground current. The ground current must be higher than 0.05 pu to be validated as a polarizing signal. If the polarizing signal is not valid, neither forward nor reverse indication is given.  
 For a choice of current polarizing, it is recommended that the polarizing signal be analyzed to ensure that a known direction is maintained irrespective of the fault location. For example, if using an autotransformer neutral current as a polarizing source, it should be ensured that a reversal of the ground current does not occur for a high-side fault. The low-side system impedance should be assumed minimal when checking for this condition. A similar situation arises for a Wye/Delta/Wye transformer, where current in one transformer winding neutral may reverse when faults on both sides of the transformer are considered.
  - If “Dual” polarizing is selected, the element performs both directional comparisons as described above. A given direction is confirmed if either voltage or current comparators indicate so. If a conflicting (simultaneous forward and reverse) indication occurs, the forward direction overrides the reverse direction.
- **NEUTRAL DIR OC1 POL VOLT:** Selects the polarizing voltage used by the directional unit when “Voltage” or “Dual” polarizing mode is set. The polarizing voltage can be programmed to be either the zero-sequence voltage calculated from the phase voltages (“Calculated  $V_0$ ”) or supplied externally as an auxiliary voltage (“Measured  $V_X$ ”).

- **NEUTRAL DIR OC1 OP CURR:** This setting indicates whether the 3I<sub>0</sub> current calculated from the phase currents, or the ground current shall be used by this protection. This setting acts as a switch between the neutral and ground modes of operation (67N and 67G). If set to "Calculated 3I<sub>0</sub>" the element uses the phase currents and applies the positive-sequence restraint; if set to "Measured IG" the element uses ground current supplied to the ground CT of the CT bank configured as **NEUTRAL DIR OC1 SOURCE**. Naturally, it is not possible to use the ground current as an operating and polarizing signal simultaneously. Therefore, "Voltage" is the only applicable selection for the polarizing mode under the "Measured IG" selection of this setting.
- **NEUTRAL DIR OC1 POS-SEQ RESTRAINT:** This setting controls the amount of the positive-sequence restraint. Set to 0.063 for backward compatibility with firmware revision 3.40 and older. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.
- **NEUTRAL DIR OC1 OFFSET:** This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines. See the Chapter 9 for information on how to calculate this setting. In regular applications, the offset impedance ensures proper operation even if the zero-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the zero-sequence impedance of the protected circuit. Practically, it shall be several times smaller. See Chapter 8 for additional details. The offset impedance shall be entered in secondary ohms.
- **NEUTRAL DIR OC1 FWD ECA:** This setting defines the characteristic angle (ECA) for the forward direction in the "Voltage" polarizing mode. The "Current" polarizing mode uses a fixed ECA of 0°. The ECA in the reverse direction is the angle set for the forward direction shifted by 180°.
- **NEUTRAL DIR OC1 FWD LIMIT ANGLE:** This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.
- **NEUTRAL DIR OC1 FWD PICKUP:** This setting defines the pickup level for the overcurrent unit of the element in the forward direction. When selecting this setting it must be kept in mind that the design uses a 'positive-sequence restraint' technique for the "Calculated 3I<sub>0</sub>" mode of operation.
- **NEUTRAL DIR OC1 REV LIMIT ANGLE:** This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.
- **NEUTRAL DIR OC1 REV PICKUP:** This setting defines the pickup level for the overcurrent unit of the element in the reverse direction. When selecting this setting it must be kept in mind that the design uses a 'positive-sequence restraint' technique for the "Calculated 3I<sub>0</sub>" mode of operation.

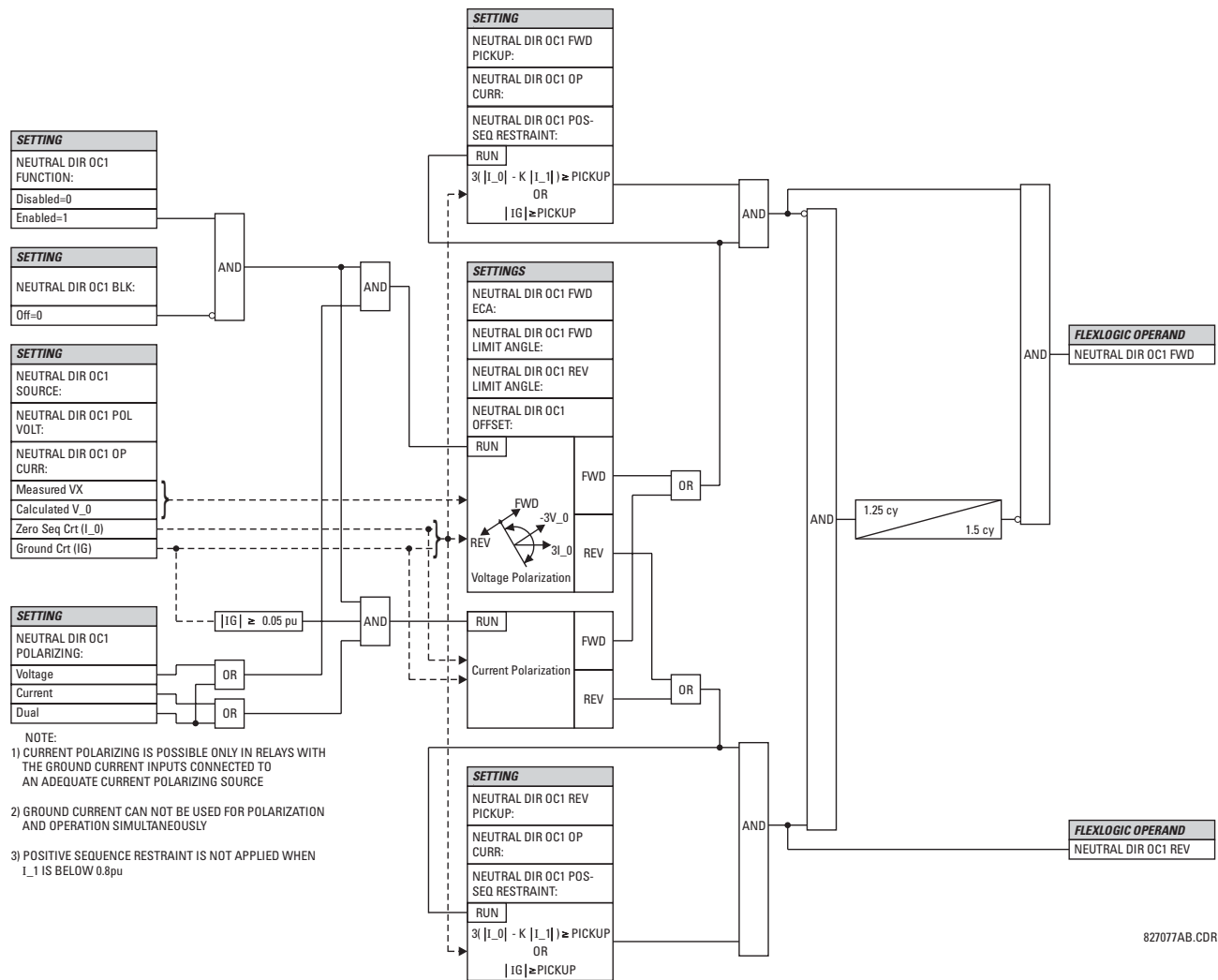


Figure 5-70: NEUTRAL DIRECTIONAL OVERCURRENT LOGIC

## 5.5.9 GROUND CURRENT

## a) GROUND TIME OVERCURRENT (ANSI 51G)

PATH: SETTINGS ⇒ ↓ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ ↓ GROUND CURRENT ⇒ GROUND TOC1(2)

|               |    |                                     |  |
|---------------|----|-------------------------------------|--|
| ■ GROUND TOC1 | ◀▶ | GROUND TOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                     |
| MESSAGE       | ▲▼ | GROUND TOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                          |
| MESSAGE       | ▲▼ | GROUND TOC1<br>INPUT: Phasor        | Range: Phasor, RMS                           |
| MESSAGE       | ▲▼ | GROUND TOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001  |
| MESSAGE       | ▲▼ | GROUND TOC1<br>CURVE: IEEE Mod Inv  | Range: see the Overcurrent Curve Types table |
| MESSAGE       | ▲▼ | GROUND TOC1<br>TD MULTIPLIER: 1.00  | Range: 0.00 to 600.00 in steps of 0.01       |
| MESSAGE       | ▲▼ | GROUND TOC1<br>RESET: Instantaneous | Range: Instantaneous, Timed                  |
| MESSAGE       | ▲▼ | GROUND TOC1 BLOCK:<br>Off           | Range: FlexLogic™ operand                    |
| MESSAGE       | ▲▼ | GROUND TOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled         |
| MESSAGE       | ▲  | GROUND TOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                     |

This element can provide a desired time-delay operating characteristic versus the applied current or be used as a simple Definite Time element. The ground current input value is the quantity measured by the ground input CT and is the fundamental phasor or RMS magnitude. Two methods of resetting operation are available; “Timed” and “Instantaneous” (refer to the *Inverse Time Overcurrent Curve Characteristics* section for details). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.



NOTE

These elements measure the current that is connected to the ground channel of a CT/VT module. This channel may be equipped with a standard or sensitive input. The conversion range of a standard channel is from 0.02 to 46 times the CT rating. The conversion range of a sensitive channel is from 0.002 to 4.6 times the CT rating.

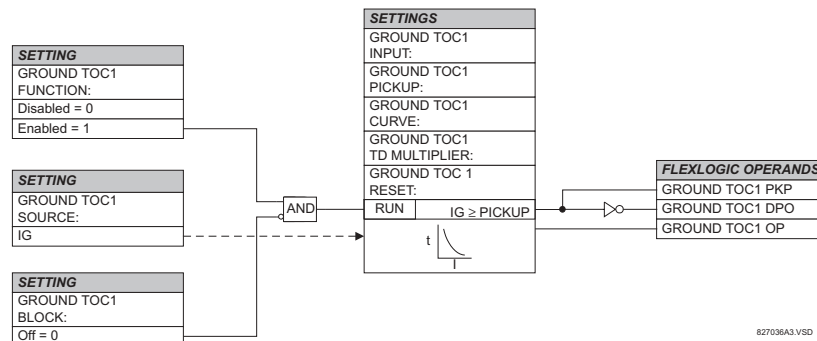


Figure 5-71: GROUND TOC1 SCHEME LOGIC

## b) GROUND INSTANTANEOUS OVERCURRENT (ANSI 50G)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ GROUND CURRENT ⇒ GROUND IOC1(2)

|               |    |                                     |   |
|---------------|----|-------------------------------------|---|
| ■ GROUND IOC1 | ◀▶ | GROUND IOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                    |
| MESSAGE ▲▼    |    | GROUND IOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                         |
| MESSAGE ▲▼    |    | GROUND IOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE ▲▼    |    | GROUND IOC1 PICKUP<br>DELAY: 0.00 s | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE ▲▼    |    | GROUND IOC1 RESET<br>DELAY: 0.00 s  | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE ▲▼    |    | GROUND IOC1 BLOCK:<br>Off           | Range: FlexLogic™ operand                   |
| MESSAGE ▲▼    |    | GROUND IOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled        |
| MESSAGE ▲     |    | GROUND IOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                    |

The Ground Instantaneous Overcurrent element may be used as an instantaneous element with no intentional delay or as a Definite Time element. The ground current input is the quantity measured by the ground input CT and is the fundamental phasor magnitude.

5

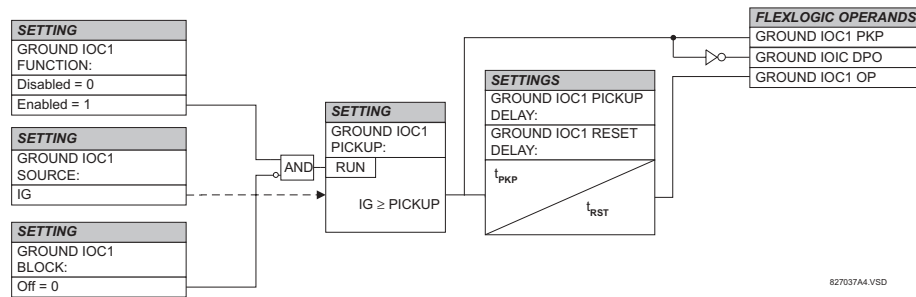


Figure 5-72: GROUND IOC1 SCHEME LOGIC



These elements measure the current that is connected to the ground channel of a CT/VT module. This channel may be equipped with a standard or sensitive input. The conversion range of a standard channel is from 0.02 to 46 times the CT rating. The conversion range of a sensitive channel is from 0.002 to 4.6 times the CT rating.

5.5.10 NEGATIVE SEQUENCE CURRENT

a) MAIN MENU

PATH: SETTINGS ⇨ ⚡ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ ⚡ PHASE CURRENT

|   |  |  |                 |
|---|--|--|-----------------|
| <div> <div> <div>■ NEGATIVE SEQUENCE</div> <div>■ CURRENT</div> </div> <div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> </div> | <div>⏪ ⏩</div> <div>⏮ ⏭</div> <div>⏭ ⏮</div> <div>⏮ ⏭</div> <div>⏮ ⏭</div> | <div> <div>■ NEG SEQ TOC1</div> <div>■</div> </div>    | See page 5-119. |
|   |  | <div> <div>■ NEG SEQ TOC2</div> <div>■</div> </div>    |                 |
|   |  | <div> <div>■ NEG SEQ IOC1</div> <div>■</div> </div>    | See page 5-120. |
|   |  | <div> <div>■ NEG SEQ IOC2</div> <div>■</div> </div>    |                 |
|   |  | <div> <div>■ NEG SEQ DIR OC1</div> <div>■</div> </div> | See page 5-121. |
|   |  | <div> <div>■ NEG SEQ DIR OC2</div> <div>■</div> </div> |                 |

The D30 relay provides two (2) Negative Sequence Time Overcurrent elements, two (2) Negative Sequence Instantaneous Overcurrent elements, and two (2) Negative Sequence Directional Overcurrent elements. For additional information on the Negative Sequence Time Overcurrent curves, refer to the Inverse TOC Curves section earlier.



## b) NEGATIVE SEQUENCE TIME OVERCURRENT (ANSI 51\_2)

PATH: SETTINGS ↓ GROUPED ELEMENTS ⇨ SETTING GROUP 1(6) ⇨ NEGATIVE SEQUENCE CURRENT ⇨ NEG SEQ TOC1(2)

|                |    |                                      |   |
|----------------|----|--------------------------------------|---|
| ■ NEG SEQ TOC1 | ◀▶ | NEG SEQ TOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                    |
| MESSAGE ▲▼     |    | NEG SEQ TOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                         |
| MESSAGE ▲▼     |    | NEG SEQ TOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE ▲▼     |    | NEG SEQ TOC1<br>CURVE: IEEE Mod Inv  | Range: see OVERCURRENT CURVE TYPES table    |
| MESSAGE ▲▼     |    | NEG SEQ TOC1<br>TD MULTIPLIER: 1.00  | Range: 0.00 to 600.00 in steps of 0.01      |
| MESSAGE ▲▼     |    | NEG SEQ TOC1<br>RESET: Instantaneous | Range: Instantaneous, Timed                 |
| MESSAGE ▲▼     |    | NEG SEQ TOC1 BLOCK:<br>Off           | Range: FlexLogic™ operand                   |
| MESSAGE ▲▼     |    | NEG SEQ TOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled        |
| MESSAGE ▲      |    | NEG SEQ TOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                    |

The negative sequence time overcurrent element may be used to determine and clear unbalance in the system. The input for calculating negative sequence current is the fundamental phasor value.

Two methods of resetting operation are available; “Timed” and “Instantaneous” (refer to the *Inverse Time Overcurrent Characteristics* sub-section for details on curve setup, trip times and reset operation). When the element is blocked, the time accumulator will reset according to the reset characteristic. For example, if the element reset characteristic is set to “Instantaneous” and the element is blocked, the time accumulator will be cleared immediately.

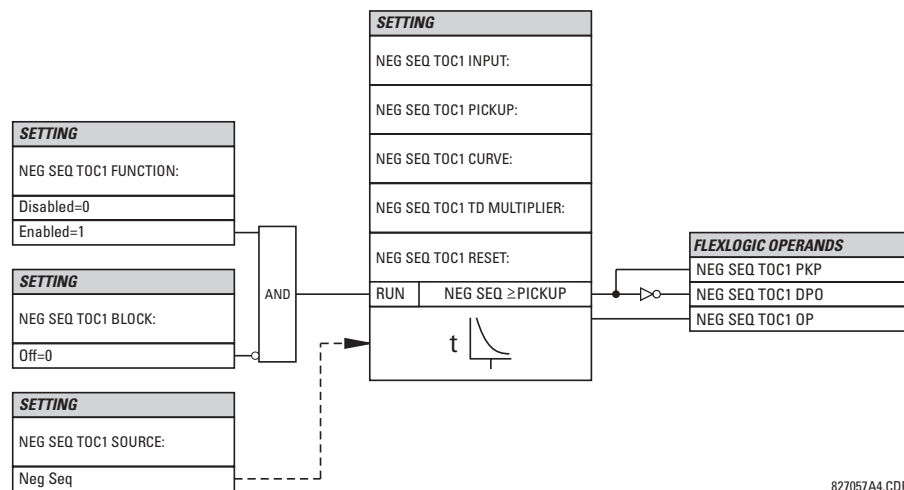


Figure 5-73: NEGATIVE SEQUENCE TOC1 SCHEME LOGIC

## c) NEGATIVE SEQUENCE INSTANTANEOUS OVERCURRENT (ANSI 50\_2)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ NEGATIVE SEQUENCE CURRENT ⇒ NEG SEQ OC1(2)

|                |    |                                      |   |
|----------------|----|--------------------------------------|---|
| ■ NEG SEQ IOC1 |    | NEG SEQ IOC1<br>FUNCTION: Disabled   | Range: Disabled, Enabled                    |
| MESSAGE        | ▲▼ | NEG SEQ IOC1 SIGNAL<br>SOURCE: SRC 1 | Range: SRC 1, SRC 2                         |
| MESSAGE        | ▲▼ | NEG SEQ IOC1<br>PICKUP: 1.000 pu     | Range: 0.000 to 30.000 pu in steps of 0.001 |
| MESSAGE        | ▲▼ | NEG SEQ IOC1 PICKUP<br>DELAY: 0.00 s | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE        | ▲▼ | NEG SEQ IOC1 RESET<br>DELAY: 0.00 s  | Range: 0.00 to 600.00 s in steps of 0.01    |
| MESSAGE        | ▲▼ | NEG SEQ IOC1 BLOCK:<br>Off           | Range: FlexLogic™ operand                   |
| MESSAGE        | ▲▼ | NEG SEQ IOC1<br>TARGET: Self-reset   | Range: Self-reset, Latched, Disabled        |
| MESSAGE        | ▲  | NEG SEQ IOC1<br>EVENTS: Disabled     | Range: Disabled, Enabled                    |

5

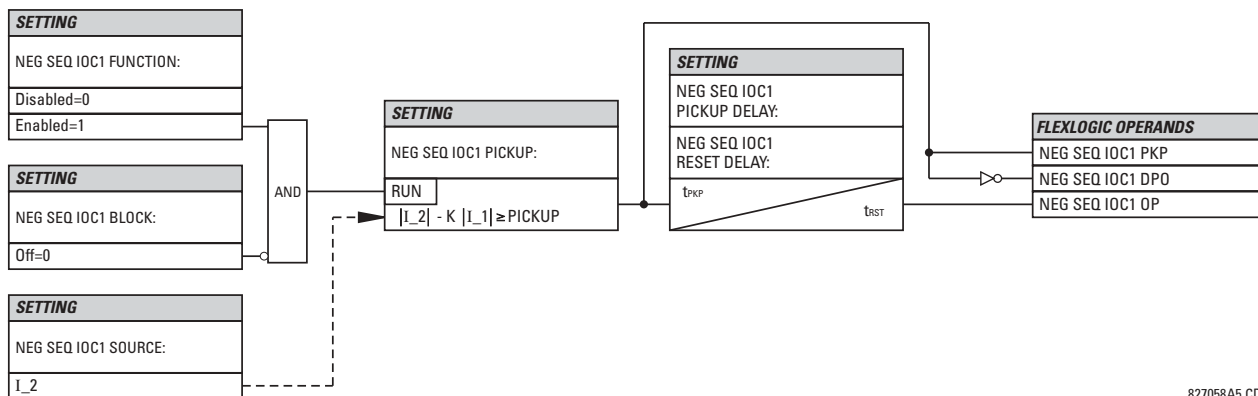
The Negative Sequence Instantaneous Overcurrent element may be used as an instantaneous function with no intentional delay or as a Definite Time function. The element responds to the negative-sequence current fundamental frequency phasor magnitude (calculated from the phase currents) and applies a “positive-sequence” restraint for better performance: a small portion (12.5%) of the positive-sequence current magnitude is subtracted from the negative-sequence current magnitude when forming the operating quantity:

$$I_{op} = |I_2| - K \cdot |I_1| \quad \text{where } K = 1/8 \quad (\text{EQ 5.15})$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative-sequence currents resulting from:

- system unbalances under heavy load conditions
- transformation errors of current transformers (CTs) during three-phase faults
- fault inception and switch-off transients during three-phase faults

The positive-sequence restraint must be considered when testing for pickup accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay (single phase injection:  $I_{op} = 0.2917 \cdot I_{injected}$ ; three phase injection, opposite rotation:  $I_{op} = I_{injected}$ ).



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Figure 5-74: NEGATIVE SEQUENCE IOC1 SCHEME LOGIC

## d) NEGATIVE SEQUENCE DIRECTIONAL OVERCURRENT (ANSI 67\_2)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ NEGATIVE SEQUENCE CURRENT ⇒ NEG SEQ DIR OC1(2)

|   |   |  |
|---|---|--|
| <div> <div>■ NEG SEQ DIR OC1</div> <div> <div>◀▶</div> <div>NEG SEQ DIR OC1</div> <div>FUNCTION: Disabled</div> </div> </div> |   | Range: Disabled, Enabled                 |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1</div> <div>SOURCE: SRC 1</div> </div>        | Range: SRC 1, SRC 2                      |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1</div> <div>OFFSET: 0.00 Ω</div> </div>       | Range: 0.00 to 250.00 Ω in steps of 0.01 |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1</div> <div>TYPE: Neg Sequence</div> </div>   | Range: Neg Sequence, Zero Sequence       |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 POS-SEQ RESTRAINT: 0.125</div> </div>        | Range: 0.000 to 0.500 in steps of 0.001  |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 FWD</div> <div>ECA: 75° Lag</div> </div>     | Range: 0 to 90° Lag in steps of 1        |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 FWD</div> <div>LIMIT ANGLE: 90°</div> </div> | Range: 40 to 90° in steps of 1           |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 FWD</div> <div>PICKUP: 0.05 pu</div> </div>  | Range: 0.05 to 30.00 pu in steps of 0.01 |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 REV</div> <div>LIMIT ANGLE: 90°</div> </div> | Range: 40 to 90° in steps of 1           |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 REV</div> <div>PICKUP: 0.05 pu</div> </div>  | Range: 0.05 to 30.00 pu in steps of 0.01 |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1 BLK:</div> <div>Off</div> </div>             | Range: FlexLogic™ operand                |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1</div> <div>TARGET: Self-reset</div> </div>   | Range: Self-reset, Latched, Disabled     |
| MESSAGE   | <div> <div>▲▼</div> <div>NEG SEQ DIR OC1</div> <div>EVENTS: Disabled</div> </div>     | Range: Disabled, Enabled                 |

There are two Negative Sequence Directional Overcurrent protection elements available. The element provides both forward and reverse fault direction indications through its output operands NEG SEQ DIR OC1 FWD and NEG SEQ DIR OC1 REV, respectively. The output operand is asserted if the magnitude of the operating current is above a pickup level (overcurrent unit) and the fault direction is seen as 'forward' or 'reverse', respectively (directional unit).

The **overcurrent unit** of the element essentially responds to the magnitude of a fundamental frequency phasor of either the negative-sequence or zero-sequence current as per user selection. The zero-sequence current should not be mistaken with the neutral current (factor 3 difference).

A 'positive-sequence restraint' is applied for better performance: a small user-programmable portion of the positive-sequence current magnitude is subtracted from the negative- or zero-sequence current magnitude, respectively, when forming the element operating quantity.

$$I_{op} = |I_{-2}| - K \times |I_{-1}| \quad \text{or} \quad I_{op} = |I_{-0}| - K \times |I_{-1}| \quad (\text{EQ 5.16})$$

The positive-sequence restraint allows for more sensitive settings by counterbalancing spurious negative- and zero-sequence currents resulting from:

- System unbalances under heavy load conditions.
- Transformation errors of Current Transformers (CTs).
- Fault inception and switch-off transients.

The positive-sequence restraint must be considered when testing for pick-up accuracy and response time (multiple of pickup). The operating quantity depends on the way the test currents are injected into the relay:

- single-phase injection:  $I_{op} = 1/3 \times (1 - K) \times I_{injected}$
- three-phase pure zero- or negative-sequence injection, respectively:  $I_{op} = I_{injected}$
- the directional unit uses the negative-sequence current and voltage for fault direction discrimination

The following table defines the Negative Sequence Directional Overcurrent element.

| OVERCURRENT UNIT  |                                   | DIRECTIONAL UNIT |                                |                              |
|-------------------|-----------------------------------|------------------|--------------------------------|------------------------------|
| MODE              | OPERATING CURRENT                 | DIRECTION        | COMPARED PHASORS               |                              |
| Negative-Sequence | $I_{op} =  I_2  - K \times  I_1 $ | Forward          | $-V_2 + Z_{offset} \times I_2$ | $I_2 \times 1 \angle ECA$    |
|                   |                                   | Reverse          | $-V_2 + Z_{offset} \times I_2$ | $-(I_2 \times 1 \angle ECA)$ |
| Zero-Sequence     | $I_{op} =  I_0  - K \times  I_1 $ | Forward          | $-V_2 + Z_{offset} \times I_2$ | $I_2 \times 1 \angle ECA$    |
|                   |                                   | Reverse          | $-V_2 + Z_{offset} \times I_2$ | $-(I_2 \times 1 \angle ECA)$ |

The negative-sequence voltage must be higher than 1 V secondary in order to be validated for use as a polarizing signal. If the polarizing signal is not validated neither forward nor reverse indication is given. The following figure explains the usage of the voltage polarized directional unit of the element.

The figure below shows the phase angle comparator characteristics for a Phase A to ground fault, with settings of:

- ECA = 75° (Element Characteristic Angle = centerline of operating characteristic)
- FWD LA = 80° (Forward Limit Angle = ± the angular limit with the ECA for operation)
- REV LA = 80° (Reverse Limit Angle = ± the angular limit with the ECA for operation)

The element incorporates a current reversal logic: if the reverse direction is indicated for at least 1.25 of a power system cycle, the prospective forward indication will be delayed by 1.5 of a power system cycle. The element is designed to emulate an electromechanical directional device. Larger operating and polarizing signals will result in faster directional discrimination bringing more security to the element operation.

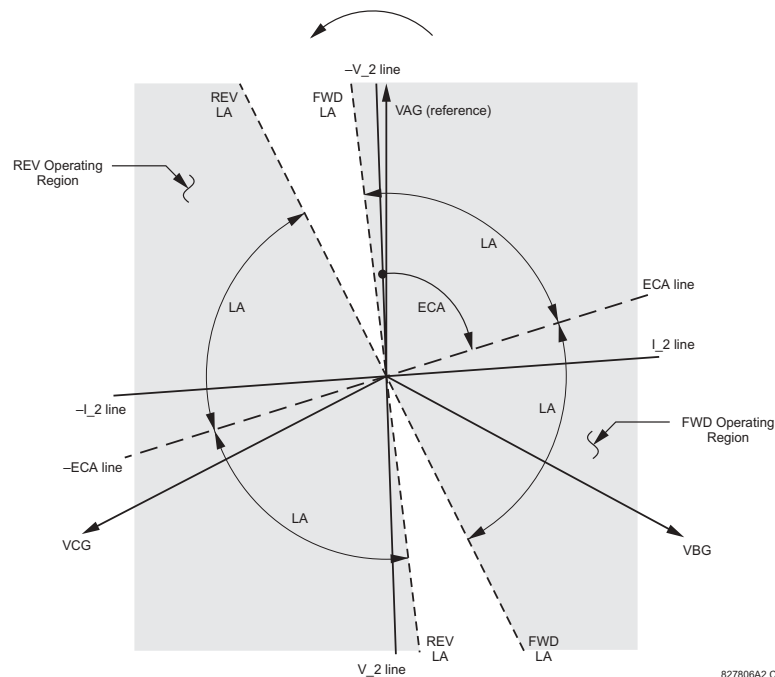


Figure 5-75: NEG SEQ DIRECTIONAL CHARACTERISTICS

The forward-looking function is designed to be more secure as compared to the reverse-looking function, and therefore, should be used for the tripping direction. The reverse-looking function is designed to be faster as compared to the forward-looking function and should be used for the blocking direction. This allows for better protection coordination. The above bias should be taken into account when using the Negative Sequence Directional Overcurrent element to 'directionalize' other protection elements.

- **NEG SEQ DIR OC1 OFFSET:** This setting specifies the offset impedance used by this protection. The primary application for the offset impedance is to guarantee correct identification of fault direction on series compensated lines (see the Application of Settings chapter for information on how to calculate this setting). In regular applications, the offset impedance ensures proper operation even if the negative-sequence voltage at the relaying point is very small. If this is the intent, the offset impedance shall not be larger than the negative-sequence impedance of the protected circuit. Practically, it shall be several times smaller. The offset impedance shall be entered in secondary ohms. See the Theory of Operation chapter for additional details.
- **NEG SEQ DIR OC1 TYPE:** This setting selects the operating mode for the overcurrent unit of the element. The choices are “Neg Sequence” and “Zero Sequence”. In some applications it is advantageous to use a directional negative-sequence overcurrent function instead of a directional zero-sequence overcurrent function as inter-circuit mutual effects are minimized.
- **NEG SEQ DIR OC1 POS-SEQ RESTRAINT:** This setting controls the amount of the positive-sequence restraint. Set to 0.063 (in “Zero Sequence” mode) or 0.125 (in “Neg Sequence” mode) for backward compatibility with firmware revision 3.40 and older. Set to zero to remove the restraint. Set higher if large system unbalances or poor CT performance are expected.
- **NEG SEQ DIR OC1 FWD ECA:** This setting select the element characteristic angle (ECA) for the forward direction. The element characteristic angle in the reverse direction is the angle set for the forward direction shifted by 180°.
- **NEG SEQ DIR OC1 FWD LIMIT ANGLE:** This setting defines a symmetrical (in both directions from the ECA) limit angle for the forward direction.
- **NEG SEQ DIR OC1 FWD PICKUP:** This setting defines the pickup level for the overcurrent unit in the forward direction. Upon **NEG SEQ DIR OC1 TYPE** selection, this pickup threshold applies to zero- or negative-sequence current. When selecting this setting it must be kept in mind that the design uses a ‘positive-sequence restraint’ technique.
- **NEG SEQ DIR OC1 REV LIMIT ANGLE:** This setting defines a symmetrical (in both directions from the ECA) limit angle for the reverse direction.
- **NEG SEQ DIR OC1 REV PICKUP:** This setting defines the pickup level for the overcurrent unit in the reverse direction. Upon **NEG SEQ DIR OC1 TYPE** selection, this pickup threshold applies to zero- or negative-sequence current. When selecting this setting it must be kept in mind that the design uses a ‘positive-sequence restraint’ technique.

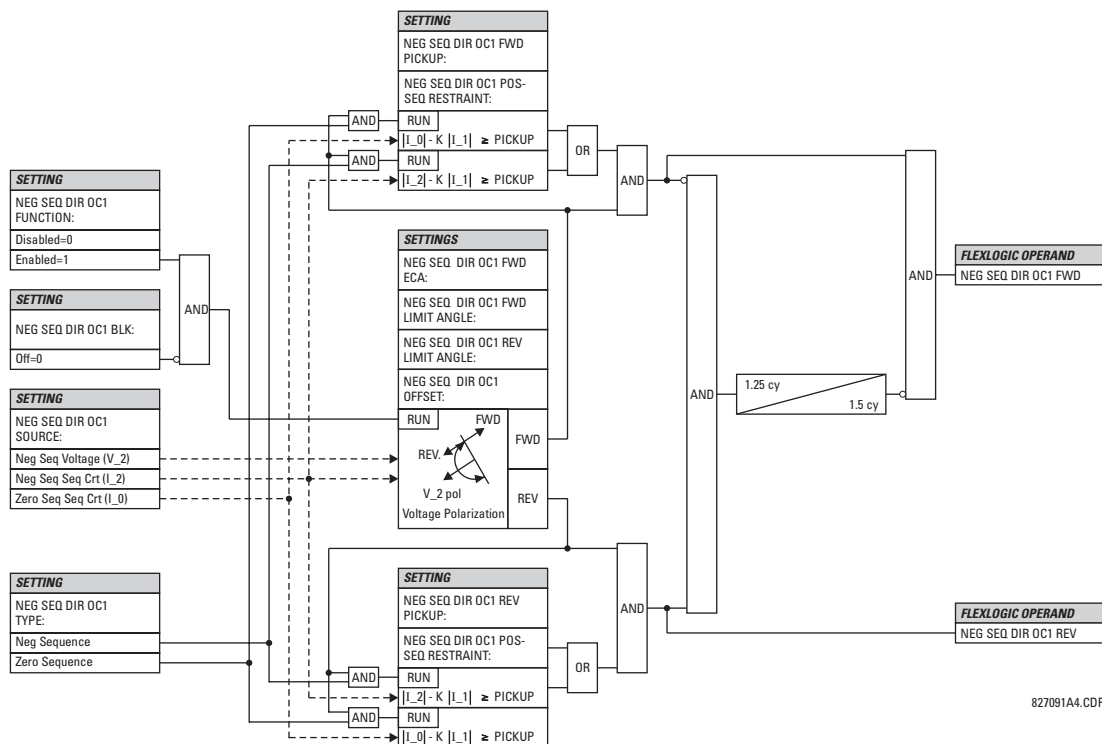


Figure 5-76: NEGATIVE SEQUENCE DIRECTIONAL OC1 SCHEME LOGIC

## 5.5.11 VOLTAGE ELEMENTS

## a) MAIN MENU

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS

|                    |    |                 |                 |
|--------------------|----|-----------------|-----------------|
| ■ VOLTAGE ELEMENTS | ◀▶ | ■ PHASE         | See page 5-125. |
| ■                  |    | ■ UNDERVOLTAGE1 |                 |
| MESSAGE            | ▲▼ | ■ PHASE         | See page 5-125. |
|                    |    | ■ UNDERVOLTAGE2 |                 |
| MESSAGE            | ▲▼ | ■ PHASE         | See page 5-126. |
|                    |    | ■ OVERVOLTAGE1  |                 |
| MESSAGE            | ▲▼ | ■ NEUTRAL OV1   | See page 5-127. |
|                    |    | ■               |                 |
| MESSAGE            | ▲▼ | ■ NEG SEQ OV    | See page 5-128. |
|                    |    | ■               |                 |
| MESSAGE            | ▲▼ | ■ AUXILIARY UV1 | See page 5-129. |
|                    |    | ■               |                 |
| MESSAGE            | ▲  | ■ AUXILIARY OV1 | See page 5-130. |
|                    |    | ■               |                 |

These protection elements can be used for a variety of applications such as:

**Undervoltage Protection:** For voltage sensitive loads, such as induction motors, a drop in voltage increases the drawn current which may cause dangerous overheating in the motor. The undervoltage protection feature can be used to either cause a trip or generate an alarm when the voltage drops below a specified voltage setting for a specified time delay.

**Permissive Functions:** The undervoltage feature may be used to block the functioning of external devices by operating an output relay when the voltage falls below the specified voltage setting. The undervoltage feature may also be used to block the functioning of other elements through the block feature of those elements.

**Source Transfer Schemes:** In the event of an undervoltage, a transfer signal may be generated to transfer a load from its normal source to a standby or emergency power source.

The undervoltage elements can be programmed to have a Definite Time delay characteristic. The Definite Time curve operates when the voltage drops below the pickup level for a specified period of time. The time delay is adjustable from 0 to 600.00 seconds in steps of 10 ms. The undervoltage elements can also be programmed to have an inverse time delay characteristic. The undervoltage delay setting defines the family of curves shown below.

$$T = \frac{D}{\left(1 - \frac{V}{V_{pickup}}\right)}$$

where:  $T$  = Operating Time  
 $D$  = Undervoltage Delay Setting  
 ( $D = 0.00$  operates instantaneously)  
 $V$  = Secondary Voltage applied to the relay  
 $V_{pickup}$  = Pickup Level



**At 0% of pickup, the operating time equals the UNDERVOLTAGE DELAY setting.**

NOTE

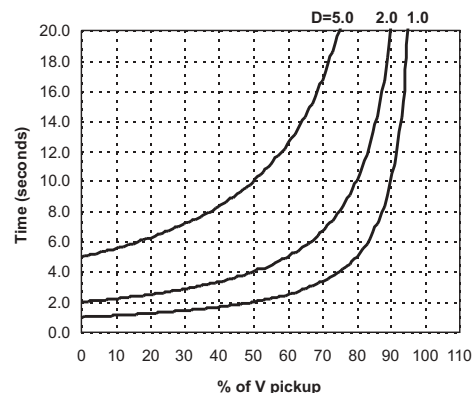


Figure 5-77: INVERSE TIME UNDERVOLTAGE CURVES

## b) PHASE UNDERVOLTAGE (ANSI 27P)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS ⇒ PHASE UNDERVOLTAGE1(2)

|                 |    |                      |  |
|-----------------|----|----------------------|--|
| ■ PHASE         | ◀▶ | PHASE UV1            | Range: Disabled, Enabled                   |
| ■ UNDERVOLTAGE1 |    | FUNCTION: Disabled   |  |
| MESSAGE         | ▲▼ | PHASE UV1 SIGNAL     | Range: SRC 1, SRC 2                        |
|                 |    | SOURCE: SRC 1        |  |
| MESSAGE         | ▲▼ | PHASE UV1 MODE:      | Range: Phase to Ground, Phase to Phase     |
|                 |    | Phase to Ground      |  |
| MESSAGE         | ▲▼ | PHASE UV1            | Range: 0.000 to 3.000 pu in steps of 0.001 |
|                 |    | PICKUP: 1.000 pu     |  |
| MESSAGE         | ▲▼ | PHASE UV1            | Range: Definite Time, Inverse Time         |
|                 |    | CURVE: Definite Time |  |
| MESSAGE         | ▲▼ | PHASE UV1            | Range: 0.00 to 600.00 s in steps of 0.01   |
|                 |    | DELAY: 1.00 s        |  |
| MESSAGE         | ▲▼ | PHASE UV1 MINIMUM    | Range: 0.000 to 3.000 pu in steps of 0.001 |
|                 |    | VOLTAGE: 0.100 pu    |  |
| MESSAGE         | ▲▼ | PHASE UV1 BLOCK:     | Range: FlexLogic™ operand                  |
|                 |    | Off                  |  |
| MESSAGE         | ▲▼ | PHASE UV1            | Range: Self-reset, Latched, Disabled       |
|                 |    | TARGET: Self-reset   |  |
| MESSAGE         | ▲▼ | PHASE UV1            | Range: Disabled, Enabled                   |
|                 |    | EVENTS: Disabled     |  |

This element may be used to give a desired time-delay operating characteristic versus the applied fundamental voltage (phase-to-ground or phase-to-phase for Wye VT connection, or phase-to-phase for Delta VT connection) or as a Definite Time element. The element resets instantaneously if the applied voltage exceeds the dropout voltage. The delay setting selects the minimum operating time of the phase undervoltage. The minimum voltage setting selects the operating voltage below which the element is blocked (a setting of "0" will allow a dead source to be considered a fault condition).

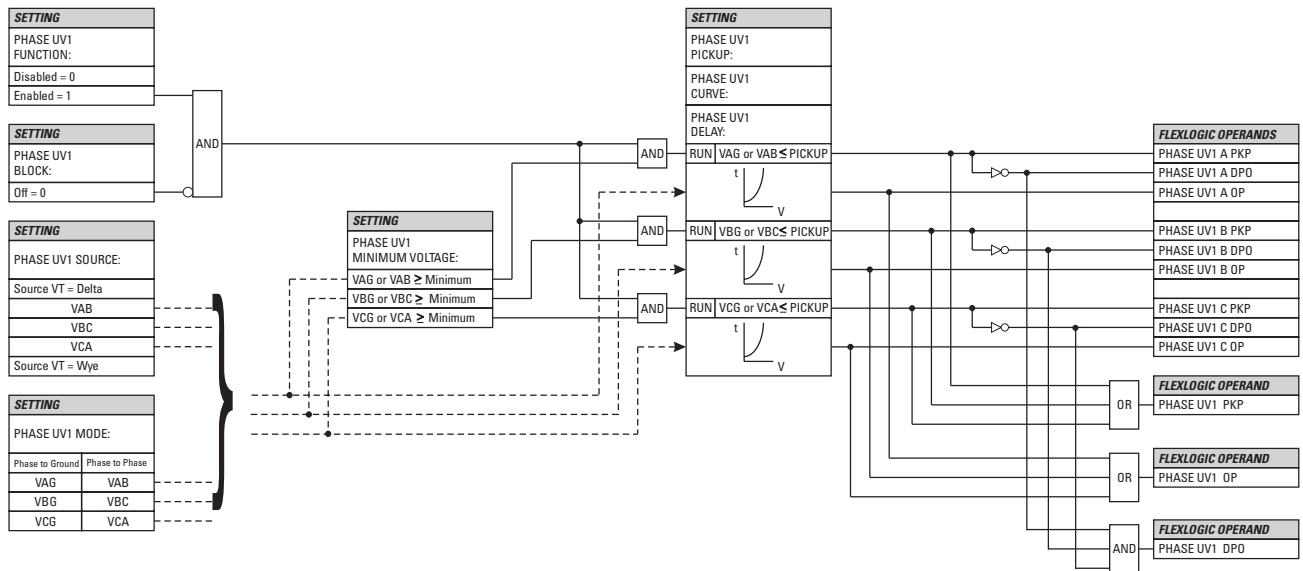


Figure 5-78: PHASE UNDERVOLTAGE1 SCHEME LOGIC

## c) PHASE OVERVOLTAGE (ANSI 59P)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS ⇒ PHASE OVERVOLTAGE1

|   |         |   |  |
|---|---------|---|--|
| <div> <div>■ PHASE</div> <div>■ OVERVOLTAGE1</div> </div> |         | <div> <div>◀▶</div> <div>PHASE OV1</div> <div>FUNCTION: Disabled</div> </div>   | Range: Disabled, Enabled                   |
|   | MESSAGE | <div> <div>▲▼</div> <div>PHASE OV1 SIGNAL</div> <div>SOURCE: SRC 1</div> </div> | Range: SRC 1, SRC 2                        |
|   | MESSAGE | <div> <div>▲▼</div> <div>PHASE OV1</div> <div>PICKUP: 1.000 pu</div> </div>     | Range: 0.000 to 3.000 pu in steps of 0.001 |
|   | MESSAGE | <div> <div>▲▼</div> <div>PHASE OV1 PICKUP</div> <div>DELAY: 1.00 s</div> </div> | Range: 0.00 to 600.00 s in steps of 0.01   |
|   | MESSAGE | <div> <div>▲▼</div> <div>PHASE OV1 RESET</div> <div>DELAY: 1.00 s</div> </div>  | Range: 0.00 to 600.00 s in steps of 0.01   |
|   | MESSAGE | <div> <div>▲▼</div> <div>PHASE OV1 BLOCK:</div> <div>Off</div> </div>           | Range: FlexLogic™ Operand                  |
|   | MESSAGE | <div> <div>▲▼</div> <div>PHASE OV1</div> <div>TARGET: Self-reset</div> </div>   | Range: Self-reset, Latched, Disabled       |
|   | MESSAGE | <div> <div>▲</div> <div>PHASE OV1</div> <div>EVENTS: Disabled</div> </div>      | Range: Disabled, Enabled                   |

The phase overvoltage element may be used as an instantaneous element with no intentional time delay or as a Definite Time element. The input voltage is the phase-to-phase voltage, either measured directly from Delta-connected VTs or as calculated from phase-to-ground (Wye) connected VTs. The specific voltages to be used for each phase are shown below.

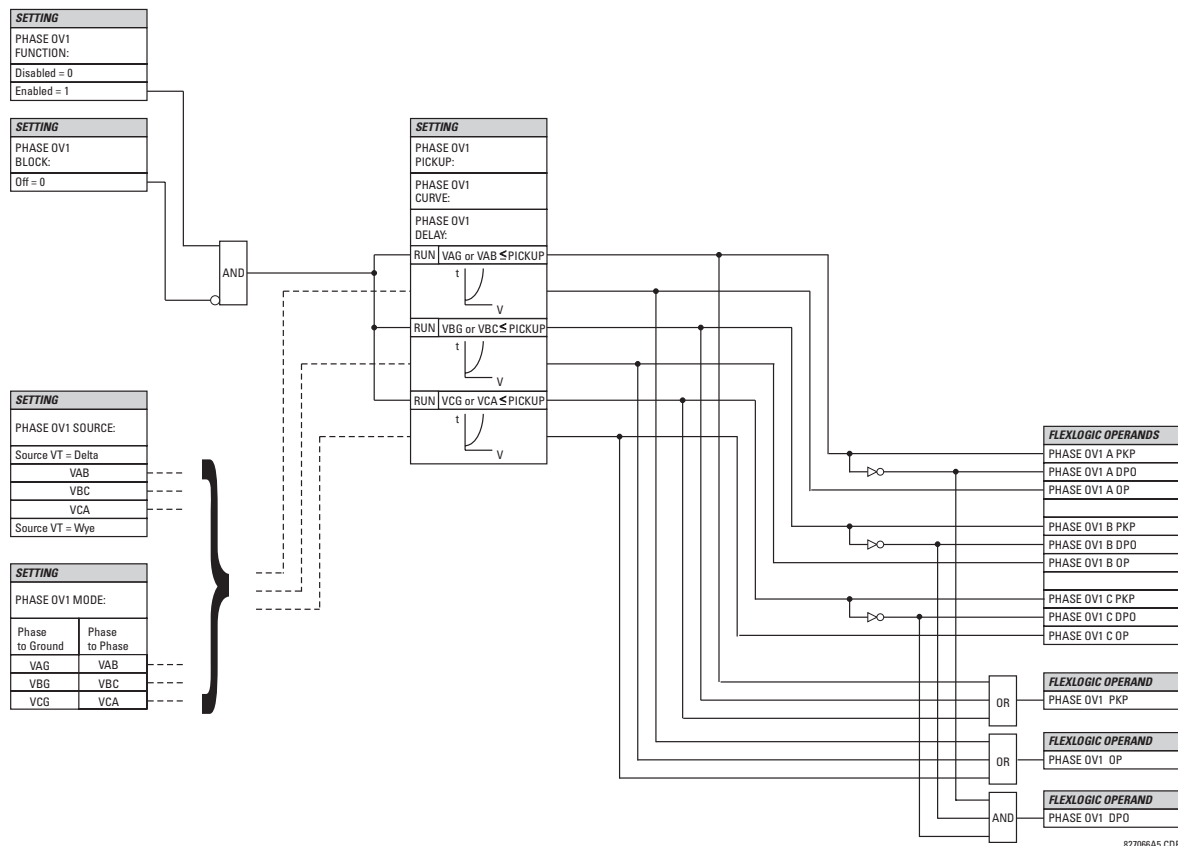


Figure 5-79: PHASE OVERVOLTAGE SCHEME LOGIC



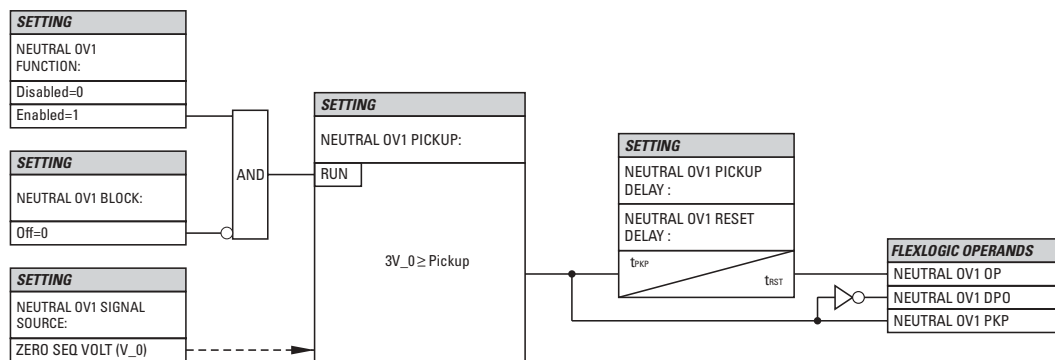
## d) NEUTRAL OVERVOLTAGE (ANSI 59N)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS ⇒ NEUTRAL OV1

|  |  |   |  |
|--|--|---|--|
| <div>■ NEUTRAL OV1</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> | <div>⏮</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> | <div>NEUTRAL OV1</div> <div>FUNCTION: Disabled</div>    | Range: Disabled, Enabled                   |
|  |  | <div>NEUTRAL OV1 SIGNAL</div> <div>SOURCE: SRC 1</div>  | Range: SRC 1, SRC 2                        |
|  |  | <div>NEUTRAL OV1 PICKUP:</div> <div>0.300 pu</div>      | Range: 0.000 to 1.250 pu in steps of 0.001 |
|  |  | <div>NEUTRAL OV1 PICKUP:</div> <div>DELAY: 1.00 s</div> | Range: 0.00 to 600.00 s in steps of 0.01   |
|  |  | <div>NEUTRAL OV1 RESET:</div> <div>DELAY: 1.00 s</div>  | Range: 0.00 to 600.00 s in steps of 0.01   |
|  |  | <div>NEUTRAL OV1 BLOCK:</div> <div>Off</div>            | Range: FlexLogic™ operand                  |
|  |  | <div>NEUTRAL OV1 TARGET:</div> <div>Self-reset</div>    | Range: Self-reset, Latched, Disabled       |
|  |  | <div>NEUTRAL OV1 EVENTS:</div> <div>Disabled</div>      | Range: Disabled, Enabled                   |

The Neutral Overvoltage element can be used to detect asymmetrical system voltage condition due to a ground fault or to the loss of one or two phases of the source. The element responds to the system neutral voltage (3V\_0), calculated from the phase voltages. The nominal secondary voltage of the phase voltage channels entered under **SETTINGS ⇒ SYSTEM SETUP ⇒ AC INPUTS ⇒ VOLTAGE BANK ⇒ PHASE VT SECONDARY** is the p.u. base used when setting the pickup level.

VT errors and normal voltage unbalance must be considered when setting this element. This function requires the VTs to be Wye connected.



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Figure 5-80: NEUTRAL OVERVOLTAGE1 SCHEME LOGIC

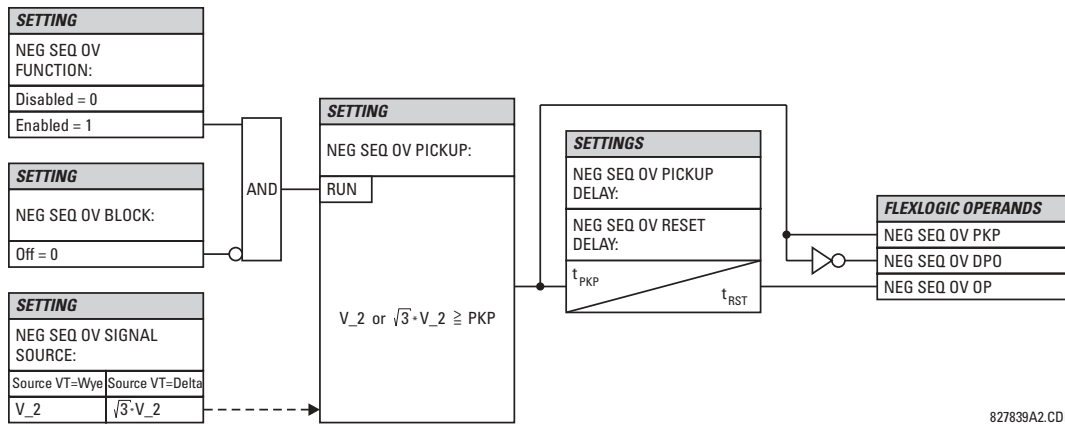
## e) NEGATIVE SEQUENCE OVERVOLTAGE (ANSI 59\_2)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS ⇒ NEG SEQ OV

|              |    |                    |  |
|--------------|----|--------------------|--|
| ■ NEG SEQ OV |    | NEG SEQ OV         | Range: Disabled, Enabled                   |
|              |    | FUNCTION: Disabled |  |
| MESSAGE      | ▲▼ | NEG SEQ OV SIGNAL  | Range: SRC 1, SRC 2                        |
|              |    | SOURCE: SRC 1      |  |
| MESSAGE      | ▲▼ | NEG SEQ OV         | Range: 0.000 to 1.250 pu in steps of 0.001 |
|              |    | PICKUP: 0.300 pu   |  |
| MESSAGE      | ▲▼ | NEG SEQ OV PICKUP  | Range: 0.00 to 600.00 s in steps of 0.01   |
|              |    | DELAY: 0.50 s      |  |
| MESSAGE      | ▲▼ | NEG SEQ OV RESET   | Range: 0.00 to 600.00 s in steps of 0.01   |
|              |    | DELAY: 0.50 s      |  |
| MESSAGE      | ▲▼ | NEG SEQ OV BLOCK:  | Range: FlexLogic™ operand                  |
|              |    | Off                |  |
| MESSAGE      | ▲▼ | NEG SEQ OV         | Range: Self-reset, Latched, Disabled       |
|              |    | TARGET: Self-reset |  |
| MESSAGE      | ▲  | NEG SEQ OV         | Range: Disabled, Enabled                   |
|              |    | EVENTS: Disabled   |  |

5

The negative sequence overvoltage element may be used to detect loss of one or two phases of the source, a reversed phase sequence of voltage, or a non-symmetrical system voltage condition.



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## f) AUXILIARY UNDERVOLTAGE (ANSI 27X)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS ⇒ AUXILIARY UV1

|   |   |  |  |
|---|---|--|--|
| <div>■ AUXILIARY UV1</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> | <div>⏮⏭</div> <div>⏮⏭</div> <div>⏮⏭</div> <div>⏮⏭</div> <div>⏮⏭</div> <div>⏮⏭</div> <div>⏮⏭</div> <div>⏮⏭</div> | <div>AUX UV1</div> <div>FUNCTION: Disabled</div>         | Range: Disabled, Enabled                   |
|   |   | <div>AUX UV1 SIGNAL</div> <div>SOURCE: SRC 1</div>       | Range: SRC 1, SRC 2                        |
|   |   | <div>AUX UV1 PICKUP:</div> <div>0.700 pu</div>           | Range: 0.000 to 3.000 pu in steps of 0.001 |
|   |   | <div>AUX UV1 CURVE:</div> <div>Definite Time</div>       | Range: Definite Time, Inverse Time         |
|   |   | <div>AUX UV1 DELAY:</div> <div>1.00 s</div>              | Range: 0.00 to 600.00 s in steps of 0.01   |
|   |   | <div>AUX UV1 MINIMUM:</div> <div>VOLTAGE: 0.100 pu</div> | Range: 0.000 to 3.000 pu in steps of 0.001 |
|   |   | <div>AUX UV1 BLOCK:</div> <div>Off</div>                 | Range: FlexLogic™ operand                  |
|   |   | <div>AUX UV1 TARGET:</div> <div>Self-reset</div>         | Range: Self-reset, Latched, Disabled       |
|   |   | <div>AUX UV1 EVENTS:</div> <div>Disabled</div>           | Range: Disabled, Enabled                   |

This element is intended for monitoring undervoltage conditions of the auxiliary voltage. The **AUX UV1 PICKUP** selects the voltage level at which the time undervoltage element starts timing. The nominal secondary voltage of the auxiliary voltage channel entered under **SETTINGS ⇒ SYSTEM SETUP ⇒ AC INPUTS ⇒ VOLTAGE BANK X5 ⇒ AUXILIARY VT X5 SECONDARY** is the p.u. base used when setting the pickup level.

The **AUX UV1 DELAY** setting selects the minimum operating time of the auxiliary undervoltage element. Both **AUX UV1 PICKUP** and **AUX UV1 DELAY** settings establish the operating curve of the undervoltage element. The auxiliary undervoltage element can be programmed to use either Definite Time Delay or Inverse Time Delay characteristics. The operating characteristics and equations for both Definite and Inverse Time Delay are as for the Phase Undervoltage element.

The element resets instantaneously. The minimum voltage setting selects the operating voltage below which the element is blocked.

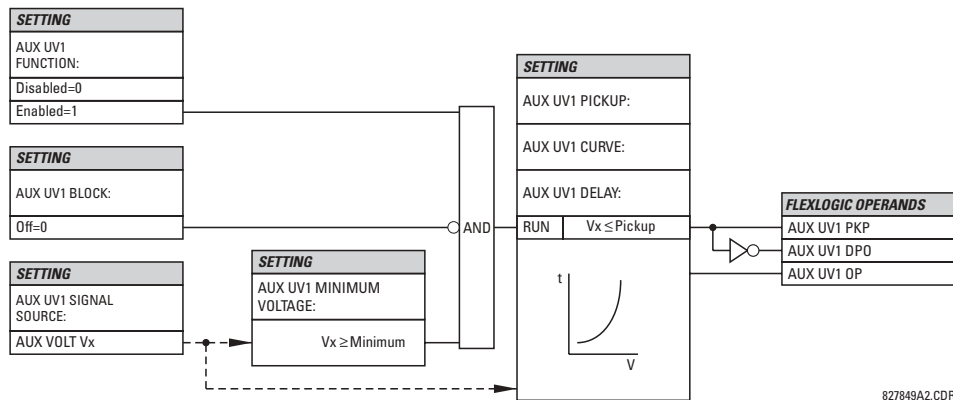


Figure 5-82: AUXILIARY UNDERVOLTAGE SCHEME LOGIC

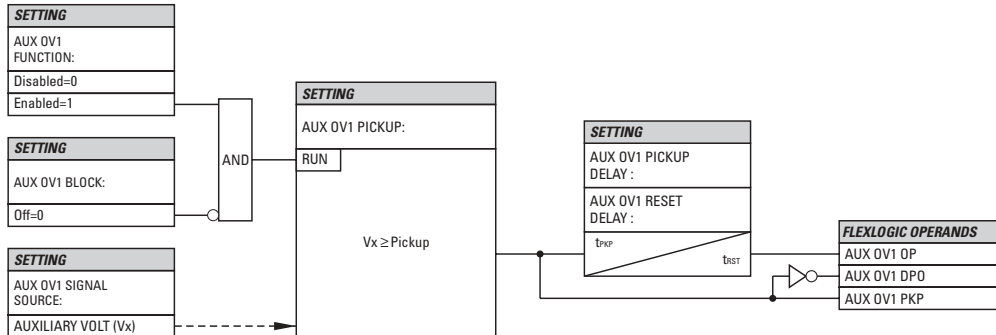
## g) AUXILIARY OVERVOLTAGE (ANSI 59X)

PATH: SETTINGS ⇒ GROUPED ELEMENTS ⇒ SETTING GROUP 1(6) ⇒ VOLTAGE ELEMENTS ⇒ AUXILIARY OV1

|  |  |  |  |
|--|--|--|--|
| <div>■ AUXILIARY OV1</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> | <div>⏮</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> <div>⏭</div> | <div>AUX OV1</div> <div>FUNCTION: Disabled</div>   | Range: Disabled, Enabled                   |
|  |  | <div>AUX OV1 SIGNAL</div> <div>SOURCE: SRC 1</div> | Range: SRC 1, SRC 2                        |
|  |  | <div>AUX OV1 PICKUP:</div> <div>0.300 pu</div>     | Range: 0.000 to 3.000 pu in steps of 0.001 |
|  |  | <div>AUX OV1 PICKUP</div> <div>DELAY: 1.00 s</div> | Range: 0.00 to 600.00 s in steps of 0.01   |
|  |  | <div>AUX OV1 RESET</div> <div>DELAY: 1.00 s</div>  | Range: 0.00 to 600.00 s in steps of 0.01   |
|  |  | <div>AUX OV1 BLOCK:</div> <div>Off</div>           | Range: FlexLogic™ operand                  |
|  |  | <div>AUX OV1 TARGET:</div> <div>Self-reset</div>   | Range: Self-reset, Latched, Disabled       |
|  |  | <div>AUX OV1 EVENTS:</div> <div>Disabled</div>     | Range: Disabled, Enabled                   |

5

This element is intended for monitoring overvoltage conditions of the auxiliary voltage. A typical application for this element is monitoring the zero-sequence voltage (3V<sub>0</sub>) supplied from an open-corner-delta VT connection. The nominal secondary voltage of the auxiliary voltage channel entered under **SYSTEM SETUP ⇒ AC INPUTS ⇒ VOLTAGE BANK X5 ⇒ AUXILIARY VT X5 SECONDARY** is the p.u. base used when setting the pickup level.



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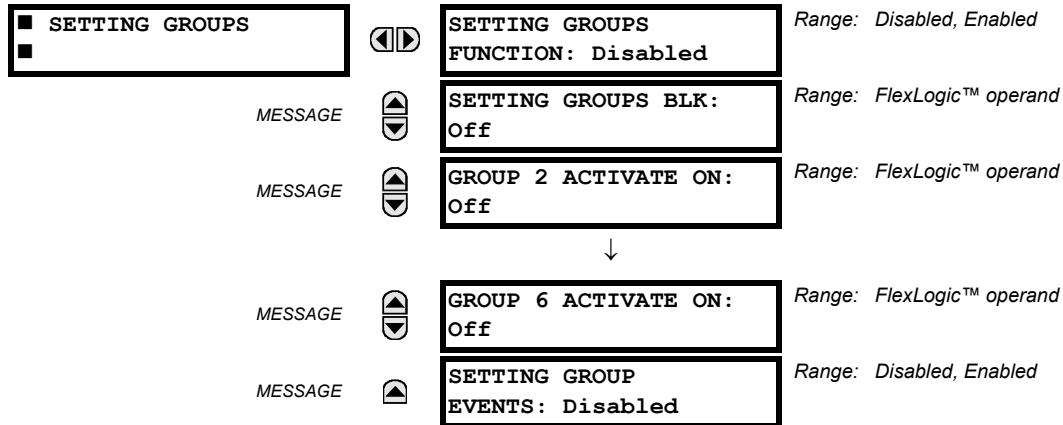
Figure 5-83: AUXILIARY OVERVOLTAGE SCHEME LOGIC

## 5.6.1 OVERVIEW

Control elements are generally used for control rather than protection. See the *Introduction to Elements* section at the beginning of this chapter for further information.

## 5.6.2 SETTING GROUPS

PATH: SETTINGS ⇌ CONTROL ELEMENTS ⇌ SETTINGS GROUPS



The Setting Groups menu controls the activation/deactivation of up to six possible groups of settings in the **GROUPED ELEMENTS** settings menu. The faceplate 'Settings In Use' LEDs indicate which active group (with a non-flashing energized LED) is in service.

The **SETTING GROUPS BLK** setting prevents the active setting group from changing when the FlexLogic™ parameter is set to "On". This can be useful in applications where it is undesirable to change the settings under certain conditions, such as the breaker being open.

Each **GROUP n ACTIVATE ON** setting selects a FlexLogic™ operand which, when set, will make the particular setting group active for use by any grouped element. A priority scheme ensures that only one group is active at a given time – the highest-numbered group which is activated by its **GROUP n ACTIVATE ON** parameter takes priority over the lower-numbered groups. There is no "activate on" setting for Group 1 (the default active group), because Group 1 automatically becomes active if no other group is active.

The relay can be set up via a FlexLogic™ equation to receive requests to activate or de-activate a particular non-default settings group. The following FlexLogic™ equation (see the figure below) illustrates requests via remote communications (e.g. VIRTUAL INPUT 1) or from a local contact input (e.g. H7a) to initiate the use of a particular settings group, and requests from several overcurrent pickup measuring elements to inhibit the use of the particular settings group. The assigned VIRTUAL OUTPUT 1 operand is used to control the "On" state of a particular settings group.

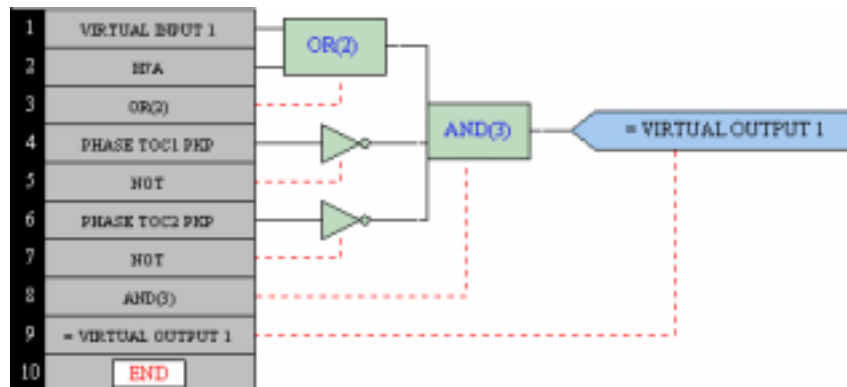


Figure 5-84: EXAMPLE FLEXLOGIC™ CONTROL OF A SETTINGS GROUP

## 5.6.3 SELECTOR SWITCH

PATH: SETTINGS ⇌ CONTROL ELEMENTS ⇌ SELECTOR SWITCH ⇌ SELECTOR SWITCH 1(2)

|                     |    |                                      |   |
|---------------------|----|--------------------------------------|---|
| ■ SELECTOR SWITCH 1 |    | SELECTOR 1 FUNCTION:<br>Disabled     | Range: Disabled, Enabled                  |
| MESSAGE             | ▲▼ | SELECTOR 1 FULL<br>RANGE: 7          | Range: 1 to 7 in steps of 1               |
| MESSAGE             | ▲▼ | SELECTOR 1 TIME-OUT:<br>5.0 s        | Range: 3.0 to 60.0 s in steps of 0.1      |
| MESSAGE             | ▲▼ | SELECTOR 1 STEP-UP:<br>Off           | Range: FlexLogic™ operand                 |
| MESSAGE             | ▲▼ | SELECTOR 1 STEP-UP<br>MODE: Time-out | Range: Time-out, Acknowledge              |
| MESSAGE             | ▲▼ | SELECTOR 1 ACK:<br>Off               | Range: FlexLogic™ operand                 |
| MESSAGE             | ▲▼ | SELECTOR 1 3BIT A0:<br>Off           | Range: FlexLogic™ operand                 |
| MESSAGE             | ▲▼ | SELECTOR 1 3BIT A1:<br>Off           | Range: FlexLogic™ operand                 |
| MESSAGE             | ▲▼ | SELECTOR 1 3BIT A2:<br>Off           | Range: FlexLogic™ operand                 |
| MESSAGE             | ▲▼ | SELECTOR 1 3BIT<br>MODE: Time-out    | Range: Time-out, Acknowledge              |
| MESSAGE             | ▲▼ | SELECTOR 1 3BIT ACK:<br>Off          | Range: FlexLogic™ operand                 |
| MESSAGE             | ▲▼ | SELECTOR 1 POWER-UP<br>MODE: Restore | Range: Restore, Synchronize, Sync/Restore |
| MESSAGE             | ▲▼ | SELECTOR 1 TARGETS:<br>Self-reset    | Range: Self-reset, Latched, Disabled      |
| MESSAGE             | ▲  | SELECTOR 1 EVENTS:<br>Disabled       | Range: Disabled, Enabled                  |

The Selector Switch element is intended to replace a mechanical selector switch. Typical applications include setting group control or control of multiple logic sub-circuits in user-programmable logic.

The element provides for two control inputs. The step-up control allows stepping through selector position one step at a time with each pulse of the control input, such as a user-programmable pushbutton. The 3-bit control input allows setting the selector to the position defined by a 3-bit word.

The element allows pre-selecting a new position without applying it. The pre-selected position gets applied either after time-out or upon acknowledgement via separate inputs (user setting). The selector position is stored in non-volatile memory. Upon power-up, either the previous position is restored or the relay synchronizes to the current 3-bit word (user setting). Basic alarm functionality alerts the user under abnormal conditions; e.g. the 3-bit control input being out of range.

- **SELECTOR 1 FULL RANGE:** This setting defines the upper position of the selector. When stepping up through available positions of the selector, the upper position wraps up to the lower position (Position 1). When using a direct 3-bit control word for programming the selector to a desired position, the change would take place only if the control word is within the range of 1 to the **SELECTOR FULL RANGE**. If the control word is outside the range, an alarm is established by setting the SELECTOR ALARM FlexLogic™ operand for 3 seconds.
- **SELECTOR 1 TIME-OUT:** This setting defines the time-out period for the selector. This value is used by the relay in the following two ways. When the **SELECTOR STEP-UP MODE** is "Time-out", the setting specifies the required period of

inactivity of the control input after which the pre-selected position is automatically applied. When the **SELECTOR STEP-UP MODE** is “Acknowledge”, the setting specifies the period of time for the acknowledging input to appear. The timer is re-started by any activity of the control input. The acknowledging input must come before the **SELECTOR 1 TIME-OUT** timer expires; otherwise, the change will not take place and an alarm will be set.

- **SELECTOR 1 STEP-UP:** This setting specifies a control input for the selector switch. The switch is shifted to a new position at each rising edge of this signal. The position changes incrementally, wrapping up from the last (**SELECTOR 1 FULL RANGE**) to the first (Position 1). Consecutive pulses of this control operand must not occur faster than every 50 ms. After each rising edge of the assigned operand, the time-out timer is restarted and the **SELECTOR SWITCH 1: POS Z CHNG INITIATED** target message is displayed, where **Z** the pre-selected position. The message is displayed for the time specified by the **FLASH MESSAGE TIME** setting. The pre-selected position is applied after the selector times out (“Time-out” mode), or when the acknowledging signal appears before the element times out (“Acknowledge” mode). When the new position is applied, the relay displays the **SELECTOR SWITCH 1: POSITION Z IN USE** message. Typically, a user-programmable pushbutton is configured as the stepping up control input.
- **SELECTOR 1 STEP-UP MODE:** This setting defines the selector mode of operation. When set to “Time-out”, the selector will change its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require any explicit confirmation of the intent to change the selector’s position. When set to “Acknowledge”, the selector will change its position only after the intent is confirmed through a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector does not accept the change and an alarm is established by setting the **SELECTOR STP ALARM** output FlexLogic™ operand for 3 seconds.
- **SELECTOR 1 ACK:** This setting specifies an acknowledging input for the stepping up control input. The pre-selected position is applied on the rising edge of the assigned operand. This setting is active only under “Acknowledge” mode of operation. The acknowledging signal must appear within the time defined by the **SELECTOR 1 TIME-OUT** setting after the last activity of the control input. A user-programmable pushbutton is typically configured as the acknowledging input.
- **SELECTOR 1 3BIT A0, A1, and A2:** These settings specify a 3-bit control input of the selector. The 3-bit control word pre-selects the position using the following encoding convention:

| A2 | A1 | A0 | POSITION |
|----|----|----|----------|
| 0  | 0  | 0  | rest     |
| 0  | 0  | 1  | 1        |
| 0  | 1  | 0  | 2        |
| 0  | 1  | 1  | 3        |
| 1  | 0  | 0  | 4        |
| 1  | 0  | 1  | 5        |
| 1  | 1  | 0  | 6        |
| 1  | 1  | 1  | 7        |

The “rest” position (0, 0, 0) does not generate an action and is intended for situations when the device generating the 3-bit control word is having a problem. When **SELECTOR 1 3BIT MODE** is “Time-out”, the pre-selected position is applied in **SELECTOR 1 TIME-OUT** seconds after the last activity of the 3-bit input. When **SELECTOR 1 3BIT MODE** is “Acknowledge”, the pre-selected position is applied on the rising edge of the **SELECTOR 1 3BIT ACK** acknowledging input.

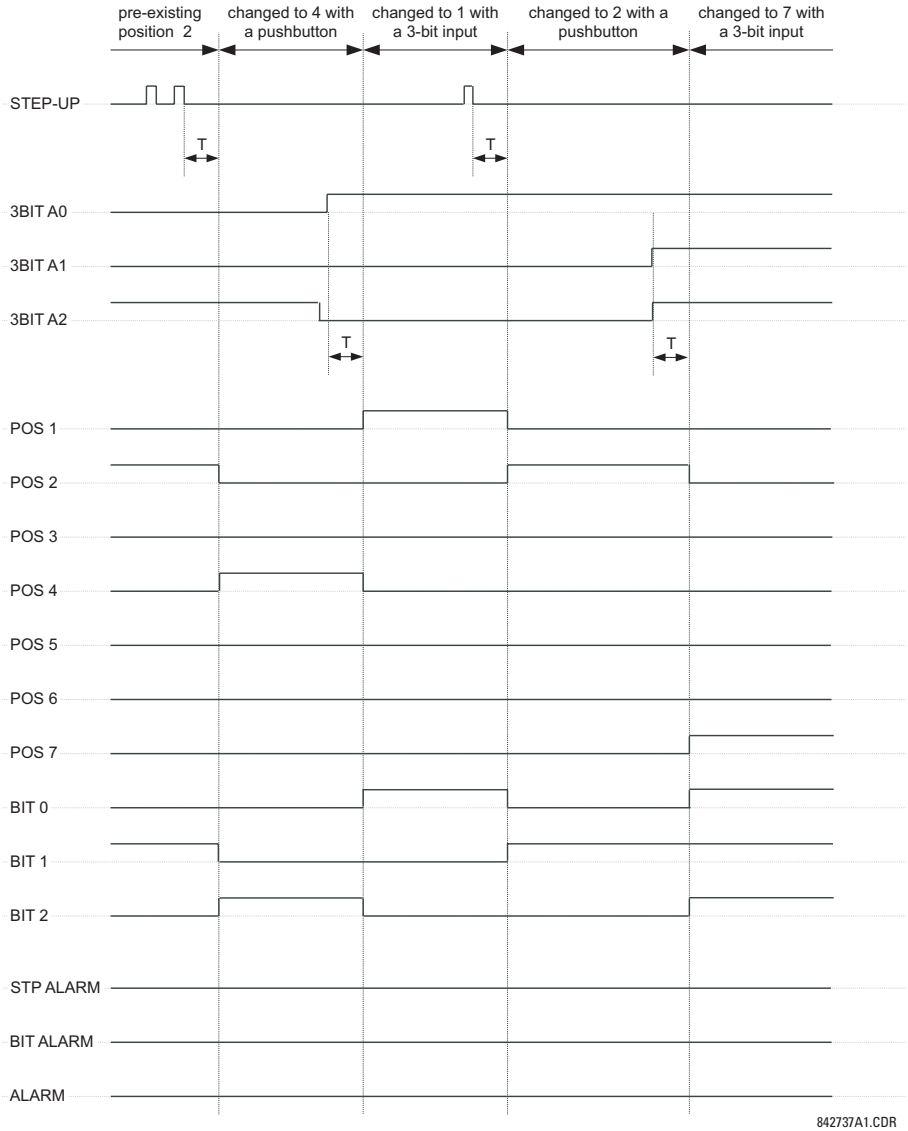
The stepping up control input (**SELECTOR 1 STEP-UP**) and the 3-bit control inputs (**SELECTOR 1 3BIT A0** through **A2**) lock-out mutually: once the stepping up sequence is initiated, the 3-bit control input is inactive; once the 3-bit control sequence is initiated, the stepping up input is inactive.

- **SELECTOR 1 3BIT MODE:** This setting defines the selector mode of operation. When set to “Time-out”, the selector changes its position after a pre-defined period of inactivity at the control input. The change is automatic and does not require explicit confirmation to change the selector position. When set to “Acknowledge”, the selector changes its position only after confirmation via a separate acknowledging signal. If the acknowledging signal does not appear within a pre-defined period of time, the selector rejects the change and an alarm established by invoking the **SELECTOR BIT ALARM** FlexLogic™ operand for 3 seconds.
- **SELECTOR 1 3BIT ACK:** This setting specifies an acknowledging input for the 3-bit control input. The pre-selected position is applied on the rising edge of the assigned FlexLogic™ operand. This setting is active only under the “Acknowledge” mode of operation. The acknowledging signal must appear within the time defined by the **SELECTOR TIME-OUT** setting after the last activity of the 3-bit control inputs. Note that the stepping up control input and 3-bit control input have independent acknowledging signals (**SELECTOR 1 ACK** and **SELECTOR 1 3BIT ACK**, accordingly).

- **SELECTOR 1 POWER-UP MODE:** This setting specifies behavior of the element on power up of the relay. When set to “Restore”, the last selector position, stored in non-volatile memory, is restored after powering up the relay. When set to “Synchronize”, the selector sets to the current 3-bit control input after powering up the relay. This operation does not wait for time-out or the acknowledging input. When powering up, the rest position (0, 0, 0) and the out-of-range 3-bit control words are also ignored, the output is set to Position 0 (no output operand selected), and an alarm is established (SELECTOR 1 PWR ALARM). If the position restored from memory is out-of-range, Position 0 (no output operand selected) is applied and an alarm is set (SELECTOR 1 PWR ALARM).
- **SELECTOR 1 EVENTS:** If enabled, the following events are logged:

| EVENT NAME           | DESCRIPTION  |
|----------------------|--|
| SELECTOR 1 POS Z     | Selector 1 changed its position to Z.  |
| SELECTOR 1 STP ALARM | The selector position pre-selected via the stepping up control input has not been confirmed before the time out. |
| SELECTOR 1 BIT ALARM | The selector position pre-selected via the 3-bit control input has not been confirmed before the time out.       |

The following figures illustrate the operation of the Selector Switch. In these diagrams, “T” represents a time-out setting.



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Figure 5–85: TIME-OUT MODE



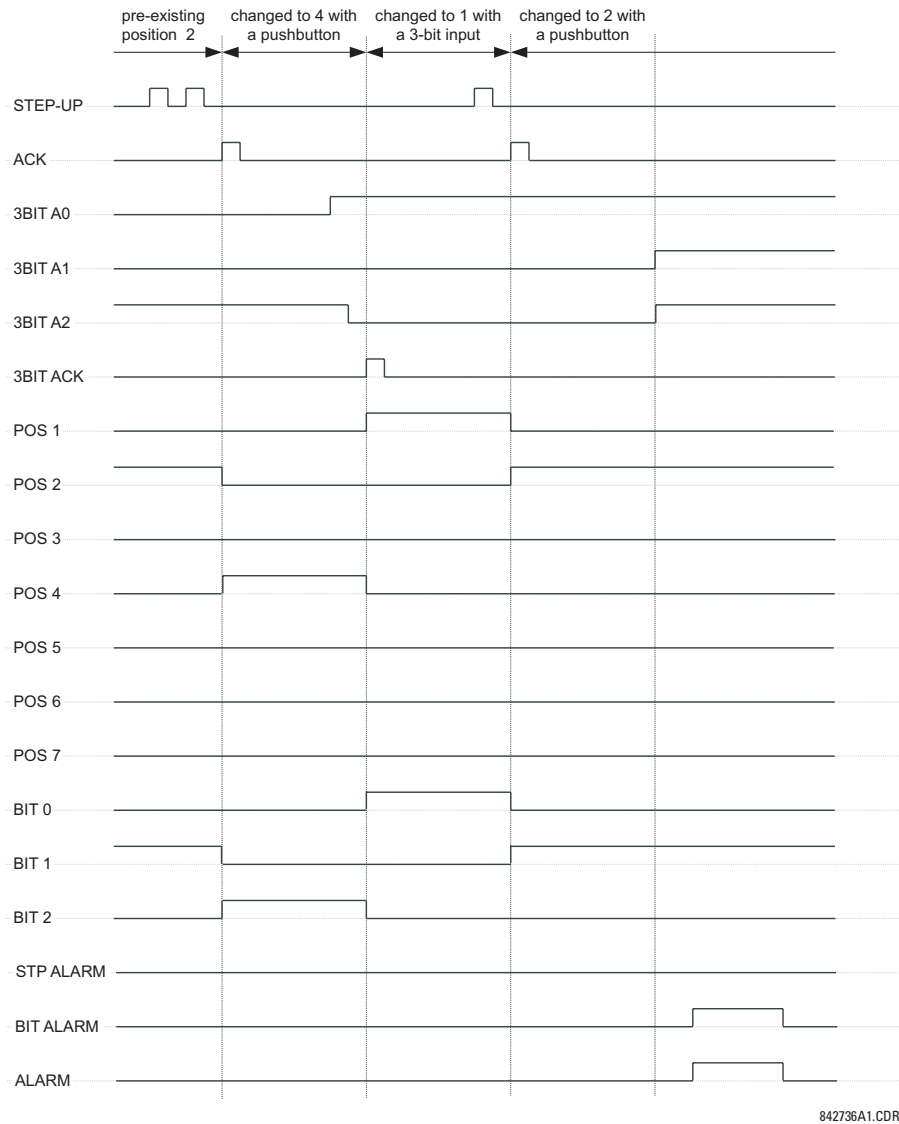


Figure 5–86: ACKNOWLEDGE MODE

## APPLICATION EXAMPLE

Consider an application where the selector switch is used to control Setting Groups 1 through 4 in the relay. The setting groups are to be controlled from both User-Programmable Pushbutton 1 and from an external device via Contact Inputs 1 through 3. The active setting group shall be available as an encoded 3-bit word to the external device and SCADA via output contacts 1 through 3. The pre-selected setting group shall be applied automatically after 5 seconds of inactivity of the control inputs. When the relay powers up, it should synchronize the setting group to the 3-bit control input.

Make the following changes to Setting Group Control in the **SETTINGS** ⇒ **CONTROL ELEMENTS** ⇒ **SETTING GROUPS** menu:

**SETTING GROUPS FUNCTION:** "Enabled"

**SETTING GROUPS BLK:** "Off"

**GROUP 2 ACTIVATE ON:** "SELECTOR 1 POS 2"

**GROUP 3 ACTIVATE ON:** "SELECTOR 1 POS 3"

**GROUP 4 ACTIVATE ON:** "SELECTOR 1 POS 4"

**GROUP 5 ACTIVATE ON:** "Off"

**GROUP 6 ACTIVATE ON:** "Off"

Make the following changes to Selector Switch element in the **SETTINGS** ⇒ **CONTROL ELEMENTS** ⇒ **SELECTOR SWITCH** ⇒ **SELECTOR SWITCH 1** menu to assign control to User Programmable Pushbutton 1 and Contact Inputs 1 through 3:

**SELECTOR 1 FUNCTION:** "Enabled"

**SELECTOR 1 FULL-RANGE:** "4"

**SELECTOR 1 STEP-UP MODE:** "Time-out"

**SELECTOR 1 TIME-OUT:** "5.0 s"

**SELECTOR 1 STEP-UP:** "PUSHBUTTON 1 ON"

**SELECTOR 1 ACK:** "Off"

**SELECTOR 1 3BIT A0:** "CONT IP 1 ON"

**SELECTOR 1 3BIT A1:** "CONT IP 2 ON"

**SELECTOR 1 3BIT A2:** "CONT IP 3 ON"

**SELECTOR 1 3BIT MODE:** "Time-out"

**SELECTOR 1 3BIT ACK:** "Off"

**SELECTOR 1 POWER-UP MODE:** "Synchronize"

Now, assign the contact output operation (assume the H6E module) to the Selector Switch element by making the following changes in the **SETTINGS** ⇒ **INPUTS/OUTPUTS** ⇒ **CONTACT OUTPUTS** menu:

**OUTPUT H1 OPERATE:** "SELECTOR 1 BIT 0"

**OUTPUT H2 OPERATE:** "SELECTOR 1 BIT 1"

**OUTPUT H3 OPERATE:** "SELECTOR 1 BIT 2"

Finally, assign configure User-Programmable Pushbutton 1 by making the following changes in the **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **USER-PROGRAMMABLE PUSHBUTTONS** ⇒ **USER PUSHBUTTON 1** menu:

**PUSHBUTTON 1 FUNCTION:** "Self-reset"

**PUSHBUTTON 1 DROP-OUT TIME:** "0.10 s"

The logic for the selector switch is shown below:

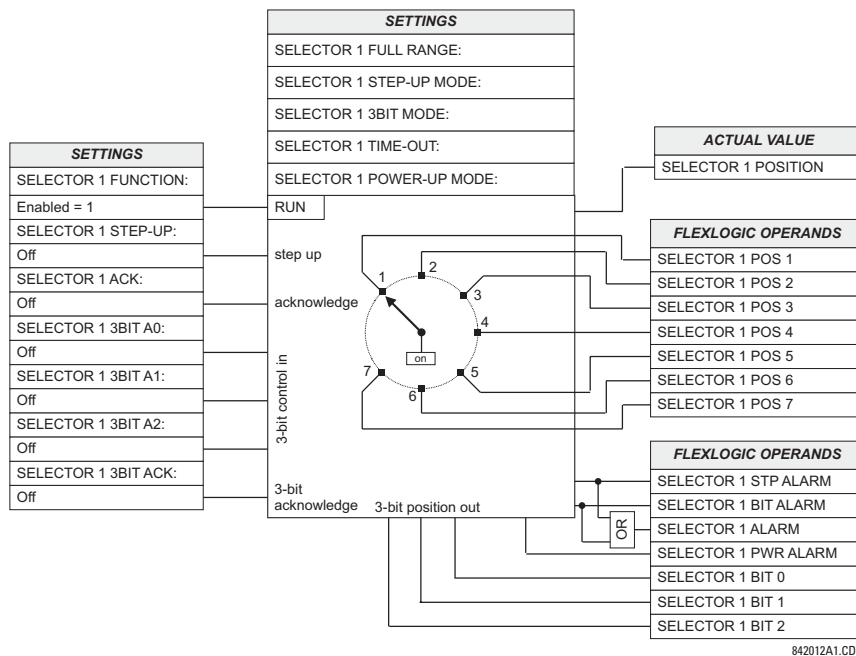


Figure 5-87: SELECTOR SWITCH LOGIC

## 5.6.4 SYNCHROCHECK

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ SYNCHROCHECK ⇒ SYNCHROCHECK 1(2)

|                  |    |  |  |
|------------------|----|--|--|
| ■ SYNCHROCHECK 1 |    | SYNCHK1 FUNCTION:<br>Disabled              | Range: Disabled, Enabled   |
| MESSAGE          | ▲▼ | SYNCHK1 BLOCK:<br>Off                      | Range: FlexLogic™ operand  |
| MESSAGE          | ▲▼ | SYNCHK1 V1 SOURCE:<br>SRC 1                | Range: SRC 1, SRC 2  |
| MESSAGE          | ▲▼ | SYNCHK1 V2 SOURCE:<br>SRC 2                | Range: SRC 1, SRC 2  |
| MESSAGE          | ▲▼ | SYNCHK1 MAX VOLT<br>DIFF: 10000 V          | Range: 0 to 100000 V in steps of 1   |
| MESSAGE          | ▲▼ | SYNCHK1 MAX ANGLE<br>DIFF: 30°             | Range: 0 to 100° in steps of 1   |
| MESSAGE          | ▲▼ | SYNCHK1 MAX FREQ<br>DIFF: 1.00 Hz          | Range: 0.00 to 2.00 Hz in steps of 0.01  |
| MESSAGE          | ▲▼ | SYNCHK1 MAX FREQ<br>HYSTERESIS: 0.06 Hz    | Range: 0.00 to 0.10 Hz in steps of 0.01  |
| MESSAGE          | ▲▼ | SYNCHK1 DEAD SOURCE<br>SELECT: LV1 and DV2 | Range: None, LV1 and DV2, DV1 and LV2, DV1 or DV2,<br>DV1 Xor DV2, DV1 and DV2 |
| MESSAGE          | ▲▼ | SYNCHK1 DEAD V1<br>MAX VOLT: 0.30 pu       | Range: 0.00 to 1.25 pu in steps of 0.01  |
| MESSAGE          | ▲▼ | SYNCHK1 DEAD V2<br>MAX VOLT: 0.30 pu       | Range: 0.00 to 1.25 pu in steps of 0.01  |
| MESSAGE          | ▲▼ | SYNCHK1 LIVE V1<br>MIN VOLT: 0.70 pu       | Range: 0.00 to 1.25 pu in steps of 0.01  |
| MESSAGE          | ▲▼ | SYNCHK1 LIVE V2<br>MIN VOLT: 0.70 pu       | Range: 0.00 to 1.25 pu in steps of 0.01  |
| MESSAGE          | ▲▼ | SYNCHK1 TARGET:<br>Self-reset              | Range: Self-reset, Latched, Disabled   |
| MESSAGE          | ▲  | SYNCHK1 EVENTS:<br>Disabled                | Range: Disabled, Enabled   |

There are two identical synchrocheck elements available, numbered 1 and 2.

The synchronism check function is intended for supervising the paralleling of two parts of a system which are to be joined by the closure of a circuit breaker. The synchrocheck elements are typically used at locations where the two parts of the system are interconnected through at least one other point in the system.

Synchrocheck verifies that the voltages (V1 and V2) on the two sides of the supervised circuit breaker are within set limits of magnitude, angle and frequency differences. The time that the two voltages remain within the admissible angle difference is determined by the setting of the phase angle difference  $\Delta\Phi$  and the frequency difference  $\Delta F$  (slip frequency). It can be defined as the time it would take the voltage phasor V1 or V2 to traverse an angle equal to  $2 \times \Delta\Phi$  at a frequency equal to the frequency difference  $\Delta F$ . This time can be calculated by:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F} \quad (\text{EQ 5.17})$$

where:  $\Delta\Phi$  = phase angle difference in degrees;  $\Delta F$  = frequency difference in Hz.

As an example; for the default values ( $\Delta\Phi = 30^\circ$ ,  $\Delta F = 0.1$  Hz), the time while the angle between the two voltages will be less than the set value is:

$$T = \frac{1}{\frac{360^\circ}{2 \times \Delta\Phi} \times \Delta F} = \frac{1}{\frac{360^\circ}{2 \times 30^\circ} \times 0.1 \text{ Hz}} = 1.66 \text{ sec.} \quad (\text{EQ 5.18})$$

If one or both sources are de-energized, the synchrocheck programming can allow for closing of the circuit breaker using undervoltage control to by-pass the synchrocheck measurements (Dead Source function).

- **SYNCHK1 V1 SOURCE:** This setting selects the source for voltage V1 (see NOTES below).
- **SYNCHK1 V2 SOURCE:** This setting selects the source for voltage V2, which must not be the same as used for the V1 (see NOTES below).
- **SYNCHK1 MAX VOLT DIFF:** This setting selects the maximum primary voltage difference in 'kV' between the two sources. A primary voltage magnitude difference between the two input voltages below this value is within the permissible limit for synchronism.
- **SYNCHK1 MAX ANGLE DIFF:** This setting selects the maximum angular difference in degrees between the two sources. An angular difference between the two input voltage phasors below this value is within the permissible limit for synchronism.
- **SYNCHK1 MAX FREQ DIFF:** This setting selects the maximum frequency difference in 'Hz' between the two sources. A frequency difference between the two input voltage systems below this value is within the permissible limit for synchronism.
- **SYNCHK1 MAX FREQ HYSTERESIS:** This setting specifies the required hysteresis for the maximum frequency difference condition. The condition becomes satisfied when the frequency difference becomes lower than **SYNCHK1 MAX FREQ DIFF**. Once the Synchrocheck element has operated, the frequency difference must increase above the **SYNCHK1 MAX FREQ DIFF + SYNCHK1 MAX FREQ HYSTERESIS** sum to drop out (assuming the other two conditions, voltage and angle, remain satisfied).
- **SYNCHK1 DEAD SOURCE SELECT:** This setting selects the combination of dead and live sources that will by-pass synchronism check function and permit the breaker to be closed when one or both of the two voltages (V1 or/and V2) are below the maximum voltage threshold. A dead or live source is declared by monitoring the voltage level. Six options are available:
 

|              |   |
|--------------|---|
| None:        | Dead Source function is disabled  |
| LV1 and DV2: | Live V1 and Dead V2   |
| DV1 and LV2: | Dead V1 and Live V2   |
| DV1 or DV2:  | Dead V1 or Dead V2  |
| DV1 Xor DV2: | Dead V1 exclusive-or Dead V2 (one source is Dead and the other is Live) |
| DV1 and DV2: | Dead V1 and Dead V2   |
- **SYNCHK1 DEAD V1 MAX VOLT:** This setting establishes a maximum voltage magnitude for V1 in 'pu'. Below this magnitude, the V1 voltage input used for synchrocheck will be considered "Dead" or de-energized.
- **SYNCHK1 DEAD V2 MAX VOLT:** This setting establishes a maximum voltage magnitude for V2 in 'pu'. Below this magnitude, the V2 voltage input used for synchrocheck will be considered "Dead" or de-energized.
- **SYNCHK1 LIVE V1 MIN VOLT:** This setting establishes a minimum voltage magnitude for V1 in 'pu'. Above this magnitude, the V1 voltage input used for synchrocheck will be considered "Live" or energized.
- **SYNCHK1 LIVE V2 MIN VOLT:** This setting establishes a minimum voltage magnitude for V2 in 'pu'. Above this magnitude, the V2 voltage input used for synchrocheck will be considered "Live" or energized.

**NOTES ON THE SYNCHROCHECK FUNCTION:**

- The selected sources for synchrocheck inputs V1 and V2 (which must not be the same source) may include both a three-phase and an auxiliary voltage. The relay will automatically select the specific voltages to be used by the synchrocheck element in accordance with the following table.

| NO. | V1 OR V2<br>(SOURCE Y)        | V2 OR V1<br>(SOURCE Z)        | AUTO-SELECTED<br>COMBINATION |           | AUTO-SELECTED VOLTAGE                        |
|-----|-------------------------------|-------------------------------|------------------------------|-----------|--|
|     |                               |                               | SOURCE Y                     | SOURCE Z  |  |
| 1   | Phase VTs and<br>Auxiliary VT | Phase VTs and<br>Auxiliary VT | Phase                        | Phase     | VAB  |
| 2   | Phase VTs and<br>Auxiliary VT | Phase VT                      | Phase                        | Phase     | VAB  |
| 3   | Phase VT                      | Phase VT                      | Phase                        | Phase     | VAB  |
| 4   | Phase VT and<br>Auxiliary VT  | Auxiliary VT                  | Phase                        | Auxiliary | V auxiliary<br>(as set for Source z)         |
| 5   | Auxiliary VT                  | Auxiliary VT                  | Auxiliary                    | Auxiliary | V auxiliary<br>(as set for selected sources) |

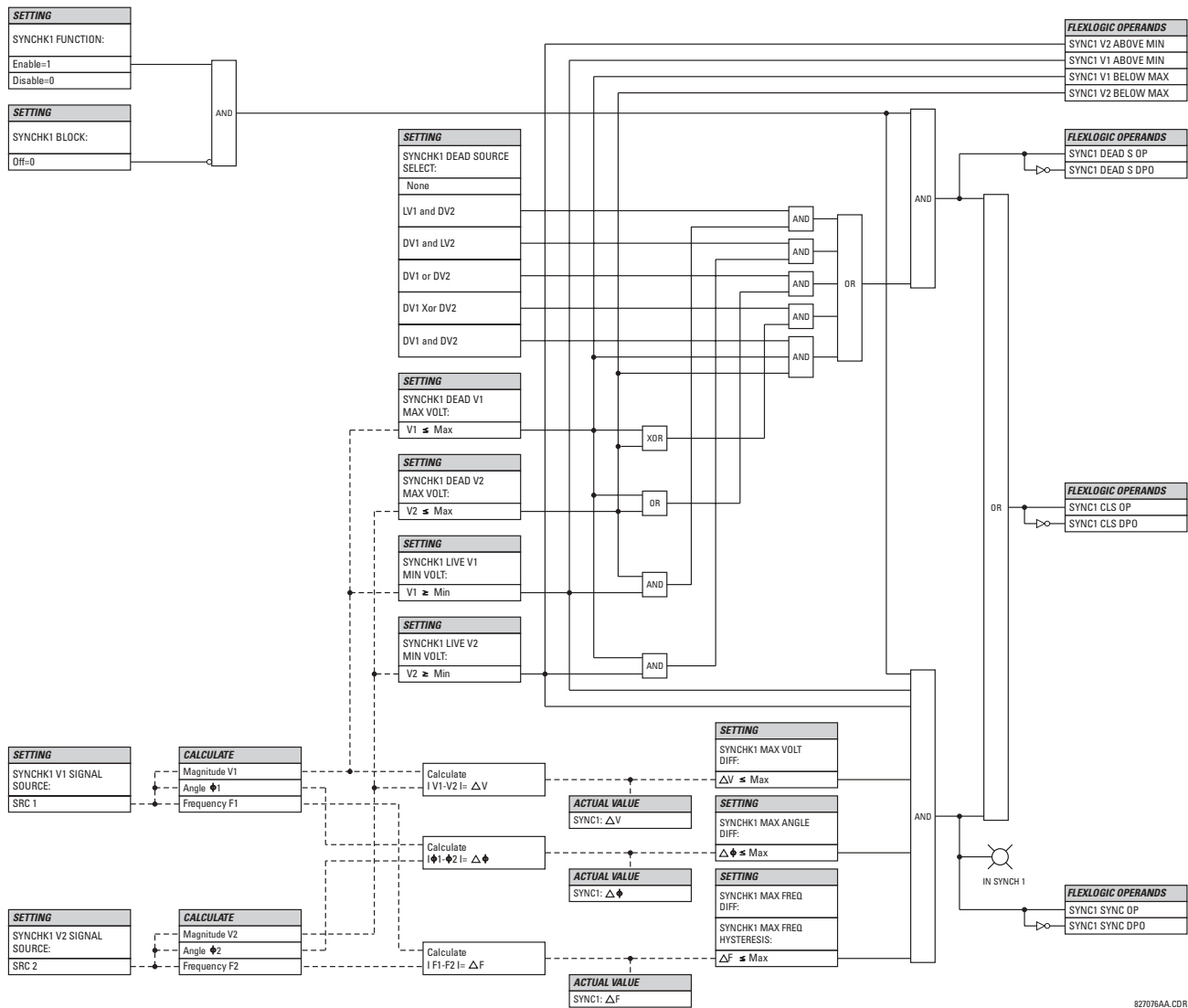
The voltages V1 and V2 will be matched automatically so that the corresponding voltages from the two sources will be used to measure conditions. A phase to phase voltage will be used if available in both sources; if one or both of the Sources have only an auxiliary voltage, this voltage will be used. For example, if an auxiliary voltage is programmed to VAG, the synchrocheck element will automatically select VAG from the other source. If the comparison is required on a specific voltage, the user can externally connect that specific voltage to auxiliary voltage terminals and then use this "Auxiliary Voltage" to check the synchronism conditions.

If using a single CT/VT module with both phase voltages and an auxiliary voltage, ensure that only the auxiliary voltage is programmed in one of the sources to be used for synchrocheck.



**Exception:** *Synchronism cannot be checked between Delta connected phase VTs and a Wye connected auxiliary voltage.*

- The relay measures frequency and Volts/Hz from an input on a given source with priorities as established by the configuration of input channels to the source. The relay will use the phase channel of a three-phase set of voltages if programmed as part of that source. The relay will use the auxiliary voltage channel only if that channel is programmed as part of the Source and a three-phase set is not.








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Figure 5-88: SYNCHROCHECK SCHEME LOGIC

## 5.6.5 AUTORECLOSE

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ AUTORECLOSE ⇒ AUTORECLOSE 1

|                 |    |   |  |
|-----------------|----|---|--|
| ■ AUTORECLOSE 1 |    | AR1 FUNCTION:<br>Disabled                   | Range: Disabled, Enabled                 |
| MESSAGE         | ▲▼ | AR1 INITIATE:<br>Off                        | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 BLOCK:<br>Off                           | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 MAX NUMBER OF<br>SHOTS: 1               | Range: 1, 2, 3, 4                        |
| MESSAGE         | ▲▼ | AR1 REDUCE MAX TO 1:<br>Off                 | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 REDUCE MAX TO 2:<br>Off                 | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 REDUCE MAX TO 3:<br>Off                 | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 MANUAL CLOSE:<br>Off                    | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 MNL RST FRM LO:<br>Off                  | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 RESET LOCKOUT IF<br>BREAKER CLOSED: Off | Range: Off, On                           |
| MESSAGE         | ▲▼ | AR1 RESET LOCKOUT ON<br>MANUAL CLOSE: Off   | Range: Off, On                           |
| MESSAGE         | ▲▼ | AR1 BKR CLOSED:<br>Off                      | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 BKR OPEN:<br>Off                        | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 BLK TIME UPON<br>MNL CLS: 10.000 s      | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE         | ▲▼ | AR1 DEAD TIME 1:<br>1.000 s                 | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE         | ▲▼ | AR1 DEAD TIME 2:<br>2.000 s                 | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE         | ▲▼ | AR1 DEAD TIME 3:<br>3.000 s                 | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE         | ▲▼ | AR1 DEAD TIME 4:<br>4.000 s                 | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE         | ▲▼ | AR1 ADD DELAY 1:<br>Off                     | Range: FlexLogic™ operand                |
| MESSAGE         | ▲▼ | AR1 DELAY 1:<br>0.000 s                     | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE         | ▲▼ | AR1 ADD DELAY 2:<br>Off                     | Range: FlexLogic™ operand                |

|         |   |                                     |  |
|---------|---|-------------------------------------|--|
| MESSAGE |  | AR1 DELAY 2:<br>0.000 s             | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE |  | AR1 RESET LOCKOUT<br>DELAY: 60.000  | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE |  | AR1 RESET TIME:<br>60.000 s         | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE |  | AR1 INCOMPLETE SEQ<br>TIME: 5.000 s | Range: 0.00 to 655.35 s in steps of 0.01 |
| MESSAGE |  | AR1 EVENTS:<br>Disabled             | Range: Disabled, Enabled                 |

The maximum number of autoreclosure elements available is equal to the number of installed CT banks.

The autoreclosure feature is intended for use with transmission and distribution lines, in three-pole tripping schemes for single breaker applications. Up to four selectable reclosures ‘shots’ are possible prior to locking out. Each shot has an independently settable dead time. The protection settings can be changed between shots if so desired, using FlexLogic™. Logic inputs are available for disabling or blocking the scheme.

Faceplate panel LEDs indicate the state of the autoreclose scheme as follows:

- Reclose Enabled: The scheme is enabled and may reclose if initiated.
- Reclose Disabled: The scheme is disabled.
- Reclose In Progress: An autoreclosure has been initiated but the breaker has not yet been signaled to close.
- Reclose Locked Out: The scheme has generated the maximum number of breaker closures allowed and, as the fault persists, will not close the breaker again; known as ‘Lockout’. The scheme may also be sent in ‘Lockout’ when the incomplete sequence timer times out or when a block signal occurs while in ‘reclose in progress’. The scheme must be reset from Lockout in order to perform reclose for further faults.

The reclosure scheme is considered *enabled* when all of the following conditions are true:

- The **AR1 FUNCTION** is set to “Enabled”.
- The scheme is not in the ‘Lockout’ state.
- The ‘Block’ input is not asserted.
- The **AR1 BLK TIME UPON MNL CLS** timer is not active.

The autoreclose scheme is initiated by a trip signal from any selected protection feature operand. The scheme is initiated provided the circuit breaker is in the closed state before protection operation.

The reclose-in-progress (RIP) is set when a reclosing cycle begins following a reclose initiate signal. Once the cycle is successfully initiated, the RIP signal will seal-in and the scheme will continue through its sequence until one of the following conditions is satisfied:

- The close signal is issued when the dead timer times out, or
- The scheme goes to lockout.

While RIP is active, the scheme checks that the breaker is open and the shot number is below the limit, and then begins measuring the dead time.

Each of the four possible shots has an independently settable dead time. Two additional timers can be used to increase the initial set dead times 1 to 4 by a delay equal to **AR1 DELAY 1** or **AR1 DELAY 2** or the sum of these two delays depending on the selected settings. This offers enhanced setting flexibility using FlexLogic™ operands to turn the two additional timers “on” and “off”. These operands may possibly include **AR1 SHOT CNT =n**, **SETTING GROUP ACT 1**, etc. The autoreclose provides up to maximum 4 selectable shots. Maximum number of shots can be dynamically modified through the settings **AR1 REDUCE MAX TO 1 (2, 3)**, using the appropriate FlexLogic™ operand.

Scheme lockout blocks all phases of the reclosing cycle, preventing automatic reclosure, if any of the following occurs:

- The maximum shot number was reached.
- A ‘Block’ input is in effect (for instance; Breaker Failure, bus differential protection operated, etc.).



- The 'Incomplete Sequence' timer times out.

The recloser will be latched in the Lockout state until a 'Reset from lockout' signal is asserted, either from a manual close of the breaker or from a manual reset command (local or remote). The reset from lockout can be accomplished by operator command, by manually closing the breaker, or whenever the breaker has been closed and stays closed for a preset time.

After the dead time elapses, the scheme issues the close signal. The close signal is latched until the breaker closes or the scheme goes to Lockout.

A reset timer output resets the recloser following a successful reclosure sequence. The reset time is based on the breaker 'reclaim time' which is the minimum time required between successive reclose sequences.

#### SETTINGS:

- **AR1 INITIATE:** Selects the FlexLogic™ operand that initiates the scheme, typically the trip signal from protection.
- **AR1 BLOCK:** Selects the FlexLogic™ operand that blocks the autoreclosure initiate (it could be from the breaker failure, bus differential protection, etc.).
- **AR1 MAX NUMBER OF SHOTS:** Specifies the number of reclosures that can be attempted before reclosure goes to "Lockout" because the fault is permanent.
- **AR1 REDUCE MAX TO 1(3):** Selects the FlexLogic™ operand that changes the maximum number of shots from the initial setting to 1, 2, or 3, respectively.
- **AR1 MANUAL CLOSE:** Selects the logic input set when the breaker is manually closed.
- **AR1 MNL RST FRM LO:** Selects the FlexLogic™ operand that resets the autoreclosure from Lockout condition. Typically this is a manual reset from lockout, local or remote.
- **AR1 RESET LOCKOUT IF BREAKER CLOSED:** This setting allows the autoreclosure scheme to reset from Lockout if the breaker has been manually closed and stays closed for a preset time. In order for this setting to be effective, the next setting (**AR1 RESET LOCKOUT ON MANUAL CLOSE**) should be disabled.
- **AR1 RESET LOCKOUT ON MANUAL CLOSE:** This setting allows the autoreclosure scheme to reset from Lockout when the breaker is manually closed regardless if the breaker remains closed or not. This setting overrides the previous setting (**AR1 RESET LOCKOUT IF BREAKER CLOSED**).
- **AR1 BLK TIME UPON MNL CLS:** The autoreclosure scheme can be disabled for a programmable time delay after the associated circuit breaker is manually closed. This prevents reclosing onto a fault after a manual close. This delay must be longer than the slowest expected trip from any protection not blocked after manual closing. If no overcurrent trips occur after a manual close and this time expires, the autoreclosure scheme is enabled.
- **AR1 DEAD TIME 1 to AR1 DEAD TIME 4:** These are the intentional delays before first, second, third, and fourth breaker automatic reclosures (1st, 2nd, and 3rd shots), respectively, and should be set longer than the estimated deionizing time following a three pole trip.
- **AR1 ADD DELAY 1:** This setting selects the FlexLogic™ operand that introduces an additional delay (Delay 1) to the initial set Dead Time (1 to 4). When this setting is "Off", Delay 1 is by-passed.
- **AR1 DELAY 1:** This setting establishes the extent of the additional dead time Delay 1.
- **AR1 ADD DELAY 2:** This setting selects the FlexLogic™ operand that introduces an additional delay (Delay 2) to the initial set Dead Time (1 to 4). When this setting is "Off", Delay 2 is by-passed.
- **AR1 DELAY 2:** This setting establishes the extent of the additional dead time Delay 2.
- **AR1 RESET LOCKOUT DELAY:** This setting establishes how long the breaker should stay closed after a manual close command, in order for the autorecloser to reset from Lockout.
- **AR1 RESET TIME:** A reset timer output resets the recloser following a successful reclosure sequence. The setting is based on the breaker 'reclaim time' which is the minimum time required between successive reclose sequences.
- **AR1 INCOMPLETE SEQ TIME:** This timer defines the maximum time interval allowed for a single reclose shot. It is started whenever a reclosure is initiated and is active when the scheme is in the 'reclose-in-progress' state. If all conditions allowing a breaker closure are not satisfied when this time expires, the scheme goes to "Lockout".



**This timer must be set to a delay less than the reset timer.**

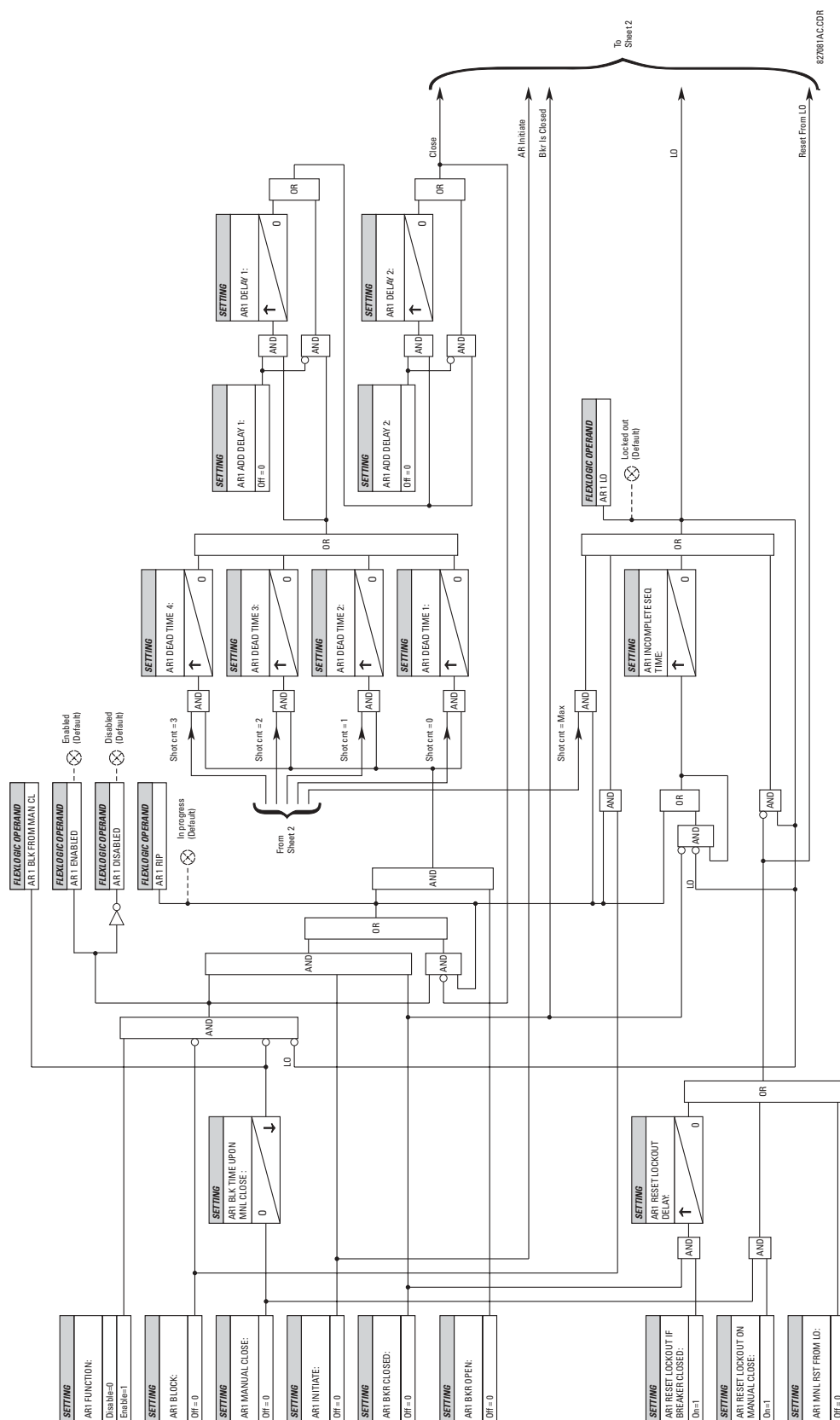
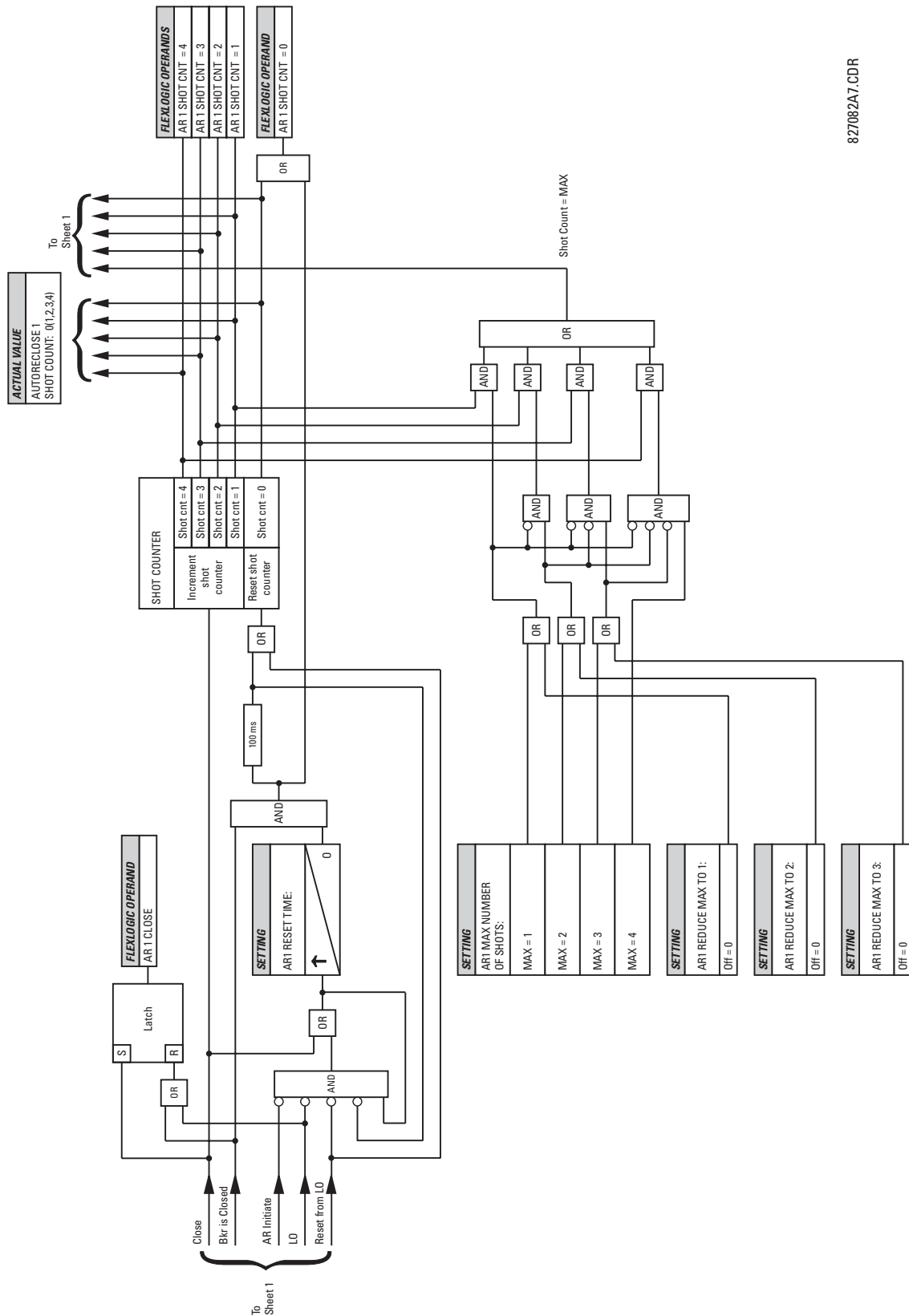
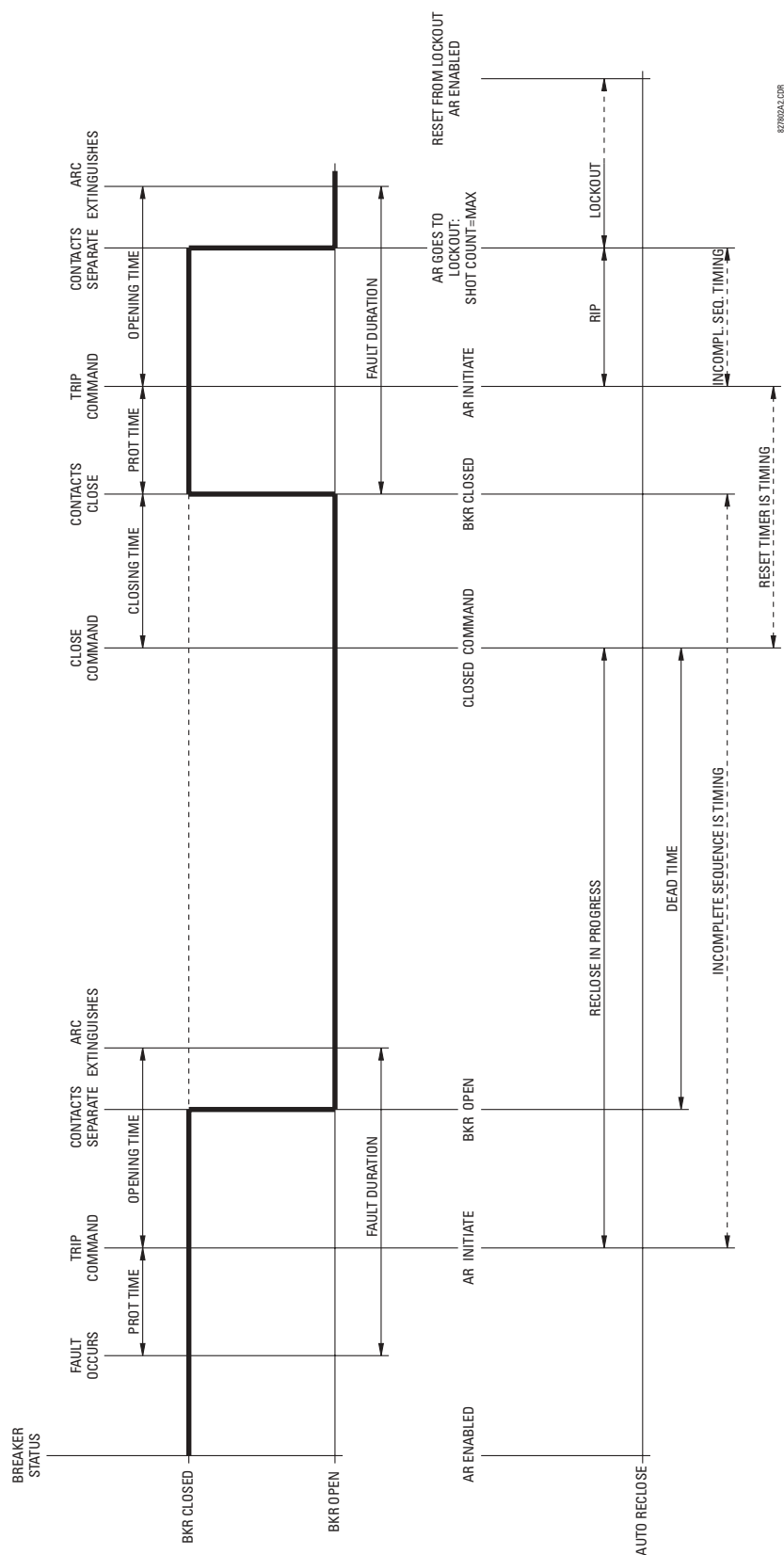


Figure 5-89: AUTORECLOSURE SCHEME LOGIC (Sheet 1 of 2)



**Figure 5–90: AUTORECLOSURE SCHEME LOGIC (Sheet 2 of 2)**



**Figure 5-91: SINGLE SHOT AUTOECLOSING SEQUENCE - PERMANENT FAULT**

## 5.6.6 DIGITAL ELEMENTS

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ DIGITAL ELEMENTS ⇒ DIGITAL ELEMENT 1(16)

|                     |    |   |  |
|---------------------|----|---|--|
| ■ DIGITAL ELEMENT 1 | ◀▶ | DIGITAL ELEMENT 1<br>FUNCTION: Disabled | Range: Disabled, Enabled                       |
| MESSAGE             | ▲▼ | DIG ELEM 1 NAME:<br>Dig Element 1       | Range: 16 alphanumeric characters              |
| MESSAGE             | ▲▼ | DIG ELEM 1 INPUT:<br>Off                | Range: FlexLogic™ operand                      |
| MESSAGE             | ▲▼ | DIG ELEM 1 PICKUP<br>DELAY: 0.000 s     | Range: 0.000 to 999999.999 s in steps of 0.001 |
| MESSAGE             | ▲▼ | DIG ELEM 1 RESET<br>DELAY: 0.000 s      | Range: 0.000 to 999999.999 s in steps of 0.001 |
| MESSAGE             | ▲▼ | DIG ELEM 1 BLOCK:<br>Off                | Range: FlexLogic™ operand                      |
| MESSAGE             | ▲▼ | DIGITAL ELEMENT 1<br>TARGET: Self-reset | Range: Self-reset, Latched, Disabled           |
| MESSAGE             | ▲  | DIGITAL ELEMENT 1<br>EVENTS: Disabled   | Range: Disabled, Enabled                       |

There are 16 identical Digital Elements available, numbered 1 to 16. A digital element can monitor any FlexLogic™ operand and present a target message and/or enable events recording depending on the output operand state. The digital element settings include a 'name' which will be referenced in any target message, a blocking input from any selected FlexLogic™ operand, and a timer for pickup and reset delays for the output operand.

- **DIGITAL ELEMENT 1 INPUT:** Selects a FlexLogic™ operand to be monitored by the digital element.
- **DIGITAL ELEMENT 1 PICKUP DELAY:** Sets the time delay to pickup. If a pickup delay is not required, set to "0".
- **DIGITAL ELEMENT 1 RESET DELAY:** Sets the time delay to reset. If a reset delay is not required, set to "0".

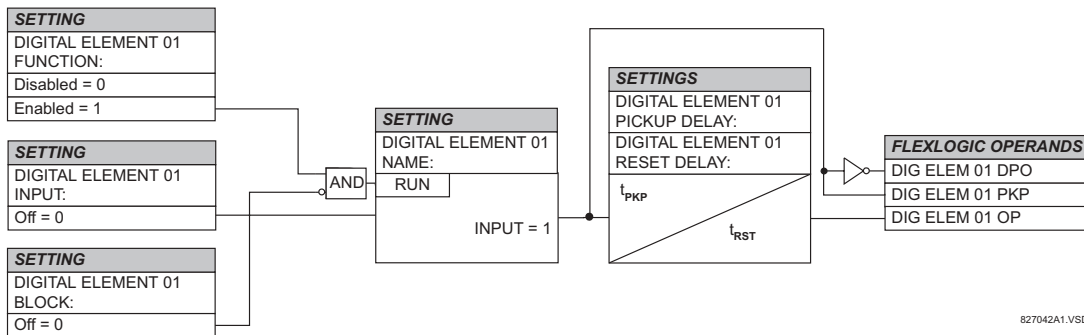


Figure 5-92: DIGITAL ELEMENT SCHEME LOGIC

## CIRCUIT MONITORING APPLICATIONS:

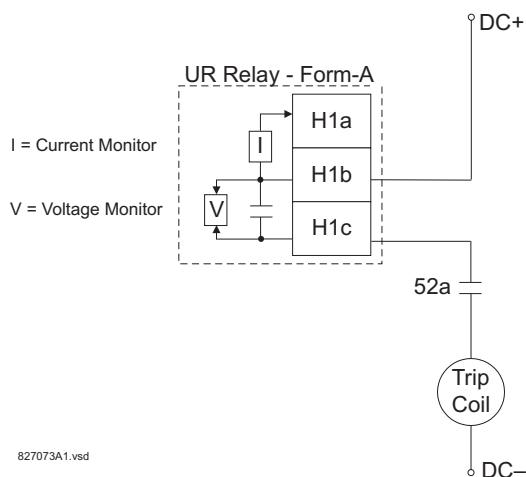
Some versions of the digital input modules include an active Voltage Monitor circuit connected across Form-A contacts. The voltage monitor circuit limits the trickle current through the output circuit (see technical specifications for Form-A).

As long as the current through the Voltage Monitor is above a threshold (see technical specifications for Form-A), the FlexLogic™ operand "Cont Op # VOn" will be set. (# represents the output contact number). If the output circuit has a high resistance or the DC current is interrupted, the trickle current will drop below the threshold and the FlexLogic™ operand "Cont Op # VOff" will be set. Consequently, the state of these operands can be used as indicators of the integrity of the circuits in which Form-A contacts are inserted.

**EXAMPLE 1: BREAKER TRIP CIRCUIT INTEGRITY MONITORING**

In many applications it is desired to monitor the breaker trip circuit integrity so problems can be detected before a trip operation is required. The circuit is considered to be healthy when the voltage monitor connected across the trip output contact detects a low level of current, well below the operating current of the breaker trip coil. If the circuit presents a high resistance, the trickle current will fall below the monitor threshold and an alarm would be declared.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact which is open when the breaker is open (see diagram below). To prevent unwanted alarms in this situation, the trip circuit monitoring logic must include the breaker position.



**Figure 5-93: TRIP CIRCUIT EXAMPLE 1**

Assume the output contact H1 is a trip contact. Using the contact output settings, this output will be given an ID name, e.g. "Cont Op 1". Assume a 52a breaker auxiliary contact is connected to contact input H7a to monitor breaker status. Using the contact input settings, this input will be given an ID name, e.g. "Cont Ip 1" and will be set "On" when the breaker is closed. Using Digital Element 1 to monitor the breaker trip circuit, the settings will be:

| DIGITAL ELEMENT 1 |                   | DIGITAL ELEMENT 1  |
|-------------------|-------------------|--------------------|
|                   | FUNCTION: Enabled |                    |
| MESSAGE           | DIG ELEM 1 NAME:  | Bkr Trip Cct Out   |
| MESSAGE           | DIG ELEM 1 INPUT: | Cont Op 1 Voff     |
| MESSAGE           | DIG ELEM 1 PICKUP | DELAY: 0.200 s     |
| MESSAGE           | DIG ELEM 1 RESET  | DELAY: 0.100 s     |
| MESSAGE           | DIG ELEM 1 BLOCK: | Cont Ip 1 Off      |
| MESSAGE           | DIGITAL ELEMENT 1 | TARGET: Self-reset |
| MESSAGE           | DIGITAL ELEMENT 1 | EVENTS: Enabled    |



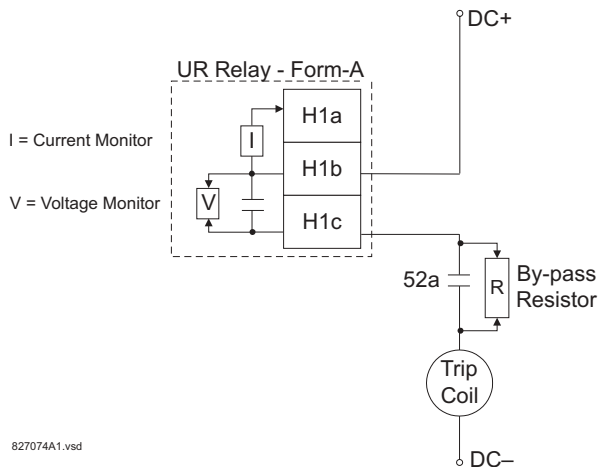
The PICKUP DELAY setting should be greater than the operating time of the breaker to avoid nuisance alarms.

NOTE

**EXAMPLE 2: BREAKER TRIP CIRCUIT INTEGRITY MONITORING**

If it is required to monitor the trip circuit continuously, independent of the breaker position (open or closed), a method to maintain the monitoring current flow through the trip circuit when the breaker is open must be provided (as shown in the figure below). This can be achieved by connecting a suitable resistor (see figure below) across the auxiliary contact in the trip circuit. In this case, it is not required to supervise the monitoring circuit with the breaker position – the **BLOCK** setting is selected to “Off”. In this case, the settings will be:

|                     |    |   |
|---------------------|----|---|
| ■ DIGITAL ELEMENT 1 | ◀▶ | DIGITAL ELEMENT 1<br>FUNCTION: Enabled  |
| MESSAGE             | ▲▼ | DIG ELEM 1 NAME:<br>Bkr Trip Cct Out    |
| MESSAGE             | ▲▼ | DIG ELEM 1 INPUT:<br>Cont Op 1 Voff     |
| MESSAGE             | ▲▼ | DIG ELEM 1 PICKUP<br>DELAY: 0.200 s     |
| MESSAGE             | ▲▼ | DIG ELEM 1 RESET<br>DELAY: 0.100 s      |
| MESSAGE             | ▲▼ | DIG ELEM 1 BLOCK:<br>Off                |
| MESSAGE             | ▲▼ | DIGITAL ELEMENT 1<br>TARGET: Self-reset |
| MESSAGE             | ▲  | DIGITAL ELEMENT 1<br>EVENTS: Enabled    |

**Table 5-19: VALUES OF RESISTOR 'R'**

| POWER SUPPLY (V DC) | RESISTANCE (OHMS) | POWER (WATTS) |
|---------------------|-------------------|---------------|
| 24                  | 1000              | 2             |
| 30                  | 5000              | 2             |
| 48                  | 10000             | 2             |
| 110                 | 25000             | 5             |
| 125                 | 25000             | 5             |
| 250                 | 50000             | 5             |

**Figure 5-94: TRIP CIRCUIT EXAMPLE 2**

## 5.6.7 DIGITAL COUNTERS

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ DIGITAL COUNTERS ⇒ COUNTER 1(8)

|  |  |  |                          |
|--|--|--|--------------------------|
| <div> <div>COUNTER 1</div> <div> <div>MESSAGE</div> <div> <div>▲</div> <div>▼</div> </div> </div> </div> |  | <div>COUNTER 1</div> <div>FUNCTION: Disabled</div> | Range: Disabled, Enabled |
| <div> <div>COUNTER 1 NAME:</div> <div>Counter 1</div> </div>   |  | Range: 12 alphanumeric characters                  |                          |
| <div> <div>COUNTER 1 UNITS:</div> <div></div> </div>   |  | Range: 6 alphanumeric characters                   |                          |
| <div> <div>COUNTER 1 PRESET:</div> <div>0</div> </div>   |  | Range: -2,147,483,648 to +2,147,483,647            |                          |
| <div> <div>COUNTER 1 COMPARE:</div> <div>0</div> </div>  |  | Range: -2,147,483,648 to +2,147,483,647            |                          |
| <div> <div>COUNTER 1 UP:</div> <div>Off</div> </div>   |  | Range: FlexLogic™ operand                          |                          |
| <div> <div>COUNTER 1 DOWN:</div> <div>Off</div> </div>   |  | Range: FlexLogic™ operand                          |                          |
| <div> <div>COUNTER 1 BLOCK:</div> <div>Off</div> </div>  |  | Range: FlexLogic™ operand                          |                          |
| <div> <div>CNT1 SET TO PRESET:</div> <div>Off</div> </div>   |  | Range: FlexLogic™ operand                          |                          |
| <div> <div>COUNTER 1 RESET:</div> <div>Off</div> </div>  |  | Range: FlexLogic™ operand                          |                          |
| <div> <div>COUNT1 FREEZE/RESET:</div> <div>Off</div> </div>  |  | Range: FlexLogic™ operand                          |                          |
| <div> <div>COUNT1 FREEZE/COUNT:</div> <div>Off</div> </div>  |  | Range: FlexLogic™ operand                          |                          |

There are 8 identical digital counters, numbered from 1 to 8. A digital counter counts the number of state transitions from Logic 0 to Logic 1. The counter is used to count operations such as the pickups of an element, the changes of state of an external contact (e.g. breaker auxiliary switch), or pulses from a watt-hour meter.

- **COUNTER 1 UNITS:** Assigns a label to identify the unit of measure pertaining to the digital transitions to be counted. The units label will appear in the corresponding actual values status.
- **COUNTER 1 PRESET:** Sets the count to a required preset value before counting operations begin, as in the case where a substitute relay is to be installed in place of an in-service relay, or while the counter is running.
- **COUNTER 1 COMPARE:** Sets the value to which the accumulated count value is compared. Three FlexLogic™ output operands are provided to indicate if the present value is 'more than (HI)', 'equal to (EQL)', or 'less than (LO)' the set value.
- **COUNTER 1 UP:** Selects the FlexLogic™ operand for incrementing the counter. If an enabled UP input is received when the accumulated value is at the limit of +2,147,483,647 counts, the counter will rollover to -2,147,483,648.
- **COUNTER 1 DOWN:** Selects the FlexLogic™ operand for decrementing the counter. If an enabled DOWN input is received when the accumulated value is at the limit of -2,147,483,648 counts, the counter will rollover to +2,147,483,647.
- **COUNTER 1 BLOCK:** Selects the FlexLogic™ operand for blocking the counting operation. All counter operands are blocked.



- **CNT1 SET TO PRESET:** Selects the FlexLogic™ operand used to set the count to the preset value. The counter will be set to the preset value in the following situations:
  1. When the counter is enabled and the **CNT1 SET TO PRESET** operand has the value 1 (when the counter is enabled and **CNT1 SET TO PRESET** operand is 0, the counter will be set to 0).
  2. When the counter is running and the **CNT1 SET TO PRESET** operand changes the state from 0 to 1 (**CNT1 SET TO PRESET** changing from 1 to 0 while the counter is running has no effect on the count).
  3. When a reset or reset/freeze command is sent to the counter and the **CNT1 SET TO PRESET** operand has the value 1 (when a reset or reset/freeze command is sent to the counter and the **CNT1 SET TO PRESET** operand has the value 0, the counter will be set to 0).
- **COUNTER 1 RESET:** Selects the FlexLogic™ operand for setting the count to either “0” or the preset value depending on the state of the **CNT1 SET TO PRESET** operand.
- **COUNTER 1 FREEZE/RESET:** Selects the FlexLogic™ operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and resetting the count to “0”.
- **COUNTER 1 FREEZE/COUNT:** Selects the FlexLogic™ operand for capturing (freezing) the accumulated count value into a separate register with the date and time of the operation, and continuing counting. The present accumulated value and captured frozen value with the associated date/time stamp are available as actual values. If control power is interrupted, the accumulated and frozen values are saved into non-volatile memory during the power down operation.

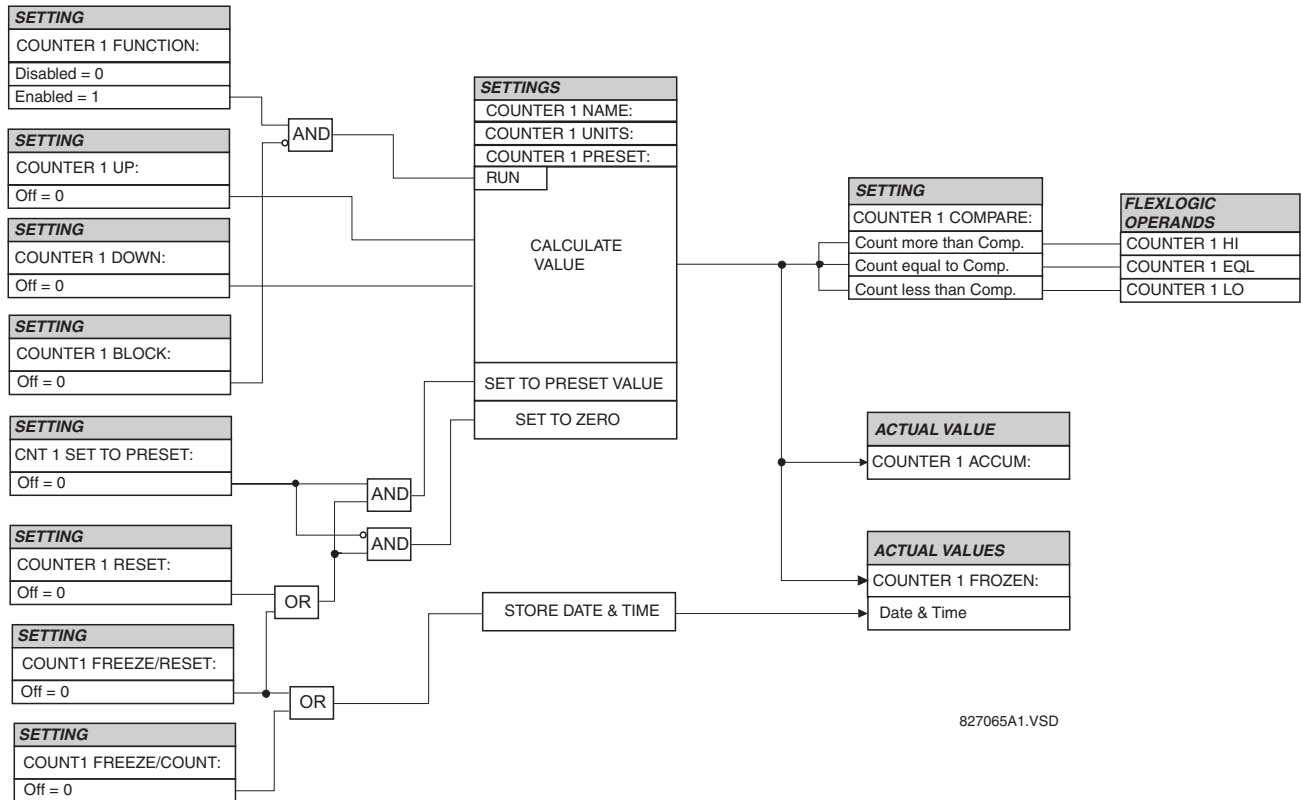


Figure 5-95: DIGITAL COUNTER SCHEME LOGIC

## 5.6.8 MONITORING ELEMENTS

## a) MAIN MENU

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ MONITORING ELEMENTS

|                            |    |                                 |                 |
|----------------------------|----|---------------------------------|-----------------|
| ■ MONITORING<br>■ ELEMENTS | ◀▶ | ■ BREAKER 1<br>■ ARCING CURRENT | See below.      |
| MESSAGE                    | ▲▼ | ■ BREAKER 2<br>■ ARCING CURRENT | See below.      |
| MESSAGE                    | ▲  | ■ VT FUSE FAILURE 1<br>■        | See page 5-154. |
| MESSAGE                    | ▲  | ■ VT FUSE FAILURE 2<br>■        | See page 5-154. |

## b) BREAKER ARCING CURRENT

PATH: SETTINGS ⇒ CONTROL ELEMENTS ⇒ MONITORING ELEMENTS ⇒ BREAKER 1(2) ARCING CURRENT

|                                 |    |   |  |
|---------------------------------|----|---|--|
| ■ BREAKER 1<br>■ ARCING CURRENT | ◀▶ | BKR 1 ARC AMP<br>FUNCTION: Disabled               | Range: Disabled, Enabled                               |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP<br>SOURCE: SRC 1                    | Range: SRC 1, SRC 2                                    |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP INIT-A:<br>Off                      | Range: FlexLogic™ operand                              |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP INIT-B:<br>Off                      | Range: FlexLogic™ operand                              |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP INIT-C:<br>Off                      | Range: FlexLogic™ operand                              |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP<br>DELAY: 0.000 s                   | Range: 0.000 to 65.535 s in steps of 0.001             |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP LIMIT:<br>1000 kA <sup>2</sup> -cyc | Range: 0 to 50000 kA <sup>2</sup> -cycle in steps of 1 |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP BLOCK:<br>Off                       | Range: FlexLogic™ operand                              |
| MESSAGE                         | ▲▼ | BKR 1 ARC AMP<br>TARGET: Self-reset               | Range: Self-reset, Latched, Disabled                   |
| MESSAGE                         | ▲  | BKR 1 ARC AMP<br>EVENTS: Disabled                 | Range: Disabled, Enabled                               |

There is one Breaker Arcing Current element available per CT bank, with a minimum of 2 elements. This element calculates an estimate of the per-phase wear on the breaker contacts by measuring and integrating the current squared passing through the breaker contacts as an arc. These per-phase values are added to accumulated totals for each phase and compared to a programmed threshold value. When the threshold is exceeded in any phase, the relay can set an output operand to "1". The accumulated value for each phase can be displayed as an actual value.

The operation of the scheme is shown in the following logic diagram. The same output operand that is selected to operate the output relay used to trip the breaker, indicating a tripping sequence has begun, is used to initiate this feature. A time delay is introduced between initiation and the starting of integration to prevent integration of current flow through the breaker before the contacts have parted. This interval includes the operating time of the output relay, any other auxiliary relays and the breaker mechanism. For maximum measurement accuracy, the interval between change-of-state of the operand (from 0 to 1) and contact separation should be measured for the specific installation. Integration of the measured current continues for 100 ms, which is expected to include the total arcing period.

The feature is programmed to perform fault duration calculations. Fault duration is defined as a time between operation of the disturbance detector occurring before initiation of this feature, and reset of an internal low-set overcurrent function. Correction is implemented to account for a non-zero reset time of the overcurrent function.

Breaker arcing currents and fault duration values are available under the **ACTUAL VALUES** ⇒ **RECORDS** ⇒ **MAINTENANCE** ⇒ **BREAKER 1(2)** menus.

- **BKR 1(2) ARC AMP INIT-A(C)**: Select the same output operands that are configured to operate the output relays used to trip the breaker. In three-pole tripping applications, the same operand should be configured to initiate arcing current calculations for poles A, B and C of the breaker. In single-pole tripping applications, per-pole tripping operands should be configured to initiate the calculations for the poles that are actually tripped.
- **BKR 1(2) ARC AMP DELAY**: This setting is used to program the delay interval between the time the tripping sequence is initiated and the time the breaker contacts are expected to part, starting the integration of the measured current.
- **BKR 1(2) ARC AMP LIMIT**: Selects the threshold value above which the output operand is set.

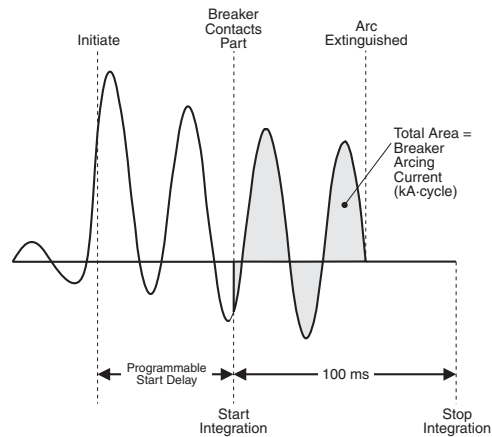


Figure 5-96: ARCING CURRENT MEASUREMENT

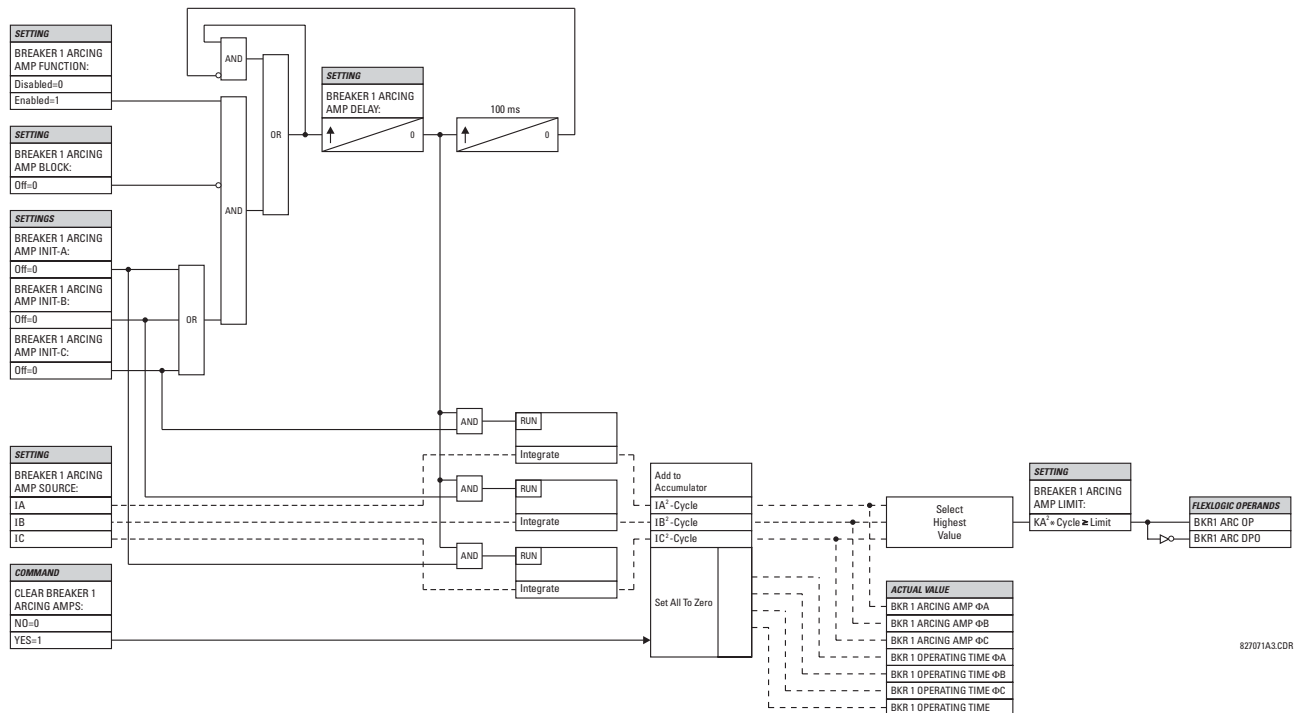


Figure 5-97: BREAKER ARCING CURRENT SCHEME LOGIC

## c) VT FUSE FAILURE

PATH: SETTINGS ⇨ CONTROL ELEMENTS ⇨ MONITORING ELEMENTS ⇨ VT FUSE FAILURE 1(2)



Every signal source includes a fuse failure scheme.

The VT fuse failure detector can be used to raise an alarm and/or block elements that may operate incorrectly for a full or partial loss of AC potential caused by one or more blown fuses. Some elements that might be blocked (via the BLOCK input) are distance, voltage restrained overcurrent, and directional current.

There are two classes of fuse failure that may occur:

Class A: Loss of one or two phases.

Class B: Loss of all three phases.

Different means of detection are required for each class. An indication of Class A failures is a significant level of negative sequence voltage, whereas an indication of Class B failures is when positive sequence current is present and there is an insignificant amount of positive sequence voltage. These noted indications of fuse failure could also be present when faults are present on the system, so a means of detecting faults and inhibiting fuse failure declarations during these events is provided. Once the fuse failure condition is declared, it will be sealed-in until the cause that generated it disappears.

An additional condition is introduced to inhibit a fuse failure declaration when the monitored circuit is de-energized; positive sequence voltage and current are both below threshold levels.

The VT FUSE FAILURE 1(2) FUNCTION setting enables/disables the fuse failure feature for each source.

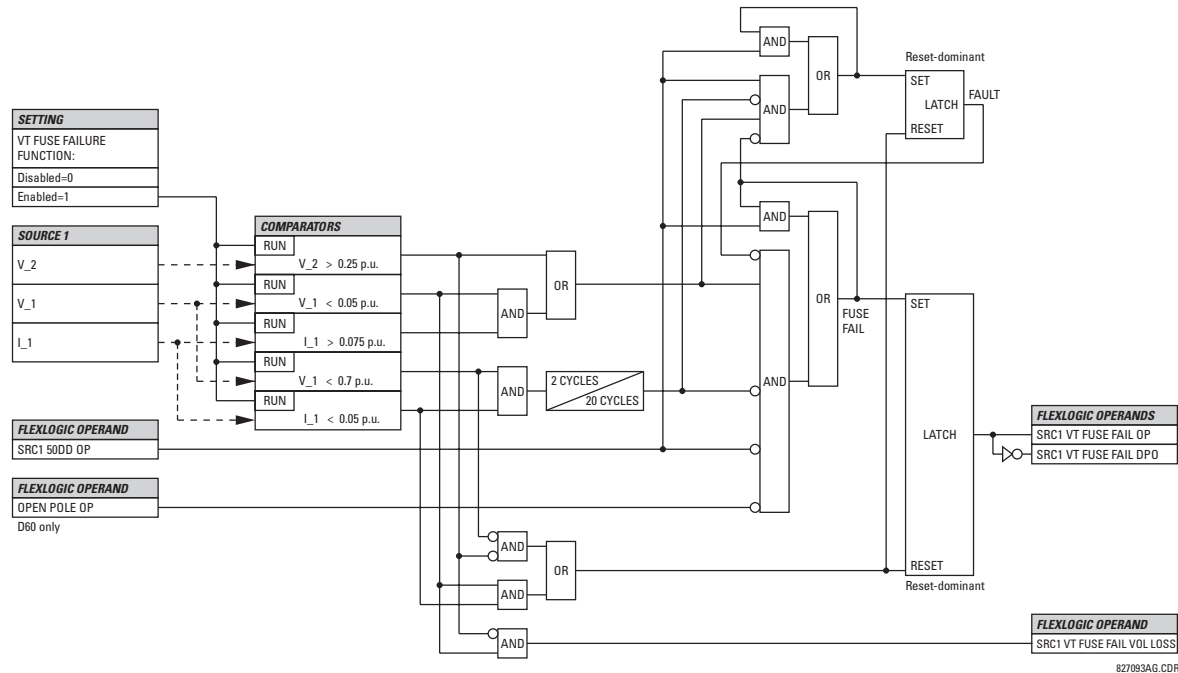
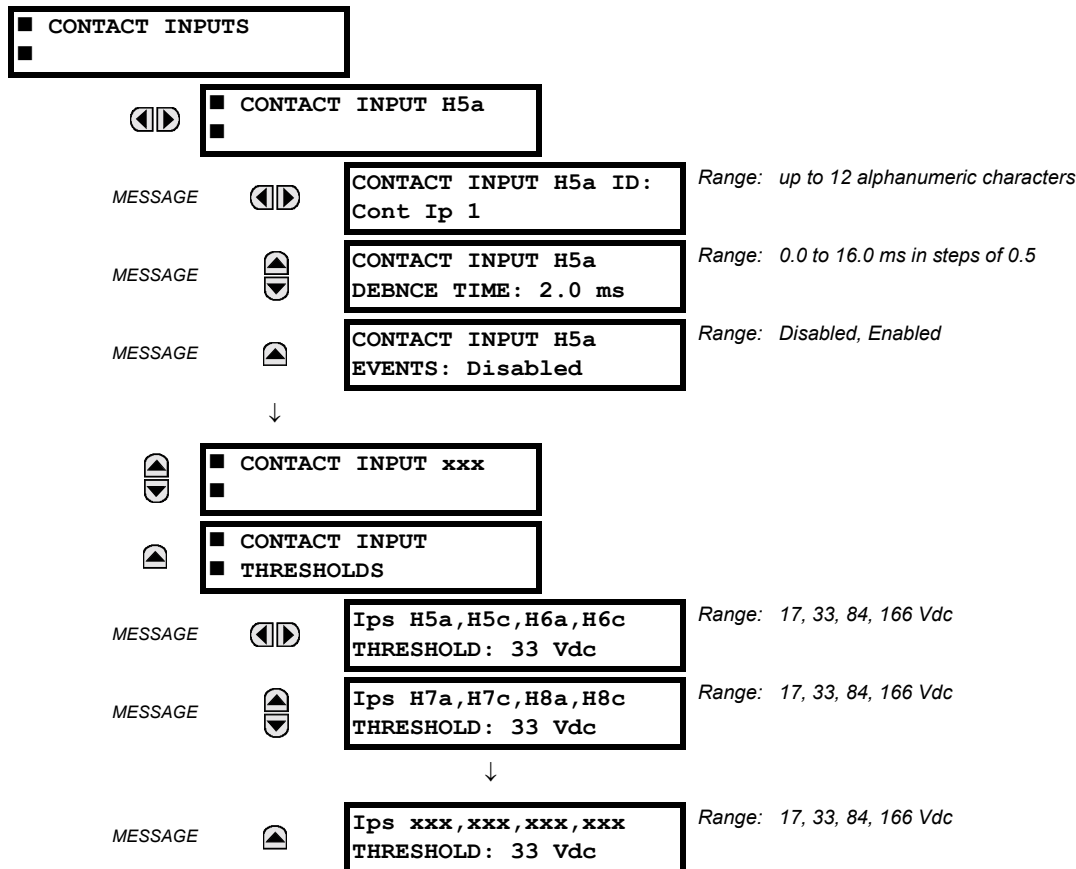


Figure 5-98: VT FUSE FAIL SCHEME LOGIC

## 5.7.1 CONTACT INPUTS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ CONTACT INPUTS



The contact inputs menu contains configuration settings for each contact input as well as voltage thresholds for each group of four contact inputs. Upon startup, the relay processor determines (from an assessment of the installed modules) which contact inputs are available and then display settings for only those inputs.

An alphanumeric ID may be assigned to a contact input for diagnostic, setting, and event recording purposes. The **CONTACT IP X On** (Logic 1) FlexLogic™ operand corresponds to contact input “X” being closed, while **CONTACT IP X Off** corresponds to contact input “X” being open. The **CONTACT INPUT DEBNCE TIME** defines the time required for the contact to overcome ‘contact bouncing’ conditions. As this time differs for different contact types and manufacturers, set it as a maximum contact debounce time (per manufacturer specifications) plus some margin to ensure proper operation. If **CONTACT INPUT EVENTS** is set to “Enabled”, every change in the contact input state will trigger an event.

A raw status is scanned for all Contact Inputs synchronously at the constant rate of 0.5 ms as shown in the figure below. The DC input voltage is compared to a user-settable threshold. A new contact input state must be maintained for a user-settable debounce time in order for the D30 to validate the new contact state. In the figure below, the debounce time is set at 2.5 ms; thus the 6th sample in a row validates the change of state (mark no. 1 in the diagram). Once validated (debounced), the contact input asserts a corresponding FlexLogic™ operand and logs an event as per user setting.

A time stamp of the first sample in the sequence that validates the new state is used when logging the change of the contact input into the Event Recorder (mark no. 2 in the diagram).

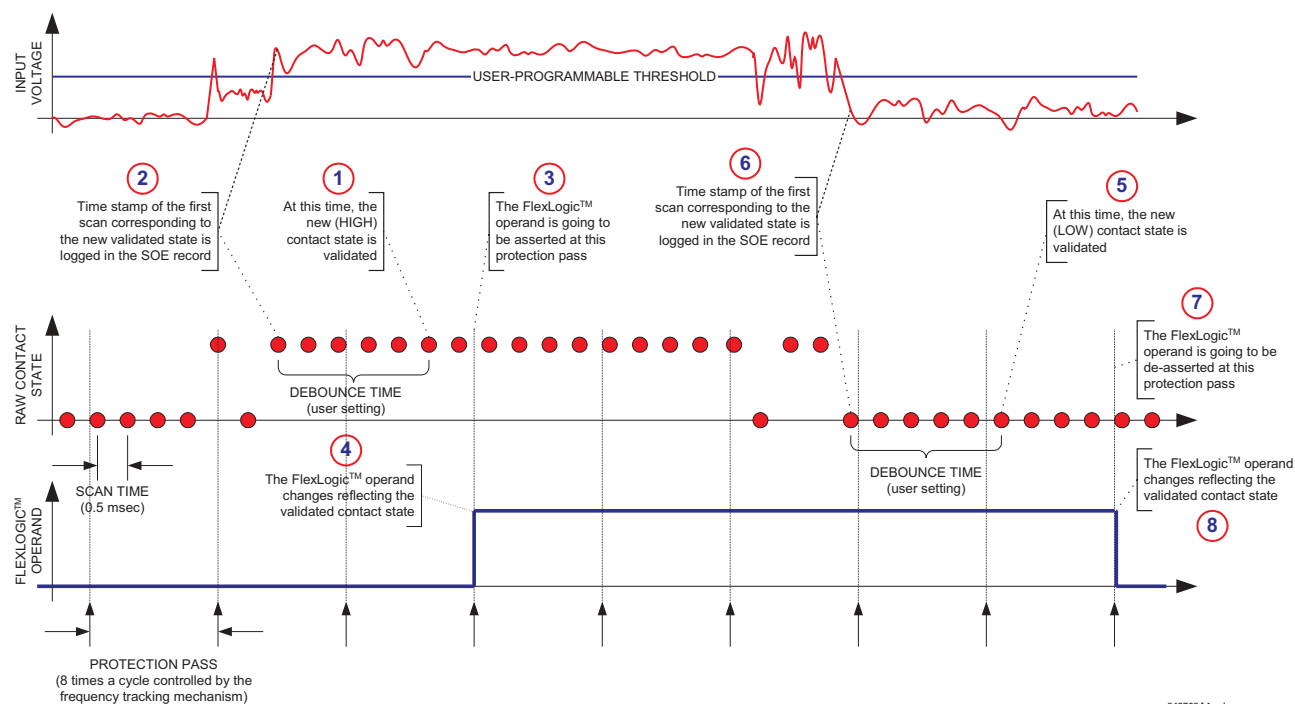
Protection and control elements, as well as FlexLogic™ equations and timers, are executed eight times in a power system cycle. The protection pass duration is controlled by the frequency tracking mechanism. The FlexLogic™ operand reflecting the debounced state of the contact is updated at the protection pass following the validation (marks no. 3 and 4 on the figure below). The update is performed at the beginning of the protection pass so all protection and control functions, as well as FlexLogic™ equations, are fed with the updated states of the contact inputs.

The FlexLogic™ operand response time to the contact input change is equal to the debounce time setting plus up to one protection pass (variable and depending on system frequency if frequency tracking enabled). If the change of state occurs just after a protection pass, the recognition is delayed until the subsequent protection pass; that is, by the entire duration of the protection pass. If the change occurs just prior to a protection pass, the state is recognized immediately. Statistically a delay of half the protection pass is expected. Owing to the 0.5 ms scan rate, the time resolution for the input contact is below 1msec.

For example, 8 protection passes per cycle on a 60 Hz system correspond to a protection pass every 2.1 ms. With a contact debounce time setting of 3.0 ms, the FlexLogic™ operand-assert time limits are:  $3.0 + 0.0 = 3.0$  ms and  $3.0 + 2.1 = 5.1$  ms. These time limits depend on how soon the protection pass runs after the debouncing time.

Regardless of the contact debounce time setting, the contact input event is time-stamped with a 1  $\mu$ s accuracy using the time of the first scan corresponding to the new state (mark no. 2 below). Therefore, the time stamp reflects a change in the DC voltage across the contact input terminals that was not accidental as it was subsequently validated using the debounce timer. Keep in mind that the associated FlexLogic™ operand is asserted/de-asserted later, after validating the change.

The debounce algorithm is symmetrical: the same procedure and debounce time are used to filter the LOW-HIGH (marks no. 1, 2, 3, and 4 in the figure below) and HIGH-LOW (marks no. 5, 6, 7, and 8 below) transitions.



**Figure 5-99: INPUT CONTACT DEBOUNCING MECHANISM AND TIME-STAMPING SAMPLE TIMING**

Contact inputs are isolated in groups of four to allow connection of wet contacts from different voltage sources for each group. The **CONTACT INPUT THRESHOLDS** determine the minimum voltage required to detect a closed contact input. This value should be selected according to the following criteria: 17 for 24 V sources, 33 for 48 V sources, 84 for 110 to 125 V sources and 166 for 250 V sources.

For example, to use contact input H5a as a status input from the breaker 52b contact to seal-in the trip relay and record it in the Event Records menu, make the following settings changes:

**CONTACT INPUT H5A ID:** "Breaker Closed (52b)"

**CONTACT INPUT H5A EVENTS:** "Enabled"

Note that the 52b contact is closed when the breaker is open and open when the breaker is closed.

## 5.7.2 VIRTUAL INPUTS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ VIRTUAL INPUTS ⇒ VIRTUAL INPUT 1(32)

|                        |  |   |   |
|------------------------|--|---|---|
| <b>VIRTUAL INPUT 1</b> |  | <b>VIRTUAL INPUT 1</b><br><b>FUNCTION:</b> Disabled | Range: Disabled, Enabled                |
| MESSAGE                |  | <b>VIRTUAL INPUT 1 ID:</b><br>Virt Ip 1             | Range: Up to 12 alphanumeric characters |
| MESSAGE                |  | <b>VIRTUAL INPUT 1</b><br><b>TYPE:</b> Latched      | Range: Self-Reset, Latched              |
| MESSAGE                |  | <b>VIRTUAL INPUT 1</b><br><b>EVENTS:</b> Disabled   | Range: Disabled, Enabled                |

There are 32 virtual inputs that can be individually programmed to respond to input signals from the keypad (Commands menu) and communications protocols. All virtual input operands are defaulted to OFF = 0 unless the appropriate input signal is received. **Virtual input states are preserved through a control power loss.**

If the **VIRTUAL INPUT x FUNCTION** is to “Disabled”, the input will be forced to 'Off' (Logic 0) regardless of any attempt to alter the input. If set to “Enabled”, the input operates as shown on the logic diagram and generates output FlexLogic™ operands in response to received input signals and the applied settings.

There are two types of operation: Self-Reset and Latched. If **VIRTUAL INPUT x TYPE** is “Self-Reset”, when the input signal transits from OFF = 0 to ON = 1, the output operand will be set to ON = 1 for only one evaluation of the FlexLogic™ equations and then return to OFF = 0. If set to “Latched”, the virtual input sets the state of the output operand to the same state as the most recent received input, ON = 1 or OFF = 0.



The “Self-Reset” operating mode generates the output operand for a single evaluation of the FlexLogic™ equations. If the operand is to be used anywhere other than internally in a FlexLogic™ equation, it will likely have to be lengthened in time. A FlexLogic™ timer with a delayed reset can perform this function.

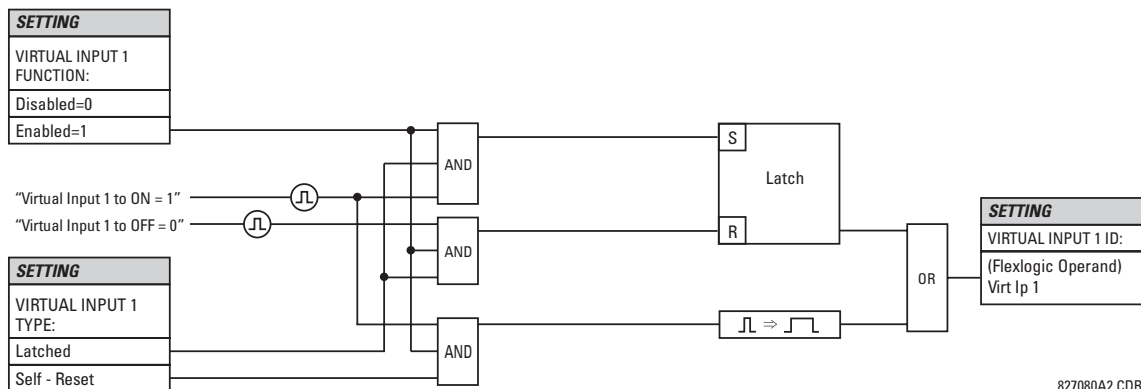


Figure 5-100: VIRTUAL INPUTS SCHEME LOGIC

## 5.7.3 CONTACT OUTPUTS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ CONTACT OUTPUTS ⇒ CONTACT OUTPUT H1

|                     |    |                                      |   |
|---------------------|----|--------------------------------------|---|
| ■ CONTACT OUTPUT H1 | ◀▶ | CONTACT OUTPUT H1 ID<br>Cont Op 1    | Range: Up to 12 alphanumeric characters |
| MESSAGE             | ▲▼ | OUTPUT H1 OPERATE:<br>Off            | Range: FlexLogic™ operand               |
| MESSAGE             | ▲▼ | OUTPUT H1 SEAL-IN:<br>Off            | Range: FlexLogic™ operand               |
| MESSAGE             | ▲  | CONTACT OUTPUT H1<br>EVENTS: Enabled | Range: Disabled, Enabled                |

Upon startup of the relay, the main processor will determine from an assessment of the modules installed in the chassis which contact outputs are available and present the settings for only these outputs.

An ID may be assigned to each contact output. The signal that can **OPERATE** a contact output may be any FlexLogic™ operand (virtual output, element state, contact input, or virtual input). An additional FlexLogic™ operand may be used to **SEAL-IN** the relay. Any change of state of a contact output can be logged as an Event if programmed to do so.

For example, the trip circuit current is monitored by providing a current threshold detector in series with some Form-A contacts (see the trip circuit example in the *Digital Elements* section). The monitor will set a flag (see the specifications for Form-A). The name of the FlexLogic™ operand set by the monitor, consists of the output relay designation, followed by the name of the flag; e.g. 'Cont Op 1 IOn' or 'Cont Op 1 IOff'.

In most breaker control circuits, the trip coil is connected in series with a breaker auxiliary contact used to interrupt current flow after the breaker has tripped, to prevent damage to the less robust initiating contact. This can be done by monitoring an auxiliary contact on the breaker which opens when the breaker has tripped, but this scheme is subject to incorrect operation caused by differences in timing between breaker auxiliary contact change-of-state and interruption of current in the trip circuit. The most dependable protection of the initiating contact is provided by directly measuring current in the tripping circuit, and using this parameter to control resetting of the initiating relay. This scheme is often called 'trip seal-in'.

This can be realized in the D30 using the 'Cont Op 1 IOn' FlexLogic™ operand to seal-in the contact output as follows:

CONTACT OUTPUT H1 ID: "Cont Op 1"  
 OUTPUT H1 OPERATE: any suitable FlexLogic™ operand  
 OUTPUT H1 SEAL-IN: "Cont Op 1 IOn"  
 CONTACT OUTPUT H1 EVENTS: "Enabled"

## 5.7.4 LATCHING OUTPUTS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ LATCHING OUTPUTS ⇒ LATCHING OUTPUT H1a

|                            |    |                                      |   |
|----------------------------|----|--------------------------------------|---|
| ■ LATCHING<br>■ OUTPUT H1a | ◀▶ | OUTPUT H1a ID<br>L-Cont Op 1         | Range: Up to 12 alphanumeric characters |
| MESSAGE                    | ▲▼ | OUTPUT H1a OPERATE:<br>Off           | Range: FlexLogic™ operand               |
| MESSAGE                    | ▲▼ | OUTPUT H1a RESET:<br>Off             | Range: FlexLogic™ operand               |
| MESSAGE                    | ▲▼ | OUTPUT H1a TYPE:<br>Operate-dominant | Range: Operate-dominant, Reset-dominant |
| MESSAGE                    | ▲  | OUTPUT H1a EVENTS:<br>Disabled       | Range: Disabled, Enabled                |



The D30 latching output contacts are mechanically bi-stable and controlled by two separate (open and close) coils. As such they retain their position even if the relay is not powered up. The relay recognizes all latching output contact cards and populates the setting menu accordingly. On power up, the relay reads positions of the latching contacts from the hardware before executing any other functions of the relay (such as protection and control features or FlexLogic™).

The latching output modules, either as a part of the relay or as individual modules, are shipped from the factory with all latching contacts opened. It is highly recommended to double-check the programming and positions of the latching contacts when replacing a module.

Since the relay asserts the output contact and reads back its position, it is possible to incorporate self-monitoring capabilities for the latching outputs. If any latching outputs exhibits a discrepancy, the **LATCHING OUTPUT ERROR** self-test error is declared. The error is signaled by the LATCHING OUT ERROR FlexLogic™ operand, event, and target message.

- **OUTPUT H1a OPERATE:** This setting specifies a FlexLogic™ operand to operate the ‘close coil’ of the contact. The relay will seal-in this input to safely close the contact. Once the contact is closed and the **RESET** input is logic 0 (off), any activity of the **OPERATE** input, such as subsequent chattering, will not have any effect. With both the **OPERATE** and **RESET** inputs active (logic 1), the response of the latching contact is specified by the **OUTPUT H1A TYPE** setting.
- **OUTPUT H1a RESET:** This setting specifies a FlexLogic™ operand to operate the ‘trip coil’ of the contact. The relay will seal-in this input to safely open the contact. Once the contact is opened and the **OPERATE** input is logic 0 (off), any activity of the **RESET** input, such as subsequent chattering, will not have any effect. With both the **OPERATE** and **RESET** inputs active (logic 1), the response of the latching contact is specified by the **OUTPUT H1A TYPE** setting.
- **OUTPUT H1a TYPE:** This setting specifies the contact response under conflicting control inputs; that is, when both the **OPERATE** and **RESET** signals are applied. With both control inputs applied simultaneously, the contact will close if set to “Operate-dominant” and will open if set to “Reset-dominant”.

#### Application Example 1:

A latching output contact H1a is to be controlled from two user-programmable pushbuttons (buttons number 1 and 2). The following settings should be applied.

Program the Latching Outputs by making the following changes in the **SETTINGS** ⇨ **INPUTS/OUTPUT** ⇨ **LATCHING OUTPUTS** ⇨ **LATCHING OUTPUT H1a** menu (assuming an H4L module):

**OUTPUT H1a OPERATE:** “PUSHBUTTON 1 ON”  
**OUTPUT H1a RESET:** “PUSHBUTTON 2 ON”

Program the pushbuttons by making the following changes in the **PRODUCT SETUP** ⇨ **USER-PROGRAMMABLE PUSHBUTTONS** ⇨ **USER PUSHBUTTON 1** and **USER PUSHBUTTON 2** menus:

**PUSHBUTTON 1 FUNCTION:** “Self-reset”      **PUSHBUTTON 2 FUNCTION:** “Self-reset”  
**PUSHBTN 1 DROP-OUT TIME:** “0.00 s”      **PUSHBTN 2 DROP-OUT TIME:** “0.00 s”

#### Application Example 2:

A relay, having two latching contacts H1a and H1c, is to be programmed. The H1a contact is to be a Type-a contact, while the H1c contact is to be a Type-b contact (Type-a means closed after exercising the operate input; Type-b means closed after exercising the reset input). The relay is to be controlled from virtual outputs: VO1 to operate and VO2 to reset.

Program the Latching Outputs by making the following changes in the **SETTINGS** ⇨ **INPUTS/OUTPUT** ⇨ **LATCHING OUTPUTS** ⇨ **LATCHING OUTPUT H1a** and **LATCHING OUTPUT H1c** menus (assuming an H4L module):

**OUTPUT H1a OPERATE:** “VO1”      **OUTPUT H1c OPERATE:** “VO2”  
**OUTPUT H1a RESET:** “VO2”      **OUTPUT H1c RESET:** “VO1”

Since the two physical contacts in this example are mechanically separated and have individual control inputs, they will not operate at exactly the same time. A discrepancy in the range of a fraction of a maximum operating time may occur. Therefore, a pair of contacts programmed to be a multi-contact relay will not guarantee any specific sequence of operation (such as make before break). If required, the sequence of operation must be programmed explicitly by delaying some of the control inputs as shown in the next application example.

#### Application Example 3:

A make before break functionality must be added to the preceding example. An overlap of 20 ms is required to implement this functionality as described below:

Write the following FlexLogic™ equation (enerVista UR Setup example shown):

| FLEXLOGIC ENTRY   | TYPE                         | SYNTAX             |
|-------------------|------------------------------|--------------------|
| View Graphic:     | View                         | View               |
| FlexLogic Entry 1 | Read Virtual Outputs On      | Virt Op 1 On (VO1) |
| FlexLogic Entry 2 | TIMER                        | Timer 1            |
| FlexLogic Entry 3 | Write Virtual Output[Assign] | = Virt Op 3 (VO3)  |
| FlexLogic Entry 4 | Read Virtual Outputs On      | Virt Op 2 On (VO2) |
| FlexLogic Entry 5 | TIMER                        | Timer 2            |
| FlexLogic Entry 6 | Write Virtual Output[Assign] | = Virt Op 4 (VO4)  |
| FlexLogic Entry 7 | End of List                  |                    |

Both timers (Timer 1 and Timer 2) should be set to 20 ms pickup and 0 ms dropout.

Program the Latching Outputs by making the following changes in the **SETTINGS** ⇒ **INPUTS/OUTPUT** ⇒ **LATCHING OUTPUTS** ⇒ **LATCHING OUTPUT H1a** and **LATCHING OUTPUT H1c** menus (assuming an H4L module):

**OUTPUT H1a OPERATE:** "VO1"

**OUTPUT H1a RESET:** "VO4"

**OUTPUT H1c OPERATE:** "VO2"

**OUTPUT H1c RESET:** "VO3"

#### Application Example 4:

A latching contact H1a is to be controlled from a single virtual output VO1. The contact should stay closed as long as VO1 is high, and should stay opened when VO1 is low. Program the relay as follows.

Write the following FlexLogic™ equation (enerVista UR Setup example shown):

| FLEXLOGIC ENTRY   | TYPE                         | SYNTAX             |
|-------------------|------------------------------|--------------------|
| View Graphic:     | View                         | View               |
| FlexLogic Entry 1 | Read Virtual Outputs On      | Virt Op 1 On (VO1) |
| FlexLogic Entry 2 | NOT                          | 1 Input            |
| FlexLogic Entry 3 | Write Virtual Output[Assign] | = Virt Op 2 (VO2)  |
| FlexLogic Entry 4 | End of List                  |                    |

Program the Latching Outputs by making the following changes in the **SETTINGS** ⇒ **INPUTS/OUTPUT** ⇒ **LATCHING OUTPUTS** ⇒ **LATCHING OUTPUT H1a** menu (assuming an H4L module):

**OUTPUT H1a OPERATE:** "VO1"

**OUTPUT H1a RESET:** "VO2"

#### 5.7.5 VIRTUAL OUTPUTS

**PATH:** **SETTINGS** ⇒ **INPUTS/OUTPUTS** ⇒ **VIRTUAL OUTPUTS** ⇒ **VIRTUAL OUTPUT 1(64)**

|   |  |   |
|---|--|---|
| <div> <div>VIRTUAL OUTPUT 1</div> <div>MESSAGE</div> </div> | <div> <div>VIRTUAL OUTPUT 1 ID</div> <div>Virt Op 1</div> </div>     | Range: Up to 12 alphanumeric characters |
|   | <div> <div>VIRTUAL OUTPUT 1</div> <div>EVENTS: Disabled</div> </div> | Range: Disabled, Enabled                |

There are 64 virtual outputs that may be assigned via FlexLogic™. If not assigned, the output will be forced to 'OFF' (Logic 0). An ID may be assigned to each virtual output. Virtual outputs are resolved in each pass through the evaluation of the FlexLogic™ equations. Any change of state of a virtual output can be logged as an event if programmed to do so.

For example, if Virtual Output 1 is the trip signal from FlexLogic™ and the trip relay is used to signal events, the settings would be programmed as follows:

**VIRTUAL OUTPUT 1 ID:** "Trip"

**VIRTUAL OUTPUT 1 EVENTS:** "Disabled"

## 5.7.6 REMOTE DEVICES

## a) REMOTE INPUTS/OUTPUTS OVERVIEW

Remote inputs and outputs, which are a means of exchanging information regarding the state of digital points between remote devices, are provided in accordance with the IEC 61850 “Generic Object Oriented Substation Event (GSSE)” specifications.



**The IEC 61850 specification requires that communications between devices be implemented on Ethernet communications facilities. For UR-series relays, Ethernet communications is provided only on the type 9G and 9H versions of the CPU module.**

The sharing of digital point state information between GSSE equipped relays is essentially an extension to FlexLogic™ to allow distributed FlexLogic™ by making operands available to/from devices on a common communications network. In addition to digital point states, GSSE messages identify the originator of the message and provide other information required by the communication specification. All devices listen to network messages and capture data from only those messages that have originated in selected devices.

GSSE messages are designed to be short, high priority and with a high level of reliability. The GSSE message structure contains space for 128 bit pairs representing digital point state information. The IEC 61850 specification provides 32 “DNA” bit pairs, which are status bits representing pre-defined events. All remaining bit pairs are “UserSt” bit pairs, which are status bits representing user-definable events. The D30 implementation provides 32 of the 96 available UserSt bit pairs.

The IEC 61850 specification includes features that are used to cope with the loss of communication between transmitting and receiving devices. Each transmitting device will send a GSSE message upon a successful power-up, when the state of any included point changes, or after a specified interval (the ‘default update’ time) if a change-of-state has not occurred. The transmitting device also sends a ‘hold time’ which is set to three times the programmed default time, which is required by the receiving device.

Receiving devices are constantly monitoring the communications network for messages they require, as recognized by the identification of the originating device carried in the message. Messages received from remote devices include the message ‘hold’ time for the device. The receiving relay sets a timer assigned to the originating device to the ‘hold’ time interval, and if it has not received another message from this device at time-out, the remote device is declared to be non-communicating, so it will use the programmed default state for all points from that specific remote device. This mechanism allows a receiving device to fail to detect a single transmission from a remote device which is sending messages at the slowest possible rate, as set by its ‘default update’ timer, without reverting to use of the programmed default states. If a message is received from a remote device before the ‘hold’ time expires, all points for that device are updated to the states contained in the message and the hold timer is restarted. The status of a remote device, where “Offline” indicates non-communicating, can be displayed.

The GSSE facility provides for remote inputs and 64 remote outputs.

## b) LOCAL DEVICES: ID OF DEVICE FOR TRANSMITTING GSSE MESSAGES

In a D30 relay, the device ID that identifies the originator of the message is programmed in the **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **INSTALLATION** ⇒ **RELAY NAME** setting.

## c) REMOTE DEVICES: ID OF DEVICE FOR RECEIVING GSSE MESSAGES

**PATH:** **SETTINGS** ⇒ **INPUTS/OUTPUTS** ⇒ **REMOTE DEVICES** ⇒ **REMOTE DEVICE 1(16)**

|  |               |   |  |
|--|---------------|---|--|
| <div> <div>■</div> <div>REMOTE DEVICE 1</div> </div> <div> <div>■</div> <div></div> </div> | <div>◀▶</div> | <div>REMOTE DEVICE 1 ID:</div> <div>Remote Device 1</div> | <i>Range: up to 20 alphanumeric characters</i> |
|--|---------------|---|--|

Sixteen remote devices, numbered from 1 to 16, can be selected for setting purposes. A receiving relay must be programmed to capture messages from only those originating remote devices of interest. This setting is used to select specific remote devices by entering (bottom row) the exact identification (ID) assigned to those devices.

## 5.7.7 REMOTE INPUTS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ REMOTE INPUTS ⇒ REMOTE INPUT 1(32)

|  |               |   |   |
|--|---------------|---|---|
| <div>■ REMOTE INPUT 1</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> | <div>◀▶</div> | <div>REMOTE IN 1 DEVICE:</div> <div>Remote Device 1</div> | Range: 1 to 16 inclusive                            |
|  | <div>▲▼</div> | <div>REMOTE IN 1 BIT PAIR:</div> <div>None</div>          | Range: None, DNA-1 to DNA-32, UserSt-1 to UserSt-32 |
|  | <div>▲▼</div> | <div>REMOTE IN 1 DEFAULT STATE:</div> <div>Off</div>      | Range: On, Off, Latest/On, Latest/Off               |
|  | <div>▲</div>  | <div>REMOTE IN 1 EVENTS:</div> <div>Disabled</div>        | Range: Disabled, Enabled                            |

Remote Inputs which create FlexLogic™ operands at the receiving relay, are extracted from GSSE messages originating in remote devices. The relay provides 32 remote inputs, each of which can be selected from a list consisting of 64 selections: DNA-1 through DNA-32 and UserSt-1 through UserSt-32. The function of DNA inputs is defined in the IEC 61850 specification and is presented in the IEC 61850 DNA Assignments table in the *Remote Outputs* section. The function of UserSt inputs is defined by the user selection of the FlexLogic™ operand whose state is represented in the GSSE message. A user must program a DNA point from the appropriate FlexLogic™ operand.

Remote Input 1 must be programmed to replicate the logic state of a specific signal from a specific remote device for local use. This programming is performed via the three settings shown above.

**REMOTE IN 1 DEVICE** selects the number (1 to 16) of the remote device which originates the required signal, as previously assigned to the remote device via the setting **REMOTE DEVICE NN ID** (see the *Remote Devices* section). **REMOTE IN 1 BIT PAIR** selects the specific bits of the GSSE message required.

The **REMOTE IN 1 DEFAULT STATE** setting selects the logic state for this point if the local relay has just completed startup or the remote device sending the point is declared to be non-communicating. The following choices are available:

- Setting **REMOTE IN 1 DEFAULT STATE** to “On” value defaults the input to Logic 1.
- Setting **REMOTE IN 1 DEFAULT STATE** to “Off” value defaults the input to Logic 0.
- Setting **REMOTE IN 1 DEFAULT STATE** to “Latest/On” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 1. When communication resumes, the input becomes fully operational.
- Setting **REMOTE IN 1 DEFAULT STATE** to “Latest/Off” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 0. When communication resumes, the input becomes fully operational.



NOTE

For additional information on the GSSE specification, refer to the *Remote Devices* section in this chapter.

## 5.7.8 REMOTE OUTPUTS

## a) DNA BIT PAIRS

**PATH:** SETTINGS ⇒ INPUTS/OUTPUTS ⇒ REMOTE OUTPUTS DNA BIT PAIRS ⇒ REMOTE OUPUTS DNA- 1(32) BIT PAIR

■ REMOTE OUTPUTS  
 ■ DNA- 1 BIT PAIR

◀▶

DNA- 1 OPERAND:  
 Off

MESSAGE ▲

DNA- 1 EVENTS:  
 Disabled

*Range: FlexLogic™ Operand*  
  
*Range: Disabled, Enabled*

Remote Outputs (1 to 32) are FlexLogic™ operands inserted into GSSE messages that are transmitted to remote devices on a LAN. Each digital point in the message must be programmed to carry the state of a specific FlexLogic™ operand. The above operand setting represents a specific DNA function (as shown in the following table) to be transmitted.

**Table 5–20: IEC 61850 DNA2 ASSIGNMENTS**

| DNA   | DEFINITION               | INTENDED FUNCTION                              | LOGIC 0        | LOGIC 1       |
|-------|--------------------------|--|----------------|---------------|
| 1     | OperDev                  |  | Trip           | Close         |
| 2     | Lock Out                 |  | LockoutOff     | LockoutOn     |
| 3     | Initiate Reclosing       | Initiate remote reclose sequence               | InitRecloseOff | InitRecloseOn |
| 4     | Block Reclosing          | Prevent/cancel remote reclose sequence         | BlockOff       | BlockOn       |
| 5     | Breaker Failure Initiate | Initiate remote breaker failure scheme         | BFIOff         | BFION         |
| 6     | Send Transfer Trip       | Initiate remote trip operation                 | TxXfrTripOff   | TxXfrTripOn   |
| 7     | Receive Transfer Trip    | Report receipt of remote transfer trip command | RxXfrTripOff   | RxXfrTripOn   |
| 8     | Send Perm                | Report permissive affirmative                  | TxPermOff      | TxPermOn      |
| 9     | Receive Perm             | Report receipt of permissive affirmative       | RxPermOff      | RxPermOn      |
| 10    | Stop Perm                | Override permissive affirmative                | StopPermOff    | StopPermOn    |
| 11    | Send Block               | Report block affirmative                       | TxBlockOff     | TxBlockOn     |
| 12    | Receive Block            | Report receipt of block affirmative            | RxBlockOff     | RxBlockOn     |
| 13    | Stop Block               | Override block affirmative                     | StopBlockOff   | StopBlockOn   |
| 14    | BkrDS                    | Report breaker disconnect 3-phase state        | Open           | Closed        |
| 15    | BkrPhsADS                | Report breaker disconnect phase A state        | Open           | Closed        |
| 16    | BkrPhsBDS                | Report breaker disconnect phase B state        | Open           | Closed        |
| 17    | BkrPhsCDS                | Report breaker disconnect phase C state        | Open           | Closed        |
| 18    | DiscSwDS                 |  | Open           | Closed        |
| 19    | Interlock DS             |  | DSLCKOff       | DSLCKOn       |
| 20    | LineEndOpen              | Report line open at local end                  | Open           | Closed        |
| 21    | Status                   | Report operating status of local GSSE device   | Offline        | Available     |
| 22    | Event                    |  | EventOff       | EventOn       |
| 23    | Fault Present            |  | FaultOff       | FaultOn       |
| 24    | Sustained Arc            | Report sustained arc                           | SustArcOff     | SustArcOn     |
| 25    | Downed Conductor         | Report downed conductor                        | DownedOff      | DownedOn      |
| 26    | Sync Closing             |  | SyncClsOff     | SyncClsOn     |
| 27    | Mode                     | Report mode status of local GSSE device        | Normal         | Test          |
| 28→32 | Reserved                 |  |                |               |



For more information on GSSE specifications, see the *Remote Inputs/Outputs Overview* in the *Remote Devices* section.

NOTE

## b) USERST BIT PAIRS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ REMOTE OUTPUTS UserSt BIT PAIRS ⇒ REMOTE OUTPUTS UserSt- 1(32) BIT PAIR

|  |   |                               |                           |
|--|---|-------------------------------|---------------------------|
| <input checked="" type="checkbox"/> REMOTE OUTPUTS<br><input checked="" type="checkbox"/> UserSt- 1 BIT PAIR | <input type="button" value="◀"/> <input type="button" value="▶"/> | UserSt- 1 OPERAND:<br>Off     | Range: FlexLogic™ operand |
|  | MESSAGE <input type="button" value="▲"/>                          | UserSt- 1 EVENTS:<br>Disabled | Range: Disabled, Enabled  |

Remote Outputs 1 to 32 originate as GSSE messages to be transmitted to remote devices. Each digital point in the message must be programmed to carry the state of a specific FlexLogic™ operand. The setting above is used to select the operand which represents a specific UserSt function (as selected by the user) to be transmitted.

The following setting represents the time between sending GSSE messages when there has been no change of state of any selected digital point. This setting is located in the **PRODUCT SETUP ⇒ COMMUNICATIONS ⇒ IEC 61850 PROTOCOL** settings menu.

|                                   |                                |
|-----------------------------------|--------------------------------|
| DEFAULT GSSE UPDATE<br>TIME: 60 s | Range: 1 to 60 s in steps of 1 |
|-----------------------------------|--------------------------------|



For more information on GSSE specifications, see the *Remote Inputs/Outputs Overview* in the *Remote Devices* section.

## 5.7.9 RESETTING

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ RESETTING

|   |   |                       |                           |
|---|---|-----------------------|---------------------------|
| <input checked="" type="checkbox"/> RESETTING | <input type="button" value="◀"/> <input type="button" value="▶"/> | RESET OPERAND:<br>Off | Range: FlexLogic™ operand |
|---|---|-----------------------|---------------------------|

Some events can be programmed to latch the faceplate LED event indicators and the target message on the display. Once set, the latching mechanism will hold all of the latched indicators or messages in the set state after the initiating condition has cleared until a RESET command is received to return these latches (not including FlexLogic™ latches) to the reset state. The RESET command can be sent from the faceplate Reset button, a remote device via a communications channel, or any programmed operand.

When the RESET command is received by the relay, two FlexLogic™ operands are created. These operands, which are stored as events, reset the latches if the initiating condition has cleared. The three sources of RESET commands each create the RESET OP FlexLogic™ operand. Each individual source of a RESET command also creates its individual operand RESET OP (PUSHBUTTON), RESET OP (COMMS) or RESET OP (OPERAND) to identify the source of the command. The setting shown above selects the operand that will create the RESET OP (OPERAND) operand.

## 5.7.10 DIRECT INPUTS/OUTPUTS

## a) DIRECT INPUTS

PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ DIRECT INPUTS ⇒ DIRECT INPUT 1(32)

|  |   |                                      |                                       |
|--|---|--------------------------------------|---------------------------------------|
| <input checked="" type="checkbox"/> DIRECT INPUT 1 | <input type="button" value="◀"/> <input type="button" value="▶"/> | DIRECT INPUT 1<br>DEVICE ID: 1       | Range: 1 to 16                        |
|  | MESSAGE <input type="button" value="▲"/>                          | DIRECT INPUT 1<br>BIT NUMBER: 1      | Range: 1 to 32                        |
|  | MESSAGE <input type="button" value="▲"/>                          | DIRECT INPUT 1<br>DEFAULT STATE: Off | Range: On, Off, Latest/On, Latest/Off |
|  | MESSAGE <input type="button" value="▲"/>                          | DIRECT INPUT 1<br>EVENTS: Disabled   | Range: Enabled, Disabled              |

These settings specify how the direct input information is processed. The **DIRECT INPUT DEVICE ID** represents the source of this direct input. The specified direct input is driven by the device identified here.

The **DIRECT INPUT 1 BIT NUMBER** is the bit number to extract the state for this direct input. Direct Input x is driven by the bit identified here as **DIRECT INPUT 1 BIT NUMBER**. This corresponds to the direct output number of the sending device.

The **DIRECT INPUT 1 DEFAULT STATE** represents the state of the direct input when the associated direct device is offline. The following choices are available:

- Setting **DIRECT INPUT 1 DEFAULT STATE** to “On” value defaults the input to Logic 1.
- Setting **DIRECT INPUT 1 DEFAULT STATE** to “Off” value defaults the input to Logic 0.
- Setting **DIRECT INPUT 1 DEFAULT STATE** to “Latest/On” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 1. When communication resumes, the input becomes fully operational.
- Setting **DIRECT INPUT 1 DEFAULT STATE** to “Latest/Off” freezes the input in case of lost communications. If the latest state is not known, such as after relay power-up but before the first communication exchange, the input will default to Logic 0. When communication resumes, the input becomes fully operational.

### b) DIRECT OUTPUTS

**PATH: SETTINGS ⇒ INPUTS/OUTPUTS ⇒ DIRECT OUTPUTS ⇒ DIRECT OUTPUT 1(32)**

|  |   |  |                           |
|--|---|--|---------------------------|
| <div> <div>DIRECT OUTPUT 1</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>⬆⬇⬆</div> </div> | <div>DIRECT OUT 1 OPERAND:</div> <div>Off</div>        | Range: FlexLogic™ operand |
|  |   | <div>DIRECT OUTPUT 1</div> <div>EVENTS: Disabled</div> | Range: Enabled, Disabled  |

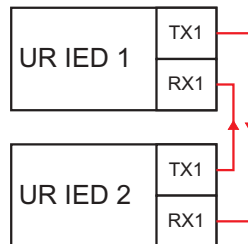
The **DIR OUT 1 OPERAND** is the FlexLogic™ operand that determines the state of this Direct Output.

### c) APPLICATION EXAMPLES

The examples introduced in the earlier *Direct Inputs/Outputs* section (part of the *Product Setup* section) direct inputs/outputs are continued below to illustrate usage of the direct inputs and outputs.

#### EXAMPLE 1: EXTENDING INPUT/OUTPUT CAPABILITIES OF A D30 RELAY

Consider an application that requires additional quantities of digital inputs and/or output contacts and/or lines of programmable logic that exceed the capabilities of a single UR-series chassis. The problem is solved by adding an extra UR-series IED, such as the C30, to satisfy the additional inputs/outputs and programmable logic requirements. The two IEDs are connected via single-channel digital communication cards as shown below.



**Figure 5–101: INPUT/OUTPUT EXTENSION VIA DIRECT INPUTS/OUTPUTS**

Assume Contact Input 1 from UR IED 2 is to be used by UR IED 1. The following settings should be applied (Direct Input 5 and bit number 12 are used, as an example):

UR IED 1: **DIRECT INPUT 5 DEVICE ID = “2”**  
**DIRECT INPUT 5 BIT NUMBER = “12”**

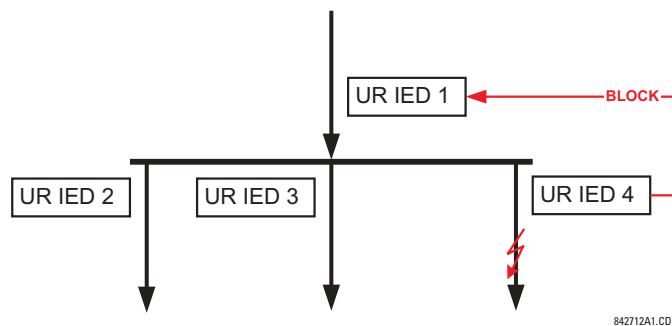
UR IED 2: **DIRECT OUT 12 OPERAND = “Cont Ip 1 On”**

The Cont Ip 1 On operand of UR IED 2 is now available in UR IED 1 as DIRECT INPUT 5 ON.

#### EXAMPLE 2: INTERLOCKING BUSBAR PROTECTION

A simple interlocking busbar protection scheme can be accomplished by sending a blocking signal from downstream devices, say 2, 3 and 4, to the upstream device that monitors a single incomer of the busbar, as shown in the figure below.





**Figure 5-102: SAMPLE INTERLOCKING BUSBAR PROTECTION SCHEME**

Assume that Phase Instantaneous Overcurrent 1 is used by Devices 2, 3, and 4 to block Device 1. If not blocked, Device 1 would trip the bus upon detecting a fault and applying a short coordination time delay.

The following settings should be applied (assume Bit 3 is used by all 3 devices to send the blocking signal and Direct Inputs 7, 8, and 9 are used by the receiving device to monitor the three blocking signals):

UR IED 2: **DIRECT OUT 3 OPERAND:** "PHASE IOC1 OP"

UR IED 3: **DIRECT OUT 3 OPERAND:** "PHASE IOC1 OP"

UR IED 4: **DIRECT OUT 3 OPERAND:** "PHASE IOC1 OP"

UR IED 1: **DIRECT INPUT 7 DEVICE ID:** "2"

**DIRECT INPUT 7 BIT NUMBER:** "3"

**DIRECT INPUT 7 DEFAULT STATE:** select "On" for security, select "Off" for dependability

**DIRECT INPUT 8 DEVICE ID:** "3"

**DIRECT INPUT 8 BIT NUMBER:** "3"

**DIRECT INPUT 8 DEFAULT STATE:** select "On" for security, select "Off" for dependability

**DIRECT INPUT 9 DEVICE ID:** "4"

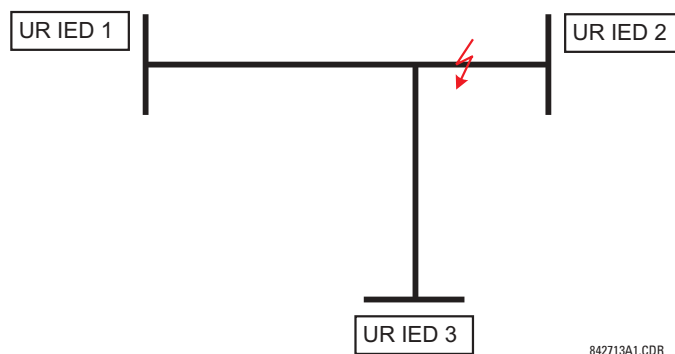
**DIRECT INPUT 9 BIT NUMBER:** "3"

**DIRECT INPUT 9 DEFAULT STATE:** select "On" for security, select "Off" for dependability

Now the three blocking signals are available in UR IED 1 as DIRECT INPUT 7 ON, DIRECT INPUT 8 ON, and DIRECT INPUT 9 ON. Upon losing communications or a device, the scheme is inclined to block (if any default state is set to "On"), or to trip the bus on any overcurrent condition (all default states set to "Off").

#### EXAMPLE 2: PILOT-AIDED SCHEMES

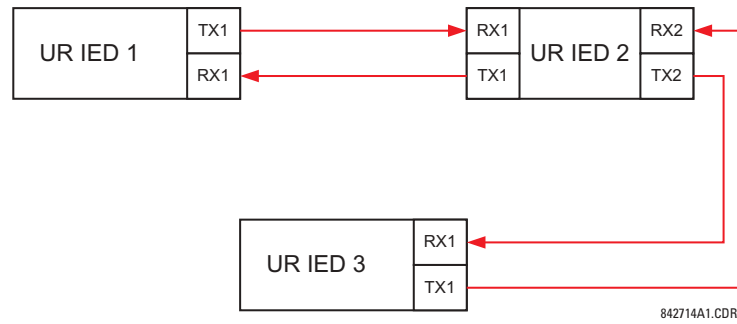
Consider a three-terminal line protection application shown in the figure below.



**Figure 5-103: THREE-TERMINAL LINE APPLICATION**

Assume the Hybrid Permissive Overreaching Transfer Trip (Hybrid POTT) scheme is applied using the architecture shown below. The scheme output operand HYB POTT TX1 is used to key the permission.



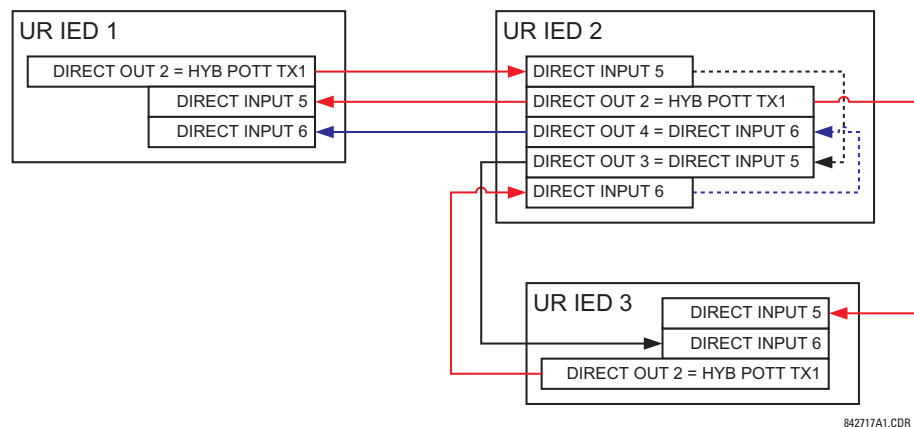


**Figure 5-104: SINGLE-CHANNEL OPEN-LOOP CONFIGURATION**

In the above architecture, Devices 1 and 3 do not communicate directly. Therefore, Device 2 must act as a 'bridge'. The following settings should be applied:

- UR IED 1:**
- DIRECT OUT 2 OPERAND:** "HYB POTT TX1"
  - DIRECT INPUT 5 DEVICE ID:** "2"
  - DIRECT INPUT 5 BIT NUMBER:** "2" (this is a message from IED 2)
  - DIRECT INPUT 6 DEVICE ID:** "2"
  - DIRECT INPUT 6 BIT NUMBER:** "4" (effectively, this is a message from IED 3)
- UR IED 3:**
- DIRECT OUT 2 OPERAND:** "HYB POTT TX1"
  - DIRECT INPUT 5 DEVICE ID:** "2"
  - DIRECT INPUT 5 BIT NUMBER:** "2" (this is a message from IED 2)
  - DIRECT INPUT 6 DEVICE ID:** "2"
  - DIRECT INPUT 6 BIT NUMBER:** "3" (effectively, this is a message from IED 1)
- UR IED 2:**
- DIRECT INPUT 5 DEVICE ID:** "1"
  - DIRECT INPUT 5 BIT NUMBER:** "2"
  - DIRECT INPUT 6 DEVICE ID:** "3"
  - DIRECT INPUT 6 BIT NUMBER:** "2"
  - DIRECT OUT 2 OPERAND:** "HYB POTT TX1"
  - DIRECT OUT 3 OPERAND:** "DIRECT INPUT 5" (forward a message from 1 to 3)
  - DIRECT OUT 4 OPERAND:** "DIRECT INPUT 6" (forward a message from 3 to 1)

Signal flow between the three IEDs is shown in the figure below:



**Figure 5-105: SIGNAL FLOW FOR DIRECT INPUT/OUTPUT EXAMPLE 3**

In three-terminal applications, both the remote terminals must grant permission to trip. Therefore, at each terminal, Direct Inputs 5 and 6 should be ANDed in FlexLogic™ and the resulting operand configured as the permission to trip (**HYB POTT RX1** setting).

## 5.8.1 DCMA INPUTS

PATH: SETTINGS ⇒ TRANSDUCER I/O ⇒ DCMA INPUTS ⇒ DCMA INPUT H1(W8)

|                 |    |                                     |  |
|-----------------|----|-------------------------------------|--|
| ■ DCMA INPUT H1 | ◀▶ | DCMA INPUT H1<br>FUNCTION: Disabled | Range: Disabled, Enabled   |
| MESSAGE         | ▲▼ | DCMA INPUT H1 ID:<br>DCMA Ip 1      | Range: up to 20 alphanumeric characters  |
| MESSAGE         | ▲▼ | DCMA INPUT H1<br>UNITS: $\mu$ A     | Range: 6 alphanumeric characters   |
| MESSAGE         | ▲▼ | DCMA INPUT H1<br>RANGE: 0 to -1 mA  | Range: 0 to -1 mA, 0 to +1 mA, -1 to +1 mA, 0 to 5 mA, 0 to 10mA, 0 to 20 mA, 4 to 20 mA |
| MESSAGE         | ▲▼ | DCMA INPUT H1 MIN<br>VALUE: 0.000   | Range: -9999.999 to +9999.999 in steps of 0.001  |
| MESSAGE         | ▲▼ | DCMA INPUT H1 MAX<br>VALUE: 0.000   | Range: -9999.999 to +9999.999 in steps of 0.001  |

Hardware and software is provided to receive signals from external transducers and convert these signals into a digital format for use as required. The relay will accept inputs in the range of -1 to +20 mA DC, suitable for use with most common transducer output ranges; all inputs are assumed to be linear over the complete range. Specific hardware details are contained in Chapter 3.

Before the dcma input signal can be used, the value of the signal measured by the relay must be converted to the range and quantity of the external transducer primary input parameter, such as DC voltage or temperature. The relay simplifies this process by internally scaling the output from the external transducer and displaying the actual primary parameter.

dcma input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown above for the first channel of a type 5F transducer module installed in slot H.

The function of the channel may be either "Enabled" or "Disabled". If "Disabled", no actual values are created for the channel. An alphanumeric "ID" is assigned to each channel; this ID will be included in the channel actual value, along with the programmed units associated with the parameter measured by the transducer, such as volts, °C, megawatts, etc. This ID is also used to reference the channel as the input parameter to features designed to measure this type of parameter. The **DCMA INPUT H1 RANGE** setting specifies the mA DC range of the transducer connected to the input channel.

The **DCMA INPUT H1 MIN VALUE** and **DCMA INPUT H1 MAX VALUE** settings are used to program the span of the transducer in primary units. For example, a temperature transducer might have a span from 0 to 250°C; in this case the **DCMA INPUT H1 MIN VALUE** value is "0" and the **DCMA INPUT H1 MAX VALUE** value is "250". Another example would be a watts transducer with a span from -20 to +180 MW; in this case the **DCMA INPUT H1 MIN VALUE** value would be "-20" and the **DCMA INPUT H1 MAX VALUE** value "180". Intermediate values between the min and max values are scaled linearly.

## 5.8.2 RTD INPUTS

PATH: SETTINGS ⇒ TRANSDUCER I/O ⇒ RTD INPUTS ⇒ RTD INPUT H1(W8)

|                |    |                                    |  |
|----------------|----|------------------------------------|--|
| ■ RTD INPUT H1 | ◀▶ | RTD INPUT H1<br>FUNCTION: Disabled | Range: Disabled, Enabled                                   |
| MESSAGE        | ▲▼ | RTD INPUT H1 ID:<br>RTD Ip 1       | Range: Up to 20 alphanumeric characters                    |
| MESSAGE        | ▲▼ | RTD INPUT H1 TYPE:<br>100Ω Nickel  | Range: 100Ω Nickel, 10Ω Copper, 100Ω Platinum, 120Ω Nickel |

Hardware and software is provided to receive signals from external Resistance Temperature Detectors and convert these signals into a digital format for use as required. These channels are intended to be connected to any of the RTD types in common use. Specific hardware details are contained in Chapter 3.

RTD input channels are arranged in a manner similar to CT and VT channels. The user configures individual channels with the settings shown here.

The channels are arranged in sub-modules of two channels, numbered from 1 through 8 from top to bottom. On power-up, the relay will automatically generate configuration settings for every channel, based on the order code, in the same general manner that is used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number. The relay generates an actual value for each available input channel.

Settings are automatically generated for every channel available in the specific relay as shown above for the first channel of a type 5C transducer module installed in slot H.

The function of the channel may be either “Enabled” or “Disabled”. If “Disabled”, there will not be an actual value created for the channel. An alphanumeric ID is assigned to the channel; this ID will be included in the channel actual values. It is also used to reference the channel as the input parameter to features designed to measure this type of parameter. Selecting the type of RTD connected to the channel configures the channel.

Actions based on RTD overtemperature, such as trips or alarms, are done in conjunction with the FlexElements™ feature. In FlexElements™, the operate level is scaled to a base of 100°C. For example, a trip level of 150°C is achieved by setting the operate level at 1.5 pu. FlexElement™ operands are available to FlexLogic™ for further interlocking or to operate an output contact directly.

5

## 5.8.3 DCMA OUTPUTS

PATH: SETTINGS ⇒ TRANSDUCER I/O ⇒ DCMA OUTPUTS ⇒ DCMA OUTPUT H1(W8)

|                  |    |                                     |   |
|------------------|----|-------------------------------------|---|
| ■ DCMA OUTPUT H1 | ◀▶ | DCMA OUTPUT H1<br>SOURCE: Off       | Range: Off, any analog actual value parameter |
| MESSAGE          | ▲▼ | DCMA OUTPUT H1<br>RANGE: -1 to 1 mA | Range: -1 to 1 mA, 0 to 1 mA, 4 to 20 mA      |
| MESSAGE          | ▲▼ | DCMA OUTPUT H1<br>MIN VAL: 0.000 pu | Range: -90.000 to 90.000 pu in steps of 0.001 |
| MESSAGE          | ▲▼ | DCMA OUTPUT H1<br>MAX VAL: 1.000 pu | Range: -90.000 to 90.000 pu in steps of 0.001 |

Hardware and software is provided to generate dcmA signals that allow interfacing with external equipment. Specific hardware details are contained in Chapter 3. The dcmA output channels are arranged in a manner similar to transducer input or CT and VT channels. The user configures individual channels with the settings shown below.

The channels are arranged in sub-modules of two channels, numbered 1 through 8 from top to bottom. On power-up, the relay automatically generates configuration settings for every channel, based on the order code, in the same manner used for CTs and VTs. Each channel is assigned a slot letter followed by the row number, 1 through 8 inclusive, which is used as the channel number.

Both the output range and a signal driving a given output are user-programmable via the following settings menu (an example for channel M5 is shown).

The relay checks the driving signal ( $x$  in equations below) for the minimum and maximum limits, and subsequently re-scales so the limits defined as **MIN VAL** and **MAX VAL** match the output range of the hardware defined as **RANGE**. The following equation is applied:

$$I_{out} = \begin{cases} I_{min} & \text{if } x < \text{MIN VAL} \\ I_{max} & \text{if } x > \text{MAX VAL} \\ k(x - \text{MIN VAL}) + I_{min} & \text{otherwise} \end{cases} \quad (\text{EQ 5.19})$$

where:  $x$  is a driving signal specified by the **SOURCE** setting

$I_{min}$  and  $I_{max}$  are defined by the **RANGE** setting

$k$  is a scaling constant calculated as:

$$k = \frac{I_{max} - I_{min}}{\text{MAX VAL} - \text{MIN VAL}} \quad (\text{EQ 5.20})$$

The feature is intentionally inhibited if the **MAX VAL** and **MIN VAL** settings are entered incorrectly, e.g. when **MAX VAL** – **MIN VAL** < 0.1 pu. The resulting characteristic is illustrated in the following figure.

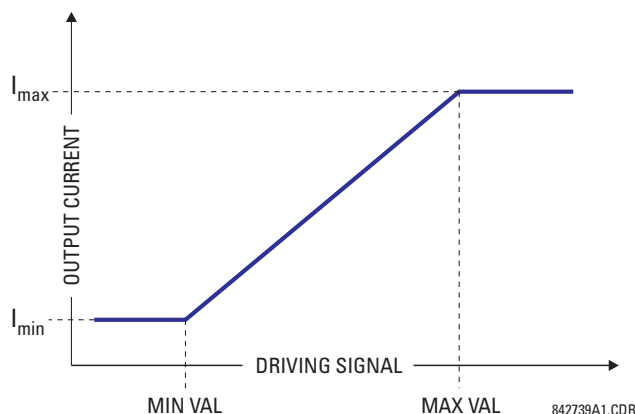


Figure 5-106: DCMA OUTPUT CHARACTERISTIC

The dcmA output settings are described below.

- **DCMA OUTPUT H1 SOURCE:** This setting specifies an internal analog value to drive the analog output. Actual values (FlexAnalog parameters) such as power, current amplitude, voltage amplitude, power factor, etc. can be configured as sources driving dcmA outputs. Refer to Appendix A for a complete list of FlexAnalog parameters.
- **DCMA OUTPUT H1 RANGE:** This setting allows selection of the output range. Each dcmA channel may be set independently to work with different ranges. The three most commonly used output ranges are available.
- **DCMA OUTPUT H1 MIN VAL:** This setting allows setting the minimum limit for the signal that drives the output. This setting is used to control the mapping between an internal analog value and the output current (see the following examples). The setting is entered in per-unit values. The base units are defined in the same manner as the FlexElement™ base units.
- **DCMA OUTPUT H1 MAX VAL:** This setting allows setting the maximum limit for the signal that drives the output. This setting is used to control the mapping between an internal analog value and the output current (see the following examples). The setting is entered in per-unit values. The base units are defined in the same manner as the FlexElement™ base units.

Three application examples are described below.

#### EXAMPLE 1:

A three phase active power on a 13.8 kV system measured via UR-series relay source 1 is to be monitored by the dcmA H1 output of the range of –1 to 1 mA. The following settings are applied on the relay: CT ratio = 1200:5, VT secondary 115, VT connection is delta, and VT ratio = 120. The nominal current is 800 A primary and the nominal power factor is 0.90. The power is to be monitored in both importing and exporting directions and allow for 20% overload compared to the nominal.

The nominal three-phase power is:

$$P = \sqrt{3} \times 13.8 \text{ kV} \times 0.8 \text{ kA} \times 0.9 = 17.21 \text{ MW} \quad (\text{EQ 5.21})$$

The three-phase power with 20% overload margin is:

$$P_{max} = 1.2 \times 17.21 \text{ MW} = 20.65 \text{ MW} \quad (\text{EQ 5.22})$$

The base unit for power (refer to the FlexElements section in this chapter for additional details) is:

$$P_{BASE} = 115 \text{ V} \times 120 \times 1.2 \text{ kA} = 16.56 \text{ MW} \quad (\text{EQ 5.23})$$

The minimum and maximum power values to be monitored (in pu) are:

$$\text{minimum power} = \frac{-20.65 \text{ MW}}{16.56 \text{ MW}} = -1.247 \text{ pu}, \quad \text{maximum power} = \frac{20.65 \text{ MW}}{16.56 \text{ MW}} = 1.247 \text{ pu} \quad (\text{EQ 5.24})$$

The following settings should be entered:

**DCMA OUTPUT H1 SOURCE:** "SRC 1 P"  
**DCMA OUTPUT H1 RANGE:** "-1 to 1 mA"  
**DCMA OUTPUT H1 MIN VAL:** "-1.247 pu"  
**DCMA OUTPUT H1 MIN VALL** "1.247 pu"

With the above settings, the output will represent the power with the scale of 1 mA per 20.65 MW. The worst-case error for this application can be calculated by superimposing the following two sources of error:

- $\pm 0.5\%$  of the full scale for the analog output module, or  $\pm 0.005 \times (1 - (-1)) \times 20.65 \text{ MW} = \pm 0.207 \text{ MW}$
- $\pm 1\%$  of reading error for the active power at power factor of 0.9

For example at the reading of 20 MW, the worst-case error is  $0.01 \times 20 \text{ MW} + 0.207 \text{ MW} = 0.407 \text{ MW}$ .

#### EXAMPLE 2:

The phase A current (true RMS value) is to be monitored via the H2 current output working with the range from 4 to 20 mA. The CT ratio is 5000:5 and the maximum load current is 4200 A. The current should be monitored from 0 A upwards, allowing for 50% overload.

The phase current with the 50% overload margin is:

$$I_{max} = 1.5 \times 4.2 \text{ kA} = 6.3 \text{ kA} \quad (\text{EQ 5.25})$$

The base unit for current (refer to the FlexElements section in this chapter for additional details) is:

$$I_{BASE} = 5 \text{ kA} \quad (\text{EQ 5.26})$$

The minimum and maximum power values to be monitored (in pu) are:

$$\text{minimum current} = \frac{0 \text{ kA}}{5 \text{ kA}} = 0 \text{ pu}, \quad \text{maximum current} = \frac{6.3 \text{ kA}}{5 \text{ kA}} = 1.26 \text{ pu} \quad (\text{EQ 5.27})$$

The following settings should be entered:

**DCMA OUTPUT H2 SOURCE:** "SRC 1 Ia RMS"  
**DCMA OUTPUT H2 RANGE:** "4 to 20 mA"  
**DCMA OUTPUT H2 MIN VAL:** "0.000 pu"  
**DCMA OUTPUT H2 MIN VAL:** "1.260 pu"

The worst-case error for this application could be calculated by superimposing the following two sources of error:

- $\pm 0.5\%$  of the full scale for the analog output module, or  $\pm 0.005 \times (20 - 4) \times 6.3 \text{ kA} = \pm 0.504 \text{ kA}$
- $\pm 0.25\%$  of reading or  $\pm 0.1\%$  of rated (whichever is greater) for currents between 0.1 and 2.0 of nominal

For example, at the reading of 4.2 kA, the worst-case error is  $\max(0.0025 \times 4.2 \text{ kA}, 0.001 \times 5 \text{ kA}) + 0.504 \text{ kA} = 0.515 \text{ kA}$ .

#### EXAMPLE 3:

A positive-sequence voltage on a 400 kV system measured via Source 2 is to be monitored by the dcma H3 output with a range of 0 to 1 mA. The VT secondary setting is 66.4 V, the VT ratio setting is 6024, and the VT connection setting is "Delta". The voltage should be monitored in the range from 70% to 110% of nominal.

The minimum and maximum positive-sequence voltages to be monitored are:

$$V_{min} = 0.7 \times \frac{400 \text{ kV}}{\sqrt{3}} = 161.66 \text{ kV}, \quad V_{max} = 1.1 \times \frac{400 \text{ kV}}{\sqrt{3}} = 254.03 \text{ kV} \quad (\text{EQ 5.28})$$

The base unit for voltage (refer to the FlexElements section in this chapter for additional details) is:

$$V_{BASE} = 0.0664 \text{ kV} \times 6024 = 400 \text{ kV} \quad (\text{EQ 5.29})$$

The minimum and maximum voltage values to be monitored (in pu) are:

$$\text{minimum voltage} = \frac{161.66 \text{ kV}}{400 \text{ kV}} = 0.404 \text{ pu}, \quad \text{maximum voltage} = \frac{254.03 \text{ kV}}{400 \text{ kV}} = 0.635 \text{ pu} \quad (\text{EQ 5.30})$$

The following settings should be entered:

**DCMA OUTPUT H3 SOURCE:** "SRC 2 V\_1 mag"

**DCMA OUTPUT H3 RANGE:** "0 to 1 mA"

**DCMA OUTPUT H3 MIN VAL:** "0.404 pu"

**DCMA OUTPUT H3 MIN VAL:** "0.635 pu"

The limit settings differ from the expected 0.7 pu and 1.1 pu because the relay calculates the positive-sequence quantities scaled to the phase-to-ground voltages, even if the VTs are connected in "Delta" (refer to the *Metering Conventions* section in Chapter 6), while at the same time the VT nominal voltage is 1 pu for the settings. Consequently the settings required in this example differ from naturally expected by the factor of  $\sqrt{3}$ .

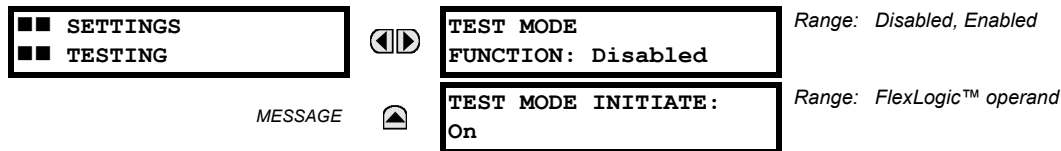
The worst-case error for this application could be calculated by superimposing the following two sources of error:

- $\pm 0.5\%$  of the full scale for the analog output module, or  $\pm 0.005 \times (1 - 0) \times 254.03 \text{ kV} = \pm 1.27 \text{ kV}$
- $\pm 0.5\%$  of reading

For example, under nominal conditions, the positive-sequence reads 230.94 kV and the worst-case error is  $0.005 \times 230.94 \text{ kV} + 1.27 \text{ kV} = 2.42 \text{ kV}$ .

## 5.9.1 TEST MODE

PATH: SETTINGS ⇌ TESTING ⇌ TEST MODE



The relay provides test settings to verify that functionality using simulated conditions for contact inputs and outputs. The Test Mode is indicated on the relay faceplate by a flashing Test Mode LED indicator.

To initiate the Test mode, the **TEST MODE FUNCTION** setting must be “Enabled” and the **TEST MODE INITIATE** setting must be set to Logic 1. In particular:

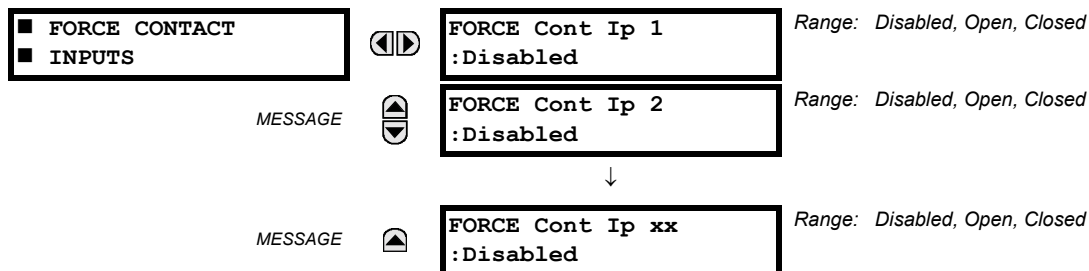
- To initiate Test Mode through relay settings, set **TEST MODE INITIATE** to “On”. The Test Mode starts when the **TEST MODE FUNCTION** setting is changed from “Disabled” to “Enabled”.
- To initiate Test Mode through a user-programmable condition, such as FlexLogic™ operand (pushbutton, digital input, communication-based input, or a combination of these), set **TEST MODE FUNCTION** to “Enabled” and set **TEST MODE INITIATE** to the desired operand. The Test Mode starts when the selected operand assumes a Logic 1 state.

When in Test Mode, the D30 remains fully operational, allowing for various testing procedures. In particular, the protection and control elements, FlexLogic™, and communication-based inputs and outputs function normally.

The only difference between the normal operation and the Test Mode is the behavior of the input and output contacts. The former can be forced to report as open or closed or remain fully operational; the latter can be forced to open, close, freeze, or remain fully operational. The response of the digital input and output contacts to the Test Mode is programmed individually for each input and output using the Force Contact Inputs and Force Contact Outputs test functions described in the following sections.

## 5.9.2 FORCE CONTACT INPUTS

PATH: SETTINGS ⇌ TESTING ⇌ FORCE CONTACT INPUTS



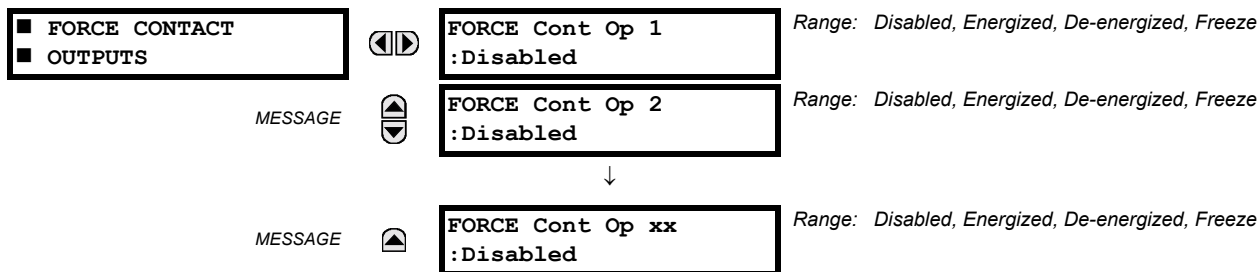
The relay digital inputs (contact inputs) could be pre-programmed to respond to the Test Mode in the following ways:

- If set to “Disabled”, the input remains fully operational. It is controlled by the voltage across its input terminals and can be turned on and off by external circuitry. This value should be selected if a given input must be operational during the test. This includes, for example, an input initiating the test, or being a part of a user pre-programmed test sequence.
- If set to “Open”, the input is forced to report as opened (Logic 0) for the entire duration of the Test Mode regardless of the voltage across the input terminals.
- If set to “Closed”, the input is forced to report as closed (Logic 1) for the entire duration of the Test Mode regardless of the voltage across the input terminals.

The Force Contact Inputs feature provides a method of performing checks on the function of all contact inputs. Once enabled, the relay is placed into Test Mode, allowing this feature to override the normal function of contact inputs. The Test Mode LED will be On, indicating that the relay is in Test Mode. The state of each contact input may be programmed as “Disabled”, “Open”, or “Closed”. All contact input operations return to normal when all settings for this feature are disabled.

## 5.9.3 FORCE CONTACT OUTPUTS

PATH: SETTINGS ⇒ TESTING ⇒ FORCE CONTACT OUTPUTS



The relay contact outputs can be pre-programmed to respond to the Test Mode.

If set to “Disabled”, the contact output remains fully operational. It operates when its control operand is Logic 1 and resets when its control operand is Logic 0. If set to “Energize”, the output will close and remain closed for the entire duration of the Test Mode, regardless of the status of the operand configured to control the output contact. If set to “De-energize”, the output will open and remain opened for the entire duration of the Test Mode regardless of the status of the operand configured to control the output contact. If set to “Freeze”, the output retains its position from before entering the Test Mode, regardless of the status of the operand configured to control the output contact.

These settings are applied two ways. First, external circuits may be tested by energizing or de-energizing contacts. Second, by controlling the output contact state, relay logic may be tested and undesirable effects on external circuits avoided.

**Example 1: Initiating a Test from User-Programmable Pushbutton 1**

The Test Mode should be initiated from User-Programmable Pushbutton 1. The pushbutton will be programmed as “Latched” (pushbutton pressed to initiate the test, and pressed again to terminate the test). During the test, Digital Input 1 should remain operational, Digital Inputs 2 and 3 should open, and Digital Input 4 should close. Also, Contact Output 1 should freeze, Contact Output 2 should open, Contact Output 3 should close, and Contact Output 4 should remain fully operational. The required settings are shown below.

To enable User-Programmable Pushbutton 1 to initiate the Test mode, make the following changes in the **SETTINGS ⇒ TESTING ⇒ TEST MODE** menu:

**TEST MODE FUNCTION:** “Enabled” and **TEST MODE INITIATE:** “PUSHBUTTON 1 ON”

Make the following changes to configure the Contact I/Os. In the **SETTINGS ⇒ TESTING ⇒ FORCE CONTACT INPUTS** and **FORCE CONTACT OUTPUTS** menus, set:

**FORCE Cont Ip 1:** “Disabled”, **FORCE Cont Ip 2:** “Open”, **FORCE Cont Ip 3:** “Open”, and **FORCE Cont Ip 4:** “Closed”

**FORCE Cont Op 1:** “Freeze”, **FORCE Cont Op 2:** “De-energized”, **FORCE Cont Op 3:** “Open”, and **FORCE Cont Op 4:** “Disabled”

**Example 2: Initiating a Test from User-Programmable Pushbutton 1 or through Remote Input 1**

The Test should be initiated locally from User-Programmable Pushbutton 1 or remotely through Remote Input 1. Both the pushbutton and the remote input will be programmed as “Latched”. The required settings are shown below.

Write the following FlexLogic™ equation (enerVista UR Setup example shown):

| FLEXLOGIC ENTRY   | TYPE                         | SYNTAX           |
|-------------------|------------------------------|------------------|
| View Graphic      | View                         | View             |
| FlexLogic Entry 1 | Remote Inputs On             | Remote IP 1 ON   |
| FlexLogic Entry 2 | Protection Element           | PUSHBUTTON 1 ON  |
| FlexLogic Entry 3 | OR                           | 2 Input          |
| FlexLogic Entry 4 | Write Virtual Output(Assign) | = Vrt Op 1 (VO1) |
| FlexLogic Entry 5 | End of List                  |                  |

Set the User Programmable Pushbutton as latching by changing **SETTINGS ⇒ PRODUCT SETUP ⇒ USER-PROGRAMMABLE PUSHBUTTONS ⇒ USER PUSHBUTTON 1 ⇒ PUSHBUTTON 1 FUNCTION** to “Latched”. To enable either Pushbutton 1 or Remote Input 1 to initiate the Test mode, make the following changes in the **SETTINGS ⇒ TESTING ⇒ TEST MODE** menu:

**TEST MODE FUNCTION:** “Enabled” and **TEST MODE INITIATE:** “VO1”



## 6.1.1 ACTUAL VALUES MAIN MENU

|   |    |   |                |
|---|----|---|----------------|
| <div> <div> <div>■ ■ ACTUAL VALUES</div> <div>■ ■ STATUS</div> </div> <div>▼</div> </div> | ◀▶ | <div> <div>■ CONTACT INPUTS</div> <div>■</div> </div>             | See page 6-3.  |
| ▼   | ▲▼ | <div> <div>■ VIRTUAL INPUTS</div> <div>■</div> </div>             | See page 6-3.  |
|   | ▲▼ | <div> <div>■ REMOTE INPUTS</div> <div>■</div> </div>              | See page 6-3.  |
|   | ▲▼ | <div> <div>■ CONTACT OUTPUTS</div> <div>■</div> </div>            | See page 6-4.  |
|   | ▲▼ | <div> <div>■ VIRTUAL OUTPUTS</div> <div>■</div> </div>            | See page 6-4.  |
|   | ▲▼ | <div> <div>■ AUTORECLOSE</div> <div>■</div> </div>                | See page 6-4.  |
|   | ▲▼ | <div> <div>■ REMOTE DEVICES</div> <div>■ STATUS</div> </div>      | See page 6-4.  |
|   | ▲▼ | <div> <div>■ REMOTE DEVICES</div> <div>■ STATISTICS</div> </div>  | See page 6-5.  |
|   | ▲▼ | <div> <div>■ DIGITAL COUNTERS</div> <div>■</div> </div>           | See page 6-5.  |
|   | ▲▼ | <div> <div>■ SELECTOR SWITCHES</div> <div>■</div> </div>          | See page 6-5.  |
|   | ▲▼ | <div> <div>■ FLEX STATES</div> <div>■</div> </div>                | See page 6-5.  |
|   | ▲▼ | <div> <div>■ ETHERNET</div> <div>■</div> </div>                   | See page 6-6.  |
|   | ▲▼ | <div> <div>■ DIRECT INPUTS</div> <div>■</div> </div>              | See page 6-6.  |
|   | ▲  | <div> <div>■ DIRECT DEVICES</div> <div>■ STATUS</div> </div>      | See page 6-7.  |
| ▲   | ◀▶ | <div> <div>■ SOURCE SRC 1</div> <div>■</div> </div>               | See page 6-11. |
| ▼   | ▲▼ | <div> <div>■ SOURCE SRC 2</div> <div>■</div> </div>               |                |
|   | ▲▼ | <div> <div>■ SYNCHROCHECK</div> <div>■</div> </div>               | See page 6-12. |
|   | ▲▼ | <div> <div>■ TRACKING FREQUENCY</div> <div>■</div> </div>         | See page 6-13. |
|   | ▲▼ | <div> <div>■ FLEXELEMENTS</div> <div>■</div> </div>               | See page 6-13. |
|   | ▲▼ | <div> <div>■ TRANSDUCER I/O</div> <div>■ DCMA INPUTS</div> </div> | See page 6-13. |
|   | ▲  | <div> <div>■ TRANSDUCER I/O</div> <div>■ RTD INPUTS</div> </div>  | See page 6-13. |

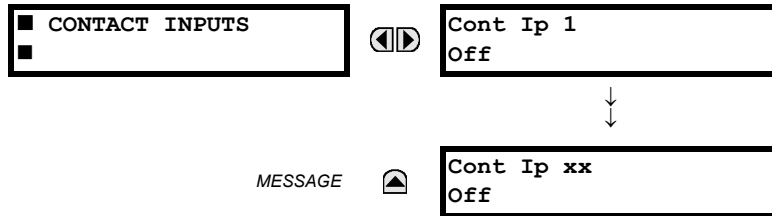
|                   |    |                      |  |                |  |
|-------------------|----|----------------------|--|----------------|--|
| ▲                 |    |                      |  |                |  |
| ■ ■ ACTUAL VALUES | ◀▶ | ■ FAULT REPORTS      |  | See page 6-14. |  |
| ■ ■ RECORDS       |    | ■                    |  |                |  |
| ▼                 | ▲▼ | ■ EVENT RECORDS      |  | See page 6-16. |  |
|                   | ▲▼ | ■                    |  |                |  |
|                   | ▲▼ | ■ OSCILLOGRAPHY      |  | See page 6-16. |  |
|                   |    | ■                    |  |                |  |
|                   | ▲  | ■ MAINTENANCE        |  | See page 6-17. |  |
|                   |    | ■                    |  |                |  |
| ▲                 |    |                      |  |                |  |
| ■ ■ ACTUAL VALUES | ◀▶ | ■ MODEL INFORMATION  |  | See page 6-18. |  |
| ■ ■ PRODUCT INFO  |    | ■                    |  |                |  |
|                   | ▲  | ■ FIRMWARE REVISIONS |  | See page 6-18. |  |
|                   |    | ■                    |  |                |  |



For status reporting, 'On' represents Logic 1 and 'Off' represents Logic 0.

### 6.2.1 CONTACT INPUTS

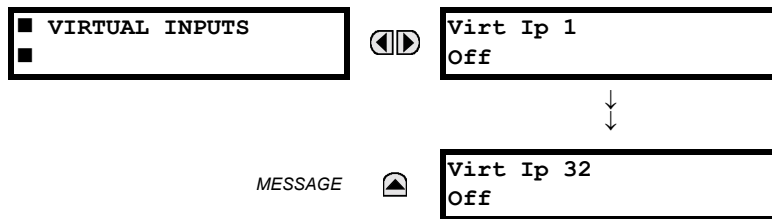
PATH: ACTUAL VALUES ⇒ STATUS ⇒ CONTACT INPUTS



The present status of the contact inputs is shown here. The first line of a message display indicates the ID of the contact input. For example, 'Cont Ip 1' refers to the contact input in terms of the default name-array index. The second line of the display indicates the logic state of the contact input.

### 6.2.2 VIRTUAL INPUTS

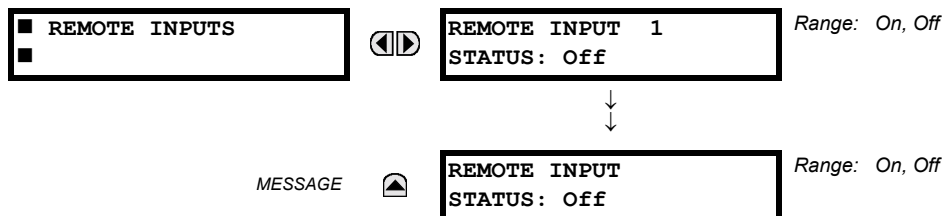
PATH: ACTUAL VALUES ⇒ STATUS ⇒ VIRTUAL INPUTS



The present status of the 32 virtual inputs is shown here. The first line of a message display indicates the ID of the virtual input. For example, 'Virt Ip 1' refers to the virtual input in terms of the default name. The second line of the display indicates the logic state of the virtual input.

### 6.2.3 REMOTE INPUTS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ REMOTE INPUTS

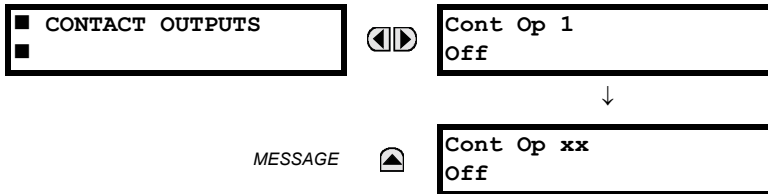


The present state of the remote inputs is shown here.

The state displayed will be that of the remote point unless the remote device has been established to be "Offline" in which case the value shown is the programmed default state for the remote input.

## 6.2.4 CONTACT OUTPUTS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ CONTACT OUTPUTS



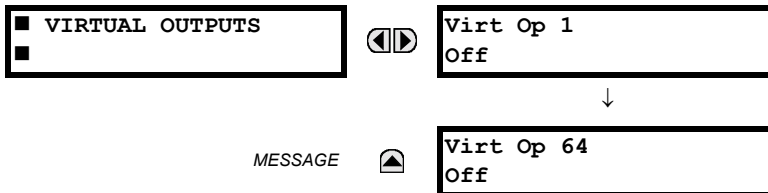
The present state of the contact outputs is shown here. The first line of a message display indicates the ID of the contact output. For example, 'Cont Op 1' refers to the contact output in terms of the default name-array index. The second line of the display indicates the logic state of the contact output.



**NOTE** For Form-A outputs, the state of the voltage(V) and/or current(I) detectors will show as: Off, VOff, IOff, On, VOn, and/or IOn. For Form-C outputs, the state will show as Off or On.

## 6.2.5 VIRTUAL OUTPUTS

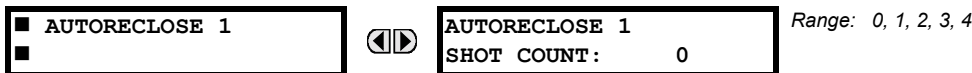
PATH: ACTUAL VALUES ⇒ STATUS ⇒ VIRTUAL OUTPUTS



The present state of up to 64 virtual outputs is shown here. The first line of a message display indicates the ID of the virtual output. For example, 'Virt Op 1' refers to the virtual output in terms of the default name-array index. The second line of the display indicates the logic state of the virtual output, as calculated by the FlexLogic™ equation for that output.

## 6.2.6 AUTORECLOSE

PATH: ACTUAL VALUES ⇒ STATUS ⇒ AUTORECLOSE ⇒ AUTORECLOSE 1

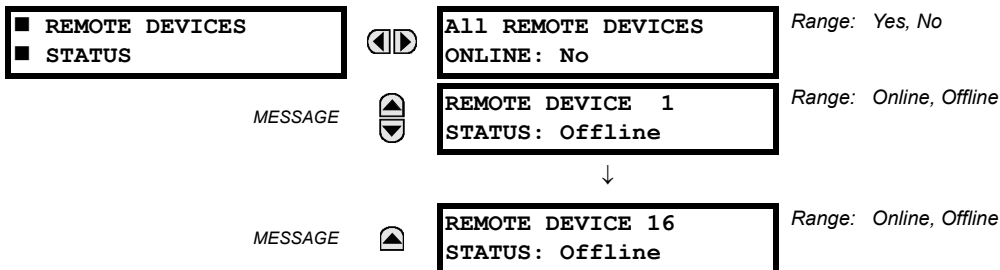


The automatic reclosure shot count is shown here.

## 6.2.7 REMOTE DEVICES

## a) STATUS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ REMOTE DEVICES STATUS



The present state of up to 16 programmed Remote Devices is shown here. The **ALL REMOTE DEVICES ONLINE** message indicates whether or not all programmed Remote Devices are online. If the corresponding state is "No", then at least one required Remote Device is not online.

## b) STATISTICS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ REMOTE DEVICES STATISTICS ⇒ REMOTE DEVICE 1(16)

|                   |           |                             |
|-------------------|-----------|-----------------------------|
| ■ REMOTE DEVICE 1 | ◀▶        | REMOTE DEVICE 1<br>StNum: 0 |
| ■                 | MESSAGE ▲ | REMOTE DEVICE 1<br>SqNum: 0 |

Statistical data (2 types) for up to 16 programmed Remote Devices is shown here.

The **StNum** number is obtained from the indicated Remote Device and is incremented whenever a change of state of at least one DNA or UserSt bit occurs. The **SqNum** number is obtained from the indicated Remote Device and is incremented whenever a GSSE message is sent. This number will rollover to zero when a count of 4,294,967,295 is incremented.

## 6.2.8 DIGITAL COUNTERS

PATH: ACTUAL VALUES ⇒ DIGITAL COUNTERS ⇒ DIGITAL COUNTERS Counter 1(8)

|                    |           |  |
|--------------------|-----------|--|
| ■ DIGITAL COUNTERS | ◀▶        | Counter 1 ACCUM:<br>0                    |
| ■ Counter 1        | MESSAGE ▲ | Counter 1 FROZEN:<br>0                   |
|                    | MESSAGE ▲ | Counter 1 FROZEN:<br>YYYY/MM/DD HH:MM:SS |
|                    | MESSAGE ▲ | Counter 1 MICROS:<br>0                   |

The present status of the 8 digital counters is shown here. The status of each counter, with the user-defined counter name, includes the accumulated and frozen counts (the count units label will also appear). Also included, is the date/time stamp for the frozen count. The **Counter n MICROS** value refers to the microsecond portion of the time stamp.

## 6.2.9 SELECTOR SWITCHES

PATH: ACTUAL VALUES ⇒ STATUS ⇒ SELECTOR SWITCHES

|                     |           |                                    |                             |
|---------------------|-----------|------------------------------------|-----------------------------|
| ■ SELECTOR SWITCHES | ◀▶        | SELECTOR SWITCH 1<br>POSITION: 0/7 | Range: Current Position / 7 |
|                     | MESSAGE ▲ | SELECTOR SWITCH 2<br>POSITION: 0/7 | Range: Current Position / 7 |

The display shows both the current position and the full range. The current position only (an integer from 0 through 7) is the actual value.

## 6.2.10 FLEX STATES

PATH: ACTUAL VALUES ⇒ STATUS ⇒ FLEX STATES

|               |           |                       |                |
|---------------|-----------|-----------------------|----------------|
| ■ FLEX STATES | ◀▶        | PARAM 1: Off<br>Off   | Range: Off, On |
|               | MESSAGE ▲ | PARAM 256: Off<br>Off | Range: Off, On |

There are 256 FlexState bits available. The second line value indicates the state of the given FlexState bit.

6.2.11 ETHERNET

PATH: ACTUAL VALUES ⇒ STATUS ⇒ ⚙️ ETHERNET

ETHERNET

MESSAGE

ETHERNET PRI LINK  
STATUS: OK

ETHERNET SEC LINK  
STATUS: OK

Range: Fail, OK

Range: Fail, OK

6.2.12 DIRECT INPUTS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ ⚙️ DIRECT INPUTS

DIRECT INPUTS

MESSAGE

AVG MSG RETURN  
TIME CH1: 0 ms

UNRETURNED MSG  
COUNT CH1: 0

CRC FAIL COUNT  
CH1: 0

AVG MSG RETURN  
TIME CH2: 0 ms

UNRETURNED MSG  
COUNT CH2: 0

CRC FAIL COUNT  
CH2: 0

DIRECT INPUT 1:  
On

MESSAGE

MESSAGE

MESSAGE

MESSAGE

MESSAGE

MESSAGE

DIRECT INPUT 32:  
On

MESSAGE

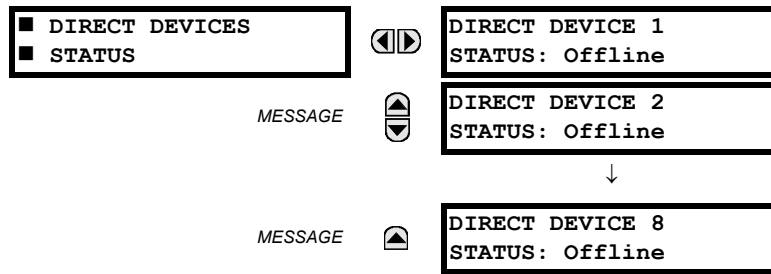
The **AVERAGE MSG RETURN TIME** is the time taken for direct output messages to return to the sender in a direct input/output ring configuration (this value is not applicable for non-ring configurations). This is a rolling average calculated for the last 10 messages. There are two return times for dual-channel communications modules.

The **UNRETURNED MSG COUNT** values (one per communications channel) count the direct output messages that do not make the trip around the communications ring. The **CRC FAIL COUNT** values (one per communications channel) count the direct output messages that have been received but fail the CRC check. High values for either of these counts may indicate on a problem with wiring, the communication channel, or the relay(s). The **UNRETURNED MSG COUNT** and **CRC FAIL COUNT** values can be cleared using the **CLEAR DIRECT I/O COUNTERS** command.

The **DIRECT INPUT x** values represent the state of the x-th direct input.

## 6.2.13 DIRECT DEVICES STATUS

PATH: ACTUAL VALUES ⇒ STATUS ⇒ DIRECT DEVICES STATUS



These actual values represent the state of Direct Devices 1 through 8.

## 6.3.1 METERING CONVENTIONS

## a) UR CONVENTION FOR MEASURING POWER AND ENERGY

The following figure illustrates the conventions established for use in UR-series relays.

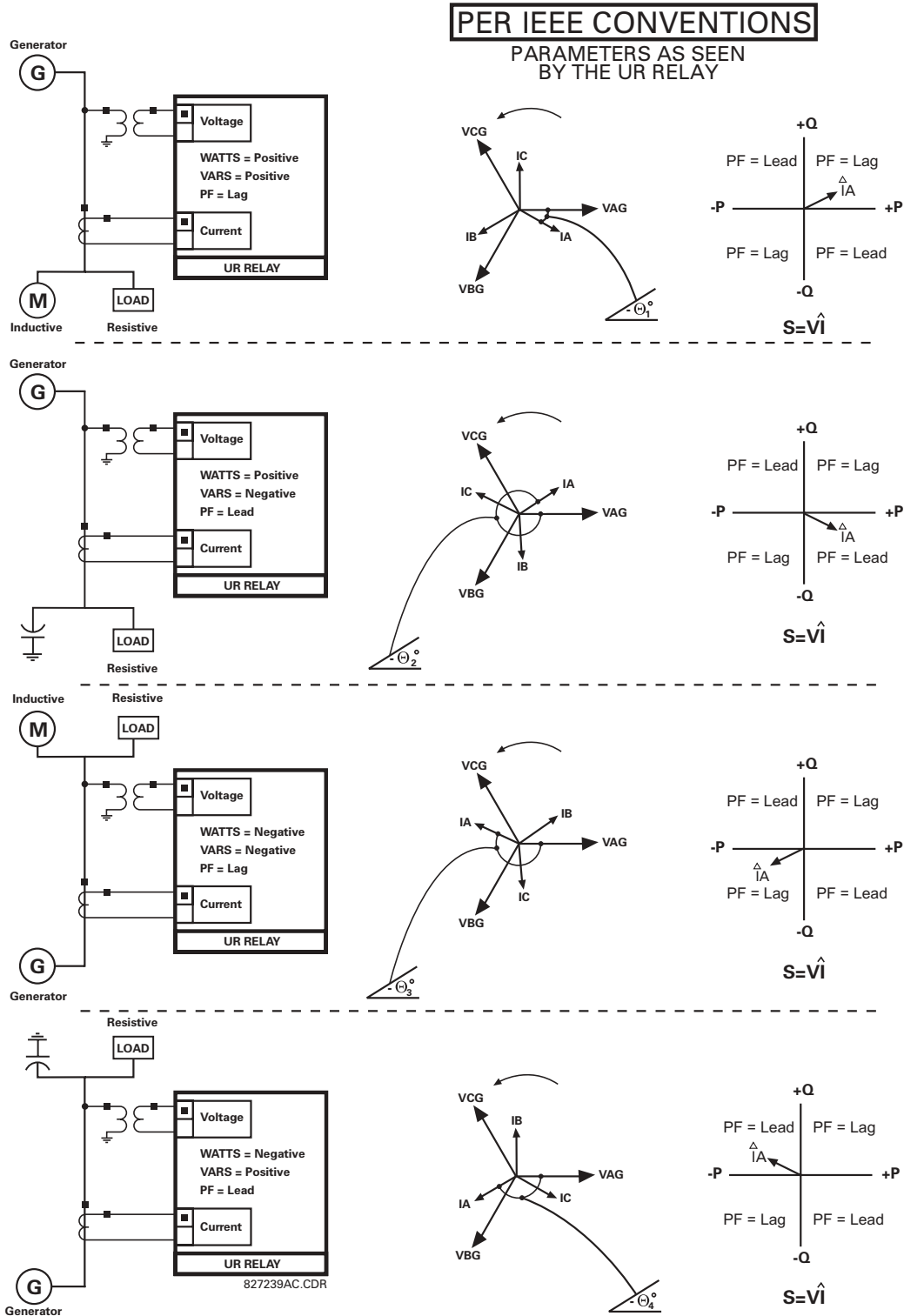


Figure 6-1: FLOW DIRECTION OF SIGNED VALUES FOR WATTS AND VARS



### b) UR CONVENTION FOR MEASURING PHASE ANGLES

All phasors calculated by UR-series relays and used for protection, control and metering functions are rotating phasors that maintain the correct phase angle relationships with each other at all times.

For display and oscillography purposes, all phasor angles in a given relay are referred to an AC input channel pre-selected by the **SETTINGS** ⇒ **SYSTEM SETUP** ⇒ **POWER SYSTEM** ⇒ **FREQUENCY AND PHASE REFERENCE** setting. This setting defines a particular source to be used as the reference.

The relay will first determine if any “Phase VT” bank is indicated in the Source. If it is, voltage channel VA of that bank is used as the angle reference. Otherwise, the relay determines if any “Aux VT” bank is indicated; if it is, the auxiliary voltage channel of that bank is used as the angle reference. If neither of the two conditions is satisfied, then two more steps of this hierarchical procedure to determine the reference signal include “Phase CT” bank and “Ground CT” bank.

If the AC signal pre-selected by the relay upon configuration is not measurable, the phase angles are not referenced. The phase angles are assigned as positive in the leading direction, and are presented as negative in the lagging direction, to more closely align with power system metering conventions. This is illustrated below.

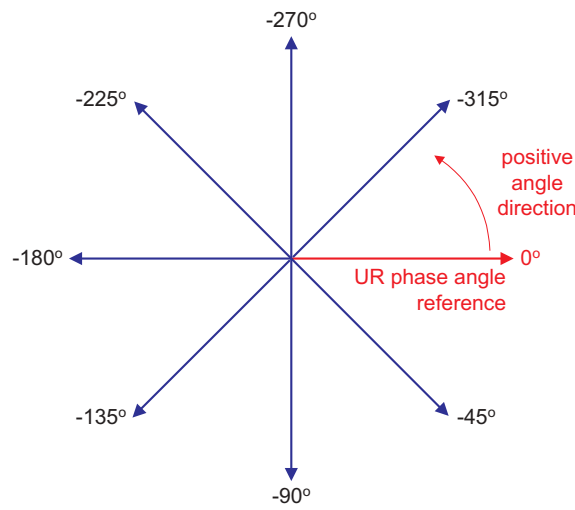


Figure 6-2: UR PHASE ANGLE MEASUREMENT CONVENTION

### c) UR CONVENTION FOR MEASURING SYMMETRICAL COMPONENTS

The UR-series of relays calculate voltage symmetrical components for the power system phase A line-to-neutral voltage, and symmetrical components of the currents for the power system phase A current. Owing to the above definition, phase angle relations between the symmetrical currents and voltages stay the same irrespective of the connection of instrument transformers. This is important for setting directional protection elements that use symmetrical voltages.

For display and oscillography purposes the phase angles of symmetrical components are referenced to a common reference as described in the previous sub-section.

#### WYE-Connected Instrument Transformers:

- ABC phase rotation:

$$V_{-0} = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

$$V_{-1} = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

$$V_{-2} = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

- ACB phase rotation:

$$V_{-0} = \frac{1}{3}(V_{AG} + V_{BG} + V_{CG})$$

$$V_{-1} = \frac{1}{3}(V_{AG} + a^2V_{BG} + aV_{CG})$$

$$V_{-2} = \frac{1}{3}(V_{AG} + aV_{BG} + a^2V_{CG})$$

The above equations apply to currents as well.

**DELTA-Connected Instrument Transformers:**

- ABC phase rotation:

$$V_0 = N/A$$

$$V_1 = \frac{1\angle-30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

$$V_2 = \frac{1\angle30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

- ACB phase rotation:

$$V_0 = N/A$$

$$V_1 = \frac{1\angle30^\circ}{3\sqrt{3}}(V_{AB} + a^2V_{BC} + aV_{CA})$$

$$V_2 = \frac{1\angle-30^\circ}{3\sqrt{3}}(V_{AB} + aV_{BC} + a^2V_{CA})$$

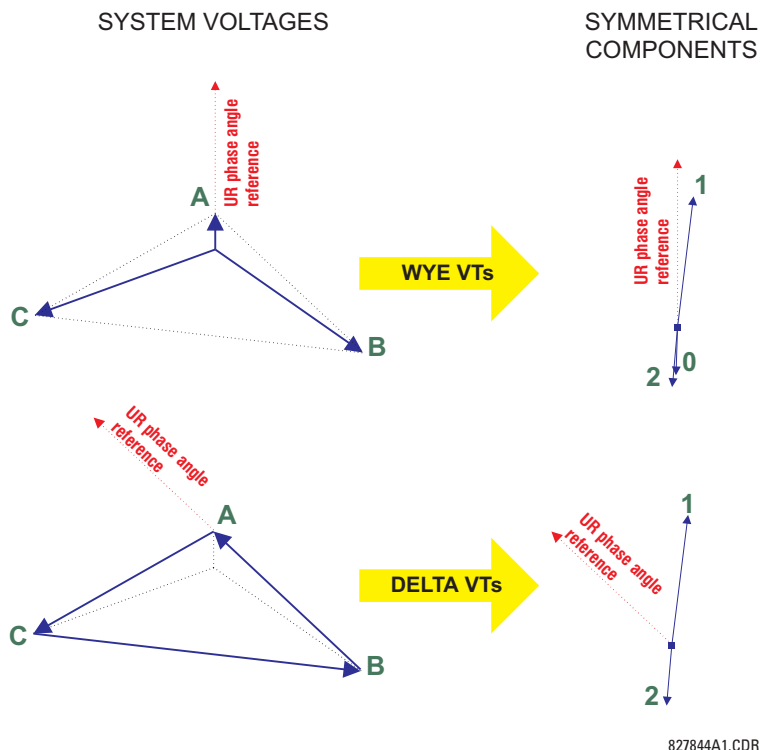
The zero-sequence voltage is not measurable under the Delta connection of instrument transformers and is defaulted to zero. The table below shows an example of symmetrical components calculations for the ABC phase rotation.

**Table 6-1: SYMMETRICAL COMPONENTS CALCULATION EXAMPLE**

| SYSTEM VOLTAGES, SEC. V *   |                 |                 |                 |                 |                 | VT<br>CONN. | RELAY INPUTS, SEC. V |                 |                | SYMM. COMP, SEC. V |                |                |
|---|-----------------|-----------------|-----------------|-----------------|-----------------|-------------|----------------------|-----------------|----------------|--------------------|----------------|----------------|
| V <sub>AG</sub>   | V <sub>BG</sub> | V <sub>CG</sub> | V <sub>AB</sub> | V <sub>BC</sub> | V <sub>CA</sub> |             | F5AC                 | F6AC            | F7AC           | V <sub>0</sub>     | V <sub>1</sub> | V <sub>2</sub> |
| 13.9<br>∠0°   | 76.2<br>∠-125°  | 79.7<br>∠-250°  | 84.9<br>∠-313°  | 138.3<br>∠-97°  | 85.4<br>∠-241°  | WYE         | 13.9<br>∠0°          | 76.2<br>∠-125°  | 79.7<br>∠-250° | 19.5<br>∠-192°     | 56.5<br>∠-7°   | 23.3<br>∠-187° |
| UNKNOWN (only V <sub>1</sub> and V <sub>2</sub><br>can be determined) |                 |                 | 84.9<br>∠0°     | 138.3<br>∠-144° | 85.4<br>∠-288°  | DELTA       | 84.9<br>∠0°          | 138.3<br>∠-144° | 85.4<br>∠-288° | N/A                | 56.5<br>∠-54°  | 23.3<br>∠-234° |

- \* The power system voltages are phase-referenced – for simplicity – to V<sub>AG</sub> and V<sub>AB</sub>, respectively. This, however, is a relative matter. It is important to remember that the UR displays are always referenced as specified under **SETTINGS** ⇒ **SYSTEM SETUP** ⇒ **POWER SYSTEM** ⇒ **FREQUENCY AND PHASE REFERENCE**.

The example above is illustrated in the following figure.

**Figure 6-3: MEASUREMENT CONVENTION FOR SYMMETRICAL COMPONENTS**

## 6.3.2 SOURCES

PATH: ACTUAL VALUES ⇒ METERING ⇒ SOURCE SRC 1 ⇒

|  |   |   |
|--|---|---|
| <div> <div>■ PHASE CURRENT</div> <div>■ SRC 1</div> </div>               |   | <div> <div>◀▶</div> <div>SRC 1 RMS Ia: 0.000<br/>b: 0.000 c: 0.000 A</div> </div> |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 RMS Ia:<br/>0.000 A</div> </div>           |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 RMS Ib:<br/>0.000 A</div> </div>           |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 RMS Ic:<br/>0.000 A</div> </div>           |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 RMS In:<br/>0.000 A</div> </div>           |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR Ia:<br/>0.000 A 0.0°</div> </div>   |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR Ib:<br/>0.000 A 0.0°</div> </div>   |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR Ic:<br/>0.000 A 0.0°</div> </div>   |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR In:<br/>0.000 A 0.0°</div> </div>   |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 ZERO SEQ I0:<br/>0.000 A 0.0°</div> </div> |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 POS SEQ I1:<br/>0.000 A 0.0°</div> </div>  |   |
| MESSAGE  | <div> <div>▲</div> <div>SRC 1 NEG SEQ I2:<br/>0.000 A 0.0°</div> </div>   |   |
| <div>▲</div> <div> <div>■ GROUND CURRENT</div> <div>■ SRC 1</div> </div> |   | <div> <div>◀▶</div> <div>SRC 1 RMS Ig:<br/>0.000 A</div> </div>                   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR Ig:<br/>0.000 A 0.0°</div> </div>   |   |
| MESSAGE  | <div> <div>▲</div> <div>SRC 1 PHASOR Igd:<br/>0.000 A 0.0°</div> </div>   |   |
| <div>▲</div> <div> <div>■ PHASE VOLTAGE</div> <div>■ SRC 1</div> </div>  |   | <div> <div>◀▶</div> <div>SRC 1 RMS Vag:<br/>0.000 V</div> </div>                  |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 RMS Vbg:<br/>0.000 V</div> </div>          |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 RMS Vcg:<br/>0.000 V</div> </div>          |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR Vag:<br/>0.000 V 0.0°</div> </div>  |   |
| MESSAGE  | <div> <div>▲▼</div> <div>SRC 1 PHASOR Vbg:<br/>0.000 V 0.0°</div> </div>  |   |

|                                |    |                                    |
|--------------------------------|----|------------------------------------|
| MESSAGE                        | ▲▼ | SRC 1 PHASOR Vcg:<br>0.000 V 0.0°  |
| MESSAGE                        | ▲▼ | SRC 1 RMS Vab:<br>0.000 V          |
| MESSAGE                        | ▲▼ | SRC 1 RMS Vbc:<br>0.000 V          |
| MESSAGE                        | ▲▼ | SRC 1 RMS Vca:<br>0.000 V          |
| MESSAGE                        | ▲▼ | SRC 1 PHASOR Vab:<br>0.000 V 0.0°  |
| MESSAGE                        | ▲▼ | SRC 1 PHASOR Vbc:<br>0.000 V 0.0°  |
| MESSAGE                        | ▲▼ | SRC 1 PHASOR Vca:<br>0.000 V 0.0°  |
| MESSAGE                        | ▲▼ | SRC 1 ZERO SEQ V0:<br>0.000 V 0.0° |
| MESSAGE                        | ▲▼ | SRC 1 POS SEQ V1:<br>0.000 V 0.0°  |
| MESSAGE                        | ▲▼ | SRC 1 NEG SEQ V2:<br>0.000 V 0.0°  |
| ▲                              |    |                                    |
| ■ AUXILIARY VOLTAGE<br>■ SRC 1 | ◀▶ | SRC 1 RMS Vx:<br>0.000 V           |
| MESSAGE                        | ▲▼ | SRC 1 PHASOR Vx:<br>0.000 V 0.0°   |
| ▲                              |    |                                    |

6

Two identical Source menus are available. The "SRC 1" text will be replaced by whatever name was programmed by the user for the associated source (see **SETTINGS** ⇒ **SYSTEM SETUP** ⇒ **SIGNAL SOURCES**).

**SOURCE FREQUENCY** is measured via software-implemented zero-crossing detection of an AC signal. The signal is either a Clarke transformation of three-phase voltages or currents, auxiliary voltage, or ground current as per source configuration (see the **SYSTEM SETUP** ⇒ **POWER SYSTEM** settings). The signal used for frequency estimation is low-pass filtered. The final frequency measurement is passed through a validation filter that eliminates false readings due to signal distortions and transients.

### 6.3.3 SYNCHROCHECK

**PATH: ACTUAL VALUES** ⇒ **METERING** ⇒ **SYNCHROCHECK** ⇒ **SYNCHROCHECK 1(2)**

|                       |    |                                       |
|-----------------------|----|---------------------------------------|
| ■ SYNCHROCHECK 1<br>■ | ◀▶ | SYNCHROCHECK 1 DELTA<br>VOLT: 0.000 V |
| MESSAGE               | ▲▼ | SYNCHROCHECK 1 DELTA<br>PHASE: 0.0°   |
| MESSAGE               | ▲▼ | SYNCHROCHECK 1 DELTA<br>FREQ: 0.00 Hz |

The Actual Values menu for Synchrocheck 2 is identical to that of Synchrocheck 1. If a synchrocheck function setting is "Disabled", the corresponding actual values menu item will not be displayed.

## 6.3.4 TRACKING FREQUENCY

PATH: ACTUAL VALUES ⇒ METERING ⇒ TRACKING FREQUENCY



The tracking frequency is displayed here. The frequency is tracked based on configuration of the reference source. The **TRACKING FREQUENCY** is based upon positive sequence current phasors from all line terminals and is synchronously adjusted at all terminals. If currents are below 0.125 pu, then the **NOMINAL FREQUENCY** is used.

## 6.3.5 FLEXELEMENTS™

PATH: ACTUAL VALUES ⇒ METERING ⇒ FLEXELEMENTS ⇒ FLEXELEMENT 1(8)



The operating signals for the FlexElements™ are displayed in pu values using the following definitions of the base units.

Table 6–2: FLEXELEMENT™ BASE UNITS

|  |  |
|--|--|
| BREAKER ARCING AMPS<br>(Brk X Arc Amp A, B, and C) | BASE = $2000 \text{ kA}^2 \times \text{cycle}$   |
| dcmA   | BASE = maximum value of the <b>DCMA INPUT MAX</b> setting for the two transducers configured under the +IN and –IN inputs. |
| FREQUENCY  | $f_{\text{BASE}} = 1 \text{ Hz}$   |
| PHASE ANGLE  | $\phi_{\text{BASE}} = 360 \text{ degrees}$ (see the UR angle referencing convention)                                       |
| POWER FACTOR                                       | $\text{PF}_{\text{BASE}} = 1.00$   |
| RTDs   | BASE = $100^\circ\text{C}$   |
| SOURCE CURRENT                                     | $I_{\text{BASE}} = \text{maximum nominal primary RMS value of the +IN and –IN inputs}$                                     |
| SOURCE POWER                                       | $P_{\text{BASE}} = \text{maximum value of } V_{\text{BASE}} \times I_{\text{BASE}} \text{ for the +IN and –IN inputs}$     |
| SOURCE VOLTAGE                                     | $V_{\text{BASE}} = \text{maximum nominal primary RMS value of the +IN and –IN inputs}$                                     |

## 6.3.6 TRANSDUCER I/O

PATH: ACTUAL VALUES ⇒ METERING ⇒ TRANSDUCER I/O DCMA INPUTS ⇒ DCMA INPUT xx



Actual values for each dcmA input channel that is enabled are displayed with the top line as the programmed Channel ID and the bottom line as the value followed by the programmed units.

PATH: ACTUAL VALUES ⇒ METERING ⇒ TRANSDUCER I/O RTD INPUTS ⇒ RTD INPUT xx



Actual values for each RTD input channel that is enabled are displayed with the top line as the programmed Channel ID and the bottom line as the value.

### 6.4.1 FAULT REPORTS

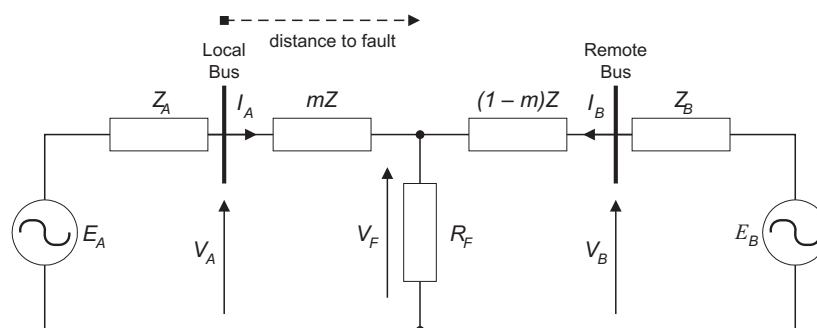
PATH: ACTUAL VALUES ⇒ RECORDS ⇒ FAULT REPORTS ⇒ FAULT REPORT 1(15)

|   |               |  |  |
|---|---------------|--|--|
| NO FAULTS TO REPORT   |               |  |  |
| or  |               |  |  |
| <div> <div> <div>■</div> <div>FAULT REPORT 1</div> </div> <div>■</div> </div> | <div>◀▶</div> | <div>FAULT 1</div> <div>LINE ID: SRC 1</div>             | Range: SRC 1, SRC 2  |
| MESSAGE   | <div>▲▼</div> | <div>FAULT 1      DATE:</div> <div>2000/08/11</div>      | Range: YYYY/MM/DD  |
| MESSAGE   | <div>▲▼</div> | <div>FAULT 1      TIME:</div> <div>00:00:00.000000</div> | Range: HH:MM:SS.ssssss   |
| MESSAGE   | <div>▲▼</div> | <div>FAULT 1      TYPE:</div> <div>ABG</div>             | Range: where applicable; not seen if the source VTs are in the "Delta" configuration |
| MESSAGE   | <div>▲▼</div> | <div>FAULT 1      LOCATION</div> <div>00.0 km</div>      | Range: where applicable; not seen if the source VTs are in the "Delta" configuration |
| MESSAGE   | <div>▲</div>  | <div>FAULT 1      RECLOSE</div> <div>SHOT: 0</div>       | Range: where applicable  |

The latest 15 fault reports can be stored. The most recent fault location calculation (when applicable) is displayed in this menu, along with the date and time stamp of the event which triggered the calculation. See the **SETTINGS ⇒ PRODUCT SETUP ⇒ ⚙️ FAULT REPORTS ⇒ FAULT REPORT 1** menu for assigning the source and trigger for fault calculations. Refer to the **COMMANDS ⇒ ⚙️ CLEAR RECORDS** menu for manual clearing of the fault reports and to the **SETTINGS ⇒ PRODUCT SETUP ⇒ ⚙️ CLEAR RELAY RECORDS** menu for automated clearing of the fault reports.

Fault type determination is required for calculation of fault location – the algorithm uses the angle between the negative and positive sequence components of the relay currents. To improve accuracy and speed of operation, the fault components of the currents are used, i.e., the pre-fault phasors are subtracted from the measured current phasors. In addition to the angle relationships, certain extra checks are performed on magnitudes of the negative and zero-sequence currents.

The single-ended fault location method assumes that the fault components of the currents supplied from the local (A) and remote (B) systems are in phase. The figure below shows an equivalent system for fault location.



### Figure 6–4: EQUIVALENT SYSTEM FOR FAULT LOCATION

The following equations hold true for this equivalent system.

$$V_A = m \cdot Z \cdot I_A + R_F \cdot (I_A + I_B) \quad (\text{EQ 6.1})$$

where:  $m$  = sought pu distance to fault,  $Z$  = positive sequence impedance of the line.

The currents from the local and remote systems can be parted between their fault (F) and pre-fault load (pre) components:

$$I_A = I_{AF} + I_{Apre} \quad (\text{EQ 6.2})$$

and neglecting shunt parameters of the line:

$$I_B = I_{BF} - I_{Apre} \quad (\text{EQ 6.3})$$

Inserting the  $I_A$  and  $I_B$  equations into the  $V_A$  equation and solving for the fault resistance yields:

$$R_F = \frac{V_A - m \cdot Z \cdot I_A}{I_{AF} \cdot \left(1 + \frac{I_{BF}}{I_{AF}}\right)} \quad (\text{EQ 6.4})$$

Assuming the fault components of the currents,  $I_{AF}$  and  $I_{BF}$  are in phase, and observing that the fault resistance, as impedance, does not have any imaginary part gives:

$$\text{Im}\left(\frac{V_A - m \cdot Z \cdot I_A}{I_{AF}}\right) = 0 \quad (\text{EQ 6.5})$$

where:  $\text{Im}()$  represents the imaginary part of a complex number. Solving the above equation for the unknown  $m$  creates the following fault location algorithm:

$$m = \frac{\text{Im}(V_A \cdot I_{AF}^*)}{\text{Im}(Z \cdot I_A \cdot I_{AF}^*)} \quad (\text{EQ 6.6})$$

where \* denotes the complex conjugate and:

$$I_{AF} = I_A - I_{Apre} \quad (\text{EQ 6.7})$$

Depending on the fault type, appropriate voltage and current signals are selected from the phase quantities before applying the two equations above (the superscripts denote phases, the subscripts denote stations):

- For AG faults:  $V_A = V_A^A$ ,  $I_A = I_A^A + K_0 \cdot I_{0A}$
  - For BG faults:  $V_A = V_A^B$ ,  $I_A = I_A^B + K_0 \cdot I_{0A}$
  - For CG faults:  $V_A = V_A^C$ ,  $I_A = I_A^{BC} + K_0 \cdot I_{0A}$
  - For AB and ABG faults:  $V_A = V_A^A - V_A^B$ ,  $I_A = I_A^A - I_A^B$
  - For BC and BCG faults:  $V_A = V_A^B - V_A^C$ ,  $I_A = I_A^B - I_A^C$
  - For CA and CAG faults:  $V_A = V_A^C - V_A^A$ ,  $I_A = I_A^C - I_A^A$
- where  $K_0$  is the zero sequence compensation factor (for the first six equations above)
- For ABC faults, all three AB, BC, and CA loops are analyzed and the final result is selected based upon consistency of the results

The element calculates the distance to the fault (with  $m$  in miles or kilometers) and the phases involved in the fault.

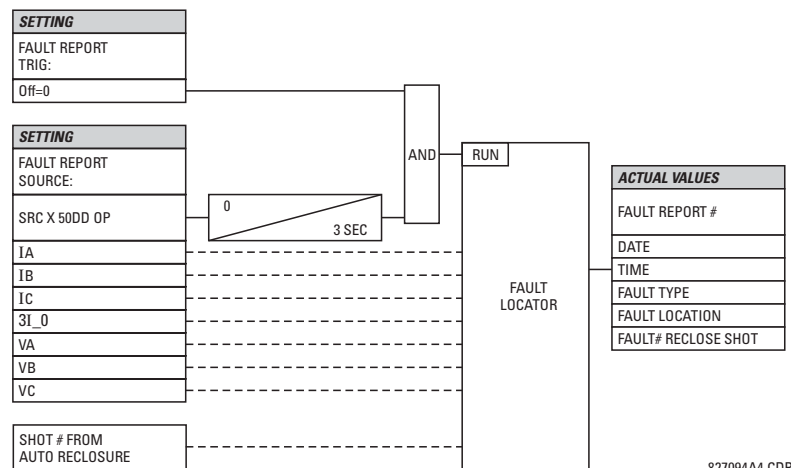
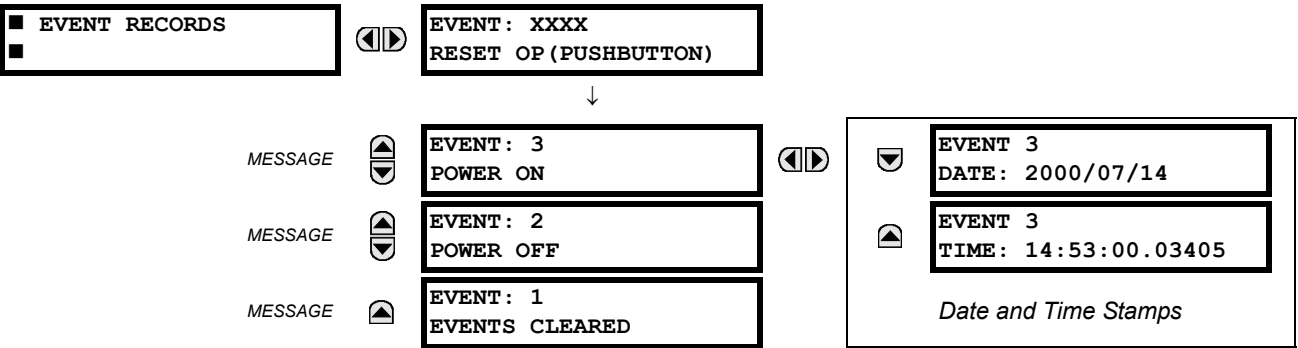


Figure 6-5: FAULT LOCATOR SCHEME

6.4.2 EVENT RECORDS

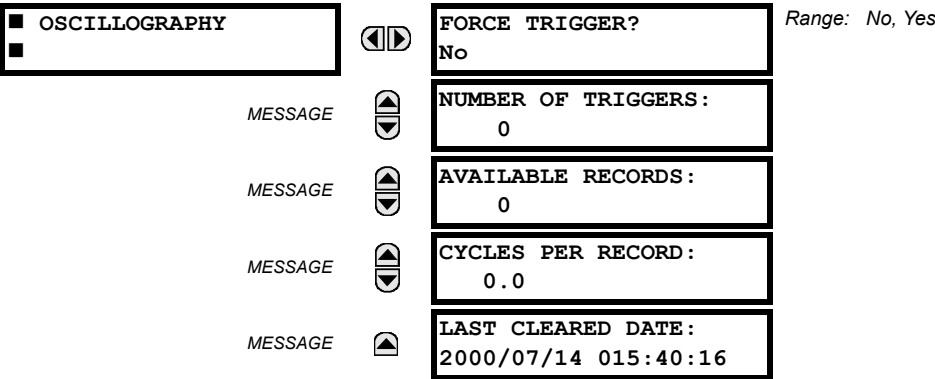
PATH: ACTUAL VALUES ⇒ RECORDS ⇒ EVENT RECORDS



The Event Records menu shows the contextual data associated with up to the last 1024 events, listed in chronological order from most recent to oldest. If all 1024 event records have been filled, the oldest record will be removed as a new record is added. Each event record shows the event identifier/sequence number, cause, and date/time stamp associated with the event trigger. Refer to the **COMMANDS** ⇒ **CLEAR RECORDS** menu for clearing event records.

6.4.3 OSCILLOGRAPHY

PATH: ACTUAL VALUES ⇒ RECORDS ⇒ OSCILLOGRAPHY



This menu allows the user to view the number of triggers involved and number of oscillography traces available. The 'cycles per record' value is calculated to account for the fixed amount of data storage for oscillography. See the Oscillography section of Chapter 5 for further details.

A trigger can be forced here at any time by setting "Yes" to the **FORCE TRIGGER?** command. Refer to the **COMMANDS** ⇒ **CLEAR RECORDS** menu for clearing the oscillography records.



## 6.4.4 BREAKER MAINTENANCE

PATH: ACTUAL VALUES ⇒ RECORDS ⇒ MAINTENANCE ⇒ BREAKER 1(2)

|             |    |   |
|-------------|----|---|
| ■ BREAKER 1 | ◀▶ | BKR 1 ARCING AMP $\phi$ A:<br>0.00 kA <sup>2</sup> -cyc |
| MESSAGE     | ▲▼ | BKR 1 ARCING AMP $\phi$ B:<br>0.00 kA <sup>2</sup> -cyc |
| MESSAGE     | ▲▼ | BKR 1 ARCING AMP $\phi$ C:<br>0.00 kA <sup>2</sup> -cyc |
| MESSAGE     | ▲▼ | BKR 1 OPERATING TIME<br>$\phi$ A: 0 ms                  |
| MESSAGE     | ▲▼ | BKR 1 OPERATING TIME<br>$\phi$ B: 0 ms                  |
| MESSAGE     | ▲▼ | BKR 1 OPERATING TIME<br>$\phi$ C: 0 ms                  |
| MESSAGE     | ▲  | BKR 1 OPERATING<br>TIME: 0 ms                           |

There is an identical menu for each of the breakers. The **BKR 1 ARCING AMP** values are in units of kA<sup>2</sup>-cycles. Refer to the **COMMANDS** ⇒ **CLEAR RECORDS** menu for clearing breaker arcing current records. The **BREAKER OPERATING TIME** is defined as the slowest operating time of breaker poles that were initiated to open.

## 6.5.1 MODEL INFORMATION

PATH: ACTUAL VALUES ⇒ ↓ PRODUCT INFO ⇒ MODEL INFORMATION

|   |   |   |                            |
|---|---|---|----------------------------|
| <div> <div>MODEL INFORMATION</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲</div> </div> | ORDER CODE LINE 1:<br>D30-E00-HCL-F8F-H6H | Example code shown         |
|   |   | ORDER CODE LINE 2:                        |                            |
|   |   | ORDER CODE LINE 3:                        |                            |
|   |   | ORDER CODE LINE 4:                        |                            |
|   |   | SERIAL NUMBER:                            |                            |
|   |   | ETHERNET MAC ADDRESS<br>000000000000      |                            |
|   |   | MANUFACTURING DATE:<br>0                  | Range: YYYY/MM/DD HH:MM:SS |
|   |   | OPERATING TIME:<br>0:00:00                |                            |

The product order code, serial number, Ethernet MAC address, date/time of manufacture, and operating time are shown here.

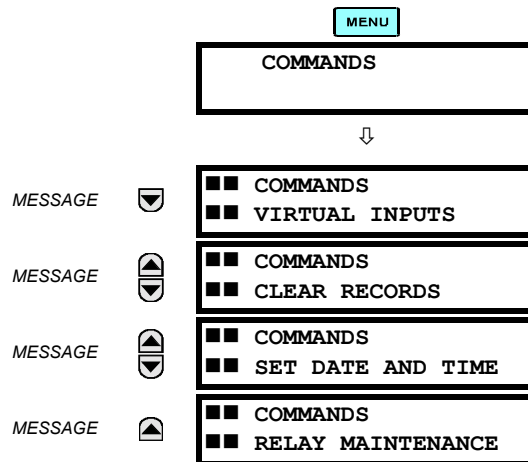
## 6.5.2 FIRMWARE REVISIONS

PATH: ACTUAL VALUES ⇒ ↓ PRODUCT INFO ⇒ ↓ FIRMWARE REVISIONS

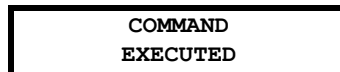
|   |   |                                       |  |
|---|---|---------------------------------------|--|
| <div> <div>FIRMWARE REVISIONS</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> <div>MESSAGE</div> </div> | <div> <div>◀▶</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲▼</div> <div>▲</div> </div> | D30 Line Relay<br>REVISION: 4.40      | Range: 0.00 to 655.35<br>Revision number of the application firmware.                    |
|   |   | MODIFICATION FILE<br>NUMBER: 0        | Range: 0 to 65535 (ID of the MOD FILE)<br>Value is 0 for each standard firmware release. |
|   |   | BOOT PROGRAM<br>REVISION: 1.13        | Range: 0.00 to 655.35<br>Revision number of the boot program firmware.                   |
|   |   | FRONT PANEL PROGRAM<br>REVISION: 0.08 | Range: 0.00 to 655.35<br>Revision number of faceplate program firmware.                  |
|   |   | COMPILE DATE:<br>2004/09/15 04:55:16  | Range: Any valid date and time.<br>Date and time when product firmware was built.        |
|   |   | BOOT DATE:<br>2004/09/15 16:41:32     | Range: Any valid date and time.<br>Date and time when the boot program was built.        |

The shown data is illustrative only. A modification file number of 0 indicates that, currently, no modifications have been installed.

## 7.1.1 COMMANDS MENU

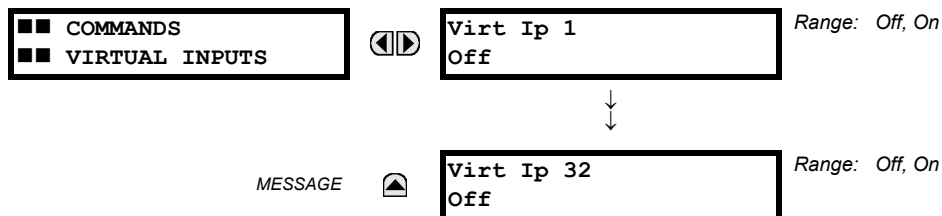


The Commands menu contains relay directives intended for operations personnel. All commands can be protected from unauthorized access via the Command Password; see the Password Security section of Chapter 5. The following flash message appears after successfully command entry:



## 7.1.2 VIRTUAL INPUTS

PATH: COMMANDS ↓ COMMANDS VIRTUAL INPUTS



The states of up to 32 virtual inputs are changed here. The first line of the display indicates the ID of the virtual input. The second line indicates the current or selected status of the virtual input. This status will be a logical state 'Off' (0) or 'On' (1).

## 7.1.3 CLEAR RECORDS

PATH: COMMANDS ↓ COMMANDS CLEAR RECORDS

|   |     |                                    |  |
|---|-----|------------------------------------|--|
| <div> <div>■ ■ COMMANDS</div> <div>■ ■ CLEAR RECORDS</div> </div> | ◀ ▶ | CLEAR FAULT REPORTS?<br>No         | Range: No, Yes   |
|   | ▲ ▼ | CLEAR EVENT RECORDS?<br>No         | Range: No, Yes   |
|   | ▲ ▼ | CLEAR OSCILLOGRAPHY?<br>No         | Range: No, Yes   |
|   | ▲ ▼ | CLEAR BREAKER 1<br>ARCING AMPS? No | Range: No, Yes   |
|   | ▲ ▼ | CLEAR BREAKER 2<br>ARCING AMPS? No | Range: No, Yes   |
|   | ▲ ▼ | CLEAR UNAUTHORIZED<br>ACCESS? No   | Range: No, Yes   |
|   | ▲ ▼ | CLEAR DIRECT I/O<br>COUNTERS? No   | Range: No, Yes<br>Valid only for units with Direct I/O module. |
|   | ▲   | CLEAR ALL RELAY<br>RECORDS? No     | Range: No, Yes   |

This menu contains commands for clearing historical data such as the Event Records. Data is cleared by changing a command setting to “Yes” and pressing the **ENTER** key. After clearing data, the command setting automatically reverts to “No”.

## 7.1.4 SET DATE AND TIME

PATH: COMMANDS ↓ SET DATE AND TIME

|   |     |   |                       |
|---|-----|---|-----------------------|
| <div> <div>■ ■ COMMANDS</div> <div>■ ■ SET DATE AND TIME</div> </div> | ◀ ▶ | SET DATE AND TIME:<br>2000/01/14 13:47:03 | (YYYY/MM/DD HH:MM:SS) |
|   |     |   |                       |

The date and time can be entered here via the faceplate keypad only if the IRIG-B signal is not in use. The time setting is based on the 24-hour clock. The complete date, as a minimum, must be entered to allow execution of this command. The new time will take effect at the moment the **ENTER** key is clicked.

## 7.1.5 RELAY MAINTENANCE

PATH: COMMANDS ↓ RELAY MAINTENANCE

|   |     |                          |                |
|---|-----|--------------------------|----------------|
| <div> <div>■ ■ COMMANDS</div> <div>■ ■ RELAY MAINTENANCE</div> </div> | ◀ ▶ | PERFORM LAMPTEST?<br>No  | Range: No, Yes |
|   | ▲   | UPDATE ORDER CODE?<br>No | Range: No, Yes |

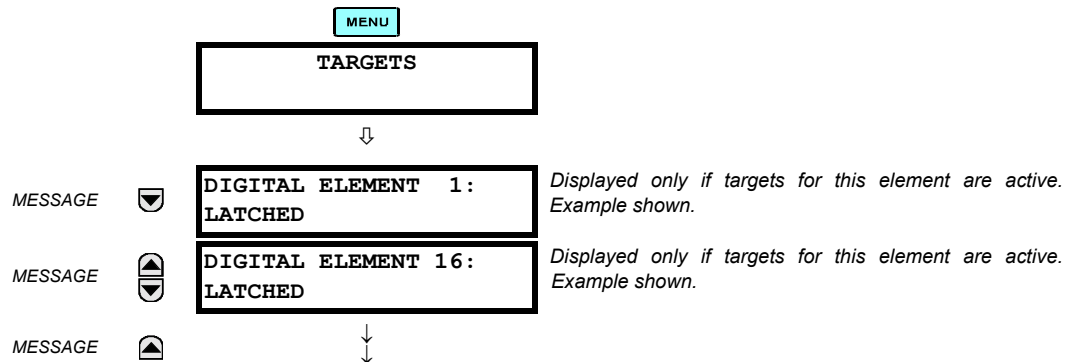
This menu contains commands for relay maintenance purposes. Commands are activated by changing a command setting to “Yes” and pressing the **ENTER** key. The command setting will then automatically revert to “No”.

The **PERFORM LAMPTEST** command turns on all faceplate LEDs and display pixels for a short duration. The **UPDATE ORDER CODE** command causes the relay to scan the backplane for the hardware modules and update the order code to match. If an update occurs, the following message is shown.

|                               |
|-------------------------------|
| UPDATING . . .<br>PLEASE WAIT |
|-------------------------------|

There is no impact if there have been no changes to the hardware modules. When an update does not occur, the **ORDER CODE NOT UPDATED** message will be shown.

## 7.2.1 TARGETS MENU



The status of any active targets will be displayed in the Targets menu. If no targets are active, the display will read **No Active Targets**:

## 7.2.2 TARGET MESSAGES

When there are no active targets, the first target to become active will cause the display to immediately default to that message. If there are active targets and the user is navigating through other messages, and when the default message timer times out (i.e. the keypad has not been used for a determined period of time), the display will again default back to the target message.

The range of variables for the target messages is described below. Phase information will be included if applicable. If a target message status changes, the status with the highest priority will be displayed.

**Table 7–1: TARGET MESSAGE PRIORITY STATUS**

| PRIORITY | ACTIVE STATUS | DESCRIPTION                              |
|----------|---------------|--|
| 1        | OP            | element operated and still picked up     |
| 2        | PKP           | element picked up and timed out          |
| 3        | LATCHED       | element had operated but has dropped out |

If a self test error is detected, a message appears indicating the cause of the error. For example **UNIT NOT PROGRAMMED** indicates that the minimal relay settings have not been programmed.

## 7.2.3 RELAY SELF-TESTS

The relay performs a number of self-test diagnostic checks to ensure device integrity. The two types of self-tests (major and minor) are listed in the tables below. When either type of self-test error occurs, the Trouble LED Indicator will turn on and a target message displayed. All errors record an event in the event recorder. Latched errors can be cleared by pressing the RESET key, providing the condition is no longer present.

Major self-test errors also result in the following:

- the critical fail relay on the power supply module is de-energized
- all other output relays are de-energized and are prevented from further operation
- the faceplate In Service LED indicator is turned off
- a RELAY OUT OF SERVICE event is recorded

Most of the minor self-test errors can be disabled. Refer to the settings in the User-Programmable Self-Tests section in Chapter 5 for additional details.

Table 7-2: MAJOR SELF-TEST ERROR MESSAGES

| SELF-TEST ERROR MESSAGE  | LATCHED TARGET MESSAGE? | DESCRIPTION OF PROBLEM   | HOW OFTEN THE TEST IS PERFORMED  | WHAT TO DO   |
|--|-------------------------|--|--|--|
| DSP ERRORS:<br>A/D Calibration, A/D Interrupt, A/D Reset, Inter DSP Rx, Sample Int, Rx Interrupt, Tx Interrupt, Rx Sample Index, Invalid Settings, Rx Checksum | Yes                     | CT/VT module with digital signal processor may have a problem.                                     | Every 1/8th of a cycle.  | Cycle the control power (if the problem recurs, contact the factory).  |
| DSP ERROR:<br>INVALID REVISION   | Yes                     | One or more DSP modules in a multiple DSP unit has Rev. C hardware                                 | Rev. C DSP needs to be replaced with a Rev. D DSP.                                   | Contact the factory  |
| EQUIPMENT MISMATCH with 2nd-line detail  | No                      | Configuration of modules does not match the order code stored in the CPU.                          | On power up; thereafter, the backplane is checked for missing cards every 5 seconds. | Check all modules against the order code, ensure they are inserted properly, and cycle control power (if problem persists, contact factory). |
| FLEXLOGIC ERR TOKEN with 2nd-line detail   | No                      | FlexLogic™ equations do not compile properly.  | Event driven; whenever Flex-Logic™ equations are modified.                           | Finish all equation editing and use self test to debug any errors.   |
| LATCHING OUTPUT ERROR  | No                      | Discrepancy in the position of a latching contact between firmware and hardware has been detected. | Every 1/8th of a cycle.  | The latching output module failed. Replace the Module.   |
| PROGRAM MEMORY Test Failed   | Yes                     | Error was found while checking Flash memory.   | Once flash is uploaded with new firmware.  | Contact the factory.   |
| UNIT NOT CALIBRATED  | No                      | Settings indicate the unit is not calibrated.  | On power up.   | Contact the factory.   |
| UNIT NOT PROGRAMMED  | No                      | <b>PRODUCT SETUP</b> ⇄ <b>INSTALLATION</b> setting indicates relay is not in a programmed state.   | On power up and whenever the <b>RELAY PROGRAMMED</b> setting is altered.             | Program all settings (especially those under <b>PRODUCT SETUP</b> ⇄ <b>INSTALLATION</b> ).   |

Table 7-3: MINOR SELF-TEST ERROR MESSAGES

| SELF-TEST ERROR MESSAGE | LATCHED TARGET MESSAGE | DESCRIPTION OF PROBLEM   | HOW OFTEN THE TEST IS PERFORMED  | WHAT TO DO  |
|-------------------------|------------------------|--|--|---|
| BATTERY FAIL            | Yes                    | Battery is not functioning.  | Monitored every 5 seconds. Reported after 1 minute if problem persists.  | Replace the battery located in the power supply module (1H or 1L).  |
| DIRECT RING BREAK       | No                     | Direct input/output settings configured for a ring, but the connection is not in a ring.                             | Every second.  | Check direct input/output configuration and/or wiring.  |
| DIRECT DEVICE OFF       | No                     | A direct device is configured but not connected.   | Every second.  | Check direct input/output configuration and/or wiring.  |
| EEPROM DATA ERROR       | Yes                    | The non-volatile memory has been corrupted.  | On power up only.  | If this message appears after an order code update is performed, press the RESET key to clear target message. In other cases, contact the factory.  |
| IRIG-B FAILURE          | No                     | A bad IRIG-B input signal has been detected  | Monitored whenever an IRIG-B signal is received.   | Ensure the IRIG-B cable is connected, check cable functionality (i.e. look for physical damage or perform continuity test), ensure IRIG-B receiver is functioning, and check input signal level (it may be less than specification). If none of these apply, contact the factory. |
| LATCHING OUT ERROR      | Yes                    | Latching output failure.   | Event driven.  | Contact the factory.  |
| LOW ON MEMORY           | Yes                    | Memory is close to 100% capacity.  | Monitored every 5 seconds.   | Contact the factory.  |
| PRI ETHERNET FAIL       | Yes                    | Primary Ethernet connection failed.  | Monitored every 2 seconds  | Check connections.  |
| PROTOTYPE FIRMWARE      | Yes                    | A prototype version of the firmware is loaded.   | On power up only.  | Contact the factory.  |
| REMOTE DEVICE OFF       | No                     | One or more GOOSE devices are not responding.  | Event driven – occurs when a device programmed to receive GOOSE messages stops receiving. Every 1 to 60 s, depending on GOOSE packets. | Check GOOSE setup.  |
| SEC ETHERNET FAIL       | Yes                    | Sec. Ethernet connection failed.   | Monitored every 2 seconds  | Check connections.  |
| SNTP FAILURE            | No                     | SNTP server not responding.  | 10 to 60 seconds.  | Check SNTP configuration and/or network connections.  |
| SYSTEM EXCEPTION        | Yes                    | Abnormal restart from modules being removed/inserted when powered-up, abnormal DC supply, or internal relay failure. | Event driven.  | Contact the factory.  |
| WATCHDOG ERROR          | No                     | Some tasks are behind schedule.  | Event driven.  | Contact the factory.  |

## 8.1.1 INTRODUCTION

The distance elements use memory voltage for polarization. Additional supervising functions – different for ground and phase distance zones – complement a classical mho characteristic to enhance directional integrity and reach accuracy:

- To avoid overreaching during resistive faults under heavy pre-fault load conditions, the ground distance elements utilize a load-adaptive (zero-sequence polarized) reactance characteristic to supervise the base mho characteristic.
- Both negative and zero-sequence currents are compared with the memory voltage to enhance directional integrity of the ground distance elements.
- It is well known that ground distance elements – as per the principle of distance relaying – may have limited accuracy during double-line-to-ground faults. In order to prevent maloperation in such cases the ground elements are blocked by an extra “fault-type comparator” that utilizes the phase angle between the negative- and zero-sequence currents.
- The phase distance elements use reactance and memory polarized directional characteristics to supervise the mho characteristic.
- Both ground and phase distance elements have the current supervision functions built-in.

The quadrilateral distance characteristic uses the reactance, directional, and current supervising functions as described above. Right and left blinders adjustable as to both the resistive and angular positions complete the characteristic.

More information regarding the distance characteristics is found in the Distance Characteristics section. An example of analysis of the steady-state operation of the distance elements is found in the Distance Elements Analysis section.

The relay provides three zones of distance protection. All zones are identical in terms of settings. Ground Zones 1 through 3 have an extra zero-sequence directional supervision implemented for their time-delayed operation after the memory expires. Consequently, Zone 1 is recommended as an underreaching element, and Zones 2 through 3 are recommended as overreaching elements and for time-delayed tripping.

The relay uses offset ground directional overcurrent functions as an optional supplement of the ground distance protection for pilot-aided schemes. The elements are described in more details in the Ground Directional Overcurrent section.

The relay provides for an adaptive distance reach control to cope with the overreaching and sub-synchronous oscillations when applied to, or in a near vicinity of series compensated lines. More details can be found in the Application on Series Compensated Lines section.

The distance elements use phase angle comparators to shape their characteristics as described in the Distance Characteristics section. The voltage and current phasors are estimated using optimized techniques as explained in the next section.

## 8.1.2 PHASOR ESTIMATION

The relay samples its input AC signals at 64 samples per power system cycle. A fast and accurate frequency tracking mechanism ensures accurate filtering and phasor estimation during off-nominal frequency conditions.

The phasor estimation process for both currents and voltages is based on the commonly used Fourier algorithm. Due to a different nature of signal distortions in the current and voltage signals digital pre-filtering algorithms have been, however, designed and optimized separately for the current and voltage channels.

The current signals are pre-filtered using an improved digital MIMIC filter. The filter removes effectively the DC component(s) guaranteeing transient overshoot below 2% regardless of the initial magnitude and time constant of the dc component(s). The filter has significantly better frequency response for higher frequencies as compared with a classical MIMIC filter. This was possible without introducing any significant phase delay thanks to the high sampling rate used by the relay.

The voltage signals are pre-filtered using a special digital filter designed to cope with CVT transients. The patented filter combines filtering and memory actions enabling the relay to cope with CVT noise under high Source Impedance Ratios (SIRs). The filter controls underestimation of the fault voltage magnitude to less than 1% of the nominal and prevents certain phase angle anomalies that can be encountered under heavy CVT noise and high SIRs.

## 8.1.3 DISTANCE CHARACTERISTICS

## a) DEFINITIONS

The relay shapes its distance characteristics using phase angle comparators and voltage and current phasors estimated as described in the previous section.

The following definitions pertain to all of the distance functions:

|                 |  |
|-----------------|--|
| $I_A, I_B, I_C$ | phase A, B, and C current phasors  |
| $I_G$           | ground current from a parallel line  |
| $V_A, V_B, V_C$ | phase A to ground, phase B to ground, and phase C to ground voltage phasors  |
| $()_1$          | positive-sequence phasor of $()$ derived from the phase quantities   |
| $()_2$          | negative-sequence phasor of $()$ derived from the phase quantities   |
| $()_0$          | zero-sequence phasor of $()$ derived from the phase quantities   |
| $()M$           | memorized value of $()$  |
| $Z$             | reach impedance ( <b>REACH</b> $\angle$ <b>RCA</b> )   |
| $Z_{REV}$       | reverse reach impedance for non-directional applications ( <b>REV REACH</b> $\angle$ <b>REV REACH RCA</b> + 180°)                              |
| $Z_D$           | directional characteristic impedance ( <b>1</b> $\angle$ <b>DIR RCA</b> )  |
| $Z_R$           | right blinder characteristic impedance: $Z_R = \text{RGT BLD} \times \sin(\text{RGT BLD RCA}) \times 1 \angle (\text{RGT BLD RCA} - 90^\circ)$ |
| $Z_L$           | left blinder characteristic impedance: $Z_L = \text{LFT BLD} \times \sin(\text{LFT BLD RCA}) \times 1 \angle (\text{LFT BLD RCA} + 90^\circ)$  |
| $K_0$           | zero-sequence compensating factor: $K_0 = (Z_0/Z_1 \text{ MAG} \angle Z_0/Z_1 \text{ ANG}) - 1$  |
| $K_0M$          | mutual zero-sequence compensating factor: $K_0M = 1/3 \times Z_0M/Z_1 \text{ MAG} \angle Z_0M/Z_1 \text{ ANG}$                                 |
| $\Theta$        | non-homogeneity angle setting ( <b>NON-HOMOGEN ANG</b> )   |

## b) DIRECTIONAL MHO CHARACTERISTIC

The dynamic 100% memory polarized mho characteristic is achieved by checking the angle between:

|                   |   |     |                  |
|-------------------|---|-----|------------------|
| AB phase element: | $(I_A - I_B) \times Z - (V_A - V_B)$                                      | and | $(V_A - V_B)_1M$ |
| BC phase element: | $(I_B - I_C) \times Z - (V_B - V_C)$                                      | and | $(V_B - V_C)_1M$ |
| CA phase element: | $(I_C - I_A) \times Z - (V_C - V_A)$                                      | and | $(V_C - V_A)_1M$ |
| A ground element: | $I_A \times Z + I_0 \times K_0 \times Z + I_G \times K_0M \times Z - V_A$ | and | $V_{A\_1M}$      |
| B ground element: | $I_B \times Z + I_0 \times K_0 \times Z + I_G \times K_0M \times Z - V_B$ | and | $V_{B\_1M}$      |
| C ground element: | $I_C \times Z + I_0 \times K_0 \times Z + I_G \times K_0M \times Z - V_C$ | and | $V_{C\_1M}$      |

The limit angle of the comparator is adjustable enabling the user to shape the characteristic as a mho or a lens as shown in the figures below. The memory-polarized mho characteristic has an excellent directional integrity built-in as explained in the Memory Polarization section.

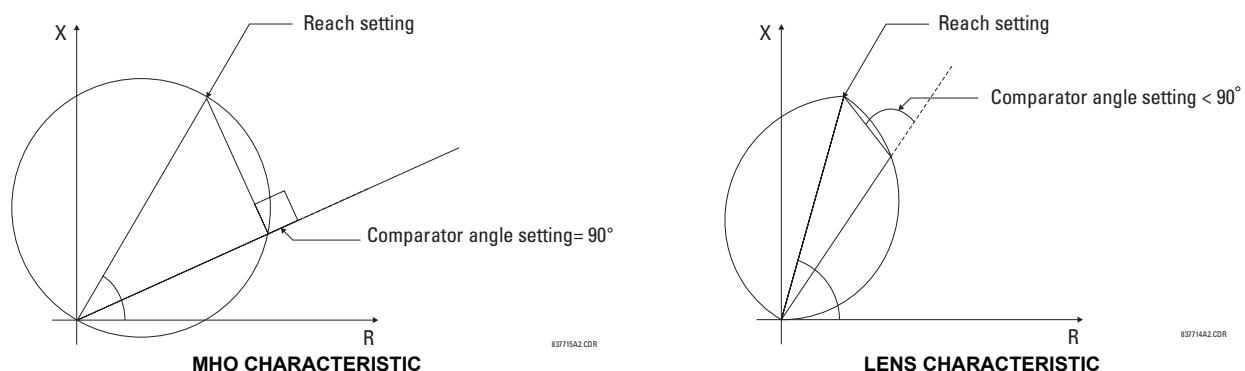


Figure 8-1: MHO AND LENS CHARACTERISTICS



**c) NON-DIRECTIONAL MHO CHARACTERISTIC**

The non-directional mho characteristic is achieved by checking the angle between:

$$\begin{aligned}
 \text{AB phase element:} & (I_A - I_B) \times Z - (V_A - V_B) \quad \text{and} \quad (V_A - V_B) - (I_A - I_B) \times Z_{REV} \\
 \text{BC phase element:} & (I_B - I_C) \times Z - (V_B - V_C) \quad \text{and} \quad (V_B - V_C) - (I_B - I_C) \times Z_{REV} \\
 \text{CA phase element:} & (I_C - I_A) \times Z - (V_C - V_A) \quad \text{and} \quad (V_C - V_A) - (I_C - I_A) \times Z_{REV} \\
 \text{A ground element:} & I_A \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_A \\
 & \text{and} \quad V_A - (I_A \times Z_{REV} + I_0 \times K0 \times Z_{REV} + I_G \times K0M \times Z_{REV}) \\
 \text{B ground element:} & I_B \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_B \\
 & \text{and} \quad V_B - (I_B \times Z_{REV} + I_0 \times K0 \times Z_{REV} + I_G \times K0M \times Z_{REV}) \\
 \text{C ground element:} & I_C \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_C \\
 & \text{and} \quad V_C - (I_C \times Z_{REV} + I_0 \times K0 \times Z_{REV} + I_G \times K0M \times Z_{REV})
 \end{aligned}$$

**d) MHO REACTANCE CHARACTERISTIC FOR DIRECTIONAL APPLICATIONS**

The reactance characteristic is achieved by checking the angle between:

$$\begin{aligned}
 \text{AB phase element:} & (I_A - I_B) \times Z - (V_A - V_B) \quad \text{and} \quad (I_A - I_B) \times Z \\
 \text{BC phase element:} & (I_B - I_C) \times Z - (V_B - V_C) \quad \text{and} \quad (I_B - I_C) \times Z \\
 \text{CA phase element:} & (I_C - I_A) \times Z - (V_C - V_A) \quad \text{and} \quad (I_C - I_A) \times Z \\
 \text{A ground element:} & I_A \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_A \quad \text{and} \quad I_0 \times Z \\
 \text{B ground element:} & I_B \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_B \quad \text{and} \quad I_0 \times Z \\
 \text{C ground element:} & I_C \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_C \quad \text{and} \quad I_0 \times Z
 \end{aligned}$$

If the mho characteristic is selected, the limit angle of the comparator is adjustable concurrently with the limit angle of the mho characteristic, resulting in a tent shape complementing the lens characteristic being effectively applied.

**e) QUADRILATERAL REACTANCE CHARACTERISTIC FOR DIRECTIONAL APPLICATIONS**

The quadrilateral reactance characteristic is achieved by checking the angle between:

$$\begin{aligned}
 \text{AB phase element:} & (I_A - I_B) \times Z - (V_A - V_B) \quad \text{and} \quad (I_A - I_B) \times Z \\
 \text{BC phase element:} & (I_B - I_C) \times Z - (V_B - V_C) \quad \text{and} \quad (I_B - I_C) \times Z \\
 \text{CA phase element:} & (I_C - I_A) \times Z - (V_C - V_A) \quad \text{and} \quad (I_C - I_A) \times Z \\
 \text{A ground element:} & I_A \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_A \quad \text{and} \quad (j \times I_0 \text{ or } j \times I_{2A}) \times e^{j\Theta} \\
 \text{B ground element:} & I_B \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_B \quad \text{and} \quad (j \times I_0 \text{ or } j \times I_{2B}) \times e^{j\Theta} \\
 \text{C ground element:} & I_C \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_C \quad \text{and} \quad (j \times I_0 \text{ or } j \times I_{2C}) \times e^{j\Theta}
 \end{aligned}$$

The ground elements are polarized from either zero-sequence or negative-sequence current as per user-settings to maximize performance in non-homogenous systems. The polarizing current is additionally shifted by the user-selectable non-homogeneity correction angle.

**f) REVERSE QUADRILATERAL REACTANCE CHARACTERISTIC FOR NON-DIRECTIONAL APPLICATIONS**

The reverse quadrilateral reactance characteristic is achieved by checking the angle between:

$$\begin{aligned}
 \text{AB phase element:} & (I_A - I_B) \times Z_{REV} - (V_A - V_B) \quad \text{and} \quad (I_A - I_B) \times Z_{REV} \\
 \text{BC phase element:} & (I_B - I_C) \times Z_{REV} - (V_B - V_C) \quad \text{and} \quad (I_B - I_C) \times Z_{REV} \\
 \text{CA phase element:} & (I_C - I_A) \times Z_{REV} - (V_C - V_A) \quad \text{and} \quad (I_C - I_A) \times Z_{REV} \\
 \text{A ground element:} & I_A \times Z + I_0 \times K0 \times Z_{REV} + I_G \times K0M \times Z_{REV} - V_A \quad \text{and} \quad (j \times I_0 \text{ or } j \times I_{2A}) \times e^{j(180 + \Theta)} \\
 \text{B ground element:} & I_B \times Z + I_0 \times K0 \times Z_{REV} + I_G \times K0M \times Z_{REV} - V_B \quad \text{and} \quad (j \times I_0 \text{ or } j \times I_{2B}) \times e^{j(180 + \Theta)} \\
 \text{C ground element:} & I_C \times Z + I_0 \times K0 \times Z_{REV} + I_G \times K0M \times Z_{REV} - V_C \quad \text{and} \quad (j \times I_0 \text{ or } j \times I_{2C}) \times e^{j(180 + \Theta)}
 \end{aligned}$$

The ground elements are polarized from either zero-sequence or negative-sequence current as per user-settings to maximize performance in non-homogenous systems. The polarizing current is additionally shifted by the user-selectable non-homogeneity correction angle.

**g) DIRECTIONAL CHARACTERISTIC**

The directional characteristic is achieved by checking the angle between:

|                   |                          |            |                  |
|-------------------|--------------------------|------------|------------------|
| AB phase element: | $(I_A - I_B) \times Z_D$ | <b>and</b> | $(V_A - V_B)_1M$ |
| BC phase element: | $(I_B - I_C) \times Z_D$ | <b>and</b> | $(V_B - V_C)_1M$ |
| CA phase element: | $(I_C - I_A) \times Z_D$ | <b>and</b> | $(V_C - V_A)_1M$ |
| A ground element: | $I_{0\_} \times Z_D$     | <b>and</b> | $V_{A\_}1M$      |
|                   | $I_{A\_2} \times Z_D$    | <b>and</b> | $V_{A\_}1M$      |
| B ground element: | $I_{0\_} \times Z_D$     | <b>and</b> | $V_{B\_}1M$      |
|                   | $I_{B\_2} \times Z_D$    | <b>and</b> | $V_{B\_}1M$      |
| C ground element: | $I_{0\_} \times Z_D$     | <b>and</b> | $V_{C\_}1M$      |
|                   | $I_{C\_2} \times Z_D$    | <b>and</b> | $V_{C\_}1M$      |

The characteristic and limit angles of the directional comparator are adjustable independently from the mho and reactance comparators. The directional characteristic improves directional integrity of the distance functions.

**h) RIGHT BLINDER**

The right blinder characteristic is achieved by checking the angle between the following signals:

|                   |   |            |   |
|-------------------|---|------------|---|
| AB phase element: | $(I_A - I_B) \times Z_R - (V_A - V_B)$  | <b>and</b> | $(I_A - I_B) \times Z_R$  |
| BC phase element: | $(I_B - I_C) \times Z_R - (V_B - V_C)$  | <b>and</b> | $(I_B - I_C) \times Z_R$  |
| CA phase element: | $(I_C - I_A) \times Z_R - (V_C - V_A)$  | <b>and</b> | $(I_C - I_A) \times Z_R$  |
| A ground element: | $I_A \times Z_R + I_{0\_} \times K0 \times Z_R + I_G \times KOM \times Z_R - V_A$ | <b>and</b> | $I_A \times Z_R + I_{0\_} \times K0 \times Z_R + I_G \times KOM \times Z_R$ |
| B ground element: | $I_B \times Z_R + I_{0\_} \times K0 \times Z_R + I_G \times KOM \times Z_R - V_B$ | <b>and</b> | $I_B \times Z_R + I_{0\_} \times K0 \times Z_R + I_G \times KOM \times Z_R$ |
| C ground element: | $I_C \times Z_R + I_{0\_} \times K0 \times Z_R + I_G \times KOM \times Z_R - V_C$ | <b>and</b> | $I_C \times Z_R + I_{0\_} \times K0 \times Z_R + I_G \times KOM \times Z_R$ |

The blinders apply to the Quad characteristic only.

**i) LEFT BLINDER**

The left blinder characteristic is achieved by checking the angle between the following signals:

|                   |   |            |   |
|-------------------|---|------------|---|
| AB phase element: | $(I_A - I_B) \times Z_L - (V_A - V_B)$  | <b>and</b> | $(I_A - I_B) \times Z_L$  |
| BC phase element: | $(I_B - I_C) \times Z_L - (V_B - V_C)$  | <b>and</b> | $(I_B - I_C) \times Z_L$  |
| CA phase element: | $(I_C - I_A) \times Z_L - (V_C - V_A)$  | <b>and</b> | $(I_C - I_A) \times Z_L$  |
| A ground element: | $I_A \times Z_L + I_{0\_} \times K0 \times Z_L + I_G \times KOM \times Z_L - V_A$ | <b>and</b> | $I_A \times Z_L + I_{0\_} \times K0 \times Z_L + I_G \times KOM \times Z_L$ |
| B ground element: | $I_B \times Z_L + I_{0\_} \times K0 \times Z_L + I_G \times KOM \times Z_L - V_B$ | <b>and</b> | $I_B \times Z_L + I_{0\_} \times K0 \times Z_L + I_G \times KOM \times Z_L$ |
| C ground element: | $I_C \times Z_L + I_{0\_} \times K0 \times Z_L + I_G \times KOM \times Z_L - V_C$ | <b>and</b> | $I_C \times Z_L + I_{0\_} \times K0 \times Z_L + I_G \times KOM \times Z_L$ |

The blinders apply to the Quad characteristic only.

**j) FAULT-TYPE CHARACTERISTIC**

The fault-type characteristic applies to ground elements only and is achieved by checking the angle between:

|                   |           |            |            |
|-------------------|-----------|------------|------------|
| A ground element: | $I_{0\_}$ | <b>and</b> | $I_{A\_2}$ |
| B ground element: | $I_{0\_}$ | <b>and</b> | $I_{B\_2}$ |
| C ground element: | $I_{0\_}$ | <b>and</b> | $I_{C\_2}$ |

The limit angle of the comparator is not adjustable and equals 50°. The fault-type characteristic is intended to block the ground distance elements during double-line-to-ground faults.

**k) ZERO-SEQUENCE DIRECTIONAL CHARACTERISTIC**

The extra zero-sequence characteristic applies to ground Zones 2 to 4 only and is achieved by checking angles between:

|                   |                      |            |            |
|-------------------|----------------------|------------|------------|
| A ground element: | $I_{0\_} \times Z_D$ | <b>and</b> | $-V_{0\_}$ |
| B ground element: | $I_{0\_} \times Z_D$ | <b>and</b> | $-V_{0\_}$ |
| C ground element: | $I_{0\_} \times Z_D$ | <b>and</b> | $-V_{0\_}$ |

The limit angle of the comparator is not adjustable and equals 90°. The zero-sequence directional characteristic improves directional integrity for time-delayed operations after the memory expires.

### I) OVERCURRENT SUPERVISION

The overcurrent supervision responds to the following currents:

$$\text{AB phase element: } (I_A - I_B) / \sqrt{3}$$

$$\text{BC phase element: } (I_B - I_C) / \sqrt{3}$$

$$\text{CA phase element: } (I_C - I_A) / \sqrt{3}$$

$$\text{A, B, C ground element: } 3 \times I_0$$

The following tables summarize the characteristics of the distance elements

**Table 8–1: DIRECTIONAL MHO PHASE DISTANCE FUNCTIONS**

| CHARACTERISTIC | COMPARATOR INPUTS |              | LIMIT ANGLE    |
|----------------|-------------------|--------------|----------------|
| Variable mho   | $I \times Z - V$  | $V_{1M}$     | COMP LIMIT     |
| Reactance      | $I \times Z - V$  | $I \times Z$ | COMP LIMIT     |
| Directional    | $I \times Z_D$    | $V_{1M}$     | DIR COMP LIMIT |

**Table 8–2: DIRECTIONAL MHO GROUND DISTANCE FUNCTIONS**

| CHARACTERISTIC | COMPARATOR INPUTS |                | LIMIT ANGLE    |
|----------------|-------------------|----------------|----------------|
| Variable mho   | $I \times Z - V$  | $V_{1M}$       | COMP LIMIT     |
| Reactance      | $I \times Z - V$  | $I_0 \times Z$ | COMP LIMIT     |
| Directional    | $I_0 \times Z_D$  | $V_{1M}$       | DIR COMP LIMIT |
| Directional    | $I_2 \times Z_D$  | $V_{1M}$       | DIR COMP LIMIT |
| Fault-type     | $I_0$             | $I_2$          | 50°            |
| Zero-sequence  | $I_0 \times Z_D$  | $-V_0$         | 90°            |

**Table 8–3: DIRECTIONAL QUADRILATERAL PHASE DISTANCE FUNCTIONS**

| CHARACTERISTIC | COMPARATOR INPUTS  |                | LIMIT ANGLE    |
|----------------|--------------------|----------------|----------------|
| Reactance      | $I \times Z - V$   | $I \times Z$   | COMP LIMIT     |
| Directional    | $I \times Z_D$     | $V_{1M}$       | DIR COMP LIMIT |
| Right Blinder  | $I \times Z_R - V$ | $I \times Z_R$ | 90°            |
| Left Blinder   | $I \times Z_L - V$ | $I \times Z_L$ | 90°            |

**Table 8–4: DIRECTIONAL QUADRILATERAL GROUND DISTANCE FUNCTIONS**

| CHARACTERISTIC | COMPARATOR INPUTS  |  | LIMIT ANGLE    |
|----------------|--------------------|--|----------------|
| Reactance      | $I \times Z - V$   | $j \times I_0 \times e^{j\theta}$ or $j \times I_2 \times e^{j\theta}$ | COMP LIMIT     |
| Directional    | $I_0 \times Z_D$   | $V_{1M}$   | DIR COMP LIMIT |
| Directional    | $I_2 \times Z_D$   | $V_{1M}$   | DIR COMP LIMIT |
| Right Blinder  | $I \times Z_R - V$ | $I \times Z_R$   | 90°            |
| Left Blinder   | $I \times Z_L - V$ | $I \times Z_L$   | 90°            |
| Fault-type     | $I_0$              | $I_2$  | 50°            |
| Zero-sequence  | $I_0 \times Z_D$   | $-V_0$   | 90°            |

**Table 8–5: NON-DIRECTIONAL MHO PHASE DISTANCE FUNCTIONS**

| CHARACTERISTIC | COMPARATOR INPUTS |                        | LIMIT ANGLE |
|----------------|-------------------|------------------------|-------------|
| Offset mho     | $I \times Z - V$  | $I \times Z_{REV} - V$ | COMP LIMIT  |

**Table 8–6: NON-DIRECTIONAL MHO GROUND DISTANCE FUNCTIONS**

| CHARACTERISTIC | COMPARATOR INPUTS |                        | LIMIT ANGLE |
|----------------|-------------------|------------------------|-------------|
| Offset mho     | $I \times Z - V$  | $I \times Z_{REV} - V$ | COMP LIMIT  |
| Fault-type     | $I_0$             | $I_2$                  | 50°         |

**Table 8–7: NON-DIRECTIONAL QUADRILATERAL PHASE DISTANCE FUNCTIONS**

| CHARACTERISTIC    | COMPARATOR INPUTS      |                    | LIMIT ANGLE |
|-------------------|------------------------|--------------------|-------------|
| Forward Reactance | $I \times Z - V$       | $I \times Z$       | COMP LIMIT  |
| Reverse Reactance | $I \times Z_{REV} - V$ | $I \times Z_{REV}$ | COMP LIMIT  |
| Right Blinder     | $I \times Z_R - V$     | $I \times Z_R$     | 90°         |
| Left Blinder      | $I \times Z_L - V$     | $I \times Z_L$     | 90°         |

**Table 8–8: NON-DIRECTIONAL QUADRILATERAL GROUND DISTANCE FUNCTIONS**

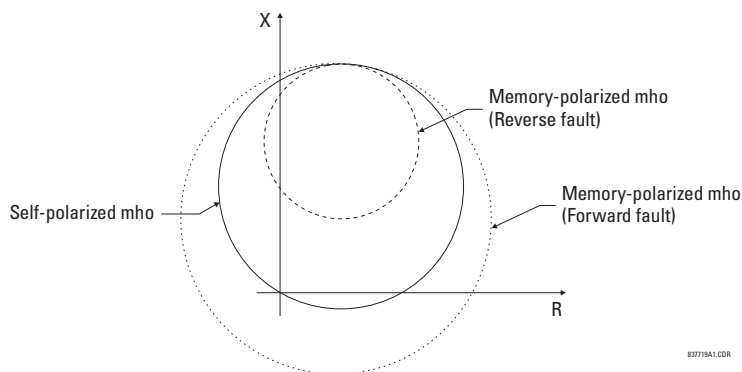
| CHARACTERISTIC    | COMPARATOR INPUTS      |  | LIMIT ANGLE |
|-------------------|------------------------|--|-------------|
| Forward Reactance | $I \times Z - V$       | $j \times I_0 \times e^{j\theta}$ or $j \times I_2 \times e^{j\theta}$   | COMP LIMIT  |
| Reverse Reactance | $I \times Z_{REV} - V$ | $-j \times I_0 \times e^{j\theta}$ or $-j \times I_2 \times e^{j\theta}$ | COMP LIMIT  |
| Right Blinder     | $I \times Z_R - V$     | $I \times Z_R$   | 90°         |
| Left Blinder      | $I \times Z_L - V$     | $I \times Z_L$   | 90°         |
| Fault-type        | $I_0$                  | $I_2$  | 50°         |

#### 8.1.4 MEMORY POLARIZATION

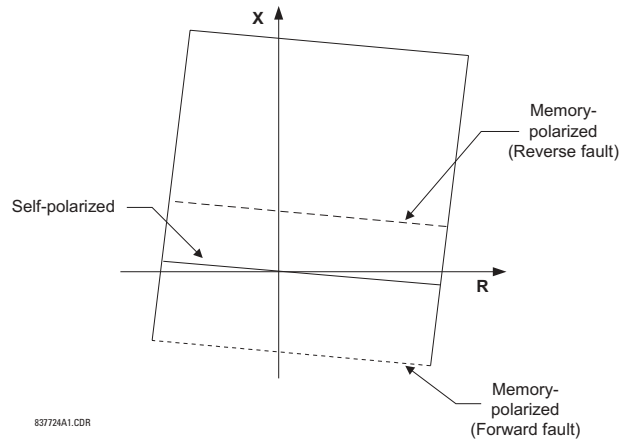
All distance functions use memory polarization. The positive-sequence voltage – either memorized or actual – is used as a polarizing signal. The memory is established when the positive-sequence voltage remains above 80% of its nominal value for five power system cycles. The memory voltage is a three-cycle old voltage.

Once established, the memory is applied for the user-specified time interval. The memory timer is started when the voltage drops below 80% of nominal. After the memory expires, the relay checks the magnitude of the actual positive-sequence voltage. If it is higher than 10% of nominal, the actual voltage is used; if lower, the memory voltage continues to be used.

The memory-polarized mho has an extra directional integrity built-in as illustrated below. The self-polarized mho characteristic is shifted in the reverse direction for a forward fault by an amount proportional to the source impedance, and in the forward direction for a reverse fault.

**Figure 8–2: DYNAMIC SHIFT OF THE MHO CHARACTERISTIC**

The same desirable effect of memory polarization applies to the directional comparator of the quadrilateral characteristic.



**Figure 8-3: DYNAMIC SHIFT OF THE MEMORY-POLARIZED DIRECTIONAL CHARACTERISTIC**

Mutual zero-sequence compensation may raise concerns regarding directional integrity on reverse faults in the situation when the relay gets 'overcompensated'. This problem does not affect the D30 because its ground distance elements use zero-sequence and negative-sequence currents in extra directional comparators. Both the currents are from the protected line and are not affected by any compensation as the latter applies only to the reach defining comparators: the mho, reactance and blinder characteristics.

### 8.1.5 DISTANCE ELEMENTS ANALYSIS

#### a) DESCRIPTION

This subsection shows how to analyze the operation of the distance elements in steady states using the results of short circuit studies. All quantities are secondary ohms, volts, and amperes. Ground phase A and phase AB distance elements are analyzed.

Assume the following settings have been entered:

Phase Rotation: ABC  
 Right Blinder Reach: 10  $\Omega$   
 Nominal Secondary Voltage: 69.28 V  
 Right Blinder RCA: 88°  
 Distance Reach: 14  $\Omega$   
 Left Blinder Reach: 5  $\Omega$   
 Distance RCA: 88°  
 Left Blinder RCA: 88°  
 Polarizing Current: Zero-sequence

Non-Homogeneity Correction Angle: 3°  
 Directional RCA: 88°  
 Z0/Z1 Magnitude: 4.55  
 Overcurrent supervision: 3 A  
 Z0/Z1 Angle: -12°  
 Distance Comparator limit angle: 75°  
 Z0M/Z1 Magnitude: 0  
 Directional Comparator limit angle: 75°

Assume the following signals are injected to the relay:

$V_A = 64.71 \text{ V } \angle 0.0^\circ$  (pre-fault)  
 $V_A = 25.43 \text{ V } \angle -19.9^\circ$   
 $V_B = 80.22 \text{ V } \angle -133.5^\circ$   
 $V_C = 77.33 \text{ V } \angle 135.7^\circ$

$I_A = 4.47 \text{ A } \angle -107.8^\circ$   
 $I_B = 2.92 \text{ A } \angle 68.9^\circ$   
 $I_C = 2.93 \text{ A } \angle -51.1^\circ$

Based on the entered setting the relay calculates:

$K0 = 3.58 \angle -15.2^\circ$   
 $K0M = 0$   
 $Z = 14.00 \Omega \angle 88^\circ$

$Z_D = 1 \Omega \angle 88^\circ$   
 $Z_R = 9.99 \Omega \angle 2^\circ$   
 $Z_L = 4.99 \Omega \angle 178^\circ$

For the assumed steady-state injection the relay calculates:

$V_{A\_1} = 58.83 \text{ V } \angle -2.1^\circ$

$V_{A\_1M} = 64.71 \text{ V } \angle 0.0^\circ$

$$\begin{aligned}
 I_0 &= 1.37 \text{ A } \angle -68.2^\circ \\
 I_{A_2} &= 1.37 \text{ A } \angle -68.1^\circ \\
 -V_0 &= 29.18 \text{ V } \angle 8.4^\circ \\
 (V_A - V_B)_1 &= 93.35 \text{ V } \angle 32.0^\circ \\
 (V_A - V_B)_{1M} &= 112.08 \text{ V } \angle 30.0^\circ \\
 I_A - I_B &= 7.39 \text{ A } \angle -109.1^\circ
 \end{aligned}$$

**b) MHO PHASE A TO GROUND ELEMENT (BEFORE MEMORY EXPIRES)**

$$\begin{aligned}
 I_A \times Z + I_0 \times K0 \times Z + I_A \times K0M \times Z - V_A &= 103.33 \text{ V } \angle -3.9^\circ \\
 V_{A_1M} &= 64.71 \text{ V } \angle 0.0^\circ \\
 I_{A_2} \times Z_D &= 1.37 \text{ V } \angle 19.8^\circ \\
 I_0 \times Z &= 19.11 \text{ V } \angle 19.8^\circ \\
 I_0 \times Z_D &= 1.37 \text{ V } \angle 19.8^\circ
 \end{aligned}$$

- Overcurrent supervision:  $|3 \times I_0| = 4.09 \text{ A} > 3 \text{ A}$
- Mho difference angle =  $|-3.9^\circ - 0^\circ| = 3.9^\circ < 75^\circ$
- Reactance difference angle =  $|-3.9^\circ - 19.8^\circ| = 23.7^\circ < 75^\circ$
- Zero-sequence directional difference angle =  $|19.8^\circ - 0.0^\circ| = 19.8^\circ < 75^\circ$
- Negative-sequence directional difference angle =  $|19.8^\circ - 0.0^\circ| = 19.8^\circ < 75^\circ$
- Fault-type comparator difference angle =  $|19.8^\circ - 19.8^\circ| = 0.0^\circ < 50^\circ$

All four comparators and the overcurrent supervision are satisfied.

**The MHO phase A ground element will operate for this fault.**

**c) MHO PHASE A TO GROUND ELEMENT (AFTER MEMORY EXPIRES)**

After the memory expires, the relay checks the actual positive-sequence voltage and compares it with 10% of the nominal voltage:

$$|V_{A_1}| = 58.83 \text{ V} > 0.1 \times 69.28 \text{ V}$$

**After the memory expires the relay will use the actual voltage for polarization.**

$$\begin{aligned}
 I_A \times Z + I_0 \times K0 \times Z + I_G \times K0M \times Z - V_A &= 103.33 \text{ V } \angle -3.9^\circ \\
 V_{A_1} &= 58.83 \text{ V } \angle -2.1^\circ \\
 I_{A_2} \times Z_D &= 1.37 \text{ V } \angle 19.8^\circ \\
 I_0 \times Z &= 19.11 \text{ V } \angle 19.8^\circ \\
 I_0 \times Z_D &= 1.37 \text{ V } \angle 19.8^\circ
 \end{aligned}$$

- Overcurrent supervision:  $|3 \times I_0| = 4.09 \text{ A} > 3 \text{ A}$
- Mho difference angle =  $|-3.9^\circ - (-2.1^\circ)| = 1.8^\circ < 75^\circ$
- Reactance difference angle =  $|-3.9^\circ - 19.8^\circ| = 23.7^\circ < 75^\circ$
- Zero-sequence directional difference angle =  $|19.8^\circ - (-2.1^\circ)| = 21.9^\circ < 75^\circ$
- Negative-sequence directional difference angle =  $|19.8^\circ - (-2.1^\circ)| = 21.9^\circ < 75^\circ$
- Fault-type comparator difference angle =  $|19.8^\circ - 19.8^\circ| = 0.0^\circ < 50^\circ$

All four comparators and the overcurrent supervision are satisfied.

**The Zone 1 MHO phase A ground element will operate for this fault.**

- Zero-sequence directional difference angle for Zones 2 through 3 (phase A) =  $|19.8^\circ - 8.4^\circ| = 11.4^\circ < 90^\circ$ .

**Zones 2 through 3 phase A ground elements will pick-up, time-out and operate.**

**d) MHO AB PHASE ELEMENT**

$$\begin{aligned}
 (I_A - I_B) \times Z - (V_A - V_B) &= 88.65 \text{ V } \angle -78.7^\circ \\
 (V_A - V_B)_{1M} &= 112.08 \text{ V } \angle 30.0^\circ \\
 (I_A - I_B) \times Z &= 103.50 \text{ V } \angle -21.2^\circ
 \end{aligned}$$

$$(I_A - I_B) \times Z_D = 7.39 \text{ V } \angle -21.2^\circ$$

- Overcurrent supervision:  $| (I_A - I_B) / \sqrt{3} | = 4.27 \text{ A} > 3 \text{ A}$
- Mho difference angle =  $| -78.7^\circ - 30.0^\circ | = 108.7^\circ > 75^\circ$
- Reactance difference angle =  $| -78.7^\circ - (-21.2^\circ) | = 57.5^\circ < 75^\circ$
- Directional difference angle =  $| -21.2^\circ - 30.0^\circ | = 51.2^\circ < 75^\circ$

The mho comparator is not satisfied.

**The MHO AB phase element will not operate for this fault.**

Repeating the above analysis one concludes that out of the six distance elements only the ground element in phase A will operate for this fault.

#### e) QUAD PHASE A TO GROUND ELEMENT (BEFORE MEMORY EXPIRES)

$$I_A \times Z + I_{0\_0} \times K0 \times Z + I_G \times K0M \times Z - V_A = 103.33 \text{ V } \angle -3.9^\circ$$

$$V_{A\_1M} = 64.71 \text{ V } \angle 0.0^\circ$$

$$j \times I_{0\_0} \times e^{j3\Theta} = 1.34 \text{ A } \angle 24.8^\circ$$

$$I_{A\_2} \times Z_D = 1.37 \text{ V } \angle 19.8^\circ$$

$$I_{0\_0} \times Z_D = 1.37 \text{ V } \angle 19.8^\circ$$

$$I_A \times Z_R + I_{0\_0} \times K0 \times Z_R + I_G \times K0M \times Z_R - V_A = 87.6 \text{ V } \angle -109.2^\circ$$

$$I_A \times Z_R + I_{0\_0} \times K0 \times Z_R = 91.5 \text{ V } \angle -93.0^\circ$$

$$I_A \times Z_L + I_{0\_0} \times K0 \times Z_L + I_G \times K0M \times Z_L - V_A = 57.0 \text{ V } \angle 108.7^\circ$$

$$I_A \times Z_L + I_{0\_0} \times K0 \times Z_L = 45.8 \text{ V } \angle 82.9^\circ$$

- Overcurrent supervision:  $| 3 \times I_{0\_0} | = 4.09 \text{ A} > 3 \text{ A}$
- Reactance difference angle =  $| -3.9^\circ - 24.8^\circ | = 28.7^\circ < 75^\circ$
- Zero-sequence difference angle =  $| -19.8^\circ - 0.0^\circ | = 19.8^\circ < 75^\circ$
- Negative-sequence directional difference angle =  $| -19.8^\circ - 0.0^\circ | = 19.8^\circ < 75^\circ$
- Right blinder difference angle =  $| -93.0^\circ - (-109.2^\circ) | = 16.2^\circ < 90^\circ$
- Left blinder difference angle =  $| 82.9^\circ - 108.7^\circ | = 25.8^\circ < 90^\circ$
- Fault-type comparator difference angle =  $| 19.8^\circ - 19.8^\circ | = 0.0^\circ < 50^\circ$

All six comparators and the overcurrent supervision are satisfied.

**The Quad Phase A ground element will operate for this fault.**

## 8.2.1 DESCRIPTION

As a Wye-Delta transformer introduces discontinuity for the zero-sequence circuit, the ground distance protection cannot be applied, except special circumstances, to respond to faults behind the transformer.

The phase distance elements, however, could be developed so that both accurate reach and correct fault phase identification is retained for faults behind the power transformer as seen from the relaying point. Without appropriate compensation, the relay's reach would depend on a type of fault, creating considerable difficulties in applying the relay.

The D30 provides for any location of the VTs and CTs with respect to the involved power transformer and the direction of any given zone.

In the following equations, the VT and CT locations are referenced as “None” if the transformer is not present between the CT/VT and the intended reach point. Otherwise, the location is to be selected as a type of a transformer as seen from the VT/CT position towards the intended reach point. The following figure explains the adopted rules.

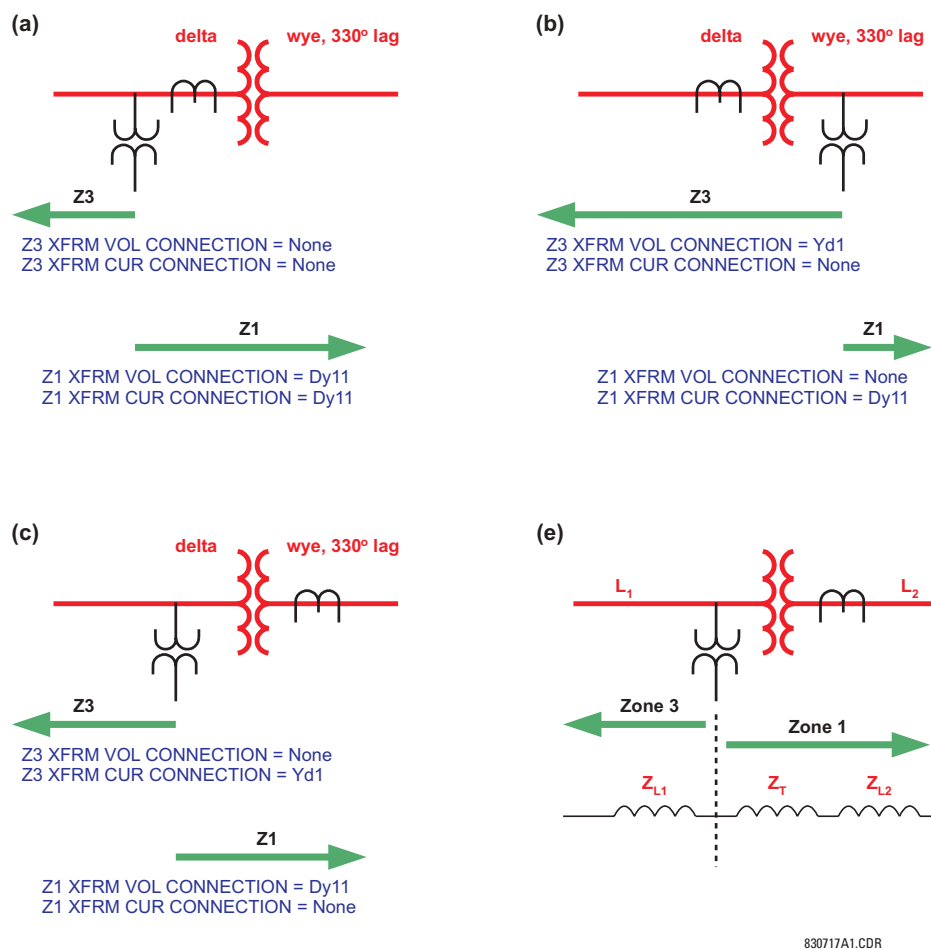


Figure 8-4: APPLICATIONS OF THE “PHS DIST XFMR VOL/CUR CONNECTION” SETTINGS



Table 8–9: PHASE DISTANCE INPUT SIGNALS FOR DELTA-WYE TRANSFORMERS

| TRANSFORMER CONNECTION | LOOP | CURRENT TRANSFORMATION       | VOLTAGE TRANSFORMATION                              |
|------------------------|------|------------------------------|---|
| None                   | AB   | $I_A - I_B$                  | $V_{AB}$  |
|                        | BC   | $I_B - I_C$                  | $V_{BC}$  |
|                        | CA   | $I_C - I_A$                  | $V_{CA}$  |
| Dy1                    | AB   | $\sqrt{3}I_A$                | $\frac{1}{\sqrt{3}}(V_{AB} - V_{CA})$               |
|                        | BC   | $\sqrt{3}I_B$                | $\frac{1}{\sqrt{3}}(V_{BC} - V_{AB})$               |
|                        | CA   | $\sqrt{3}I_C$                | $\frac{1}{\sqrt{3}}(V_{CA} - V_{BC})$               |
| Dy3                    | AB   | $I_{AB\_21P} = -\sqrt{3}I_C$ | $V_{AB\_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{CA})$ |
|                        | BC   | $I_{BC\_21P} = -\sqrt{3}I_A$ | $V_{BC\_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{AB})$ |
|                        | CA   | $I_{CA\_21P} = -\sqrt{3}I_B$ | $V_{CA\_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{BC})$ |
| Dy5                    | AB   | $I_{AB\_21P} = -\sqrt{3}I_B$ | $V_{AB\_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{AB})$ |
|                        | BC   | $I_{BC\_21P} = -\sqrt{3}I_C$ | $V_{BC\_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{BC})$ |
|                        | CA   | $I_{CA\_21P} = -\sqrt{3}I_A$ | $V_{CA\_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{CA})$ |
| Dy7                    | AB   | $I_{AB\_21P} = -\sqrt{3}I_A$ | $V_{AB\_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{AB})$ |
|                        | BC   | $I_{BC\_21P} = -\sqrt{3}I_B$ | $V_{BC\_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{BC})$ |
|                        | CA   | $I_{CA\_21P} = -\sqrt{3}I_C$ | $V_{CA\_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{CA})$ |
| Dy9                    | AB   | $I_{AB\_21P} = -\sqrt{3}I_C$ | $V_{AB\_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{BC})$ |
|                        | BC   | $I_{BC\_21P} = -\sqrt{3}I_A$ | $V_{BC\_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{CA})$ |
|                        | CA   | $I_{CA\_21P} = -\sqrt{3}I_B$ | $V_{CA\_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{AB})$ |
| Dy11                   | AB   | $I_{AB\_21P} = -\sqrt{3}I_B$ | $V_{AB\_21P} = \frac{1}{\sqrt{3}}(V_{AB} - V_{BC})$ |
|                        | BC   | $I_{BC\_21P} = -\sqrt{3}I_C$ | $V_{BC\_21P} = \frac{1}{\sqrt{3}}(V_{BC} - V_{CA})$ |
|                        | CA   | $I_{CA\_21P} = -\sqrt{3}I_A$ | $V_{CA\_21P} = \frac{1}{\sqrt{3}}(V_{CA} - V_{AB})$ |

Table 8–10: PHASE DISTANCE INPUT SIGNALS FOR WYE-DELTA TRANSFORMERS

| TRANSFORMER CONNECTION | LOOP | CURRENT TRANSFORMATION                               | VOLTAGE TRANSFORMATION       |
|------------------------|------|--|------------------------------|
| Yd1                    | AB   | $I_{AB\_21P} = \frac{1}{\sqrt{3}}(2I_A - I_B - I_C)$ | $V_{AB\_21P} = \sqrt{3}V_A$  |
|                        | BC   | $I_{BC\_21P} = \frac{1}{\sqrt{3}}(2I_B - I_A - I_C)$ | $V_{BC\_21P} = \sqrt{3}V_B$  |
|                        | CA   | $I_{CA\_21P} = \frac{1}{\sqrt{3}}(2I_C - I_A - I_B)$ | $V_{CA\_21P} = \sqrt{3}V_C$  |
| Yd3                    | AB   | $I_{AB\_21P} = \frac{1}{\sqrt{3}}(I_A + I_B - 2I_C)$ | $V_{AB\_21P} = -\sqrt{3}V_C$ |
|                        | BC   | $I_{BC\_21P} = \frac{1}{\sqrt{3}}(I_B + I_C - 2I_A)$ | $V_{BC\_21P} = -\sqrt{3}V_A$ |
|                        | CA   | $I_{CA\_21P} = \frac{1}{\sqrt{3}}(I_A + I_C - 2I_B)$ | $V_{CA\_21P} = -\sqrt{3}V_B$ |
| Yd5                    | AB   | $I_{AB\_21P} = \frac{1}{\sqrt{3}}(2I_B - I_A - I_C)$ | $V_{AB\_21P} = \sqrt{3}V_B$  |
|                        | BC   | $I_{BC\_21P} = \frac{1}{\sqrt{3}}(2I_C - I_A - I_B)$ | $V_{BC\_21P} = \sqrt{3}V_C$  |
|                        | CA   | $I_{CA\_21P} = \frac{1}{\sqrt{3}}(2I_A - I_B - I_C)$ | $V_{CA\_21P} = \sqrt{3}V_A$  |
| Yd7                    | AB   | $I_{AB\_21P} = \frac{1}{\sqrt{3}}(I_B + I_C - 2I_A)$ | $V_{AB\_21P} = -\sqrt{3}V_A$ |
|                        | BC   | $I_{BC\_21P} = \frac{1}{\sqrt{3}}(I_A + I_C - 2I_B)$ | $V_{BC\_21P} = -\sqrt{3}V_B$ |
|                        | CA   | $I_{CA\_21P} = \frac{1}{\sqrt{3}}(I_A + I_B - 2I_C)$ | $V_{CA\_21P} = -\sqrt{3}V_C$ |
| Yd9                    | AB   | $I_{AB\_21P} = \frac{1}{\sqrt{3}}(2I_C - I_A - I_B)$ | $V_{AB\_21P} = \sqrt{3}V_C$  |
|                        | BC   | $I_{BC\_21P} = \frac{1}{\sqrt{3}}(2I_A - I_B - I_C)$ | $V_{BC\_21P} = \sqrt{3}V_A$  |
|                        | CA   | $I_{CA\_21P} = \frac{1}{\sqrt{3}}(2I_B - I_A - I_C)$ | $V_{CA\_21P} = \sqrt{3}V_B$  |
| Yd11                   | AB   | $I_{AB\_21P} = \frac{1}{\sqrt{3}}(I_A + I_C - 2I_B)$ | $V_{AB\_21P} = -\sqrt{3}V_B$ |
|                        | BC   | $I_{BC\_21P} = \frac{1}{\sqrt{3}}(I_A + I_B - 2I_C)$ | $V_{BC\_21P} = -\sqrt{3}V_C$ |
|                        | CA   | $I_{CA\_21P} = \frac{1}{\sqrt{3}}(I_B + I_C - 2I_A)$ | $V_{CA\_21P} = -\sqrt{3}V_A$ |

Equations from the “Current Transformation” and “Voltage Transformation” columns are used to derive inputs to the three (AB, BC, and CA) phase distance elements. For example, if the CTs are located at the delta side of the Delta-Wye 11 transformer, and a given zone is set to look through the transformer into the system connected to the Wye winding, the CT location setting for that zone shall be set to Dy11 and the relay would use  $-\sqrt{3}I_B$  instead of a traditional  $I_A - I_B$  for the AB phase distance element.

The current supervision pickup setting applies to the currents specified in the “Current Transformation” columns.

A distance zone originates at the location of the VTs (regardless of the location of the CTs). For more information on settings please refer to Chapter 9: Application of Settings.

### 8.2.2 EXAMPLE

Consider the system shown below:

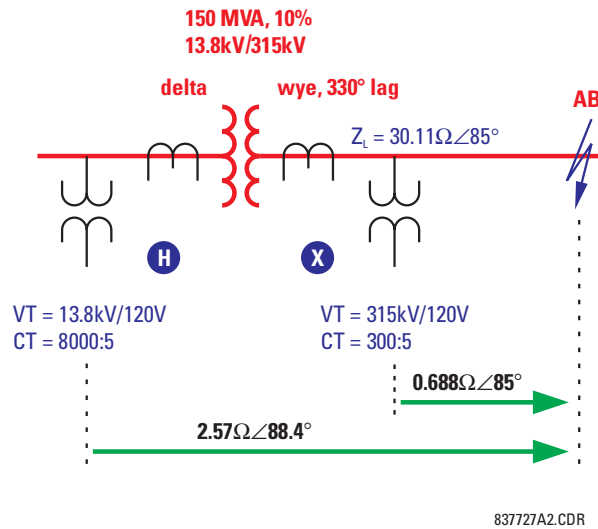


Figure 8-5: SAMPLE SYSTEM CONFIGURATION

Normally, in order to respond to the fault shown in the figure, a distance relay shall be applied at the relaying point X. The relay input signals at this location are shown in the following table.

| INPUT | PRIMARY                        | SECONDARY                     |
|-------|--------------------------------|-------------------------------|
| VA    | 100.4 kV $\angle -7.32^\circ$  | 38.25 V $\angle -7.32^\circ$  |
| VB    | 97.23 kV $\angle -53.4^\circ$  | 37.04 V $\angle -53.4^\circ$  |
| VC    | 181.8 kV $\angle -150.0^\circ$ | 69.26 V $\angle -150.0^\circ$ |
| IA    | 1.288 kA $\angle -27.6^\circ$  | 21.47 A $\angle -27.6^\circ$  |
| IB    | 1.288 kA $\angle 152.4^\circ$  | 21.47 A $\angle 152.4^\circ$  |
| IC    | 0                              | 0                             |

If installed at the location X, the relay would use the following input signals for its phase AB distance element:

$$V = V_{AB} = 77.402 \text{ kV } \angle 57.5^\circ \text{ primary or } 29.49 \text{ V } \angle 57.5^\circ \text{ secondary}$$

$$I = I_A - I_B = 2.576 \text{ kA } \angle -27.6^\circ \text{ primary or } 42.93 \text{ A } \angle -27.6^\circ \text{ secondary}$$

And consequently it would see an apparent impedance of:

$$Z_{app} = V / I = 30.05 \Omega \angle 85^\circ \text{ primary or } 0.687 \Omega \angle 85^\circ \text{ secondary}$$

If applied at location H, the relay sees the following input signals:

| INPUT | PRIMARY                        | SECONDARY                     |
|-------|--------------------------------|-------------------------------|
| VA    | 7.584 kV $\angle -5.59^\circ$  | 69.95 V $\angle -5.59^\circ$  |
| VB    | 6.269 kV $\angle -120.1^\circ$ | 54.52 V $\angle -120.1^\circ$ |
| VC    | 7.751 kV $\angle 125.5^\circ$  | 65.84 V $\angle 125.5^\circ$  |
| IA    | 16.976 kA $\angle -27.6^\circ$ | 10.61 A $\angle -27.6^\circ$  |
| IB    | 33.952 kA $\angle 152.4^\circ$ | 21.22 A $\angle 152.4^\circ$  |
| IC    | 16.976 kA $\angle -27.6^\circ$ | 10.61 A $\angle -27.6^\circ$  |

The relay is set as follows:

**XFMR VOL CONNECTION** = "Dy11"

**XFMR CUR CONNECTION** = "Dy11"

Consequently, the following signals are applied to the phase AB distance element:

$$V = \frac{1}{\sqrt{3}} V_{AB} - V_{BC} = 10.861 \text{ kV} \angle 59.9^\circ \text{ primary or } 94.45 \text{ V} \angle 59.9^\circ \text{ secondary} \quad (\text{EQ 8.1})$$

$$I = -\sqrt{3} I_B = 58.860 \text{ kA} \angle -27.6^\circ \text{ primary or } 36.75 \text{ A} \angle -27.6^\circ \text{ secondary} \quad (\text{EQ 8.2})$$

This results in the following apparent impedance:

$$Z_{app} = \frac{V}{I} = \frac{94.45 \text{ V} \angle 59.9^\circ}{36.75 \text{ kA} \angle -27.6^\circ} = 2.570 \Omega \angle 87.5^\circ \text{ secondary} \quad (\text{EQ 8.3})$$

The above value is a correct measure of the distance from the VT location to the fault. For relay location 2, this certainly includes the positive-sequence impedance of the transformer:

$$\begin{aligned} Z_T(\text{at } 13.8 \text{ kV}) &= \frac{10}{100} \times \frac{(13.8 \text{ kV})^2}{150 \text{ MVA}} = 0.127 \Omega \angle 90^\circ \\ Z_L(\text{at } 13.8 \text{ kV}) &= 30.11 \times \left(\frac{13.8}{315}\right)^2 = 0.05779 \Omega \angle 85^\circ \end{aligned} \quad (\text{EQ 8.4})$$

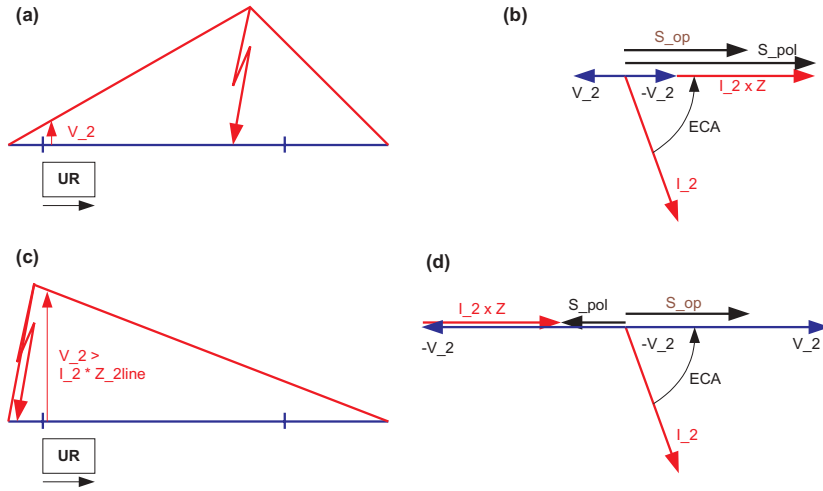
Thus,  $0.127 \Omega \angle 90^\circ + 0.05779 \Omega \angle 85^\circ = 0.1847 \Omega \angle 88.4^\circ$  primary side or  $2.569 \Omega \angle 88.4^\circ$  on the secondary side.

The above example illustrates how the relay maintains correct reach for fault behind power transformers. When installed at X, the relay shall be set to  $0.687 \Omega \angle 85^\circ$  secondary in order to reach to the fault shown in the figure. When installed at H, the relay shall be set to  $2.569 \Omega \angle 88.4^\circ$  to ensure exactly same coverage.

See Chapter 9: Application of Settings for more information on setting calculations.

## 8.3.1 DESCRIPTION

Consider the negative-sequence directional overcurrent element. As illustrated below, the negative-sequence voltage could be low during internal fault conditions.



**Figure 8-6: OFFSET IMPEDANCE AUGMENTATION**

In order to ensure operation of the element under such circumstances the angle comparator uses a polarizing voltage augmented by the negative-sequence current as per following equations:

- Forward-looking element:  $S_{pol} = -V_2 + I_2 \times Z_{offset} \times 1 \angle ECA$   
 $S_{op} = I_2 \times 1 \angle ECA$
- Reverse-looking element:  $S_{pol} = -V_2 + I_2 \times Z_{offset} \times 1 \angle ECA$   
 $S_{op} = -I_2 \times 1 \angle ECA$

where: ECA = forward ECA angle (maximum torque angle);  $Z_{offset}$  = offset impedance

The effect of the augmentation for forward and reverse fault is shown in the figures above. As long as the offset impedance is not higher than the negative-sequence line impedance the element will ensure correct and fast fault direction identification for both forward and reverse faults. The same principle applies to the neutral directional overcurrent element.

## 8.3.2 EXAMPLE

Consider relay input signals as in the Distance Elements Analysis section and assume an offset impedance of  $4 \Omega$  and ECA and limit angles of  $88^\circ$  and  $90^\circ$ , respectively. The relay calculates the following negative-sequence quantities:

$$V_2 = 6.39 \text{ V } \angle -159.6^\circ; I_2 = 1.37 \text{ A } \angle -68.1^\circ; I_1 = 2.94 \text{ A } \angle -144.2^\circ$$

and the following signals for the directional unit of the negative-sequence directional overcurrent element:

- Forward-looking element:  $S_{pol} = 11.87 \text{ V } \angle 20.2^\circ$   
 $S_{op} = 1.37 \text{ V } \angle 20.2^\circ$
- Reverse-looking element:  $S_{pol} = 11.87 \text{ V } \angle 20.2^\circ$   
 $S_{op} = 1.37 \text{ V } \angle -160.0^\circ$

After comparing the angles, a solid forward indication is given.

Assume further the pickup setting of 0.25 A for both forward and reverse directions, and the “Negative-sequence” mode setting entered for the overcurrent unit of the element. The relay calculates the operating signal using the positive-sequence restraint:

$$I_{op} = |I_2| - |I_1| / 8 = 1.003 \text{ A} > 0.25 \text{ A.}$$

The overcurrent unit will pickup and the element will operate in the forward direction.

## 8.4.1 DESCRIPTION

Faults on or in a close vicinity of series compensated lines may create problems for distance protection:

- Voltage and/or current inversion may lead to false direction discrimination by directional elements. This may potentially include both a failure to operate on a forward in-zone fault as well as misoperation on a reverse fault. Both distance and overcurrent directional elements can be affected.
- Series-capacitors and their overvoltage protection equipment (air gaps and/or Metal-Oxide Varistors) have a steady-state overreaching effect on the apparent impedance seen by the relay - a forward fault may appear much closer to the relay as compared with the actual fault location. The apparent impedance may be shifted towards the relay by as much as the total reactance of the series capacitors placed between the potential source of the relay and the fault point. This extreme steady-state overreach happens during low-current faults when the air-gaps do not flashover or the MOVs do not conduct any significant current.
- In addition to the above steady-state overreach effect; sub-synchronous oscillations in both currents and voltages may cause significant transient overreach.

Distance protection elements of the D30 deal with the problem of voltage inversion by using 100% memory polarized directional comparators. As the memory duration is set longer than the slowest fault clearing time for reverse faults, it is guaranteed that the distance element would not pick-up on reverse faults should the voltage inversion happen.

At the same time, it is guaranteed that the distance elements would pick-up for all forward faults regardless of any voltage inversion as long as the memory voltage is used. Before the memory expires the relay would respond to any fault on the protected line. Stepped distance backup zones operate after the memory voltage expires. But the backup protection responds to distant faults that do not cause any inversion of the positive-sequence voltage. As a result, the time-delayed stepped-distance zones are guaranteed to operate.

Distance protection elements of the D30 deal with the problem of current inversion by using a multi-input-comparator approach as described in the Distance Characteristics subsection. Should the current inversion happen, the distance elements are secure on reverse faults because multiple conditions involving fault-loop, negative-sequence and zero-sequence currents and the memory voltage are checked prior to declaring a forward fault.

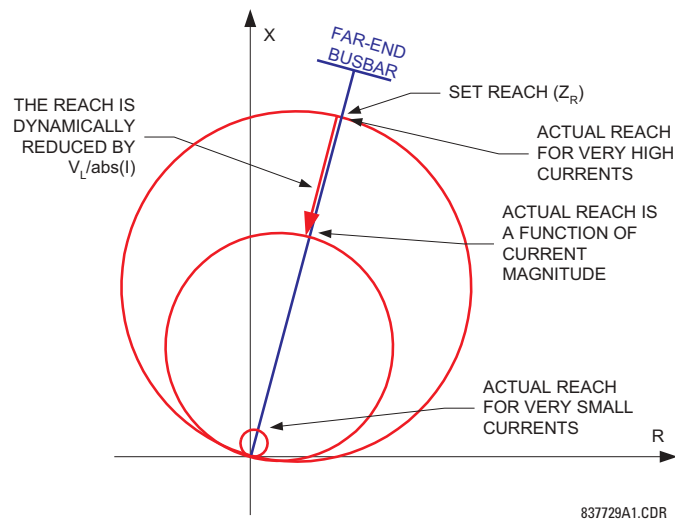
On close-in forward faults beyond the series capacitors as seen from the relaying point, the current inversion phenomenon may take place for a short period of time. The condition cannot sustain for a long time as very high fault currents would occur causing large voltage drops across the series capacitors and prompting the overvoltage protection of the capacitors to operate quickly. This would effectively remove the series compensation and eliminate the current inversion. However, when the currents used by distance comparator (fault-loop current for ground and phase distance protection, and the negative- and zero-sequence currents for ground elements) stay shifted by more than 90 degrees from their natural fault position determined by the user as the element characteristic angle, the distance elements may fail to pick-up on such a forward fault for the brief period of current inversion. This is an inherent attribute of the 100% memory polarized mho element, and not a weakness particular to the D30 relay.

Therefore, for dependability, it is recommended to use high-set phase overcurrent protection for direct tripping on close-in faults potentially causing current inversion, and overreaching ground fault directional overcurrent functions (such as negative-sequence, ground or neutral) for communication-aided schemes.

The problem of steady-state overreaching due to the negative reactance of the series capacitors may be addressed in the D30 in a traditional way by shortening the reach of an underreaching distance elements to the net inductive reactance of the line between the potential source and the far end busbar(s). This generic approach has two major drawbacks. First, it leaves large portion of the line uncovered by the directly tripping distance protection. Second, it does not solve the transient overreaching problem caused by sub-synchronous oscillations.

Therefore, the D30 offers a unique option for dynamic reach control that is effectively based on the magnitude of the current flowing through the series capacitor bank(s). The underreaching distance functions can be set as for plain uncompensated line, i.e. using the impedance of the line alone, and the relay would control an effective reach accordingly using the current magnitude as illustrated in the figure below.

The reach is reduced sufficiently to cope with both steady-state and transient overreach phenomena. For large degrees of compensation and small-current faults, the transient overreach may be as high as 100%. This means that fast distance protection is not achievable. The adaptive D30's mechanism would guarantee security on external faults. Overreaching ground fault directional overcurrent functions (such as negative-sequence, ground or neutral) shall be used for dependability.



**Figure 8-7: DYNAMIC REACH CONTROL**

Section (a) of the figure below shows the effect of adaptive reach control for low-current external fault. The reach is reduced sufficiently to cope with both transient and steady-state overreach. Section (b) shows a high-current external fault. The air gaps or MOVs conduct majority of the fault current and neither steady-state nor transient overreach takes place. The relay does not reduce its reach as it is not necessary. Section (c) shows a high-current internal fault. Because of the large current, the reach is not reduced and the element responds to this internal fault. Traditional approach would leave this fault out of the relay reach.

The neutral and negative-sequence directional protection functions of the relay cope with the voltage and/or current inversions by adding appropriate offset to their polarizing signals as explained in the Ground Directional Overcurrent section. The offset impedance can always be successfully selected to guarantee correct fault direction discrimination regardless of the degree of compensation and location of the series capacitors and the potential source.

Refer to Chapter 9: Application of Settings for detailed recommendations on settings for series compensation applications.

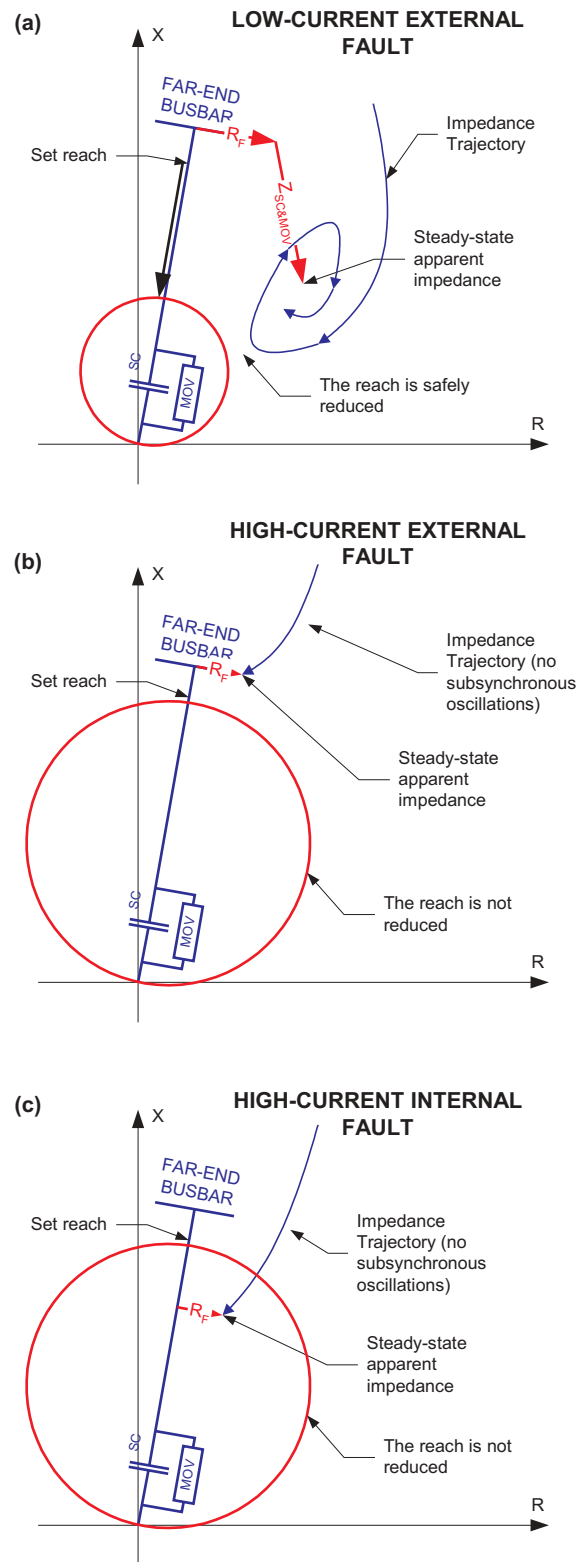


Figure 8–8: DYNAMIC REACH FOR INTERNAL AND EXTERNAL FAULTS



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**9.1.1 INTRODUCTION**

This chapter provides general application guidelines for stepped distance, overcurrent and pilot protection. Where relevant, design details and performance characteristics of the D30 are given to facilitate the process of setting the relay for a given application.

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**9.1.2 IMPACT OF MEMORY POLARIZATION**

As explained in Chapter 8, the D30 uses a memorized positive sequence voltage as a polarizing signal in order to achieve dependable operation for forward faults and secure non-operation for reverse faults.

The dynamic shift of the characteristic ensures improved directionality, but it also means that if a backup function is required for a reverse fault on the bus, then it is appropriate to reverse Zone 3 so that a time delayed backup function may be obtained. As mentioned earlier, it may be beneficial to also avoid extremely large reach settings by setting a remote backup so that it is reverse looking. This strategy can be beneficial if the reduced reach enhances the discrimination between the load and fault conditions.

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**9.1.3 HIGH SET OVERCURRENT ELEMENTS**

Especially at low SIR values, fast fault clearance times may be seen as extremely important, both from system stability, and from equipment damage viewpoints. The high-set overcurrent element, when set appropriately, can be extremely useful in achieving these goals. It helps the setting calculations if the system impedances are reasonably well known.

The overcurrent pick up should be set to the greater of the following values:

1. The maximum infeed seen by the relay, for a close in reverse fault.
2. The maximum fault level seen by the relay for a fault at 100% of the protected line.

The maximum error of the phase overcurrent elements is below 2%. A safety factor of 1.25 should be used to account for relay errors and system impedance uncertainty.

If CT saturation is an issue such as close to a generation where long lasting dc components are likely to saturate the CTs, it should be noted that the IOC elements require 1.33 cycle of data to operate for a multiple of pickup of 1.01. For higher multiples of pickup, the relation between the multiple of pickup and the amount of data required for operation before complete CT saturation is approximately linear. For example, for a multiple of pickup of 4, approximately  $1.33 / 4 = 0.332$  of power cycle is required by the phase IOC to operate. The above information should not be confused with the operating time, which includes some inherent delays such as a trip rated output contact.

## 9.2.1 PHASE DISTANCE

**a) PHASE CURRENT SUPERVISION AND THE FUSE FAILURE ELEMENT**

The phase-to-phase (delta) current is used to supervise the phase distance element, primarily to ensure that in a de-energized state the distance element will not be picked up due to noise or induced voltages, on the line.

However, this supervision feature may also be employed to prevent operation under fuse failure conditions. This obviously requires that the setting must be above maximum load current and less than the minimum fault conditions for which operation is expected. This potential problem may be avoided by the use of a separate fuse fail function, which means that the phase current supervision can be set much lower, typically 2 times the capacitance charging current of the line.

The usage of the fuse fail function is also important during double-contingency events such as an external fault during fuse fail conditions. The current supervision alone would not prevent maloperation in such circumstances.

It must be kept in mind that the Fuse Failure element provided on the D30 needs some time to detect fuse fail conditions. This may create a race between the Zone and the Fuse Failure element. Therefore, for maximum security, it is recommended to both set the current supervision above the maximum load current and use the Fuse Failure function. The current supervision prevents maloperation immediately after the fuse fail condition giving some time for the Fuse Failure element to take over and block the distance elements permanently. This is of a secondary importance for time-delayed Zone 2 as the Fuse Failure element has some extra time for guaranteed operation. The current supervision may be set below the maximum load current for the time delayed zones.

Blocking distance elements during fuse fail conditions may not be acceptable in some applications and/or under some protection philosophies. Applied solutions may vary from not using the Fuse Failure element for blocking at all; through using it and modifying – through FlexLogic™ and multiple setting groups mechanisms – other protection functions or other relays to provide some protection after detecting fuse fail conditions and blocking the distance elements; to using it and accepting the fact that the distance protection will not respond to subsequent internal faults until the problem is addressed.



To be fully operational, the Fuse Failure element must be enabled, and its output FlexLogic™ operand must be indicated as the blocking signal for the selected protection elements.

For convenience, the current supervision threshold incorporates the  $\sqrt{3}$  factor.

**b) PHASE DISTANCE ZONE 1**

As typically used for direct tripping, the Zone 1 reach must be chosen so that it does not extend beyond the far end(s) of the protected line. The Zone 1 provides nominally instantaneous protection for any phase fault within a pre-determined distance from the relay location. To ensure that no overreach occurs, typically requires a setting of 80 to 90% of the line length, which covers CT and VT errors, relay inaccuracy and transient overreach as well as uncertainty in the line impedance for each phase, although transposition may minimize this latter concern.

**c) PHASE DISTANCE ZONE 2**

The Zone 2 is an overreaching element, which essentially covers the of the line length with a time delay. The additional function for the Zone 2 is as a timed backup for faults on the remote bus. Typically the reach is set to 125% of the positive sequence impedance of the line, to ensure operation, with an adequate margin, for a fault at 100% of the line length. The necessary time delay must ensure that coordination is achieved with the clearance of a close-in fault on the next line section, including the breaker operating time.

**d) PHASE DISTANCE ZONE 3**

If a remote backup philosophy is followed, then the reach of this element must be set to account for any infeed at the remote bus, plus the impedance of the longest line which terminates on this remote bus. The time delay must coordinate with other time-delayed protections on any remote line. Circuit loading limitations created by a long zone reach may be overcome by using lens or quadrilateral characteristics and/or a load encroachment supervising characteristic. Consideration should also be given to a situation where the load impedance may enter into the relay characteristic for a time longer than the chosen time delay, which could occur transiently during a system power swing. For this reason the Power Swing Blocking function should be used.

## 9.2.2 GROUND DISTANCE

**a) NEUTRAL CURRENT SUPERVISION**

The current supervision for the ground distance elements responds to an internally calculated neutral current ( $3 \times I_0$ ). The setting for this element should be based on twice the zero-sequence line capacitance current or the maximum zero-sequence unbalance under maximum load conditions. This element should not be used to prevent an output when the load impedance is inside the distance characteristic on a steady state basis.

**b) POLARIZING CURRENT AND NON-HOMOGENEITY CORRECTION ANGLE OF THE QUAD CHARACTERISTIC**

An ideal reactance line for single-line-to-ground faults is polarized from the fault current flowing through the fault resistance. Such a line defines constant reach and could be implemented by the following angle comparator:

$$I \times Z - V \text{ vs. } j \times I_F \quad (\text{EQ 9.1})$$

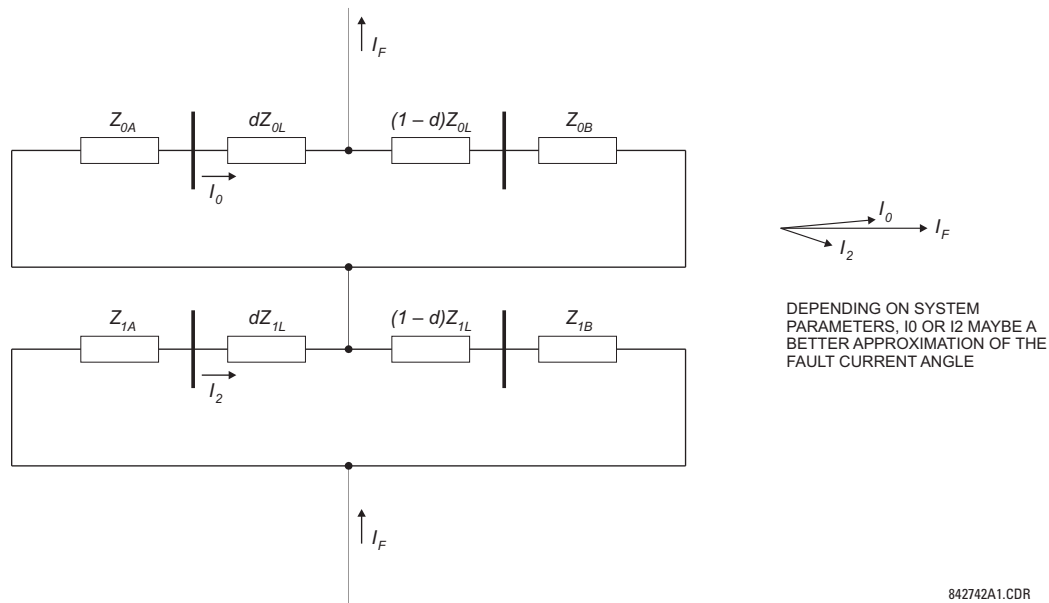
The relay could only approximate the unknown fault current by the zero-sequence or the negative-sequence currents measured at the relaying point. Depending on system parameters, either the zero-sequence or the negative-sequence current presents better approximation of the fault current angle.

Given the equivalent systems shown in the figure below, the angular difference between the zero-sequence or negative-sequence currents at the relay, and the fault current can be calculated as follows:

$$\Theta_0 = \text{angle}\left(\frac{I_F}{I_{0\_RELAY}}\right) = \text{angle}\left(\frac{Z_{0A} + Z_{0L} + Z_{0B}}{Z_{0B} + (1-d)Z_{0L}}\right) \quad (\text{EQ 9.2})$$

$$\Theta_2 = \text{angle}\left(\frac{I_F}{I_{2\_RELAY}}\right) = \text{angle}\left(\frac{Z_{1A} + Z_{1L} + Z_{1B}}{Z_{1B} + (1-d)Z_{1L}}\right) \quad (\text{EQ 9.3})$$

where: A is the local equivalent system  
 B is the remote equivalent system  
 L is the line  
 d is the per-unit (pu) intended reach of the zone (typically 0.7 to 0.9).



**Figure 9-1: UNDERSTANDING SYSTEM HOMOGENEITY**

If  $\text{abs}(\Theta_0) < \text{abs}(\Theta_2)$ , the zero-sequence network is more homogenous (the zero-sequence current better approximates the fault current), and zero-sequence polarizing should be selected. Otherwise, negative-sequence is a better polarizing signal.

The calculated  $\Theta$  angles reflect errors between the ideal and applied polarizing angles. Therefore, after selecting the polarizing current, the corresponding angle should be chosen as the non-homogeneity correction angle. For example, calculations yielding  $\Theta_0 = 5^\circ$  and  $\Theta_2 = -1^\circ$  should result in selecting the negative-sequence for polarization, and the value of  $-1^\circ$  for non-homogeneity correction.

Quite often the non-homogeneity correction angle is used to apply extra security rather than correct the angle between the relay and the fault currents. For extra security the angle should be set to negative values.

Ability to select an optimum polarizing signal and to correct for non-homogeneity should be approached with care. The best polarizing signal and the correcting angle both depend on system parameters and intended reach of the zone. If the system configuration is static, the selection is straightforward.

However, if the system configuration may change significantly, all the relevant system topologies shall be considered for calculations. Either a compromise choice is made, or different settings are applied via switchable setting groups depending on system conditions. In highly non-homogenous and dynamic systems where the correction for non-homogeneity is not feasible, conservative reach (reduced) and/or correction angle (negative) settings should be considered.

### c) GROUND DISTANCE ZONE 1

The Zone 1 reach must be set so that nominally instantaneous operation does not extend beyond the end of the protected line. However this may be somewhat more complicated than for the phase elements, because of zero sequence mutual induction with an adjacent parallel line, possibly carried on the same tower, which can be out of service and grounded at multiple points. A fault beyond 100% of the protected line may cause overreach unless the reach is reduced significantly, sometimes as low as 65% of the line length. If the line being protected does not have a significant interaction with an adjacent circuit, then the typical 80% setting may be used. If there is significant mutual coupling between the parallel lines, then the mutual compensation feature of the ground distance elements can be used instead of a drastic reduction in the reach.

However, even in this case, there is more uncertainty as compared with the phase distance elements because the zero-sequence impedance of the line and thus the zero-sequence-compensating factors may vary significantly due to weather and other conditions.

### d) GROUND DISTANCE ZONE 2

To ensure that the Zone 2 can see 100% of the line, inter-circuit mutual effects must be considered, as they can contribute to a significant under-reach. Typically this may occur on double circuit lines, when both lines may carry the same current. An analytical study should be carried out to determine the appropriate reach setting.

The main purpose of this element is to operate for faults beyond the reach of the local Zone 1 element, and therefore a time delay must be used similar to the phase fault case.

### e) GROUND DISTANCE ZONE 3

This remote back up function must have a reach which is set to account for any infeed at the remote bus, plus the impedance of the longest line which terminates on this remote bus. Similar to the phase fault case, a Zone 3 element must be time coordinated with timed clearances on the next section.

## 9.3.1 INTRODUCTION

For reasons described in Chapter 8: *Theory of Operation*, it is recommended to apply a combination of distance, ground directional overcurrent and high-set overcurrent functions for protection of series compensated lines.

The setting rules described below must take into account variety of system configurations, particularly a status of series capacitors (in-service, by-passed). Either the worst-case topology shall be considered or - if possible - adaptive settings shall be applied through the multiple settings groups mechanism.

A line compensating capacitor is a bank of three physical capacitors and their overvoltage protecting devices (air gaps and/or MOVs). If none of the MOV/gaps conducts any significant current, the positive-, negative- and zero-sequence reactance of the three-phase bank equal the reactance of the actual (phase) capacitors. Under asymmetrical conditions, however, such as a single line to ground fault, when only one MOV/gap may operate, the series capacitor bank would create extra (series) asymmetry in addition to the fault (shunt) asymmetry. The positive-, negative- and zero-sequence impedances will differ from each other and will not equal the impedance of the phase capacitors. Moreover, there may be mutual coupling between the sequence networks representing the series capacitor bank. This makes analytical analysis of fault conditions very burdensome. For setting calculations, however, it is justified to assume the zero-, positive-, and negative-sequence reactance of the capacitor bank equal the reactance of the actual (phase) capacitors. This represents a worst-case low-current fault scenario, when the steady-state effects of series compensation are most weighty.

## 9.3.2 DISTANCE

Traditionally, the reach setting of an underreaching distance function shall be set based on the net inductive impedance between the potential source of the relay and the far-end busbar, or location for which the zone must not overreach. Faults behind series capacitors on the protected and adjacent lines need to be considered for this purpose. For further illustration a sample system shown in the figure below is considered.

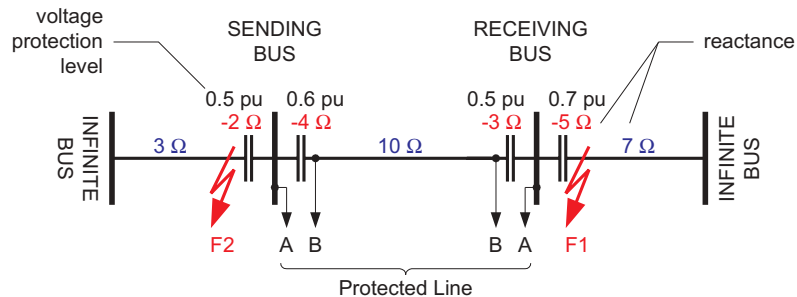


Figure 9-2: SAMPLE SERIES COMPENSATED SYSTEM

Assuming 20% security margin, the underreaching zone shall be set as follows.

At the Sending Bus, one must consider an external fault at F1 as the 5 Ω capacitor would contribute to the overreaching effect. Any fault behind F1 is less severe as extra inductive line impedance increases the apparent impedance:

Reach Setting:  $0.8 \times (10 - 3 - 5) = 1.6 \Omega$  if the line-side (B) VTs are used

Reach Setting:  $0.8 \times (10 - 4 - 3 - 5) = -1.6 \Omega$  if the bus-side (A) VTs are used

The negative value means that an underreaching zone cannot be used as the circuit between the potential source of the relay and an external fault for which the relay must not pick-up, is overcompensated, i.e. capacitive.

At the Receiving Bus, one must consider a fault at F2:

Reach Setting:  $0.8 \times (10 - 4 - 2) = 3.2 \Omega$  if the line-side (B) VTs are used

Reach Setting:  $0.8 \times (10 - 4 - 3 - 2) = 0.8 \Omega$  if the bus-side (A) VTs are used

Practically, however, to cope with the effect of sub-synchronous oscillations, one may need to reduce the reach even more. As the characteristics of sub-synchronous oscillations are in complex relations with fault and system parameters, no solid setting recommendations are given with respect to extra security margin for sub-synchronous oscillations. It is strongly recommended to use a power system simulator to verify the reach settings or to use an adaptive D30 feature for dynamic reach control.

If the adaptive reach control feature is used, the **PHS DIST Z1 VOLT LEVEL** setting shall be set accordingly.

This setting is a sum of the overvoltage protection levels for all the series capacitors located between the relay potential source and the far-end busbar, or location for which the zone must not overreach. The setting is entered in pu of the phase VT nominal voltage (RMS, not peak value).

If a minimum fault current level (phase current) is causing a voltage drop across a given capacitor that prompts its air gap to flash over or its MOV to carry practically all the current, then the series capacitor shall be excluded from the calculations (the capacitor is immediately by-passed by its overvoltage protection system and does not cause any overreach problems).

If a minimum fault current does not guarantee an immediate capacitor by-pass, then the capacitor must be included in the calculation: its overvoltage protection level, either air gap flash-over voltage or MOV knee-point voltage, shall be used (RMS, not peak value).

Assuming none of the series capacitors in the sample system is guaranteed to get by-passed, the following calculations apply:

For the Sending Bus:  $0.5 + 0.7 = 1.2$  pu if the line-side (B) VTs are used  
 $0.6 + 0.5 + 0.7 = 1.8$  pu if the bus-side (A) VTs are used

For the Receiving Bus:  $0.6 + 0.5 = 1.1$  pu if the line-side (B) VTs are used  
 $0.6 + 0.5 + 0.5 = 1.6$  pu if the bus-side (A) VTs are used

### 9.3.3 GROUND DIRECTIONAL OVERCURRENT

Ground directional overcurrent function (negative-sequence or neutral) uses an offset impedance to guarantee correct fault direction discrimination. The following setting rules apply.

1. If the net impedance between the potential source and the local equivalent system is inductive, then there is no need for an offset. Otherwise, the offset impedance shall be at least the net capacitive reactance.
2. The offset cannot be higher than the net inductive reactance between the potential source and the remote equivalent system. For simplicity and extra security, the far-end busbar may be used rather than the remote equivalent system.

As the ground directional functions are meant to provide maximum fault resistance coverage, it is justified to assume that the fault current is very low and none of the series capacitors is guaranteed to get by-passed. Consider settings of the negative-sequence directional overcurrent protection element for the Sample Series Compensated System.

For the Sending Bus relay, bus-side VTs:

- Net inductive reactance from the relay into the local system =  $-2 + 3 = 1 \Omega > 0$ ; there is no need for offset.
- Net inductive reactance from relay through far-end busbar =  $-4 + 10 - 3 = 3 \Omega$ ; the offset cannot be higher than  $3 \Omega$ .
- It is recommended to use  $1.5 \Omega$  offset impedance.

For the Sending Bus relay, line-side VTs:

- Net inductive reactance from relay into local system =  $-2 + 3 - 4 = -3 \Omega < 0$ ; an offset impedance  $\geq 3 \Omega$  must be used.
- Net inductive reactance from relay through far-end busbar =  $10 - 3 = 7 \Omega$ ; the offset cannot be higher than  $7 \Omega$ .
- It is recommended to use  $5 \Omega$  offset impedance.

For the Receiving Bus relay, bus-side VTs:

- Net inductive reactance from relay into local system =  $-5 + 7 = 2 \Omega > 0$ ; there is no need for offset.
- Net inductive reactance from relay through far-end busbar =  $-3 + 10 - 4 = 3 \Omega$ ; the offset cannot be higher than  $3 \Omega$ .
- It is recommended to use  $1.5 \Omega$  offset impedance.

For the Receiving Bus relay, line-side VTs:

- Net inductive reactance from relay into local system =  $-3 - 5 + 7 = -1 \Omega < 0$ ; an offset impedance  $\geq 1 \Omega$  must be used.
- Net inductive reactance from relay through far-end busbar =  $10 - 4 = 6 \Omega$ ; the offset cannot be higher than  $6 \Omega$ .
- It is recommended to use  $3.5 \Omega$  offset impedance.

### 9.3.4 HIGH-SET PHASE OVERCURRENT

The setting rules for high-set overcurrent protection are explained in the *High-Set Overcurrent Elements* section.

## 9.4.1 PHASE DISTANCE PROTECTION

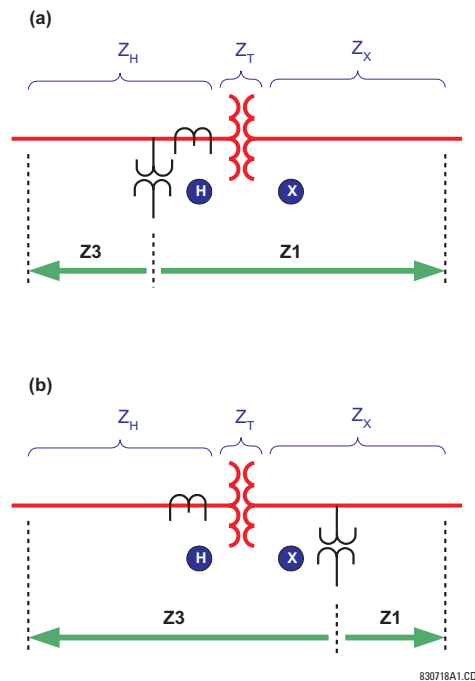
## a) DESCRIPTION

Phase distance elements of the D30 could be set to respond to faults beyond any three-phase power transformer. The relay guarantees accurate reach and targeting for any phase fault. Moreover, the current and voltage transformers may be located independently on different sides of the transformer.

The following setting rules apply to this feature:

1. A given distance zone is terminated by location of the VTs, not the CTs.
2. Consequently, the positive-sequence impedance of a transformer must be included in the reach setting only if the transformer is located between the potential source and the intended reach point.
3. The current signals require compensation if the transformer is located between the CTs and the intended reach point. If this is the case the CT connection setting shall be set to transformer connection and vector group as seen from the CTs toward the reach point. Otherwise, the CT connection setting shall be set to "None".
4. The voltage signals require compensation if the transformer is located between the VTs and the intended reach point. If this is the case the VT connection setting shall be set to transformer connection and vector group as seen from the VTs toward the reach point. Otherwise, the VT connection setting shall be set to "None".
5. The reach setting is entered in secondary ohms and as such must take into account location and ratios of VTs and CTs as well as voltage ratio of the involved power transformer.

The following equations explain the setting rules. Consider two applications as shown in the figure below:



830718A1.CDR

**Figure 9-3: PHASE DISTANCE PROTECTION LOOKING THROUGH A POWER TRANSFORMER**

where:  $Z_X$  = intended reach impedance for Zone 1 (primary ohms)  
 $Z_H$  = intended reach impedance for Zone 3 (primary ohms)  
 $Z_T$  = positive-sequence impedance of the transformer  
 $V_X, V_H$  = transformer rated voltages  
 $n_{CT}$  = transformation ratio of the CTs  
 $n_{VT}$  = transformation ratio of the VTs  
 $Z1$ : Z1 reach setting (secondary ohms)  
 $Z3$ : Zone 3 reach setting (secondary ohms)

**b) ZONE 1 SETTING IN APPLICATION (A)**

As the transformer is located between the potential source and the reach point for Zone 1, the reach impedance must include the positive-sequence impedance of the transformer. In addition, the primary impedance must be re-calculated for the voltage level of the VTs and CTs, and eventually, re-calculated to secondary quantities:

$$Z_1 = (Z_T(\text{at } X) + Z_X) \times \left(\frac{V_H}{V_X}\right)^2 \times \frac{n_{CT}}{n_{VT}} \quad (\text{EQ 9.4})$$

**c) ZONE 3 SETTING IN APPLICATION (A)**

As the transformer is not located between the potential source and the reach point for Zone 3, the reach impedance must not include the positive-sequence impedance of the transformer. Because both VTs and CTs are located on the same side as the intended reach point, no correction for the transformer ratio is required. The primary impedance must be only re-calculated to secondary quantities:

$$Z_3 = Z_H \times \frac{n_{CT}}{n_{VT}} \quad (\text{EQ 9.5})$$

**d) ZONE 1 SETTING IN APPLICATION (B)**

As the transformer is not located between the potential source and the reach point for Z1, the reach impedance must not include the positive-sequence impedance of the transformer. The CTs are located on the other side of the transformer, thus transformer ratio must be included:

$$Z_1 = Z_X \times \left(\frac{V_H}{V_X}\right) \times \frac{n_{CT}}{n_{VT}} \quad (\text{EQ 9.6})$$

**e) ZONE 3 SETTING IN APPLICATION (B)**

As the transformer is located between the potential source and the reach point for Zone 3, the reach impedance must include the positive-sequence impedance of the transformer. The VTs are located on the other side of the transformer, thus transformer ratio must be included:

$$Z_3 = (Z_T(\text{at } H) + Z_H) \times \left(\frac{V_X}{V_H}\right) \times \frac{n_{CT}}{n_{VT}} \quad (\text{EQ 9.7})$$

**9.4.2 EXAMPLE**

Given the following for the system shown in the previous section:

$Z_X = 30 \angle 85^\circ$  (intended reach of Zone 1)  
 $Z_H = 0.06 \angle 88^\circ$  (intended reach of Zone 3)  
 $n_{CT} = 8000:5 = 1600$  (located at H)  
 $n_{VT} = 315000:120 = 2625$  (located at X)  
 Transformer: 13.8/315 kV, 150 MVA, 10%, delta/wye, 315 kV side lagging  $30^\circ$

Transformer impedance:

$$Z_T(\text{at } H) = \frac{10}{100} \times \frac{(13.8)^2}{150} = 0.127 \angle 90^\circ \quad (\text{EQ 9.8})$$

The Zone 1 settings are:

$$Z_1 = 30 \times \frac{13.8}{315} \times \frac{1600}{2625} = 0.8011 \angle 85^\circ \quad (\text{EQ 9.9})$$

PHS DIST Z1 REACH: "0.80"  
 PHS DIST Z1 RCA: "85"  
 PHS DIST Z1 XMFR VOL CONNECTION: "None"  
 PHS DIST Z1 XMFR CUR CONNECTION: "Dy1"



The Zone 3 settings are:

$$Z_3 = (0.127 \angle 90^\circ + 0.006 \angle 88^\circ) \times \frac{315}{13.8} \times \frac{1600}{2625} = 2.601 \Omega \angle 89.4^\circ \quad (\text{EQ 9.10})$$

PHS DIST Z3 REACH: "2.60"

PHS DIST Z3 RCA: "89"

PHS DIST Z3 XMFR VOL CONNECTION: "Yd11"

PHS DIST Z3 XMFR CUR CONNECTION: "None"



Table A-1: FLEXANALOG DATA ITEMS (Sheet 1 of 6)

| ADDR | DATA ITEM                           | FLEXANALOG NAME            |
|------|-------------------------------------|----------------------------|
| 6144 | SRC 1 Phase A Current RMS           | SRC 1 Ia RMS               |
| 6146 | SRC 1 Phase B Current RMS           | SRC 1 Ib RMS               |
| 6148 | SRC 1 Phase C Current RMS           | SRC 1 Ic RMS               |
| 6150 | SRC 1 Neutral Current RMS           | SRC 1 In RMS               |
| 6152 | SRC 1 Phase A Current Magnitude     | SRC 1 Ia Mag               |
| 6154 | SRC 1 Phase A Current Angle         | SRC 1 Ia Angle             |
| 6155 | SRC 1 Phase B Current Magnitude     | SRC 1 Ib Mag               |
| 6157 | SRC 1 Phase B Current Angle         | SRC 1 Ib Angle             |
| 6158 | SRC 1 Phase C Current Magnitude     | SRC 1 Ic Mag               |
| 6160 | SRC 1 Phase C Current Angle         | SRC 1 Ic Angle             |
| 6161 | SRC 1 Neutral Current Magnitude     | SRC 1 In Mag               |
| 6163 | SRC 1 Neutral Current Angle         | SRC 1 In Angle             |
| 6164 | SRC 1 Ground Current RMS            | SRC 1 Ig RMS               |
| 6166 | SRC 1 Ground Current Magnitude      | SRC 1 Ig Mag               |
| 6168 | SRC 1 Ground Current Angle          | SRC 1 Ig Angle             |
| 6169 | SRC 1 Zero Seq. Current Magnitude   | SRC 1 I <sub>0</sub> Mag   |
| 6171 | SRC 1 Zero Sequence Current Angle   | SRC 1 I <sub>0</sub> Angle |
| 6172 | SRC 1 Pos. Seq. Current Magnitude   | SRC 1 I <sub>1</sub> Mag   |
| 6174 | SRC 1 Pos. Seq. Current Angle       | SRC 1 I <sub>1</sub> Angle |
| 6175 | SRC 1 Neg. Seq. Current Magnitude   | SRC 1 I <sub>2</sub> Mag   |
| 6177 | SRC 1 Neg. Seq. Current Angle       | SRC 1 I <sub>2</sub> Angle |
| 6178 | SRC 1 Differential Gnd Current Mag. | SRC 1 Igd Mag              |
| 6180 | SRC 1 Diff. Gnd. Current Angle      | SRC 1 Igd Angle            |
| 6208 | SRC 2 Phase A Current RMS           | SRC 2 Ia RMS               |
| 6210 | SRC 2 Phase B Current RMS           | SRC 2 Ib RMS               |
| 6212 | SRC 2 Phase C Current RMS           | SRC 2 Ic RMS               |
| 6214 | SRC 2 Neutral Current RMS           | SRC 2 In RMS               |
| 6216 | SRC 2 Phase A Current Magnitude     | SRC 2 Ia Mag               |
| 6218 | SRC 2 Phase A Current Angle         | SRC 2 Ia Angle             |
| 6219 | SRC 2 Phase B Current Magnitude     | SRC 2 Ib Mag               |
| 6221 | SRC 2 Phase B Current Angle         | SRC 2 Ib Angle             |
| 6222 | SRC 2 Phase C Current Magnitude     | SRC 2 Ic Mag               |
| 6224 | SRC 2 Phase C Current Angle         | SRC 2 Ic Angle             |
| 6225 | SRC 2 Neutral Current Magnitude     | SRC 2 In Mag               |
| 6227 | SRC 2 Neutral Current Angle         | SRC 2 In Angle             |
| 6228 | SRC 2 Ground Current RMS            | SRC 2 Ig RMS               |
| 6230 | SRC 2 Ground Current Magnitude      | SRC 2 Ig Mag               |
| 6232 | SRC 2 Ground Current Angle          | SRC 2 Ig Angle             |
| 6233 | SRC 2 Zero Seq. Current Magnitude   | SRC 2 I <sub>0</sub> Mag   |
| 6235 | SRC 2 Zero Sequence Current Angle   | SRC 2 I <sub>0</sub> Angle |
| 6236 | SRC 2 Pos. Seq. Current Magnitude   | SRC 2 I <sub>1</sub> Mag   |
| 6238 | SRC 2 Positive Seq. Current Angle   | SRC 2 I <sub>1</sub> Angle |
| 6239 | SRC 2 Neg. Seq. Current Magnitude   | SRC 2 I <sub>2</sub> Mag   |
| 6241 | SRC 2 Negative Seq. Current Angle   | SRC 2 I <sub>2</sub> Angle |
| 6242 | SRC 2 Differential Gnd Current Mag. | SRC 2 Igd Mag              |
| 6244 | SRC 2 Diff. Gnd Current Angle       | SRC 2 Igd Angle            |
| 6656 | SRC 1 Phase AG Voltage RMS          | SRC 1 Vag RMS              |
| 6658 | SRC 1 Phase BG Voltage RMS          | SRC 1 Vbg RMS              |
| 6660 | SRC 1 Phase CG Voltage RMS          | SRC 1 Vcg RMS              |

Table A-1: FLEXANALOG DATA ITEMS (Sheet 2 of 6)

| ADDR | DATA ITEM                         | FLEXANALOG NAME            |
|------|-----------------------------------|----------------------------|
| 6662 | SRC 1 Phase AG Voltage Magnitude  | SRC 1 Vag Mag              |
| 6664 | SRC 1 Phase AG Voltage Angle      | SRC 1 Vag Angle            |
| 6665 | SRC 1 Phase BG Voltage Magnitude  | SRC 1 Vbg Mag              |
| 6667 | SRC 1 Phase BG Voltage Angle      | SRC 1 Vbg Angle            |
| 6668 | SRC 1 Phase CG Voltage Magnitude  | SRC 1 Vcg Mag              |
| 6670 | SRC 1 Phase CG Voltage Angle      | SRC 1 Vcg Angle            |
| 6671 | SRC 1 Phase AB Voltage RMS        | SRC 1 Vab RMS              |
| 6673 | SRC 1 Phase BC Voltage RMS        | SRC 1 Vbc RMS              |
| 6675 | SRC 1 Phase CA Voltage RMS        | SRC 1 Vca RMS              |
| 6677 | SRC 1 Phase AB Voltage Magnitude  | SRC 1 Vab Mag              |
| 6679 | SRC 1 Phase AB Voltage Angle      | SRC 1 Vab Angle            |
| 6680 | SRC 1 Phase BC Voltage Magnitude  | SRC 1 Vbc Mag              |
| 6682 | SRC 1 Phase BC Voltage Angle      | SRC 1 Vbc Angle            |
| 6683 | SRC 1 Phase CA Voltage Magnitude  | SRC 1 Vca Mag              |
| 6685 | SRC 1 Phase CA Voltage Angle      | SRC 1 Vca Angle            |
| 6686 | SRC 1 Auxiliary Voltage RMS       | SRC 1 Vx RMS               |
| 6688 | SRC 1 Auxiliary Voltage Magnitude | SRC 1 Vx Mag               |
| 6690 | SRC 1 Auxiliary Voltage Angle     | SRC 1 Vx Angle             |
| 6691 | SRC 1 Zero Sequence Voltage Mag.  | SRC 1 V <sub>0</sub> Mag   |
| 6693 | SRC 1 Zero Sequence Voltage Angle | SRC 1 V <sub>0</sub> Angle |
| 6694 | SRC 1 Positive Seq. Voltage Mag.  | SRC 1 V <sub>1</sub> Mag   |
| 6696 | SRC 1 Positive Seq. Voltage Angle | SRC 1 V <sub>1</sub> Angle |
| 6697 | SRC 1 Negative Seq. Voltage Mag.  | SRC 1 V <sub>2</sub> Mag   |
| 6699 | SRC 1 Negative Seq. Voltage Angle | SRC 1 V <sub>2</sub> Angle |
| 6720 | SRC 2 Phase AG Voltage RMS        | SRC 2 Vag RMS              |
| 6722 | SRC 2 Phase BG Voltage RMS        | SRC 2 Vbg RMS              |
| 6724 | SRC 2 Phase CG Voltage RMS        | SRC 2 Vcg RMS              |
| 6726 | SRC 2 Phase AG Voltage Magnitude  | SRC 2 Vag Mag              |
| 6728 | SRC 2 Phase AG Voltage Angle      | SRC 2 Vag Angle            |
| 6729 | SRC 2 Phase BG Voltage Magnitude  | SRC 2 Vbg Mag              |
| 6731 | SRC 2 Phase BG Voltage Angle      | SRC 2 Vbg Angle            |
| 6732 | SRC 2 Phase CG Voltage Magnitude  | SRC 2 Vcg Mag              |
| 6734 | SRC 2 Phase CG Voltage Angle      | SRC 2 Vcg Angle            |
| 6735 | SRC 2 Phase AB Voltage RMS        | SRC 2 Vab RMS              |
| 6737 | SRC 2 Phase BC Voltage RMS        | SRC 2 Vbc RMS              |
| 6739 | SRC 2 Phase CA Voltage RMS        | SRC 2 Vca RMS              |
| 6741 | SRC 2 Phase AB Voltage Magnitude  | SRC 2 Vab Mag              |
| 6743 | SRC 2 Phase AB Voltage Angle      | SRC 2 Vab Angle            |
| 6744 | SRC 2 Phase BC Voltage Magnitude  | SRC 2 Vbc Mag              |
| 6746 | SRC 2 Phase BC Voltage Angle      | SRC 2 Vbc Angle            |
| 6747 | SRC 2 Phase CA Voltage Magnitude  | SRC 2 Vca Mag              |
| 6749 | SRC 2 Phase CA Voltage Angle      | SRC 2 Vca Angle            |
| 6750 | SRC 2 Auxiliary Voltage RMS       | SRC 2 Vx RMS               |
| 6752 | SRC 2 Auxiliary Voltage Magnitude | SRC 2 Vx Mag               |
| 6754 | SRC 2 Auxiliary Voltage Angle     | SRC 2 Vx Angle             |
| 6755 | SRC 2 Zero Seq. Voltage Magnitude | SRC 2 V <sub>0</sub> Mag   |
| 6757 | SRC 2 Zero Sequence Voltage Angle | SRC 2 V <sub>0</sub> Angle |
| 6758 | SRC 2 Positive Seq. Voltage Mag.  | SRC 2 V <sub>1</sub> Mag   |
| 6760 | SRC 2 Positive Seq. Voltage Angle | SRC 2 V <sub>1</sub> Angle |

A

Table A-1: FLEXANALOG DATA ITEMS (Sheet 3 of 6)

| ADDR | DATA ITEM                           | FLEXANALOG NAME            |
|------|-------------------------------------|----------------------------|
| 6761 | SRC 2 Negative Seq. Voltage Mag.    | SRC 2 V <sub>2</sub> Mag   |
| 6763 | SRC 2 Negative Seq. Voltage Angle   | SRC 2 V <sub>2</sub> Angle |
| 7168 | SRC 1 Three Phase Real Power        | SRC 1 P                    |
| 7170 | SRC 1 Phase A Real Power            | SRC 1 Pa                   |
| 7172 | SRC 1 Phase B Real Power            | SRC 1 Pb                   |
| 7174 | SRC 1 Phase C Real Power            | SRC 1 Pc                   |
| 7176 | SRC 1 Three Phase Reactive Power    | SRC 1 Q                    |
| 7178 | SRC 1 Phase A Reactive Power        | SRC 1 Qa                   |
| 7180 | SRC 1 Phase B Reactive Power        | SRC 1 Qb                   |
| 7182 | SRC 1 Phase C Reactive Power        | SRC 1 Qc                   |
| 7184 | SRC 1 Three Phase Apparent Power    | SRC 1 S                    |
| 7186 | SRC 1 Phase A Apparent Power        | SRC 1 Sa                   |
| 7188 | SRC 1 Phase B Apparent Power        | SRC 1 Sb                   |
| 7190 | SRC 1 Phase C Apparent Power        | SRC 1 Sc                   |
| 7192 | SRC 1 Three Phase Power Factor      | SRC 1 PF                   |
| 7193 | SRC 1 Phase A Power Factor          | SRC 1 Phase A PF           |
| 7194 | SRC 1 Phase B Power Factor          | SRC 1 Phase B PF           |
| 7195 | SRC 1 Phase C Power Factor          | SRC 1 Phase C PF           |
| 7200 | SRC 2 Three Phase Real Power        | SRC 2 P                    |
| 7202 | SRC 2 Phase A Real Power            | SRC 2 Pa                   |
| 7204 | SRC 2 Phase B Real Power            | SRC 2 Pb                   |
| 7206 | SRC 2 Phase C Real Power            | SRC 2 Pc                   |
| 7208 | SRC 2 Three Phase Reactive Power    | SRC 2 Q                    |
| 7210 | SRC 2 Phase A Reactive Power        | SRC 2 Qa                   |
| 7212 | SRC 2 Phase B Reactive Power        | SRC 2 Qb                   |
| 7214 | SRC 2 Phase C Reactive Power        | SRC 2 Qc                   |
| 7216 | SRC 2 Three Phase Apparent Power    | SRC 2 S                    |
| 7218 | SRC 2 Phase A Apparent Power        | SRC 2 Sa                   |
| 7220 | SRC 2 Phase B Apparent Power        | SRC 2 Sb                   |
| 7222 | SRC 2 Phase C Apparent Power        | SRC 2 Sc                   |
| 7224 | SRC 2 Three Phase Power Factor      | SRC 2 PF                   |
| 7225 | SRC 2 Phase A Power Factor          | SRC 2 Phase A PF           |
| 7226 | SRC 2 Phase B Power Factor          | SRC 2 Phase B PF           |
| 7227 | SRC 2 Phase C Power Factor          | SRC 2 Phase C PF           |
| 7552 | SRC 1 Frequency                     | SRC 1 Frequency            |
| 7553 | SRC 2 Frequency                     | SRC 2 Frequency            |
| 7680 | SRC 1 Demand Ia                     | SRC 1 Demand Ia            |
| 7682 | SRC 1 Demand Ib                     | SRC 1 Demand Ib            |
| 7684 | SRC 1 Demand Ic                     | SRC 1 Demand Ic            |
| 7686 | SRC 1 Demand Watt                   | SRC 1 Demand Watt          |
| 7688 | SRC 1 Demand Var                    | SRC 1 Demand var           |
| 7690 | SRC 1 Demand Va                     | SRC 1 Demand Va            |
| 7696 | SRC 2 Demand Ia                     | SRC 2 Demand Ia            |
| 7698 | SRC 2 Demand Ib                     | SRC 2 Demand Ib            |
| 7700 | SRC 2 Demand Ic                     | SRC 2 Demand Ic            |
| 7702 | SRC 2 Demand Watt                   | SRC 2 Demand Watt          |
| 7704 | SRC 2 Demand Var                    | SRC 2 Demand var           |
| 7706 | SRC 2 Demand Va                     | SRC 2 Demand Va            |
| 9024 | Fault 1 Prefault Ph A Current Mag.  | Prefault Ia Mag [0]        |
| 9026 | Fault 1 Prefault Ph A Current Angle | Prefault Ia Ang [0]        |
| 9027 | Fault 1 Prefault Ph B Current Mag.  | Prefault Ib Mag [0]        |
| 9029 | Fault 1 Prefault Ph B Current Angle | Prefault Ib Ang [0]        |

Table A-1: FLEXANALOG DATA ITEMS (Sheet 4 of 6)

| ADDR  | DATA ITEM                            | FLEXANALOG NAME      |
|-------|--------------------------------------|----------------------|
| 9030  | Fault 1 Prefault Ph C Current Mag.   | Prefault Ic Mag [0]  |
| 9032  | Fault 1 Prefault Ph C Current Angle  | Prefault Ic Ang [0]  |
| 9033  | Fault 1 Prefault Ph A Voltage Mag.   | Prefault Va Mag [0]  |
| 9035  | Fault 1 Prefault Ph A Voltage Angle  | Prefault Va Ang [0]  |
| 9036  | Fault 1 Prefault Ph B Voltage Mag.   | Prefault Vb Mag [0]  |
| 9038  | Fault 1 Prefault Ph B Voltage Angle  | Prefault Vb Ang [0]  |
| 9039  | Fault 1 Prefault Ph C Voltage Mag.   | Prefault Vc Mag [0]  |
| 9041  | Fault 1 Prefault Ph C Voltage Angle  | Prefault Vc Ang [0]  |
| 9042  | Fault 1 Postfault Ph A Current Mag.  | Postfault Ia Mag [0] |
| 9044  | Fault 1 Postfault Ph A Current Angle | Postfault Ia Ang [0] |
| 9045  | Fault 1 Postfault Ph B Current Mag.  | Postfault Ib Mag [0] |
| 9047  | Fault 1 Postfault Ph B Current Angle | Postfault Ib Ang [0] |
| 9048  | Fault 1 Postfault Ph C Current Mag.  | Postfault Ic Mag [0] |
| 9050  | Fault 1 Postfault Ph C Current Angle | Postfault Ic Ang [0] |
| 9051  | Fault 1 Postfault Ph A Voltage Mag.  | Postfault Va Mag [0] |
| 9053  | Fault 1 Postfault Ph A Voltage Angle | Postfault Va Ang [0] |
| 9054  | Fault 1 Postfault Ph B Voltage Mag.  | Postfault Vb Mag [0] |
| 9056  | Fault 1 Postfault Ph B Voltage Angle | Postfault Vb Ang [0] |
| 9057  | Fault 1 Postfault Ph C Voltage Mag.  | Postfault Vc Mag [0] |
| 9059  | Fault 1 Postfault Ph C Voltage Angle | Postfault Vc Ang [0] |
| 9060  | Fault 1 Type                         | Fault Type [0]       |
| 9061  | Fault 1 Location                     | Fault Location [0]   |
| 9216  | Synchrocheck 1 Delta Voltage         | Synchchk 1 Delta V   |
| 9218  | Synchrocheck 1 Delta Frequency       | Synchchk 1 Delta F   |
| 9219  | Synchrocheck 1 Delta Phase           | Synchchk 1 Delta Phs |
| 9220  | Synchrocheck 2 Delta Voltage         | Synchchk 2 Delta V   |
| 9222  | Synchrocheck 2 Delta Frequency       | Synchchk 2 Delta F   |
| 9223  | Synchrocheck 2 Delta Phase           | Synchchk 2 Delta Phs |
| 13504 | DCMA Inputs 1 Value                  | DCMA Inputs 1 Value  |
| 13506 | DCMA Inputs 2 Value                  | DCMA Inputs 2 Value  |
| 13508 | DCMA Inputs 3 Value                  | DCMA Inputs 3 Value  |
| 13510 | DCMA Inputs 4 Value                  | DCMA Inputs 4 Value  |
| 13512 | DCMA Inputs 5 Value                  | DCMA Inputs 5 Value  |
| 13514 | DCMA Inputs 6 Value                  | DCMA Inputs 6 Value  |
| 13516 | DCMA Inputs 7 Value                  | DCMA Inputs 7 Value  |
| 13518 | DCMA Inputs 8 Value                  | DCMA Inputs 8 Value  |
| 13520 | DCMA Inputs 9 Value                  | DCMA Inputs 9 Value  |
| 13522 | DCMA Inputs 10 Value                 | DCMA Inputs 10 Value |
| 13524 | DCMA Inputs 11 Value                 | DCMA Inputs 11 Value |
| 13526 | DCMA Inputs 12 Value                 | DCMA Inputs 12 Value |
| 13528 | DCMA Inputs 13 Value                 | DCMA Inputs 13 Value |
| 13530 | DCMA Inputs 14 Value                 | DCMA Inputs 14 Value |
| 13532 | DCMA Inputs 15 Value                 | DCMA Inputs 15 Value |
| 13534 | DCMA Inputs 16 Value                 | DCMA Inputs 16 Value |
| 13536 | DCMA Inputs 17 Value                 | DCMA Inputs 17 Value |
| 13538 | DCMA Inputs 18 Value                 | DCMA Inputs 18 Value |
| 13540 | DCMA Inputs 19 Value                 | DCMA Inputs 19 Value |
| 13542 | DCMA Inputs 20 Value                 | DCMA Inputs 20 Value |
| 13544 | DCMA Inputs 21 Value                 | DCMA Inputs 21 Value |
| 13546 | DCMA Inputs 22 Value                 | DCMA Inputs 22 Value |
| 13548 | DCMA Inputs 23 Value                 | DCMA Inputs 23 Value |
| 13550 | DCMA Inputs 24 Value                 | DCMA Inputs 24 Value |

Table A-1: FLEXANALOG DATA ITEMS (Sheet 5 of 6)

| ADDR  | DATA ITEM            | FLEXANALOG NAME     |
|-------|----------------------|---------------------|
| 13552 | RTD Inputs 1 Value   | RTD Inputs 1 Value  |
| 13553 | RTD Inputs 2 Value   | RTD Inputs 2 Value  |
| 13554 | RTD Inputs 3 Value   | RTD Inputs 3 Value  |
| 13555 | RTD Inputs 4 Value   | RTD Inputs 4 Value  |
| 13556 | RTD Inputs 5 Value   | RTD Inputs 5 Value  |
| 13557 | RTD Inputs 6 Value   | RTD Inputs 6 Value  |
| 13558 | RTD Inputs 7 Value   | RTD Inputs 7 Value  |
| 13559 | RTD Inputs 8 Value   | RTD Inputs 8 Value  |
| 13560 | RTD Inputs 9 Value   | RTD Inputs 9 Value  |
| 13561 | RTD Inputs 10 Value  | RTD Inputs 10 Value |
| 13562 | RTD Inputs 11 Value  | RTD Inputs 11 Value |
| 13563 | RTD Inputs 12 Value  | RTD Inputs 12 Value |
| 13564 | RTD Inputs 13 Value  | RTD Inputs 13 Value |
| 13565 | RTD Inputs 14 Value  | RTD Inputs 14 Value |
| 13566 | RTD Inputs 15 Value  | RTD Inputs 15 Value |
| 13567 | RTD Inputs 16 Value  | RTD Inputs 16 Value |
| 13568 | RTD Inputs 17 Value  | RTD Inputs 17 Value |
| 13569 | RTD Inputs 18 Value  | RTD Inputs 18 Value |
| 13570 | RTD Inputs 19 Value  | RTD Inputs 19 Value |
| 13571 | RTD Inputs 20 Value  | RTD Inputs 20 Value |
| 13572 | RTD Inputs 21 Value  | RTD Inputs 21 Value |
| 13573 | RTD Inputs 22 Value  | RTD Inputs 22 Value |
| 13574 | RTD Inputs 23 Value  | RTD Inputs 23 Value |
| 13575 | RTD Inputs 24 Value  | RTD Inputs 24 Value |
| 13576 | RTD Inputs 25 Value  | RTD Inputs 25 Value |
| 13577 | RTD Inputs 26 Value  | RTD Inputs 26 Value |
| 13578 | RTD Inputs 27 Value  | RTD Inputs 27 Value |
| 13579 | RTD Inputs 28 Value  | RTD Inputs 28 Value |
| 13580 | RTD Inputs 29 Value  | RTD Inputs 29 Value |
| 13581 | RTD Inputs 30 Value  | RTD Inputs 30 Value |
| 13582 | RTD Inputs 31 Value  | RTD Inputs 31 Value |
| 13583 | RTD Inputs 32 Value  | RTD Inputs 32 Value |
| 13584 | RTD Inputs 33 Value  | RTD Inputs 33 Value |
| 13585 | RTD Inputs 34 Value  | RTD Inputs 34 Value |
| 13586 | RTD Inputs 35 Value  | RTD Inputs 35 Value |
| 13587 | RTD Inputs 36 Value  | RTD Inputs 36 Value |
| 13588 | RTD Inputs 37 Value  | RTD Inputs 37 Value |
| 13589 | RTD Inputs 38 Value  | RTD Inputs 38 Value |
| 13590 | RTD Inputs 39 Value  | RTD Inputs 39 Value |
| 13591 | RTD Inputs 40 Value  | RTD Inputs 40 Value |
| 13592 | RTD Inputs 41 Value  | RTD Inputs 41 Value |
| 13593 | RTD Inputs 42 Value  | RTD Inputs 42 Value |
| 13594 | RTD Inputs 43 Value  | RTD Inputs 43 Value |
| 13595 | RTD Inputs 44 Value  | RTD Inputs 44 Value |
| 13596 | RTD Inputs 45 Value  | RTD Inputs 45 Value |
| 13597 | RTD Inputs 46 Value  | RTD Inputs 46 Value |
| 13598 | RTD Inputs 47 Value  | RTD Inputs 47 Value |
| 13599 | RTD Inputs 48 Value  | RTD Inputs 48 Value |
| 32768 | Tracking Frequency   | Tracking Frequency  |
| 39425 | FlexElement 1 Actual | FlexElement 1 Value |
| 39427 | FlexElement 2 Actual | FlexElement 2 Value |
| 39429 | FlexElement 3 Actual | FlexElement 3 Value |

Table A-1: FLEXANALOG DATA ITEMS (Sheet 6 of 6)

| ADDR  | DATA ITEM             | FLEXANALOG NAME      |
|-------|-----------------------|----------------------|
| 39431 | FlexElement 4 Actual  | FlexElement 4 Value  |
| 39433 | FlexElement 5 Actual  | FlexElement 5 Value  |
| 39435 | FlexElement 6 Actual  | FlexElement 6 Value  |
| 39437 | FlexElement 7 Actual  | FlexElement 7 Value  |
| 39439 | FlexElement 8 Actual  | FlexElement 8 Value  |
| 40971 | Current Setting Group | Active Setting Group |

## A

## B.1.1 INTRODUCTION

The UR-series relays support a number of communications protocols to allow connection to equipment such as personal computers, RTUs, SCADA masters, and programmable logic controllers. The Modicon Modbus RTU protocol is the most basic protocol supported by the UR. Modbus is available via RS232 or RS485 serial links or via ethernet (using the Modbus/TCP specification). The following description is intended primarily for users who wish to develop their own master communication drivers and applies to the serial Modbus RTU protocol. Note that:

- The UR always acts as a slave device, meaning that it never initiates communications; it only listens and responds to requests issued by a master computer.
- For Modbus®, a subset of the Remote Terminal Unit (RTU) protocol format is supported that allows extensive monitoring, programming, and control functions using read and write register commands.

## B.1.2 PHYSICAL LAYER

The Modbus® RTU protocol is hardware-independent so that the physical layer can be any of a variety of standard hardware configurations including RS232 and RS485. The relay includes a faceplate (front panel) RS232 port and two rear terminal communications ports that may be configured as RS485, fiber optic, 10BaseT, or 10BaseF. Data flow is half-duplex in all configurations. See Chapter 3 for details on wiring.

Each data byte is transmitted in an asynchronous format consisting of 1 start bit, 8 data bits, 1 stop bit, and possibly 1 parity bit. This produces a 10 or 11 bit data frame. This can be important for transmission through modems at high bit rates (11 bit data frames are not supported by many modems at baud rates greater than 300).

The baud rate and parity are independently programmable for each communications port. Baud rates of 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 33600, 38400, 57600, or 115200 bps are available. Even, odd, and no parity are available. Refer to the *Communications* section of Chapter 5 for further details.

The master device in any system must know the address of the slave device with which it is to communicate. The relay will not act on a request from a master if the address in the request does not match the relay's slave address (unless the address is the broadcast address – see below).

A single setting selects the slave address used for all ports, with the exception that for the faceplate port, the relay will accept any address when the Modbus® RTU protocol is used.

## B.1.3 DATA LINK LAYER

Communications takes place in packets which are groups of asynchronously framed byte data. The master transmits a packet to the slave and the slave responds with a packet. The end of a packet is marked by 'dead-time' on the communications line. The following describes general format for both transmit and receive packets. For exact details on packet formatting, refer to subsequent sections describing each function code.

**Table B-1: MODBUS PACKET FORMAT**

| DESCRIPTION   | SIZE                        |
|---------------|-----------------------------|
| SLAVE ADDRESS | 1 byte                      |
| FUNCTION CODE | 1 byte                      |
| DATA          | N bytes                     |
| CRC           | 2 bytes                     |
| DEAD TIME     | 3.5 bytes transmission time |

- **SLAVE ADDRESS:** This is the address of the slave device that is intended to receive the packet sent by the master and to perform the desired action. Each slave device on a communications bus must have a unique address to prevent bus contention. All of the relay's ports have the same address which is programmable from 1 to 254; see Chapter 5 for details. Only the addressed slave will respond to a packet that starts with its address. Note that the faceplate port is an exception to this rule; it will act on a message containing any slave address.

A master transmit packet with slave address 0 indicates a broadcast command. All slaves on the communication link take action based on the packet, but none respond to the master. Broadcast mode is only recognized when associated with Function Code 05h. For any other function code, a packet with broadcast mode slave address 0 will be ignored.

- **FUNCTION CODE:** This is one of the supported functions codes of the unit which tells the slave what action to perform. See the Supported Function Codes section for complete details. An exception response from the slave is indicated by setting the high order bit of the function code in the response packet. See the Exception Responses section for further details.
- **DATA:** This will be a variable number of bytes depending on the function code. This may include actual values, settings, or addresses sent by the master to the slave or by the slave to the master.
- **CRC:** This is a two byte error checking code. The RTU version of Modbus® includes a 16-bit cyclic redundancy check (CRC-16) with every packet which is an industry standard method used for error detection. If a Modbus slave device receives a packet in which an error is indicated by the CRC, the slave device will not act upon or respond to the packet thus preventing any erroneous operations. See the CRC-16 Algorithm section for details on calculating the CRC.
- **DEAD TIME:** A packet is terminated when no data is received for a period of 3.5 byte transmission times (about 15 ms at 2400 bps, 2 ms at 19200 bps, and 300  $\mu$ s at 115200 bps). Consequently, the transmitting device must not allow gaps between bytes longer than this interval. Once the dead time has expired without a new byte transmission, all slaves start listening for a new packet from the master except for the addressed slave.

#### B.1.4 CRC-16 ALGORITHM

The CRC-16 algorithm essentially treats the entire data stream (data bits only; start, stop and parity ignored) as one continuous binary number. This number is first shifted left 16 bits and then divided by a characteristic polynomial (11000000000000101B). The 16 bit remainder of the division is appended to the end of the packet, MSByte first. The resulting packet including CRC, when divided by the same polynomial at the receiver will give a zero remainder if no transmission errors have occurred. This algorithm requires the characteristic polynomial to be reverse bit ordered. The most significant bit of the characteristic polynomial is dropped, since it does not affect the value of the remainder.

A C programming language implementation of the CRC algorithm will be provided upon request.

**Table B-2: CRC-16 ALGORITHM**

|            |                   |  |   |
|------------|-------------------|--|---|
| SYMBOLS:   | -->               | data transfer  |   |
|            | A                 | 16 bit working register  |   |
|            | A <sub>low</sub>  | low order byte of A  |   |
|            | A <sub>high</sub> | high order byte of A   |   |
|            | CRC               | 16 bit CRC-16 result   |   |
|            | i,j               | loop counters  |   |
|            | (+)               | logical EXCLUSIVE-OR operator  |   |
|            | N                 | total number of data bytes   |   |
|            | D <sub>i</sub>    | i-th data byte (i = 0 to N-1)  |   |
|            | G                 | 16 bit characteristic polynomial = 1010000000000001 (binary) with MSbit dropped and bit order reversed   |   |
|            | shr (x)           | right shift operator (th LSbit of x is shifted into a carry flag, a '0' is shifted into the MSbit of x, all other bits are shifted right one location) |   |
| ALGORITHM: | 1.                | FFFF (hex) --> A   |   |
|            | 2.                | 0 --> i  |   |
|            | 3.                | 0 --> j  |   |
|            | 4.                | D <sub>i</sub> (+) A <sub>low</sub> --> A <sub>low</sub>   |   |
|            | 5.                | j + 1 --> j  |   |
|            | 6.                | shr (A)  |   |
|            | 7.                | Is there a carry?  | No: go to 8; Yes: G (+) A --> A and continue. |
|            | 8.                | Is j = 8?  | No: go to 5; Yes: continue                    |
|            | 9.                | i + 1 --> i  |   |
|            | 10.               | Is i = N?  | No: go to 3; Yes: continue                    |
|            | 11.               | A --> CRC  |   |



## B.2.1 SUPPORTED FUNCTION CODES

Modbus<sup>®</sup> officially defines function codes from 1 to 127 though only a small subset is generally needed. The relay supports some of these functions, as summarized in the following table. Subsequent sections describe each function code in detail.

| FUNCTION CODE |     | MODBUS DEFINITION         | GE MULTILIN DEFINITION         |
|---------------|-----|---------------------------|--------------------------------|
| HEX           | DEC |                           |                                |
| 03            | 3   | Read Holding Registers    | Read Actual Values or Settings |
| 04            | 4   | Read Holding Registers    | Read Actual Values or Settings |
| 05            | 5   | Force Single Coil         | Execute Operation              |
| 06            | 6   | Preset Single Register    | Store Single Setting           |
| 10            | 16  | Preset Multiple Registers | Store Multiple Settings        |

## B.2.2 READ ACTUAL VALUES OR SETTINGS (FUNCTION CODE 03/04H)

This function code allows the master to read one or more consecutive data registers (actual values or settings) from a relay. Data registers are always 16 bit (two byte) values transmitted with high order byte first. The maximum number of registers that can be read in a single packet is 125. See the Modbus Memory Map table for exact details on the data registers.

Since some PLC implementations of Modbus<sup>®</sup> only support one of function codes 03h and 04h, the relay interpretation allows either function code to be used for reading one or more consecutive data registers. The data starting address will determine the type of data being read. Function codes 03h and 04h are therefore identical.

The following table shows the format of the master and slave packets. The example shows a master device requesting 3 register values starting at address 4050h from slave device 11h (17 decimal); the slave device responds with the values 40, 300, and 0 from registers 4050h, 4051h, and 4052h, respectively.

Table B-3: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE

| MASTER TRANSMISSION          |               | SLAVE RESPONSE |               |
|------------------------------|---------------|----------------|---------------|
| PACKET FORMAT                | EXAMPLE (HEX) | PACKET FORMAT  | EXAMPLE (HEX) |
| SLAVE ADDRESS                | 11            | SLAVE ADDRESS  | 11            |
| FUNCTION CODE                | 04            | FUNCTION CODE  | 04            |
| DATA STARTING ADDRESS - high | 40            | BYTE COUNT     | 06            |
| DATA STARTING ADDRESS - low  | 50            | DATA #1 - high | 00            |
| NUMBER OF REGISTERS - high   | 00            | DATA #1 - low  | 28            |
| NUMBER OF REGISTERS - low    | 03            | DATA #2 - high | 01            |
| CRC - low                    | A7            | DATA #2 - low  | 2C            |
| CRC - high                   | 4A            | DATA #3 - high | 00            |
|                              |               | DATA #3 - low  | 00            |
|                              |               | CRC - low      | 0D            |
|                              |               | CRC - high     | 60            |

**B.2.3 EXECUTE OPERATION (FUNCTION CODE 05H)**

This function code allows the master to perform various operations in the relay. Available operations are shown in the Summary of Operation Codes table below.

The following table shows the format of the master and slave packets. The example shows a master device requesting the slave device 11H (17 dec) to perform a reset. The high and low Code Value bytes always have the values “FF” and “00” respectively and are a remnant of the original Modbus<sup>®</sup> definition of this function code.

**Table B–4: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION   |               | SLAVE RESPONSE        |               |
|-----------------------|---------------|-----------------------|---------------|
| PACKET FORMAT         | EXAMPLE (HEX) | PACKET FORMAT         | EXAMPLE (HEX) |
| SLAVE ADDRESS         | 11            | SLAVE ADDRESS         | 11            |
| FUNCTION CODE         | 05            | FUNCTION CODE         | 05            |
| OPERATION CODE - high | 00            | OPERATION CODE - high | 00            |
| OPERATION CODE - low  | 01            | OPERATION CODE - low  | 01            |
| CODE VALUE - high     | FF            | CODE VALUE - high     | FF            |
| CODE VALUE - low      | 00            | CODE VALUE - low      | 00            |
| CRC - low             | DF            | CRC - low             | DF            |
| CRC - high            | 6A            | CRC - high            | 6A            |

**Table B–5: SUMMARY OF OPERATION CODES FOR FUNCTION 05H**

| OPERATION CODE (HEX) | DEFINITION             | DESCRIPTION  |
|----------------------|------------------------|--|
| 0000                 | NO OPERATION           | Does not do anything.  |
| 0001                 | RESET                  | Performs the same function as the faceplate RESET key.                               |
| 0005                 | CLEAR EVENT RECORDS    | Performs the same function as the faceplate <b>CLEAR EVENT RECORDS</b> menu command. |
| 0006                 | CLEAR OSCILLOGRAPHY    | Clears all oscillography records.  |
| 1000 to 101F         | VIRTUAL IN 1-32 ON/OFF | Sets the states of Virtual Inputs 1 to 32 either “ON” or “OFF”.                      |

**B.2.4 STORE SINGLE SETTING (FUNCTION CODE 06H)**

This function code allows the master to modify the contents of a single setting register in an relay. Setting registers are always 16 bit (two byte) values transmitted high order byte first. The following table shows the format of the master and slave packets. The example shows a master device storing the value 200 at memory map address 4051h to slave device 11h (17 dec).

**Table B–6: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION          |               | SLAVE RESPONSE               |               |
|------------------------------|---------------|------------------------------|---------------|
| PACKET FORMAT                | EXAMPLE (HEX) | PACKET FORMAT                | EXAMPLE (HEX) |
| SLAVE ADDRESS                | 11            | SLAVE ADDRESS                | 11            |
| FUNCTION CODE                | 06            | FUNCTION CODE                | 06            |
| DATA STARTING ADDRESS - high | 40            | DATA STARTING ADDRESS - high | 40            |
| DATA STARTING ADDRESS - low  | 51            | DATA STARTING ADDRESS - low  | 51            |
| DATA - high                  | 00            | DATA - high                  | 00            |
| DATA - low                   | C8            | DATA - low                   | C8            |
| CRC - low                    | CE            | CRC - low                    | CE            |
| CRC - high                   | DD            | CRC - high                   | DD            |

**B.2.5 STORE MULTIPLE SETTINGS (FUNCTION CODE 10H)**

This function code allows the master to modify the contents of a one or more consecutive setting registers in a relay. Setting registers are 16-bit (two byte) values transmitted high order byte first. The maximum number of setting registers that can be stored in a single packet is 60. The following table shows the format of the master and slave packets. The example shows a master device storing the value 200 at memory map address 4051h, and the value 1 at memory map address 4052h to slave device 11h (17 decimal).

**Table B-7: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION        |               | SLAVE RESPONSE             |               |
|----------------------------|---------------|----------------------------|---------------|
| PACKET FORMAT              | EXAMPLE (HEX) | PACKET FORMAT              | EXAMPLE (HEX) |
| SLAVE ADDRESS              | 11            | SLAVE ADDRESS              | 11            |
| FUNCTION CODE              | 10            | FUNCTION CODE              | 10            |
| DATA STARTING ADDRESS - hi | 40            | DATA STARTING ADDRESS - hi | 40            |
| DATA STARTING ADDRESS - lo | 51            | DATA STARTING ADDRESS - lo | 51            |
| NUMBER OF SETTINGS - hi    | 00            | NUMBER OF SETTINGS - hi    | 00            |
| NUMBER OF SETTINGS - lo    | 02            | NUMBER OF SETTINGS - lo    | 02            |
| BYTE COUNT                 | 04            | CRC - lo                   | 07            |
| DATA #1 - high order byte  | 00            | CRC - hi                   | 64            |
| DATA #1 - low order byte   | C8            |                            |               |
| DATA #2 - high order byte  | 00            |                            |               |
| DATA #2 - low order byte   | 01            |                            |               |
| CRC - low order byte       | 12            |                            |               |
| CRC - high order byte      | 62            |                            |               |

**B.2.6 EXCEPTION RESPONSES**

Programming or operation errors usually happen because of illegal data in a packet. These errors result in an exception response from the slave. The slave detecting one of these errors sends a response packet to the master with the high order bit of the function code set to 1.

The following table shows the format of the master and slave packets. The example shows a master device sending the unsupported function code 39h to slave device 11.

**Table B-8: MASTER AND SLAVE DEVICE PACKET TRANSMISSION EXAMPLE**

| MASTER TRANSMISSION   |               | SLAVE RESPONSE        |               |
|-----------------------|---------------|-----------------------|---------------|
| PACKET FORMAT         | EXAMPLE (HEX) | PACKET FORMAT         | EXAMPLE (HEX) |
| SLAVE ADDRESS         | 11            | SLAVE ADDRESS         | 11            |
| FUNCTION CODE         | 39            | FUNCTION CODE         | B9            |
| CRC - low order byte  | CD            | ERROR CODE            | 01            |
| CRC - high order byte | F2            | CRC - low order byte  | 93            |
|                       |               | CRC - high order byte | 95            |

## B.3.1 OBTAINING RELAY FILES VIA MODBUS

## a) DESCRIPTION

The UR relay has a generic file transfer facility, meaning that you use the same method to obtain all of the different types of files from the unit. The Modbus registers that implement file transfer are found in the "Modbus File Transfer (Read/Write)" and "Modbus File Transfer (Read Only)" modules, starting at address 3100 in the Modbus Memory Map. To read a file from the UR relay, use the following steps:

1. Write the filename to the "Name of file to read" register using a write multiple registers command. If the name is shorter than 80 characters, you may write only enough registers to include all the text of the filename. Filenames are not case sensitive.
2. Repeatedly read all the registers in "Modbus File Transfer (Read Only)" using a read multiple registers command. It is not necessary to read the entire data block, since the UR relay will remember which was the last register you read. The "position" register is initially zero and thereafter indicates how many bytes (2 times the number of registers) you have read so far. The "size of..." register indicates the number of bytes of data remaining to read, to a maximum of 244.
3. Keep reading until the "size of..." register is smaller than the number of bytes you are transferring. This condition indicates end of file. Discard any bytes you have read beyond the indicated block size.
4. If you need to re-try a block, read only the "size of..." and "block of data", without reading the position. The file pointer is only incremented when you read the position register, so the same data block will be returned as was read in the previous operation. On the next read, check to see if the position is where you expect it to be, and discard the previous block if it is not (this condition would indicate that the UR relay did not process your original read request).

The UR relay retains connection-specific file transfer information, so files may be read simultaneously on multiple Modbus connections.

## b) OTHER PROTOCOLS

All the files available via Modbus may also be retrieved using the standard file transfer mechanisms in other protocols (for example, TFTP or MMS).

## c) COMTRADE, OSCILLOGRAPHY, AND DATA LOGGER FILES

Oscillography files are formatted using the COMTRADE file format per IEEE PC37.111 Draft 7c (02 September 1997). The files may be obtained in either text or binary COMTRADE format.

## d) READING OSCILLOGRAPHY FILES

Familiarity with the oscillography feature is required to understand the following description. Refer to the Oscillography section in Chapter 5 for additional details.

The Oscillography Number of Triggers register is incremented by one every time a new oscillography file is triggered (captured) and cleared to zero when oscillography data is cleared. When a new trigger occurs, the associated oscillography file is assigned a file identifier number equal to the incremented value of this register; the newest file number is equal to the Oscillography\_Number\_of\_Triggers register. This register can be used to determine if any new data has been captured by periodically reading it to see if the value has changed; if the number has increased then new data is available.

The Oscillography Number of Records register specifies the maximum number of files (and the number of cycles of data per file) that can be stored in memory of the relay. The Oscillography Available Records register specifies the actual number of files that are stored and still available to be read out of the relay.

Writing "Yes" (i.e. the value 1) to the Oscillography Clear Data register clears oscillography data files, clears both the Oscillography Number of Triggers and Oscillography Available Records registers to zero, and sets the Oscillography Last Cleared Date to the present date and time.

To read binary COMTRADE oscillography files, read the following filenames:

OSCnnnn.CFG and OSCnnn.DAT

Replace "nnn" with the desired oscillography trigger number. For ASCII format, use the following file names

OSCAnnnn.CFG and OSCAnnn.DAT

### e) READING DATA LOGGER FILES

Familiarity with the data logger feature is required to understand this description. Refer to the Data Logger section of Chapter 5 for details. To read the entire data logger in binary COMTRADE format, read the following files.

`datalog.cfg` and `datalog.dat`

To read the entire data logger in ASCII COMTRADE format, read the following files.

`dataloga.cfg` and `dataloga.dat`

To limit the range of records to be returned in the COMTRADE files, append the following to the filename before writing it:

- To read from a specific time to the end of the log: `<space> startTime`
- To read a specific range of records: `<space> startTime <space> endTime`
- Replace `<startTime>` and `<endTime>` with Julian dates (seconds since Jan. 1 1970) as numeric text.

### f) READING EVENT RECORDER FILES

To read the entire event recorder contents in ASCII format (the only available format), use the following filename:

`EVT.TXT`

To read from a specific record to the end of the log, use the following filename:

`EVTnnn.TXT` (replace `nnn` with the desired starting record number)

To read from a specific record to another specific record, use the following filename:

`EVT.TXT xxxxx yyyyy` (replace `xxxxx` with the starting record number and `yyyyy` with the ending record number)

### g) READING FAULT REPORT FILES

Fault report data has been available via the D30 file retrieval mechanism since UR firmware version 2.00. The file name is `faultReport#####.htm`. The `#####` refers to the fault report record number. The fault report number is a counter that indicates how many fault reports have ever occurred. The counter rolls over at a value of 65535. Only the last ten fault reports are available for retrieval; a request for a non-existent fault report file will yield a null file. The current value fault report counter is available in "Number of Fault Reports" Modbus register at location 0x3020.

For example, if 14 fault reports have occurred then the files `faultReport5.htm`, `faultReport6.htm`, up to `faultReport14.htm` are available to be read. The expected use of this feature has an external master periodically polling the "Number of Fault Reports" register. If the value changes, then the master reads all the new files.

The contents of the file is in standard HTML notation and can be viewed via any commercial browser.

## B.3.2 MODBUS PASSWORD OPERATION

The COMMAND password is set up at memory location 4000. Storing a value of "0" removes COMMAND password protection. When reading the password setting, the encrypted value (zero if no password is set) is returned. COMMAND security is required to change the COMMAND password. Similarly, the SETTING password is set up at memory location 4002. These are the same settings and encrypted values found in the **SETTINGS** ⇒ **PRODUCT SETUP** ⇒ **PASSWORD SECURITY** menu via the keypad. Enabling password security for the faceplate display will also enable it for Modbus, and vice-versa.

To gain COMMAND level security access, the COMMAND password must be entered at memory location 4008. To gain SETTING level security access, the SETTING password must be entered at memory location 400A. The entered SETTING password must match the current SETTING password setting, or must be zero, to change settings or download firmware.

COMMAND and SETTING passwords each have a 30-minute timer. Each timer starts when you enter the particular password, and is re-started whenever you "use" it. For example, writing a setting re-starts the SETTING password timer and writing a command register or forcing a coil re-starts the COMMAND password timer. The value read at memory location 4010 can be used to confirm whether a COMMAND password is enabled or disabled (0 for Disabled). The value read at memory location 4011 can be used to confirm whether a SETTING password is enabled or disabled.

COMMAND or SETTING password security access is restricted to the particular port or particular TCP/IP connection on which the entry was made. Passwords must be entered when accessing the relay through other ports or connections, and the passwords must be re-entered after disconnecting and re-connecting on TCP/IP.

## B.4.1 MODBUS MEMORY MAP

Table B–9: MODBUS MEMORY MAP (Sheet 1 of 38)

| ADDR  | REGISTER NAME  | RANGE           | UNITS | STEP | FORMAT | DEFAULT                             |
|---|--|-----------------|-------|------|--------|-------------------------------------|
| <b>Product Information (Read Only)</b>                          |  |                 |       |      |        |                                     |
| 0000  | UR Product Type  | 0 to 65535      | ---   | 1    | F001   | 0                                   |
| 0002  | Product Version  | 0 to 655.35     | ---   | 0.01 | F001   | 1                                   |
| <b>Product Information (Read Only -- Written by Factory)</b>    |  |                 |       |      |        |                                     |
| 0010  | Serial Number  | ---             | ---   | ---  | F203   | "0"                                 |
| 0020  | Manufacturing Date                                     | 0 to 4294967295 | ---   | 1    | F050   | 0                                   |
| 0022  | Modification Number                                    | 0 to 65535      | ---   | 1    | F001   | 0                                   |
| 0040  | Order Code   | ---             | ---   | ---  | F204   | "Order Code x"                      |
| 0090  | Ethernet MAC Address                                   | ---             | ---   | ---  | F072   | 0                                   |
| 0093  | Reserved (13 items)                                    | ---             | ---   | ---  | F001   | 0                                   |
| 00A0  | CPU Module Serial Number                               | ---             | ---   | ---  | F203   | (none)                              |
| 00B0  | CPU Supplier Serial Number                             | ---             | ---   | ---  | F203   | (none)                              |
| 00C0  | Ethernet Sub Module Serial Number (8 items)            | ---             | ---   | ---  | F203   | (none)                              |
| <b>Self Test Targets (Read Only)</b>                            |  |                 |       |      |        |                                     |
| 0200  | Self Test States (2 items)                             | 0 to 4294967295 | 0     | 1    | F143   | 0                                   |
| <b>Front Panel (Read Only)</b>                                  |  |                 |       |      |        |                                     |
| 0204  | LED Column x State (10 items)                          | 0 to 65535      | ---   | 1    | F501   | 0                                   |
| 0220  | Display Message  | ---             | ---   | ---  | F204   | (none)                              |
| 0248  | Last Key Pressed                                       | 0 to 47         | ---   | 1    | F530   | 0 (None)                            |
| <b>Keypress Emulation (Read/Write)</b>                          |  |                 |       |      |        |                                     |
| 0280  | Simulated keypress -- write zero before each keystroke | 0 to 42         | ---   | 1    | F190   | 0 (No key -- use between real keys) |
| <b>Virtual Input Commands (Read/Write Command) (32 modules)</b> |  |                 |       |      |        |                                     |
| 0400  | Virtual Input 1 State                                  | 0 to 1          | ---   | 1    | F108   | 0 (Off)                             |
| 0401  | ...Repeated for module number 2                        |                 |       |      |        |                                     |
| 0402  | ...Repeated for module number 3                        |                 |       |      |        |                                     |
| 0403  | ...Repeated for module number 4                        |                 |       |      |        |                                     |
| 0404  | ...Repeated for module number 5                        |                 |       |      |        |                                     |
| 0405  | ...Repeated for module number 6                        |                 |       |      |        |                                     |
| 0406  | ...Repeated for module number 7                        |                 |       |      |        |                                     |
| 0407  | ...Repeated for module number 8                        |                 |       |      |        |                                     |
| 0408  | ...Repeated for module number 9                        |                 |       |      |        |                                     |
| 0409  | ...Repeated for module number 10                       |                 |       |      |        |                                     |
| 040A  | ...Repeated for module number 11                       |                 |       |      |        |                                     |
| 040B  | ...Repeated for module number 12                       |                 |       |      |        |                                     |
| 040C  | ...Repeated for module number 13                       |                 |       |      |        |                                     |
| 040D  | ...Repeated for module number 14                       |                 |       |      |        |                                     |
| 040E  | ...Repeated for module number 15                       |                 |       |      |        |                                     |
| 040F  | ...Repeated for module number 16                       |                 |       |      |        |                                     |
| 0410  | ...Repeated for module number 17                       |                 |       |      |        |                                     |
| 0411  | ...Repeated for module number 18                       |                 |       |      |        |                                     |
| 0412  | ...Repeated for module number 19                       |                 |       |      |        |                                     |
| 0413  | ...Repeated for module number 20                       |                 |       |      |        |                                     |
| 0414  | ...Repeated for module number 21                       |                 |       |      |        |                                     |
| 0415  | ...Repeated for module number 22                       |                 |       |      |        |                                     |
| 0416  | ...Repeated for module number 23                       |                 |       |      |        |                                     |
| 0417  | ...Repeated for module number 24                       |                 |       |      |        |                                     |
| 0418  | ...Repeated for module number 25                       |                 |       |      |        |                                     |
| 0419  | ...Repeated for module number 26                       |                 |       |      |        |                                     |
| 041A  | ...Repeated for module number 27                       |                 |       |      |        |                                     |
| 041B  | ...Repeated for module number 28                       |                 |       |      |        |                                     |

Table B-9: MODBUS MEMORY MAP (Sheet 2 of 38)

| ADDR   | REGISTER NAME                                | RANGE                     | UNITS | STEP | FORMAT | DEFAULT |
|--|--|---------------------------|-------|------|--------|---------|
| 041C   | ...Repeated for module number 29             |                           |       |      |        |         |
| 041D   | ...Repeated for module number 30             |                           |       |      |        |         |
| 041E   | ...Repeated for module number 31             |                           |       |      |        |         |
| 041F   | ...Repeated for module number 32             |                           |       |      |        |         |
| <b>Digital Counter States (Read Only Non-Volatile) (8 modules)</b> |  |                           |       |      |        |         |
| 0800   | Digital Counter 1 Value                      | -2147483647 to 2147483647 | ---   | 1    | F004   | 0       |
| 0802   | Digital Counter 1 Frozen                     | -2147483647 to 2147483647 | ---   | 1    | F004   | 0       |
| 0804   | Digital Counter 1 Frozen Time Stamp          | 0 to 4294967295           | ---   | 1    | F050   | 0       |
| 0806   | Digital Counter 1 Frozen Time Stamp us       | 0 to 4294967295           | ---   | 1    | F003   | 0       |
| 0808   | ...Repeated for module number 2              |                           |       |      |        |         |
| 0810   | ...Repeated for module number 3              |                           |       |      |        |         |
| 0818   | ...Repeated for module number 4              |                           |       |      |        |         |
| 0820   | ...Repeated for module number 5              |                           |       |      |        |         |
| 0828   | ...Repeated for module number 6              |                           |       |      |        |         |
| 0830   | ...Repeated for module number 7              |                           |       |      |        |         |
| 0838   | ...Repeated for module number 8              |                           |       |      |        |         |
| <b>FlexStates (Read Only)</b>                                      |  |                           |       |      |        |         |
| 0900   | FlexState Bits (16 items)                    | 0 to 65535                | ---   | 1    | F001   | 0       |
| <b>Element States (Read Only)</b>                                  |  |                           |       |      |        |         |
| 1000   | Element Operate States (64 items)            | 0 to 65535                | ---   | 1    | F502   | 0       |
| <b>User Displays Actuals (Read Only)</b>                           |  |                           |       |      |        |         |
| 1080   | Formatted user-definable displays (16 items) | ---                       | ---   | ---  | F200   | (none)  |
| <b>Modbus User Map Actuals (Read Only)</b>                         |  |                           |       |      |        |         |
| 1200   | User Map Values (256 items)                  | 0 to 65535                | ---   | 1    | F001   | 0       |
| <b>Element Targets (Read Only)</b>                                 |  |                           |       |      |        |         |
| 14C0   | Target Sequence                              | 0 to 65535                | ---   | 1    | F001   | 0       |
| 14C1   | Number of Targets                            | 0 to 65535                | ---   | 1    | F001   | 0       |
| <b>Element Targets (Read/Write)</b>                                |  |                           |       |      |        |         |
| 14C2   | Target to Read                               | 0 to 65535                | ---   | 1    | F001   | 0       |
| <b>Element Targets (Read Only)</b>                                 |  |                           |       |      |        |         |
| 14C3   | Target Message                               | ---                       | ---   | ---  | F200   | " "     |
| <b>Digital I/O States (Read Only)</b>                              |  |                           |       |      |        |         |
| 1500   | Contact Input States (6 items)               | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1508   | Virtual Input States (2 items)               | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1510   | Contact Output States (4 items)              | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1518   | Contact Output Current States (4 items)      | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1520   | Contact Output Voltage States (4 items)      | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1528   | Virtual Output States (4 items)              | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1530   | Contact Output Detectors (4 items)           | 0 to 65535                | ---   | 1    | F500   | 0       |
| <b>Remote Input/Output States (Read Only)</b>                      |  |                           |       |      |        |         |
| 1540   | Remote Device 1 States                       | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1542   | Remote Input States (4 items)                | 0 to 65535                | ---   | 1    | F500   | 0       |
| 1550   | Remote Devices Online                        | 0 to 1                    | ---   | 1    | F126   | 0 (No)  |
| <b>Remote Device Status (Read Only) (16 modules)</b>               |  |                           |       |      |        |         |
| 1551   | Remote Device 1 StNum                        | 0 to 4294967295           | ---   | 1    | F003   | 0       |
| 1553   | Remote Device 1 SqNum                        | 0 to 4294967295           | ---   | 1    | F003   | 0       |
| 1555   | ...Repeated for module number 2              |                           |       |      |        |         |
| 1559   | ...Repeated for module number 3              |                           |       |      |        |         |
| 155D   | ...Repeated for module number 4              |                           |       |      |        |         |
| 1561   | ...Repeated for module number 5              |                           |       |      |        |         |
| 1565   | ...Repeated for module number 6              |                           |       |      |        |         |
| 1569   | ...Repeated for module number 7              |                           |       |      |        |         |
| 156D   | ...Repeated for module number 8              |                           |       |      |        |         |

Table B-9: MODBUS MEMORY MAP (Sheet 3 of 38)

| ADDR   | REGISTER NAME  | RANGE           | UNITS   | STEP  | FORMAT | DEFAULT  |
|--|--|-----------------|---------|-------|--------|----------|
| 1571   | ...Repeated for module number 9                        |                 |         |       |        |          |
| 1575   | ...Repeated for module number 10                       |                 |         |       |        |          |
| 1579   | ...Repeated for module number 11                       |                 |         |       |        |          |
| 157D   | ...Repeated for module number 12                       |                 |         |       |        |          |
| 1581   | ...Repeated for module number 13                       |                 |         |       |        |          |
| 1585   | ...Repeated for module number 14                       |                 |         |       |        |          |
| 1589   | ...Repeated for module number 15                       |                 |         |       |        |          |
| 158D   | ...Repeated for module number 16                       |                 |         |       |        |          |
| <b>Platform Direct Input/Output States (Read Only)</b> |  |                 |         |       |        |          |
| 15C0   | Direct Input States (6 items)                          | 0 to 65535      | ---     | 1     | F500   | 0        |
| 15C8   | Direct Outputs Average Message Return Time 1           | 0 to 65535      | ms      | 1     | F001   | 0        |
| 15C9   | Direct Outputs Average Message Return Time 2           | 0 to 65535      | ms      | 1     | F001   | 0        |
| 15CA   | Direct Inputs/Outputs Unreturned Message Count - Ch. 1 | 0 to 65535      | ---     | 1     | F001   | 0        |
| 15CB   | Direct Inputs/Outputs Unreturned Message Count - Ch. 2 | 0 to 65535      | ---     | 1     | F001   | 0        |
| 15D0   | Direct Device States                                   | 0 to 65535      | ---     | 1     | F500   | 0        |
| 15D1   | Reserved   | 0 to 65535      | ---     | 1     | F001   | 0        |
| 15D2   | Direct Inputs/Outputs CRC Fail Count 1                 | 0 to 65535      | ---     | 1     | F001   | 0        |
| 15D3   | Direct Inputs/Outputs CRC Fail Count 2                 | 0 to 65535      | ---     | 1     | F001   | 0        |
| <b>Ethernet Fibre Channel Status (Read/Write)</b>      |  |                 |         |       |        |          |
| 1610   | Ethernet Primary Fibre Channel Status                  | 0 to 2          | ---     | 1     | F134   | 0 (Fail) |
| 1611   | Ethernet Secondary Fibre Channel Status                | 0 to 2          | ---     | 1     | F134   | 0 (Fail) |
| <b>Source Current (Read Only) (6 modules)</b>          |  |                 |         |       |        |          |
| 1800   | Phase A Current RMS                                    | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1802   | Phase B Current RMS                                    | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1804   | Phase C Current RMS                                    | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1806   | Neutral Current RMS                                    | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1808   | Phase A Current Magnitude                              | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 180A   | Phase A Current Angle                                  | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 180B   | Phase B Current Magnitude                              | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 180D   | Phase B Current Angle                                  | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 180E   | Phase C Current Magnitude                              | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1810   | Phase C Current Angle                                  | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 1811   | Neutral Current Magnitude                              | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1813   | Neutral Current Angle                                  | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 1814   | Ground Current RMS                                     | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1816   | Ground Current Magnitude                               | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1818   | Ground Current Angle                                   | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 1819   | Zero Sequence Current Magnitude                        | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 181B   | Zero Sequence Current Angle                            | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 181C   | Positive Sequence Current Magnitude                    | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 181E   | Positive Sequence Current Angle                        | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 181F   | Negative Sequence Current Magnitude                    | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1821   | Negative Sequence Current Angle                        | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 1822   | Differential Ground Current Magnitude                  | 0 to 999999.999 | A       | 0.001 | F060   | 0        |
| 1824   | Differential Ground Current Angle                      | -359.9 to 0     | degrees | 0.1   | F002   | 0        |
| 1825   | Reserved (27 items)                                    | ---             | ---     | ---   | F001   | 0        |
| 1840   | ...Repeated for module number 2                        |                 |         |       |        |          |
| 1880   | ...Repeated for module number 3                        |                 |         |       |        |          |
| 18C0   | ...Repeated for module number 4                        |                 |         |       |        |          |
| 1900   | ...Repeated for module number 5                        |                 |         |       |        |          |
| 1940   | ...Repeated for module number 6                        |                 |         |       |        |          |
| <b>Source Voltage (Read Only) (6 modules)</b>          |  |                 |         |       |        |          |
| 1A00   | Phase AG Voltage RMS                                   | 0 to 999999.999 | V       | 0.001 | F060   | 0        |
| 1A02   | Phase BG Voltage RMS                                   | 0 to 999999.999 | V       | 0.001 | F060   | 0        |



Table B-9: MODBUS MEMORY MAP (Sheet 4 of 38)

| ADDR  | REGISTER NAME                       | RANGE                           | UNITS   | STEP  | FORMAT | DEFAULT |
|---|-------------------------------------|---------------------------------|---------|-------|--------|---------|
| 1A04  | Phase CG Voltage RMS                | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A06  | Phase AG Voltage Magnitude          | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A08  | Phase AG Voltage Angle              | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A09  | Phase BG Voltage Magnitude          | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A0B  | Phase BG Voltage Angle              | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A0C  | Phase CG Voltage Magnitude          | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A0E  | Phase CG Voltage Angle              | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A0F  | Phase AB or AC Voltage RMS          | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A11  | Phase BC or BA Voltage RMS          | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A13  | Phase CA or CB Voltage RMS          | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A15  | Phase AB or AC Voltage Magnitude    | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A17  | Phase AB or AC Voltage Angle        | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A18  | Phase BC or BA Voltage Magnitude    | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A1A  | Phase BC or BA Voltage Angle        | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A1B  | Phase CA or CB Voltage Magnitude    | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A1D  | Phase CA or CB Voltage Angle        | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A1E  | Auxiliary Voltage RMS               | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A20  | Auxiliary Voltage Magnitude         | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A22  | Auxiliary Voltage Angle             | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A23  | Zero Sequence Voltage Magnitude     | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A25  | Zero Sequence Voltage Angle         | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A26  | Positive Sequence Voltage Magnitude | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A28  | Positive Sequence Voltage Angle     | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A29  | Negative Sequence Voltage Magnitude | 0 to 999999.999                 | V       | 0.001 | F060   | 0       |
| 1A2B  | Negative Sequence Voltage Angle     | -359.9 to 0                     | degrees | 0.1   | F002   | 0       |
| 1A2C  | Reserved (20 items)                 | ---                             | ---     | ---   | F001   | 0       |
| 1A40  | ...Repeated for module number 2     |                                 |         |       |        |         |
| 1A80  | ...Repeated for module number 3     |                                 |         |       |        |         |
| 1AC0  | ...Repeated for module number 4     |                                 |         |       |        |         |
| 1B00  | ...Repeated for module number 5     |                                 |         |       |        |         |
| 1B40  | ...Repeated for module number 6     |                                 |         |       |        |         |
| <b>Source Power (Read Only) (6 modules)</b> |                                     |                                 |         |       |        |         |
| 1C00  | Three Phase Real Power              | -1000000000000 to 1000000000000 | W       | 0.001 | F060   | 0       |
| 1C02  | Phase A Real Power                  | -1000000000000 to 1000000000000 | W       | 0.001 | F060   | 0       |
| 1C04  | Phase B Real Power                  | -1000000000000 to 1000000000000 | W       | 0.001 | F060   | 0       |
| 1C06  | Phase C Real Power                  | -1000000000000 to 1000000000000 | W       | 0.001 | F060   | 0       |
| 1C08  | Three Phase Reactive Power          | -1000000000000 to 1000000000000 | var     | 0.001 | F060   | 0       |
| 1C0A  | Phase A Reactive Power              | -1000000000000 to 1000000000000 | var     | 0.001 | F060   | 0       |
| 1C0C  | Phase B Reactive Power              | -1000000000000 to 1000000000000 | var     | 0.001 | F060   | 0       |
| 1C0E  | Phase C Reactive Power              | -1000000000000 to 1000000000000 | var     | 0.001 | F060   | 0       |
| 1C10  | Three Phase Apparent Power          | -1000000000000 to 1000000000000 | VA      | 0.001 | F060   | 0       |
| 1C12  | Phase A Apparent Power              | -1000000000000 to 1000000000000 | VA      | 0.001 | F060   | 0       |
| 1C14  | Phase B Apparent Power              | -1000000000000 to 1000000000000 | VA      | 0.001 | F060   | 0       |
| 1C16  | Phase C Apparent Power              | -1000000000000 to 1000000000000 | VA      | 0.001 | F060   | 0       |
| 1C18  | Three Phase Power Factor            | -0.999 to 1                     | ---     | 0.001 | F013   | 0       |
| 1C19  | Phase A Power Factor                | -0.999 to 1                     | ---     | 0.001 | F013   | 0       |

Table B-9: MODBUS MEMORY MAP (Sheet 5 of 38)

| ADDR   | REGISTER NAME                          | RANGE           | UNITS                | STEP  | FORMAT | DEFAULT |
|--|--|-----------------|----------------------|-------|--------|---------|
| 1C1A   | Phase B Power Factor                   | -0.999 to 1     | ---                  | 0.001 | F013   | 0       |
| 1C1B   | Phase C Power Factor                   | -0.999 to 1     | ---                  | 0.001 | F013   | 0       |
| 1C1C   | Reserved (4 items)                     | ---             | ---                  | ---   | F001   | 0       |
| 1C20   | ...Repeated for module number 2        |                 |                      |       |        |         |
| 1C40   | ...Repeated for module number 3        |                 |                      |       |        |         |
| 1C60   | ...Repeated for module number 4        |                 |                      |       |        |         |
| 1C80   | ...Repeated for module number 5        |                 |                      |       |        |         |
| 1CA0   | ...Repeated for module number 6        |                 |                      |       |        |         |
| <b>Source Frequency (Read Only) (6 modules)</b>                            |  |                 |                      |       |        |         |
| 1D80   | Frequency                              | 2 to 90         | Hz                   | 0.01  | F001   | 0       |
| 1D81   | ...Repeated for module number 2        |                 |                      |       |        |         |
| 1D82   | ...Repeated for module number 3        |                 |                      |       |        |         |
| 1D83   | ...Repeated for module number 4        |                 |                      |       |        |         |
| 1D84   | ...Repeated for module number 5        |                 |                      |       |        |         |
| 1D85   | ...Repeated for module number 6        |                 |                      |       |        |         |
| <b>Breaker Arcing Current Actuals (Read Only Non-Volatile) (2 modules)</b> |  |                 |                      |       |        |         |
| 21E0   | Breaker 1 Arcing Current Phase A       | 0 to 999999999  | kA <sup>2</sup> -cyc | 1     | F060   | 0       |
| 21E2   | Breaker 1 Arcing Current Phase B       | 0 to 999999999  | kA <sup>2</sup> -cyc | 1     | F060   | 0       |
| 21E4   | Breaker 1 Arcing Current Phase C       | 0 to 999999999  | kA <sup>2</sup> -cyc | 1     | F060   | 0       |
| 21E6   | Breaker 1 Operating Time Phase A       | 0 to 65535      | ms                   | 1     | F001   | 0       |
| 21E7   | Breaker 1 Operating Time Phase B       | 0 to 65535      | ms                   | 1     | F001   | 0       |
| 21E8   | Breaker 1 Operating Time Phase C       | 0 to 65535      | ms                   | 1     | F001   | 0       |
| 21E9   | Breaker 1 Operating Time               | 0 to 65535      | ms                   | 1     | F001   | 0       |
| 21E6   | ...Repeated for module number 2        |                 |                      |       |        |         |
| <b>Breaker Arcing Current Commands (Read/Write Command) (2 modules)</b>    |  |                 |                      |       |        |         |
| 2224   | Breaker 1 Arcing Current Clear Command | 0 to 1          | ---                  | 1     | F126   | 0 (No)  |
| 2225   | ...Repeated for module number 2        |                 |                      |       |        |         |
| <b>Passwords Unauthorized Access (Read/Write Command)</b>                  |  |                 |                      |       |        |         |
| 2230   | Reset Unauthorized Access              | 0 to 1          | ---                  | 1     | F126   | 0 (No)  |
| <b>Fault Location (Read Only) (5 modules)</b>                              |  |                 |                      |       |        |         |
| 2340   | Prefault Phase A Current Magnitude     | 0 to 999999.999 | A                    | 0.001 | F060   | 0       |
| 2342   | Prefault Phase A Current Angle         | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2343   | Prefault Phase B Current Magnitude     | 0 to 999999.999 | A                    | 0.001 | F060   | 0       |
| 2345   | Prefault Phase B Current Angle         | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2346   | Prefault Phase C Current Magnitude     | 0 to 999999.999 | A                    | 0.001 | F060   | 0       |
| 2348   | Prefault Phase C Current Angle         | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2349   | Prefault Phase A Voltage Magnitude     | 0 to 999999.999 | V                    | 0.001 | F060   | 0       |
| 234B   | Prefault Phase A Voltage Angle         | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 234C   | Prefault Phase B Voltage Magnitude     | 0 to 999999.999 | V                    | 0.001 | F060   | 0       |
| 234E   | Prefault Phase B Voltage Angle         | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 234F   | Prefault Phase C Voltage Magnitude     | 0 to 999999.999 | V                    | 0.001 | F060   | 0       |
| 2351   | Prefault Phase C Voltage Angle         | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2352   | Fault 1 Phase A Current Magnitude      | 0 to 999999.999 | A                    | 0.001 | F060   | 0       |
| 2354   | Fault 1 Phase A Current Angle          | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2355   | Fault 1 Phase B Current Magnitude      | 0 to 999999.999 | A                    | 0.001 | F060   | 0       |
| 2357   | Fault 1 Phase B Current Angle          | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2358   | Fault 1 Phase C Current Magnitude      | 0 to 999999.999 | A                    | 0.001 | F060   | 0       |
| 235A   | Fault 1 Phase C Current Angle          | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 235B   | Fault 1 Phase A Voltage Magnitude      | 0 to 999999.999 | V                    | 0.001 | F060   | 0       |
| 235D   | Fault 1 Phase A Voltage Angle          | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 235E   | Fault 1 Phase B Voltage Magnitude      | 0 to 999999.999 | V                    | 0.001 | F060   | 0       |
| 2360   | Fault 1 Phase B Voltage Angle          | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |
| 2361   | Fault 1 Phase C Voltage Magnitude      | 0 to 999999.999 | V                    | 0.001 | F060   | 0       |
| 2363   | Fault 1 Phase C Voltage Angle          | -359.9 to 0     | degrees              | 0.1   | F002   | 0       |

Table B-9: MODBUS MEMORY MAP (Sheet 6 of 38)

| ADDR  | REGISTER NAME   | RANGE                           | UNITS   | STEP | FORMAT | DEFAULT     |
|---|---|---------------------------------|---------|------|--------|-------------|
| 2364  | Fault Type  | 0 to 11                         | ---     | 1    | F148   | 0 (NA)      |
| 2365  | Fault Location based on Line length units (km or miles) | -3276.7 to 3276.7               | ---     | 0.1  | F002   | 0           |
| 2366  | ...Repeated for module number 2                         |                                 |         |      |        |             |
| 238C  | ...Repeated for module number 3                         |                                 |         |      |        |             |
| 23B2  | ...Repeated for module number 4                         |                                 |         |      |        |             |
| 23D8  | ...Repeated for module number 5                         |                                 |         |      |        |             |
| <b>Synchrocheck Actuals (Read Only) (2 modules)</b>               |   |                                 |         |      |        |             |
| 2400  | Synchrocheck 1 Delta Voltage                            | -1000000000000 to 1000000000000 | V       | 1    | F060   | 0           |
| 2402  | Synchrocheck 1 Delta Frequency                          | 0 to 655.35                     | Hz      | 0.01 | F001   | 0           |
| 2403  | Synchrocheck 1 Delta Phase                              | 0 to 359.9                      | degrees | 0.1  | F001   | 0           |
| 2404  | ...Repeated for module number 2                         |                                 |         |      |        |             |
| <b>Autoreclose Status (Read Only) (6 modules)</b>                 |   |                                 |         |      |        |             |
| 2410  | Autoreclose Count                                       | 0 to 65535                      | ---     | 1    | F001   | 0           |
| 2411  | ...Repeated for module number 2                         |                                 |         |      |        |             |
| 2412  | ...Repeated for module number 3                         |                                 |         |      |        |             |
| 2413  | ...Repeated for module number 4                         |                                 |         |      |        |             |
| 2414  | ...Repeated for module number 5                         |                                 |         |      |        |             |
| 2415  | ...Repeated for module number 6                         |                                 |         |      |        |             |
| <b>Source 1 Current THD (Read Only)</b>                           |   |                                 |         |      |        |             |
| 2780  | SRC 1 Ia THD  | 0 to 100                        | %       | 0.1  | F001   | 0           |
| 2781  | SRC 1 Ib THD  | 0 to 100                        | %       | 0.1  | F001   | 0           |
| 2782  | SRC 1 Ic THD  | 0 to 100                        | ---     | 0.1  | F001   | 0           |
| 2783  | SRC 1 In THD  | 0 to 100                        | ---     | 0.1  | F001   | 0           |
| <b>Expanded FlexStates (Read Only)</b>                            |   |                                 |         |      |        |             |
| 2B00  | FlexStates, one per register (256 items)                | 0 to 1                          | ---     | 1    | F108   | 0 (Off)     |
| <b>Expanded Digital Input/Output states (Read Only)</b>           |   |                                 |         |      |        |             |
| 2D00  | Contact Input States, one per register (96 items)       | 0 to 1                          | ---     | 1    | F108   | 0 (Off)     |
| 2D80  | Contact Output States, one per register (64 items)      | 0 to 1                          | ---     | 1    | F108   | 0 (Off)     |
| 2E00  | Virtual Output States, one per register (64 items)      | 0 to 1                          | ---     | 1    | F108   | 0 (Off)     |
| <b>Expanded Remote Input/Output Status (Read Only)</b>            |   |                                 |         |      |        |             |
| 2F00  | Remote Device States, one per register (16 items)       | 0 to 1                          | ---     | 1    | F155   | 0 (Offline) |
| 2F80  | Remote Input States, one per register (64 items)        | 0 to 1                          | ---     | 1    | F108   | 0 (Off)     |
| <b>Oscillography Values (Read Only)</b>                           |   |                                 |         |      |        |             |
| 3000  | Oscillography Number of Triggers                        | 0 to 65535                      | ---     | 1    | F001   | 0           |
| 3001  | Oscillography Available Records                         | 0 to 65535                      | ---     | 1    | F001   | 0           |
| 3002  | Oscillography Last Cleared Date                         | 0 to 400000000                  | ---     | 1    | F050   | 0           |
| 3004  | Oscillography Number Of Cycles Per Record               | 0 to 65535                      | ---     | 1    | F001   | 0           |
| <b>Oscillography Commands (Read/Write Command)</b>                |   |                                 |         |      |        |             |
| 3005  | Oscillography Force Trigger                             | 0 to 1                          | ---     | 1    | F126   | 0 (No)      |
| 3011  | Oscillography Clear Data                                | 0 to 1                          | ---     | 1    | F126   | 0 (No)      |
| <b>Fault Report Indexing (Read Only Non-Volatile)</b>             |   |                                 |         |      |        |             |
| 3020  | Number Of Fault Reports                                 | 0 to 65535                      | ---     | 1    | F001   | 0           |
| <b>Fault Report Actuals (Read Only Non-Volatile) (15 modules)</b> |   |                                 |         |      |        |             |
| 3030  | Fault Time  | 0 to 4294967295                 | ---     | 1    | F050   | 0           |
| 3032  | ...Repeated for module number 2                         |                                 |         |      |        |             |
| 3034  | ...Repeated for module number 3                         |                                 |         |      |        |             |
| 3036  | ...Repeated for module number 4                         |                                 |         |      |        |             |
| 3038  | ...Repeated for module number 5                         |                                 |         |      |        |             |
| 303A  | ...Repeated for module number 6                         |                                 |         |      |        |             |
| 303C  | ...Repeated for module number 7                         |                                 |         |      |        |             |
| 303E  | ...Repeated for module number 8                         |                                 |         |      |        |             |
| 3040  | ...Repeated for module number 9                         |                                 |         |      |        |             |
| 3042  | ...Repeated for module number 10                        |                                 |         |      |        |             |

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| ADDR  | REGISTER NAME                                   | RANGE                 | UNITS | STEP  | FORMAT | DEFAULT |
|---|---|-----------------------|-------|-------|--------|---------|
| 3044  | ...Repeated for module number 11                |                       |       |       |        |         |
| 3046  | ...Repeated for module number 12                |                       |       |       |        |         |
| 3048  | ...Repeated for module number 13                |                       |       |       |        |         |
| 304A  | ...Repeated for module number 14                |                       |       |       |        |         |
| 304C  | ...Repeated for module number 15                |                       |       |       |        |         |
| <b>Modbus File Transfer (Read/Write)</b>          |   |                       |       |       |        |         |
| 3100  | Name of file to read                            | ---                   | ---   | ---   | F204   | (none)  |
| <b>Modbus File Transfer (Read Only)</b>           |   |                       |       |       |        |         |
| 3200  | Character position of current block within file | 0 to 4294967295       | ---   | 1     | F003   | 0       |
| 3202  | Size of currently-available data block          | 0 to 65535            | ---   | 1     | F001   | 0       |
| 3203  | Block of data from requested file (122 items)   | 0 to 65535            | ---   | 1     | F001   | 0       |
| <b>Event Recorder (Read Only)</b>                 |   |                       |       |       |        |         |
| 3400  | Events Since Last Clear                         | 0 to 4294967295       | ---   | 1     | F003   | 0       |
| 3402  | Number of Available Events                      | 0 to 4294967295       | ---   | 1     | F003   | 0       |
| 3404  | Event Recorder Last Cleared Date                | 0 to 4294967295       | ---   | 1     | F050   | 0       |
| <b>Event Recorder (Read/Write Command)</b>        |   |                       |       |       |        |         |
| 3406  | Event Recorder Clear Command                    | 0 to 1                | ---   | 1     | F126   | 0 (No)  |
| <b>DCMA Input Values (Read Only) (24 modules)</b> |   |                       |       |       |        |         |
| 34C0  | DCMA Inputs 1 Value                             | -9999.999 to 9999.999 | ---   | 0.001 | F004   | 0       |
| 34C2  | ...Repeated for module number 2                 |                       |       |       |        |         |
| 34C4  | ...Repeated for module number 3                 |                       |       |       |        |         |
| 34C6  | ...Repeated for module number 4                 |                       |       |       |        |         |
| 34C8  | ...Repeated for module number 5                 |                       |       |       |        |         |
| 34CA  | ...Repeated for module number 6                 |                       |       |       |        |         |
| 34CC  | ...Repeated for module number 7                 |                       |       |       |        |         |
| 34CE  | ...Repeated for module number 8                 |                       |       |       |        |         |
| 34D0  | ...Repeated for module number 9                 |                       |       |       |        |         |
| 34D2  | ...Repeated for module number 10                |                       |       |       |        |         |
| 34D4  | ...Repeated for module number 11                |                       |       |       |        |         |
| 34D6  | ...Repeated for module number 12                |                       |       |       |        |         |
| 34D8  | ...Repeated for module number 13                |                       |       |       |        |         |
| 34DA  | ...Repeated for module number 14                |                       |       |       |        |         |
| 34DC  | ...Repeated for module number 15                |                       |       |       |        |         |
| 34DE  | ...Repeated for module number 16                |                       |       |       |        |         |
| 34E0  | ...Repeated for module number 17                |                       |       |       |        |         |
| 34E2  | ...Repeated for module number 18                |                       |       |       |        |         |
| 34E4  | ...Repeated for module number 19                |                       |       |       |        |         |
| 34E6  | ...Repeated for module number 20                |                       |       |       |        |         |
| 34E8  | ...Repeated for module number 21                |                       |       |       |        |         |
| 34EA  | ...Repeated for module number 22                |                       |       |       |        |         |
| 34EC  | ...Repeated for module number 23                |                       |       |       |        |         |
| 34EE  | ...Repeated for module number 24                |                       |       |       |        |         |
| <b>RTD Input Values (Read Only) (48 modules)</b>  |   |                       |       |       |        |         |
| 34F0  | RTD Inputs 1 Value                              | -32768 to 32767       | °C    | 1     | F002   | 0       |
| 34F1  | ...Repeated for module number 2                 |                       |       |       |        |         |
| 34F2  | ...Repeated for module number 3                 |                       |       |       |        |         |
| 34F3  | ...Repeated for module number 4                 |                       |       |       |        |         |
| 34F4  | ...Repeated for module number 5                 |                       |       |       |        |         |
| 34F5  | ...Repeated for module number 6                 |                       |       |       |        |         |
| 34F6  | ...Repeated for module number 7                 |                       |       |       |        |         |
| 34F7  | ...Repeated for module number 8                 |                       |       |       |        |         |
| 34F8  | ...Repeated for module number 9                 |                       |       |       |        |         |
| 34F9  | ...Repeated for module number 10                |                       |       |       |        |         |
| 34FA  | ...Repeated for module number 11                |                       |       |       |        |         |

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| ADDR   | REGISTER NAME                                       | RANGE           | UNITS | STEP | FORMAT | DEFAULT      |
|--|---|-----------------|-------|------|--------|--------------|
| 34FB   | ...Repeated for module number 12                    |                 |       |      |        |              |
| 34FC   | ...Repeated for module number 13                    |                 |       |      |        |              |
| 34FD   | ...Repeated for module number 14                    |                 |       |      |        |              |
| 34FE   | ...Repeated for module number 15                    |                 |       |      |        |              |
| 34FF   | ...Repeated for module number 16                    |                 |       |      |        |              |
| 3500   | ...Repeated for module number 17                    |                 |       |      |        |              |
| 3501   | ...Repeated for module number 18                    |                 |       |      |        |              |
| 3502   | ...Repeated for module number 19                    |                 |       |      |        |              |
| 3503   | ...Repeated for module number 20                    |                 |       |      |        |              |
| 3504   | ...Repeated for module number 21                    |                 |       |      |        |              |
| 3505   | ...Repeated for module number 22                    |                 |       |      |        |              |
| 3506   | ...Repeated for module number 23                    |                 |       |      |        |              |
| 3507   | ...Repeated for module number 24                    |                 |       |      |        |              |
| 3508   | ...Repeated for module number 25                    |                 |       |      |        |              |
| 3509   | ...Repeated for module number 26                    |                 |       |      |        |              |
| 350A   | ...Repeated for module number 27                    |                 |       |      |        |              |
| 350B   | ...Repeated for module number 28                    |                 |       |      |        |              |
| 350C   | ...Repeated for module number 29                    |                 |       |      |        |              |
| 350D   | ...Repeated for module number 30                    |                 |       |      |        |              |
| 350E   | ...Repeated for module number 31                    |                 |       |      |        |              |
| 350F   | ...Repeated for module number 32                    |                 |       |      |        |              |
| 3510   | ...Repeated for module number 33                    |                 |       |      |        |              |
| 3511   | ...Repeated for module number 34                    |                 |       |      |        |              |
| 3512   | ...Repeated for module number 35                    |                 |       |      |        |              |
| 3513   | ...Repeated for module number 36                    |                 |       |      |        |              |
| 3514   | ...Repeated for module number 37                    |                 |       |      |        |              |
| 3515   | ...Repeated for module number 38                    |                 |       |      |        |              |
| 3516   | ...Repeated for module number 39                    |                 |       |      |        |              |
| 3517   | ...Repeated for module number 40                    |                 |       |      |        |              |
| 3518   | ...Repeated for module number 41                    |                 |       |      |        |              |
| 3519   | ...Repeated for module number 42                    |                 |       |      |        |              |
| 351A   | ...Repeated for module number 43                    |                 |       |      |        |              |
| 351B   | ...Repeated for module number 44                    |                 |       |      |        |              |
| 351C   | ...Repeated for module number 45                    |                 |       |      |        |              |
| 351D   | ...Repeated for module number 46                    |                 |       |      |        |              |
| 351E   | ...Repeated for module number 47                    |                 |       |      |        |              |
| 351F   | ...Repeated for module number 48                    |                 |       |      |        |              |
| <b>Expanded Direct Input/Output Status (Read Only)</b> |   |                 |       |      |        |              |
| 3560   | Direct Device States, one per register (8 items)    | 0 to 1          | ---   | 1    | F155   | 0 (Offline)  |
| 3570   | Direct Input States, one per register (96 items)    | 0 to 1          | ---   | 1    | F108   | 0 (Off)      |
| <b>Passwords (Read/Write Command)</b>                  |   |                 |       |      |        |              |
| 4000   | Command Password Setting                            | 0 to 4294967295 | ---   | 1    | F003   | 0            |
| <b>Passwords (Read/Write Setting)</b>                  |   |                 |       |      |        |              |
| 4002   | Setting Password Setting                            | 0 to 4294967295 | ---   | 1    | F003   | 0            |
| <b>Passwords (Read/Write)</b>                          |   |                 |       |      |        |              |
| 4008   | Command Password Entry                              | 0 to 4294967295 | ---   | 1    | F003   | 0            |
| 400A   | Setting Password Entry                              | 0 to 4294967295 | ---   | 1    | F003   | 0            |
| <b>Passwords (Read Only)</b>                           |   |                 |       |      |        |              |
| 4010   | Command Password Status                             | 0 to 1          | ---   | 1    | F102   | 0 (Disabled) |
| 4011   | Setting Password Status                             | 0 to 1          | ---   | 1    | F102   | 0 (Disabled) |
| <b>User Display Invoke (Read/Write Setting)</b>        |   |                 |       |      |        |              |
| 4040   | Invoke and Scroll Through User Display Menu Operand | 0 to 65535      | ---   | 1    | F300   | 0            |
| <b>LED Test (Read/Write Setting)</b>                   |   |                 |       |      |        |              |
| 4048   | LED Test Function                                   | 0 to 1          | ---   | 1    | F102   | 0 (Disabled) |

Table B-9: MODBUS MEMORY MAP (Sheet 9 of 38)

| ADDR                                       | REGISTER NAME   | RANGE           | UNITS | STEP  | FORMAT | DEFAULT         |
|--|---|-----------------|-------|-------|--------|-----------------|
| 4049                                       | LED Test Control  | 0 to 65535      | ---   | 1     | F300   | 0               |
| <b>Preferences (Read/Write Setting)</b>    |   |                 |       |       |        |                 |
| 4050                                       | Flash Message Time  | 0.5 to 10       | s     | 0.1   | F001   | 10              |
| 4051                                       | Default Message Timeout   | 10 to 900       | s     | 1     | F001   | 300             |
| 4052                                       | Default Message Intensity   | 0 to 3          | ---   | 1     | F101   | 0 (25%)         |
| 4053                                       | Screen Saver Feature  | 0 to 1          | ---   | 1     | F102   | 0 (Disabled)    |
| 4054                                       | Screen Saver Wait Time  | 1 to 65535      | min   | 1     | F001   | 30              |
| 4055                                       | Current Cutoff Level  | 0.002 to 0.02   | pu    | 0.001 | F001   | 20              |
| 4056                                       | Voltage Cutoff Level  | 0.1 to 1        | V     | 0.1   | F001   | 10              |
| <b>Communications (Read/Write Setting)</b> |   |                 |       |       |        |                 |
| 407E                                       | COM1 minimum response time  | 0 to 1000       | ms    | 10    | F001   | 0               |
| 407F                                       | COM2 minimum response time  | 0 to 1000       | ms    | 10    | F001   | 0               |
| 4080                                       | Modbus Slave Address  | 1 to 254        | ---   | 1     | F001   | 254             |
| 4083                                       | RS485 Com1 Baud Rate  | 0 to 11         | ---   | 1     | F112   | 8 (115200)      |
| 4084                                       | RS485 Com1 Parity   | 0 to 2          | ---   | 1     | F113   | 0 (None)        |
| 4085                                       | RS485 Com2 Baud Rate  | 0 to 11         | ---   | 1     | F112   | 8 (115200)      |
| 4086                                       | RS485 Com2 Parity   | 0 to 2          | ---   | 1     | F113   | 0 (None)        |
| 4087                                       | IP Address  | 0 to 4294967295 | ---   | 1     | F003   | 56554706        |
| 4089                                       | IP Subnet Mask  | 0 to 4294967295 | ---   | 1     | F003   | 4294966272      |
| 408B                                       | Gateway IP Address  | 0 to 4294967295 | ---   | 1     | F003   | 56554497        |
| 408D                                       | Network Address NSAP  | ---             | ---   | ---   | F074   | 0               |
| 4097                                       | Default GSSE Update Time  | 1 to 60         | s     | 1     | F001   | 60              |
| 409A                                       | DNP Port  | 0 to 4          | ---   | 1     | F177   | 0 (NONE)        |
| 409B                                       | DNP Address   | 0 to 65519      | ---   | 1     | F001   | 1               |
| 409C                                       | DNP Client Addresses (2 items)  | 0 to 4294967295 | ---   | 1     | F003   | 0               |
| 40A0                                       | TCP Port Number for the Modbus protocol   | 1 to 65535      | ---   | 1     | F001   | 502             |
| 40A1                                       | TCP/UDP Port Number for the DNP Protocol  | 1 to 65535      | ---   | 1     | F001   | 20000           |
| 40A2                                       | TCP Port Number for the IEC 61850 Protocol  | 1 to 65535      | ---   | 1     | F001   | 102             |
| 40A3                                       | TCP Port Number for the HTTP (Web Server) Protocol                                      | 1 to 65535      | ---   | 1     | F001   | 80              |
| 40A4                                       | Main UDP Port Number for the TFTP Protocol  | 1 to 65535      | ---   | 1     | F001   | 69              |
| 40A5                                       | Data Transfer UDP Port Numbers for the TFTP Protocol (zero means "automatic") (2 items) | 0 to 65535      | ---   | 1     | F001   | 0               |
| 40A7                                       | DNP Unsolicited Responses Function  | 0 to 1          | ---   | 1     | F102   | 0 (Disabled)    |
| 40A8                                       | DNP Unsolicited Responses Timeout   | 0 to 60         | s     | 1     | F001   | 5               |
| 40A9                                       | DNP Unsolicited Responses Max Retries   | 1 to 255        | ---   | 1     | F001   | 10              |
| 40AA                                       | DNP Unsolicited Responses Destination Address   | 0 to 65519      | ---   | 1     | F001   | 1               |
| 40AB                                       | Ethernet Operation Mode   | 0 to 1          | ---   | 1     | F192   | 0 (Half-Duplex) |
| 40AC                                       | DNP User Map Function   | 0 to 1          | ---   | 1     | F102   | 0 (Disabled)    |
| 40AD                                       | DNP Number of Sources used in Analog points list  | 1 to 6          | ---   | 1     | F001   | 1               |
| 40AE                                       | DNP Current Scale Factor  | 0 to 8          | ---   | 1     | F194   | 2 (1)           |
| 40AF                                       | DNP Voltage Scale Factor  | 0 to 8          | ---   | 1     | F194   | 2 (1)           |
| 40B0                                       | DNP Power Scale Factor  | 0 to 8          | ---   | 1     | F194   | 2 (1)           |
| 40B1                                       | DNP Energy Scale Factor   | 0 to 8          | ---   | 1     | F194   | 2 (1)           |
| 40B2                                       | DNP Other Scale Factor  | 0 to 8          | ---   | 1     | F194   | 2 (1)           |
| 40B3                                       | DNP Current Default Deadband  | 0 to 65535      | ---   | 1     | F001   | 30000           |
| 40B4                                       | DNP Voltage Default Deadband  | 0 to 65535      | ---   | 1     | F001   | 30000           |
| 40B5                                       | DNP Power Default Deadband  | 0 to 65535      | ---   | 1     | F001   | 30000           |
| 40B6                                       | DNP Energy Default Deadband   | 0 to 65535      | ---   | 1     | F001   | 30000           |
| 40B7                                       | DNP Other Default Deadband  | 0 to 65535      | ---   | 1     | F001   | 30000           |
| 40B8                                       | DNP IIN Time Sync Bit Period  | 1 to 10080      | min   | 1     | F001   | 1440            |
| 40B9                                       | DNP Message Fragment Size   | 30 to 2048      | ---   | 1     | F001   | 240             |
| 40BA                                       | DNP Client Address 3  | 0 to 4294967295 | ---   | 1     | F003   | 0               |
| 40BC                                       | DNP Client Address 4  | 0 to 4294967295 | ---   | 1     | F003   | 0               |
| 40BE                                       | DNP Client Address 5  | 0 to 4294967295 | ---   | 1     | F003   | 0               |

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| ADDR  | REGISTER NAME   | RANGE           | UNITS | STEP | FORMAT | DEFAULT              |
|---|---|-----------------|-------|------|--------|----------------------|
| 40C0  | DNP Communications Reserved (8 items)                 | 0 to 1          | ---   | 1    | F001   | 0                    |
| 40C8  | IEC 61850 Logical Device Name                         | ---             | ---   | ---  | F203   | "IECDevice"          |
| 40D0  | GSSE Function   | 0 to 1          | ---   | 1    | F102   | 1 (Enabled)          |
| 40D1  | Reserved (15 items)                                   | 0 to 1          | ---   | 1    | F001   | 0                    |
| 40E0  | TCP Port Number for the IEC 60870-5-104 Protocol      | 1 to 65535      | ---   | 1    | F001   | 2404                 |
| 40E1  | IEC 60870-5-104 Protocol Function                     | 0 to 1          | ---   | 1    | F102   | 0 (Disabled)         |
| 40E2  | IEC 60870-5-104 Protocol Common Address of ASDU       | 0 to 65535      | ---   | 1    | F001   | 0                    |
| 40E3  | IEC 60870-5-104 Protocol Cyclic Data Trans. Period    | 1 to 65535      | s     | 1    | F001   | 60                   |
| 40E4  | IEC 60870-5-104 Sources used in M_ME_NC_1 point list  | 1 to 6          | ---   | 1    | F001   | 1                    |
| 40E5  | IEC 60870-5-104 Current Default Threshold             | 0 to 65535      | ---   | 1    | F001   | 30000                |
| 40E6  | IEC 60870-5-104 Voltage Default Threshold             | 0 to 65535      | ---   | 1    | F001   | 30000                |
| 40E7  | IEC 60870-5-104 Power Default Threshold               | 0 to 65535      | ---   | 1    | F001   | 30000                |
| 40E8  | IEC 60870-5-104 Energy Default Threshold              | 0 to 65535      | ---   | 1    | F001   | 30000                |
| 40E9  | IEC 60870-5-104 Other Default Threshold               | 0 to 65535      | ---   | 1    | F001   | 30000                |
| 40EA  | IEC 60870-5-104 Client Address (5 items)              | 0 to 4294967295 | ---   | 1    | F003   | 0                    |
| 40FE  | IEC 60870-5-104 Communications Reserved (2 items)     | 0 to 1          | ---   | 1    | F001   | 0                    |
| 4100  | DNP Binary Input Block of 16 Points (58 items)        | 0 to 58         | ---   | 1    | F197   | 0 (Not Used)         |
| 4140  | DNP Object 1 Default Variation                        | 1 to 2          | ---   | 1    | F001   | 2                    |
| 4141  | DNP Object 2 Default Variation                        | 1 to 2          | ---   | 1    | F001   | 2                    |
| 4142  | DNP Object 20 Default Variation                       | 0 to 3          | ---   | 1    | F523   | 0 (1)                |
| 4143  | DNP Object 21 Default Variation                       | 0 to 3          | ---   | 1    | F524   | 0 (1)                |
| 4144  | DNP Object 22 Default Variation                       | 0 to 3          | ---   | 1    | F523   | 0 (1)                |
| 4145  | DNP Object 23 Default Variation                       | 0 to 3          | ---   | 1    | F523   | 0 (1)                |
| 4146  | DNP Object 30 Default Variation                       | 1 to 5          | ---   | 1    | F001   | 1                    |
| 4147  | DNP Object 32 Default Variation                       | 0 to 5          | ---   | 1    | F525   | 0 (1)                |
| <b>Simple Network Time Protocol (Read/Write Setting)</b>        |   |                 |       |      |        |                      |
| 4168  | Simple Network Time Protocol (SNTP) Function          | 0 to 1          | ---   | 1    | F102   | 0 (Disabled)         |
| 4169  | Simple Network Time Protocol (SNTP) Server IP Address | 0 to 4294967295 | ---   | 1    | F003   | 0                    |
| 416B  | Simple Network Time Protocol (SNTP) UDP Port Number   | 1 to 65535      | ---   | 1    | F001   | 123                  |
| <b>Clock (Read/Write Command)</b>                               |   |                 |       |      |        |                      |
| 41A0  | Real Time Clock Set Time                              | 0 to 235959     | ---   | 1    | F050   | 0                    |
| <b>Clock (Read/Write Setting)</b>                               |   |                 |       |      |        |                      |
| 41A2  | SR Date Format  | 0 to 4294967295 | ---   | 1    | F051   | 0                    |
| 41A4  | SR Time Format  | 0 to 4294967295 | ---   | 1    | F052   | 0                    |
| 41A6  | IRIG-B Signal Type                                    | 0 to 2          | ---   | 1    | F114   | 0 (None)             |
| 41A7  | Clock Events Enable / Disable                         | 0 to 1          | ---   | 1    | F102   | 0 (Disabled)         |
| <b>Fault Report Commands (Read/Write Command)</b>               |   |                 |       |      |        |                      |
| 41B2  | Fault Reports Clear Data Command                      | 0 to 1          | ---   | 1    | F126   | 0 (No)               |
| <b>Oscillography (Read/Write Setting)</b>                       |   |                 |       |      |        |                      |
| 41C0  | Oscillography Number of Records                       | 1 to 64         | ---   | 1    | F001   | 15                   |
| 41C1  | Oscillography Trigger Mode                            | 0 to 1          | ---   | 1    | F118   | 0 (Auto. Overwrite)  |
| 41C2  | Oscillography Trigger Position                        | 0 to 100        | %     | 1    | F001   | 50                   |
| 41C3  | Oscillography Trigger Source                          | 0 to 65535      | ---   | 1    | F300   | 0                    |
| 41C4  | Oscillography AC Input Waveforms                      | 0 to 4          | ---   | 1    | F183   | 2 (16 samples/cycle) |
| 41D0  | Oscillography Analog Channel <i>n</i> (16 items)      | 0 to 65535      | ---   | 1    | F600   | 0                    |
| 4200  | Oscillography Digital Channel <i>n</i> (63 items)     | 0 to 65535      | ---   | 1    | F300   | 0                    |
| <b>Trip and Alarm LEDs (Read/Write Setting)</b>                 |   |                 |       |      |        |                      |
| 4260  | Trip LED Input FlexLogic Operand                      | 0 to 65535      | ---   | 1    | F300   | 0                    |
| 4261  | Alarm LED Input FlexLogic Operand                     | 0 to 65535      | ---   | 1    | F300   | 0                    |
| <b>User Programmable LEDs (Read/Write Setting) (48 modules)</b> |   |                 |       |      |        |                      |
| 4280  | FlexLogic Operand to Activate LED                     | 0 to 65535      | ---   | 1    | F300   | 0                    |
| 4281  | User LED type (latched or self-resetting)             | 0 to 1          | ---   | 1    | F127   | 1 (Self-Reset)       |
| 4282  | ...Repeated for module number 2                       |                 |       |      |        |                      |
| 4284  | ...Repeated for module number 3                       |                 |       |      |        |                      |

Table B-9: MODBUS MEMORY MAP (Sheet 11 of 38)

| ADDR   | REGISTER NAME                                      | RANGE  | UNITS | STEP | FORMAT | DEFAULT            |
|--|--|--------|-------|------|--------|--------------------|
| 4286   | ...Repeated for module number 4                    |        |       |      |        |                    |
| 4288   | ...Repeated for module number 5                    |        |       |      |        |                    |
| 428A   | ...Repeated for module number 6                    |        |       |      |        |                    |
| 428C   | ...Repeated for module number 7                    |        |       |      |        |                    |
| 428E   | ...Repeated for module number 8                    |        |       |      |        |                    |
| 4290   | ...Repeated for module number 9                    |        |       |      |        |                    |
| 4292   | ...Repeated for module number 10                   |        |       |      |        |                    |
| 4294   | ...Repeated for module number 11                   |        |       |      |        |                    |
| 4296   | ...Repeated for module number 12                   |        |       |      |        |                    |
| 4298   | ...Repeated for module number 13                   |        |       |      |        |                    |
| 429A   | ...Repeated for module number 14                   |        |       |      |        |                    |
| 429C   | ...Repeated for module number 15                   |        |       |      |        |                    |
| 429E   | ...Repeated for module number 16                   |        |       |      |        |                    |
| 42A0   | ...Repeated for module number 17                   |        |       |      |        |                    |
| 42A2   | ...Repeated for module number 18                   |        |       |      |        |                    |
| 42A4   | ...Repeated for module number 19                   |        |       |      |        |                    |
| 42A6   | ...Repeated for module number 20                   |        |       |      |        |                    |
| 42A8   | ...Repeated for module number 21                   |        |       |      |        |                    |
| 42AA   | ...Repeated for module number 22                   |        |       |      |        |                    |
| 42AC   | ...Repeated for module number 23                   |        |       |      |        |                    |
| 42AE   | ...Repeated for module number 24                   |        |       |      |        |                    |
| 42B0   | ...Repeated for module number 25                   |        |       |      |        |                    |
| 42B2   | ...Repeated for module number 26                   |        |       |      |        |                    |
| 42B4   | ...Repeated for module number 27                   |        |       |      |        |                    |
| 42B6   | ...Repeated for module number 28                   |        |       |      |        |                    |
| 42B8   | ...Repeated for module number 29                   |        |       |      |        |                    |
| 42BA   | ...Repeated for module number 30                   |        |       |      |        |                    |
| 42BC   | ...Repeated for module number 31                   |        |       |      |        |                    |
| 42BE   | ...Repeated for module number 32                   |        |       |      |        |                    |
| 42C0   | ...Repeated for module number 33                   |        |       |      |        |                    |
| 42C2   | ...Repeated for module number 34                   |        |       |      |        |                    |
| 42C4   | ...Repeated for module number 35                   |        |       |      |        |                    |
| 42C6   | ...Repeated for module number 36                   |        |       |      |        |                    |
| 42C8   | ...Repeated for module number 37                   |        |       |      |        |                    |
| 42CA   | ...Repeated for module number 38                   |        |       |      |        |                    |
| 42CC   | ...Repeated for module number 39                   |        |       |      |        |                    |
| 42CE   | ...Repeated for module number 40                   |        |       |      |        |                    |
| 42D0   | ...Repeated for module number 41                   |        |       |      |        |                    |
| 42D2   | ...Repeated for module number 42                   |        |       |      |        |                    |
| 42D4   | ...Repeated for module number 43                   |        |       |      |        |                    |
| 42D6   | ...Repeated for module number 44                   |        |       |      |        |                    |
| 42D8   | ...Repeated for module number 45                   |        |       |      |        |                    |
| 42DA   | ...Repeated for module number 46                   |        |       |      |        |                    |
| 42DC   | ...Repeated for module number 47                   |        |       |      |        |                    |
| 42DE   | ...Repeated for module number 48                   |        |       |      |        |                    |
| <b>Installation (Read/Write Setting)</b>                 |  |        |       |      |        |                    |
| 43E0   | Relay Programmed State                             | 0 to 1 | ---   | 1    | F133   | 0 (Not Programmed) |
| 43E1   | Relay Name   | ---    | ---   | ---  | F202   | "Relay-1"          |
| <b>User Programmable Self Tests (Read/Write Setting)</b> |  |        |       |      |        |                    |
| 4441   | User Programmable Detect Ring Break Function       | 0 to 1 | ---   | 1    | F102   | 1 (Enabled)        |
| 4442   | User Programmable Direct Device Off Function       | 0 to 1 | ---   | 1    | F102   | 1 (Enabled)        |
| 4443   | User Programmable Remote Device Off Function       | 0 to 1 | ---   | 1    | F102   | 1 (Enabled)        |
| 4444   | User Programmable Primary Ethernet Fail Function   | 0 to 1 | ---   | 1    | F102   | 0 (Disabled)       |
| 4445   | User Programmable Secondary Ethernet Fail Function | 0 to 1 | ---   | 1    | F102   | 0 (Disabled)       |



Table B-9: MODBUS MEMORY MAP (Sheet 12 of 38)

| ADDR  | REGISTER NAME                           | RANGE        | UNITS | STEP  | FORMAT | DEFAULT      |
|---|---|--------------|-------|-------|--------|--------------|
| 4446  | User Programmable Battery Fail Function | 0 to 1       | ---   | 1     | F102   | 1 (Enabled)  |
| 4447  | User Programmable SNTP Fail Function    | 0 to 1       | ---   | 1     | F102   | 1 (Enabled)  |
| 4448  | User Programmable IRI-G-B Fail Function | 0 to 1       | ---   | 1     | F102   | 1 (Enabled)  |
| <b>CT Settings (Read/Write Setting) (6 modules)</b>         |   |              |       |       |        |              |
| 4480  | Phase CT Primary                        | 1 to 65000   | A     | 1     | F001   | 1            |
| 4481  | Phase CT Secondary                      | 0 to 1       | ---   | 1     | F123   | 0 (1 A)      |
| 4482  | Ground CT Primary                       | 1 to 65000   | A     | 1     | F001   | 1            |
| 4483  | Ground CT Secondary                     | 0 to 1       | ---   | 1     | F123   | 0 (1 A)      |
| 4484  | ...Repeated for module number 2         |              |       |       |        |              |
| 4488  | ...Repeated for module number 3         |              |       |       |        |              |
| 448C  | ...Repeated for module number 4         |              |       |       |        |              |
| 4490  | ...Repeated for module number 5         |              |       |       |        |              |
| 4494  | ...Repeated for module number 6         |              |       |       |        |              |
| <b>VT Settings (Read/Write Setting) (3 modules)</b>         |   |              |       |       |        |              |
| 4500  | Phase VT Connection                     | 0 to 1       | ---   | 1     | F100   | 0 (Wye)      |
| 4501  | Phase VT Secondary                      | 50 to 240    | V     | 0.1   | F001   | 664          |
| 4502  | Phase VT Ratio                          | 1 to 24000   | :1    | 1     | F060   | 1            |
| 4504  | Auxiliary VT Connection                 | 0 to 6       | ---   | 1     | F166   | 1 (Vag)      |
| 4505  | Auxiliary VT Secondary                  | 50 to 240    | V     | 0.1   | F001   | 664          |
| 4506  | Auxiliary VT Ratio                      | 1 to 24000   | :1    | 1     | F060   | 1            |
| 4508  | ...Repeated for module number 2         |              |       |       |        |              |
| 4510  | ...Repeated for module number 3         |              |       |       |        |              |
| <b>Source Settings (Read/Write Setting) (6 modules)</b>     |   |              |       |       |        |              |
| 4580  | Source Name                             | ---          | ---   | ---   | F206   | "SRC 1"      |
| 4583  | Source Phase CT                         | 0 to 63      | ---   | 1     | F400   | 0            |
| 4584  | Source Ground CT                        | 0 to 63      | ---   | 1     | F400   | 0            |
| 4585  | Source Phase VT                         | 0 to 63      | ---   | 1     | F400   | 0            |
| 4586  | Source Auxiliary VT                     | 0 to 63      | ---   | 1     | F400   | 0            |
| 4587  | ...Repeated for module number 2         |              |       |       |        |              |
| 458E  | ...Repeated for module number 3         |              |       |       |        |              |
| 4595  | ...Repeated for module number 4         |              |       |       |        |              |
| 459C  | ...Repeated for module number 5         |              |       |       |        |              |
| 45A3  | ...Repeated for module number 6         |              |       |       |        |              |
| <b>Power System (Read/Write Setting)</b>                    |   |              |       |       |        |              |
| 4600  | Nominal Frequency                       | 25 to 60     | Hz    | 1     | F001   | 60           |
| 4601  | Phase Rotation                          | 0 to 1       | ---   | 1     | F106   | 0 (ABC)      |
| 4602  | Frequency And Phase Reference           | 0 to 5       | ---   | 1     | F167   | 0 (SRC 1)    |
| 4603  | Frequency Tracking Function             | 0 to 1       | ---   | 1     | F102   | 1 (Enabled)  |
| <b>Breaker Control Global Settings (Read/Write Setting)</b> |   |              |       |       |        |              |
| 46F0  | IEC 61850 XCBR 1 SelTimOut              | 1 to 60      | s     | 1     | F001   | 30           |
| <b>Breaker Control (Read/Write Setting) (2 modules)</b>     |   |              |       |       |        |              |
| 4700  | Breaker 1 Function                      | 0 to 1       | ---   | 1     | F102   | 0 (Disabled) |
| 4701  | Breaker 1 Name                          | ---          | ---   | ---   | F206   | "Bkr 1"      |
| 4704  | Breaker 1 Mode                          | 0 to 1       | ---   | 1     | F157   | 0 (3-Pole)   |
| 4705  | Breaker 1 Open                          | 0 to 65535   | ---   | 1     | F300   | 0            |
| 4706  | Breaker 1 Close                         | 0 to 65535   | ---   | 1     | F300   | 0            |
| 4707  | Breaker 1 Phase A 3 Pole                | 0 to 65535   | ---   | 1     | F300   | 0            |
| 4708  | Breaker 1 Phase B                       | 0 to 65535   | ---   | 1     | F300   | 0            |
| 4709  | Breaker 1 Phase C                       | 0 to 65535   | ---   | 1     | F300   | 0            |
| 470A  | Breaker 1 External Alarm                | 0 to 65535   | ---   | 1     | F300   | 0            |
| 470B  | Breaker 1 Alarm Delay                   | 0 to 1000000 | s     | 0.001 | F003   | 0            |
| 470D  | Breaker 1 Push Button Control           | 0 to 1       | ---   | 1     | F102   | 0 (Disabled) |
| 470E  | Breaker 1 Manual Close Recall Time      | 0 to 1000000 | s     | 0.001 | F003   | 0            |
| 4710  | Breaker 1 IEC 61850 XCBR 1 SBOClass     | 1 to 2       | ---   | 1     | F001   | 1            |

Table B-9: MODBUS MEMORY MAP (Sheet 13 of 38)

| ADDR   | REGISTER NAME                                    | RANGE       | UNITS   | STEP | FORMAT | DEFAULT         |
|--|--|-------------|---------|------|--------|-----------------|
| 4711   | Breaker 1 IEC 61850 XCBR 1 SBOEna                | 0 to 1      | ---     | 1    | F102   | 0 (Disabled)    |
| 4712   | Breaker 1 Out Of Service                         | 0 to 65535  | ---     | 1    | F300   | 0               |
| 4713   | Reserved (5 items)                               | 0 to 65535  | s       | 1    | F001   | 0               |
| 4718   | ...Repeated for module number 2                  |             |         |      |        |                 |
| <b>Synchrocheck (Read/Write Setting) (2 modules)</b>                   |  |             |         |      |        |                 |
| 4780   | Synchrocheck 1 Function                          | 0 to 1      | ---     | 1    | F102   | 0 (Disabled)    |
| 4781   | Synchrocheck 1 V1 Source                         | 0 to 5      | ---     | 1    | F167   | 0 (SRC 1)       |
| 4782   | Synchrocheck 1 V2 Source                         | 0 to 5      | ---     | 1    | F167   | 1 (SRC 2)       |
| 4783   | Synchrocheck 1 Maximum Voltage Difference        | 0 to 100000 | V       | 1    | F060   | 10000           |
| 4785   | Synchrocheck 1 Maximum Angle Difference          | 0 to 100    | degrees | 1    | F001   | 30              |
| 4786   | Synchrocheck 1 Maximum Frequency Difference      | 0 to 2      | Hz      | 0.01 | F001   | 100             |
| 4787   | Synchrocheck 1 Dead Source Select                | 0 to 5      | ---     | 1    | F176   | 1 (LV1 and DV2) |
| 4788   | Synchrocheck 1 Dead V1 Maximum Voltage           | 0 to 1.25   | pu      | 0.01 | F001   | 30              |
| 4789   | Synchrocheck 1 Dead V2 Maximum Voltage           | 0 to 1.25   | pu      | 0.01 | F001   | 30              |
| 478A   | Synchrocheck 1 Live V1 Minimum Voltage           | 0 to 1.25   | pu      | 0.01 | F001   | 70              |
| 478B   | Synchrocheck 1 Live V2 Minimum Voltage           | 0 to 1.25   | pu      | 0.01 | F001   | 70              |
| 478C   | Synchrocheck 1 Target                            | 0 to 2      | ---     | 1    | F109   | 0 (Self-reset)  |
| 478D   | Synchrocheck 1 Events                            | 0 to 1      | ---     | 1    | F102   | 0 (Disabled)    |
| 478E   | Synchrocheck 1 Block                             | 0 to 65535  | ---     | 1    | F300   | 0               |
| 478F   | Synchrocheck 1 Frequency Hysteresis              | 0 to 0.1    | Hz      | 0.01 | F001   | 6               |
| 4790   | ...Repeated for module number 2                  |             |         |      |        |                 |
| <b>Flexcurves A and B (Read/Write Settings)</b>                        |  |             |         |      |        |                 |
| 4800   | FlexCurve A (120 items)                          | 0 to 65535  | ms      | 1    | F011   | 0               |
| 48F0   | FlexCurve B (120 items)                          | 0 to 65535  | ms      | 1    | F011   | 0               |
| <b>Modbus User Map (Read/Write Setting)</b>                            |  |             |         |      |        |                 |
| 4A00   | Modbus Address Settings for User Map (256 items) | 0 to 65535  | ---     | 1    | F001   | 0               |
| <b>User Displays Settings (Read/Write Setting) (16 modules)</b>        |  |             |         |      |        |                 |
| 4C00   | User display 1 top line text                     | ---         | ---     | ---  | F202   | ""              |
| 4C0A   | User display 1 bottom line text                  | ---         | ---     | ---  | F202   | ""              |
| 4C14   | Modbus addresses of displayed items (5 items)    | 0 to 65535  | ---     | 1    | F001   | 0               |
| 4C19   | Reserved (7 items)                               | ---         | ---     | ---  | F001   | 0               |
| 4C20   | ...Repeated for module number 2                  |             |         |      |        |                 |
| 4C40   | ...Repeated for module number 3                  |             |         |      |        |                 |
| 4C60   | ...Repeated for module number 4                  |             |         |      |        |                 |
| 4C80   | ...Repeated for module number 5                  |             |         |      |        |                 |
| 4CA0   | ...Repeated for module number 6                  |             |         |      |        |                 |
| 4CC0   | ...Repeated for module number 7                  |             |         |      |        |                 |
| 4CE0   | ...Repeated for module number 8                  |             |         |      |        |                 |
| 4D00   | ...Repeated for module number 9                  |             |         |      |        |                 |
| 4D20   | ...Repeated for module number 10                 |             |         |      |        |                 |
| 4D40   | ...Repeated for module number 11                 |             |         |      |        |                 |
| 4D60   | ...Repeated for module number 12                 |             |         |      |        |                 |
| 4D80   | ...Repeated for module number 13                 |             |         |      |        |                 |
| 4DA0   | ...Repeated for module number 14                 |             |         |      |        |                 |
| 4DC0   | ...Repeated for module number 15                 |             |         |      |        |                 |
| 4DE0   | ...Repeated for module number 16                 |             |         |      |        |                 |
| <b>User Programmable Pushbuttons (Read/Write Setting) (12 modules)</b> |  |             |         |      |        |                 |
| 4E00   | User Programmable Pushbutton 1 Function          | 0 to 2      | ---     | 1    | F109   | 2 (Disabled)    |
| 4E01   | User Programmable Pushbutton 1 Top Line          | ---         | ---     | ---  | F202   | (none)          |
| 4E0B   | User Programmable Pushbutton 1 On Text           | ---         | ---     | ---  | F202   | (none)          |
| 4E15   | User Programmable Pushbutton 1 Off Text          | ---         | ---     | ---  | F202   | (none)          |
| 4E1F   | User Programmable Pushbutton 1 Drop-Out Time     | 0 to 60     | s       | 0.05 | F001   | 0               |
| 4E20   | User Programmable Pushbutton 1 Target            | 0 to 2      | ---     | 1    | F109   | 0 (Self-reset)  |
| 4E21   | User Programmable Pushbutton 1 Events            | 0 to 1      | ---     | 1    | F102   | 0 (Disabled)    |

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| ADDR   | REGISTER NAME                                     | RANGE      | UNITS | STEP | FORMAT | DEFAULT         |
|--|---|------------|-------|------|--------|-----------------|
| 4E22   | User Programmable Pushbutton 1 Reserved (2 items) | 0 to 65535 | ---   | 1    | F001   | 0               |
| 4E24   | ...Repeated for module number 2                   |            |       |      |        |                 |
| 4E48   | ...Repeated for module number 3                   |            |       |      |        |                 |
| 4E6C   | ...Repeated for module number 4                   |            |       |      |        |                 |
| 4E90   | ...Repeated for module number 5                   |            |       |      |        |                 |
| 4EB4   | ...Repeated for module number 6                   |            |       |      |        |                 |
| 4ED8   | ...Repeated for module number 7                   |            |       |      |        |                 |
| 4EFC   | ...Repeated for module number 8                   |            |       |      |        |                 |
| 4F20   | ...Repeated for module number 9                   |            |       |      |        |                 |
| 4F44   | ...Repeated for module number 10                  |            |       |      |        |                 |
| 4F68   | ...Repeated for module number 11                  |            |       |      |        |                 |
| 4F8C   | ...Repeated for module number 12                  |            |       |      |        |                 |
| <b>Flexlogic (Read/Write Setting)</b>                                  |   |            |       |      |        |                 |
| 5000   | FlexLogic Entry (512 items)                       | 0 to 65535 | ---   | 1    | F300   | 16384           |
| <b>Flexlogic Timers (Read/Write Setting) (32 modules)</b>              |   |            |       |      |        |                 |
| 5800   | Timer 1 Type                                      | 0 to 2     | ---   | 1    | F129   | 0 (millisecond) |
| 5801   | Timer 1 Pickup Delay                              | 0 to 60000 | ---   | 1    | F001   | 0               |
| 5802   | Timer 1 Dropout Delay                             | 0 to 60000 | ---   | 1    | F001   | 0               |
| 5803   | Timer 1 Reserved (5 items)                        | 0 to 65535 | ---   | 1    | F001   | 0               |
| 5808   | ...Repeated for module number 2                   |            |       |      |        |                 |
| 5810   | ...Repeated for module number 3                   |            |       |      |        |                 |
| 5818   | ...Repeated for module number 4                   |            |       |      |        |                 |
| 5820   | ...Repeated for module number 5                   |            |       |      |        |                 |
| 5828   | ...Repeated for module number 6                   |            |       |      |        |                 |
| 5830   | ...Repeated for module number 7                   |            |       |      |        |                 |
| 5838   | ...Repeated for module number 8                   |            |       |      |        |                 |
| 5840   | ...Repeated for module number 9                   |            |       |      |        |                 |
| 5848   | ...Repeated for module number 10                  |            |       |      |        |                 |
| 5850   | ...Repeated for module number 11                  |            |       |      |        |                 |
| 5858   | ...Repeated for module number 12                  |            |       |      |        |                 |
| 5860   | ...Repeated for module number 13                  |            |       |      |        |                 |
| 5868   | ...Repeated for module number 14                  |            |       |      |        |                 |
| 5870   | ...Repeated for module number 15                  |            |       |      |        |                 |
| 5878   | ...Repeated for module number 16                  |            |       |      |        |                 |
| 5880   | ...Repeated for module number 17                  |            |       |      |        |                 |
| 5888   | ...Repeated for module number 18                  |            |       |      |        |                 |
| 5890   | ...Repeated for module number 19                  |            |       |      |        |                 |
| 5898   | ...Repeated for module number 20                  |            |       |      |        |                 |
| 58A0   | ...Repeated for module number 21                  |            |       |      |        |                 |
| 58A8   | ...Repeated for module number 22                  |            |       |      |        |                 |
| 58B0   | ...Repeated for module number 23                  |            |       |      |        |                 |
| 58B8   | ...Repeated for module number 24                  |            |       |      |        |                 |
| 58C0   | ...Repeated for module number 25                  |            |       |      |        |                 |
| 58C8   | ...Repeated for module number 26                  |            |       |      |        |                 |
| 58D0   | ...Repeated for module number 27                  |            |       |      |        |                 |
| 58D8   | ...Repeated for module number 28                  |            |       |      |        |                 |
| 58E0   | ...Repeated for module number 29                  |            |       |      |        |                 |
| 58E8   | ...Repeated for module number 30                  |            |       |      |        |                 |
| 58F0   | ...Repeated for module number 31                  |            |       |      |        |                 |
| 58F8   | ...Repeated for module number 32                  |            |       |      |        |                 |
| <b>Phase Time Overcurrent (Read/Write Grouped Setting) (6 modules)</b> |   |            |       |      |        |                 |
| 5900   | Phase TOC 1 Function                              | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)    |
| 5901   | Phase TOC 1 Signal Source                         | 0 to 5     | ---   | 1    | F167   | 0 (SRC 1)       |
| 5902   | Phase TOC 1 Input                                 | 0 to 1     | ---   | 1    | F122   | 0 (Phasor)      |

Table B-9: MODBUS MEMORY MAP (Sheet 15 of 38)

| ADDR   | REGISTER NAME                              | RANGE      | UNITS | STEP  | FORMAT | DEFAULT           |
|--|--|------------|-------|-------|--------|-------------------|
| 5903   | Phase TOC 1 Pickup                         | 0 to 30    | pu    | 0.001 | F001   | 1000              |
| 5904   | Phase TOC 1 Curve                          | 0 to 16    | ---   | 1     | F103   | 0 (IEEE Mod Inv)  |
| 5905   | Phase TOC 1 Multiplier                     | 0 to 600   | ---   | 0.01  | F001   | 100               |
| 5906   | Phase TOC 1 Reset                          | 0 to 1     | ---   | 1     | F104   | 0 (Instantaneous) |
| 5907   | Phase TOC 1 Voltage Restraint              | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5908   | Phase TOC 1 Block For Each Phase (3 items) | 0 to 65535 | ---   | 1     | F300   | 0                 |
| 590B   | Phase TOC 1 Target                         | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset)    |
| 590C   | Phase TOC 1 Events                         | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 590D   | Reserved (3 items)                         | 0 to 1     | ---   | 1     | F001   | 0                 |
| 5910   | ...Repeated for module number 2            |            |       |       |        |                   |
| 5920   | ...Repeated for module number 3            |            |       |       |        |                   |
| 5930   | ...Repeated for module number 4            |            |       |       |        |                   |
| 5940   | ...Repeated for module number 5            |            |       |       |        |                   |
| 5950   | ...Repeated for module number 6            |            |       |       |        |                   |
| <b>Phase Instantaneous Overcurrent (Read/Write Grouped Setting) (12 modules)</b>   |  |            |       |       |        |                   |
| 5A00   | Phase IOC1 Function                        | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5A01   | Phase IOC1 Signal Source                   | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)         |
| 5A02   | Phase IOC1 Pickup                          | 0 to 30    | pu    | 0.001 | F001   | 1000              |
| 5A03   | Phase IOC1 Delay                           | 0 to 600   | s     | 0.01  | F001   | 0                 |
| 5A04   | Phase IOC1 Reset Delay                     | 0 to 600   | s     | 0.01  | F001   | 0                 |
| 5A05   | Phase IOC1 Block For Each Phase (3 items)  | 0 to 65535 | ---   | 1     | F300   | 0                 |
| 5A08   | Phase IOC1 Target                          | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset)    |
| 5A09   | Phase IOC1 Events                          | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5A0A   | Reserved (6 items)                         | 0 to 1     | ---   | 1     | F001   | 0                 |
| 5A10   | ...Repeated for module number 2            |            |       |       |        |                   |
| 5A20   | ...Repeated for module number 3            |            |       |       |        |                   |
| 5A30   | ...Repeated for module number 4            |            |       |       |        |                   |
| 5A40   | ...Repeated for module number 5            |            |       |       |        |                   |
| 5A50   | ...Repeated for module number 6            |            |       |       |        |                   |
| 5A60   | ...Repeated for module number 7            |            |       |       |        |                   |
| 5A70   | ...Repeated for module number 8            |            |       |       |        |                   |
| 5A80   | ...Repeated for module number 9            |            |       |       |        |                   |
| 5A90   | ...Repeated for module number 10           |            |       |       |        |                   |
| 5AA0   | ...Repeated for module number 11           |            |       |       |        |                   |
| 5AB0   | ...Repeated for module number 12           |            |       |       |        |                   |
| <b>Neutral Time Overcurrent (Read/Write Grouped Setting) (6 modules)</b>           |  |            |       |       |        |                   |
| 5B00   | Neutral TOC1 Function                      | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5B01   | Neutral TOC1 Signal Source                 | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)         |
| 5B02   | Neutral TOC1 Input                         | 0 to 1     | ---   | 1     | F122   | 0 (Phasor)        |
| 5B03   | Neutral TOC1 Pickup                        | 0 to 30    | pu    | 0.001 | F001   | 1000              |
| 5B04   | Neutral TOC1 Curve                         | 0 to 16    | ---   | 1     | F103   | 0 (IEEE Mod Inv)  |
| 5B05   | Neutral TOC1 Multiplier                    | 0 to 600   | ---   | 0.01  | F001   | 100               |
| 5B06   | Neutral TOC1 Reset                         | 0 to 1     | ---   | 1     | F104   | 0 (Instantaneous) |
| 5B07   | Neutral TOC1 Block                         | 0 to 65535 | ---   | 1     | F300   | 0                 |
| 5B08   | Neutral TOC1 Target                        | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset)    |
| 5B09   | Neutral TOC1 Events                        | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5B0A   | Reserved (6 items)                         | 0 to 1     | ---   | 1     | F001   | 0                 |
| 5B10   | ...Repeated for module number 2            |            |       |       |        |                   |
| 5B20   | ...Repeated for module number 3            |            |       |       |        |                   |
| 5B30   | ...Repeated for module number 4            |            |       |       |        |                   |
| 5B40   | ...Repeated for module number 5            |            |       |       |        |                   |
| 5B50   | ...Repeated for module number 6            |            |       |       |        |                   |
| <b>Neutral Instantaneous Overcurrent (Read/Write Grouped Setting) (12 modules)</b> |  |            |       |       |        |                   |
| 5C00   | Neutral IOC1 Function                      | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |

Table B-9: MODBUS MEMORY MAP (Sheet 16 of 38)

| ADDR  | REGISTER NAME                    | RANGE      | UNITS | STEP  | FORMAT | DEFAULT           |
|---|----------------------------------|------------|-------|-------|--------|-------------------|
| 5C01  | Neutral IOC1 Signal Source       | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)         |
| 5C02  | Neutral IOC1 Pickup              | 0 to 30    | pu    | 0.001 | F001   | 1000              |
| 5C03  | Neutral IOC1 Delay               | 0 to 600   | s     | 0.01  | F001   | 0                 |
| 5C04  | Neutral IOC1 Reset Delay         | 0 to 600   | s     | 0.01  | F001   | 0                 |
| 5C05  | Neutral IOC1 Block               | 0 to 65535 | ---   | 1     | F300   | 0                 |
| 5C06  | Neutral IOC1 Target              | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset)    |
| 5C07  | Neutral IOC1 Events              | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5C08  | Reserved (8 items)               | 0 to 1     | ---   | 1     | F001   | 0                 |
| 5C10  | ...Repeated for module number 2  |            |       |       |        |                   |
| 5C20  | ...Repeated for module number 3  |            |       |       |        |                   |
| 5C30  | ...Repeated for module number 4  |            |       |       |        |                   |
| 5C40  | ...Repeated for module number 5  |            |       |       |        |                   |
| 5C50  | ...Repeated for module number 6  |            |       |       |        |                   |
| 5C60  | ...Repeated for module number 7  |            |       |       |        |                   |
| 5C70  | ...Repeated for module number 8  |            |       |       |        |                   |
| 5C80  | ...Repeated for module number 9  |            |       |       |        |                   |
| 5C90  | ...Repeated for module number 10 |            |       |       |        |                   |
| 5CA0  | ...Repeated for module number 11 |            |       |       |        |                   |
| 5CB0  | ...Repeated for module number 12 |            |       |       |        |                   |
| <b>Ground Time Overcurrent (Read/Write Grouped Setting) (6 modules)</b>           |                                  |            |       |       |        |                   |
| 5D00  | Ground TOC1 Function             | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5D01  | Ground TOC1 Signal Source        | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)         |
| 5D02  | Ground TOC1 Input                | 0 to 1     | ---   | 1     | F122   | 0 (Phasor)        |
| 5D03  | Ground TOC1 Pickup               | 0 to 30    | pu    | 0.001 | F001   | 1000              |
| 5D04  | Ground TOC1 Curve                | 0 to 16    | ---   | 1     | F103   | 0 (IEEE Mod Inv)  |
| 5D05  | Ground TOC1 Multiplier           | 0 to 600   | ---   | 0.01  | F001   | 100               |
| 5D06  | Ground TOC1 Reset                | 0 to 1     | ---   | 1     | F104   | 0 (Instantaneous) |
| 5D07  | Ground TOC1 Block                | 0 to 65535 | ---   | 1     | F300   | 0                 |
| 5D08  | Ground TOC1 Target               | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset)    |
| 5D09  | Ground TOC1 Events               | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5D0A  | Reserved (6 items)               | 0 to 1     | ---   | 1     | F001   | 0                 |
| 5D10  | ...Repeated for module number 2  |            |       |       |        |                   |
| 5D20  | ...Repeated for module number 3  |            |       |       |        |                   |
| 5D30  | ...Repeated for module number 4  |            |       |       |        |                   |
| 5D40  | ...Repeated for module number 5  |            |       |       |        |                   |
| 5D50  | ...Repeated for module number 6  |            |       |       |        |                   |
| <b>Ground Instantaneous Overcurrent (Read/Write Grouped Setting) (12 modules)</b> |                                  |            |       |       |        |                   |
| 5E00  | Ground IOC1 Signal Source        | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)         |
| 5E01  | Ground IOC1 Function             | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5E02  | Ground IOC1 Pickup               | 0 to 30    | pu    | 0.001 | F001   | 1000              |
| 5E03  | Ground IOC1 Delay                | 0 to 600   | s     | 0.01  | F001   | 0                 |
| 5E04  | Ground IOC1 Reset Delay          | 0 to 600   | s     | 0.01  | F001   | 0                 |
| 5E05  | Ground IOC1 Block                | 0 to 65535 | ---   | 1     | F300   | 0                 |
| 5E06  | Ground IOC1 Target               | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset)    |
| 5E07  | Ground IOC1 Events               | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)      |
| 5E08  | Reserved (8 items)               | 0 to 1     | ---   | 1     | F001   | 0                 |
| 5E10  | ...Repeated for module number 2  |            |       |       |        |                   |
| 5E20  | ...Repeated for module number 3  |            |       |       |        |                   |
| 5E30  | ...Repeated for module number 4  |            |       |       |        |                   |
| 5E40  | ...Repeated for module number 5  |            |       |       |        |                   |
| 5E50  | ...Repeated for module number 6  |            |       |       |        |                   |
| 5E60  | ...Repeated for module number 7  |            |       |       |        |                   |
| 5E70  | ...Repeated for module number 8  |            |       |       |        |                   |
| 5E80  | ...Repeated for module number 9  |            |       |       |        |                   |

Table B-9: MODBUS MEMORY MAP (Sheet 17 of 38)

| ADDR  | REGISTER NAME                                 | RANGE       | UNITS | STEP  | FORMAT | DEFAULT           |
|---|---|-------------|-------|-------|--------|-------------------|
| 5E90  | ...Repeated for module number 10              |             |       |       |        |                   |
| 5EA0  | ...Repeated for module number 11              |             |       |       |        |                   |
| 5EB0  | ...Repeated for module number 12              |             |       |       |        |                   |
| <b>Autoreclose (Read/Write Setting) (6 modules)</b>   |   |             |       |       |        |                   |
| 6240  | Autoreclose 1 Function                        | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 6241  | Autoreclose 1 Initiate                        | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6242  | Autoreclose 1 Block                           | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6243  | Autoreclose 1 Max Number of Shots             | 1 to 4      | ---   | 1     | F001   | 1                 |
| 6244  | Autoreclose 1 Manual Close                    | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6245  | Autoreclose 1 Manual Reset from LO            | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6246  | Autoreclose 1 Reset Lockout if Breaker Closed | 0 to 1      | ---   | 1     | F108   | 0 (Off)           |
| 6247  | Autoreclose 1 Reset Lockout On Manual Close   | 0 to 1      | ---   | 1     | F108   | 0 (Off)           |
| 6248  | Autoreclose 1 Breaker Closed                  | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6249  | Autoreclose 1 Breaker Open                    | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 624A  | Autoreclose 1 Block Time Upon Manual Close    | 0 to 655.35 | s     | 0.01  | F001   | 1000              |
| 624B  | Autoreclose 1 Dead Time Shot 1                | 0 to 655.35 | s     | 0.01  | F001   | 100               |
| 624C  | Autoreclose 1 Dead Time Shot 2                | 0 to 655.35 | s     | 0.01  | F001   | 200               |
| 624D  | Autoreclose 1 Dead Time Shot 3                | 0 to 655.35 | s     | 0.01  | F001   | 300               |
| 624E  | Autoreclose 1 Dead Time Shot 4                | 0 to 655.35 | s     | 0.01  | F001   | 400               |
| 624F  | Autoreclose 1 Reset Lockout Delay             | 0 to 655.35 | s     | 0.01  | F001   | 6000              |
| 6250  | Autoreclose 1 Reset Time                      | 0 to 655.35 | s     | 0.01  | F001   | 6000              |
| 6251  | Autoreclose 1 Incomplete Sequence Time        | 0 to 655.35 | s     | 0.01  | F001   | 500               |
| 6252  | Autoreclose 1 Events                          | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 6253  | Autoreclose 1 Reduce Max 1                    | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6254  | Autoreclose 1 Reduce Max 2                    | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6255  | Autoreclose 1 Reduce Max 3                    | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6256  | Autoreclose 1 Add Delay 1                     | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6257  | Autoreclose 1 Delay 1                         | 0 to 655.35 | s     | 0.01  | F001   | 0                 |
| 6258  | Autoreclose 1 Add Delay 2                     | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6259  | Autoreclose 1 Delay 2                         | 0 to 655.35 | s     | 0.01  | F001   | 0                 |
| 625A  | Autoreclose 1 Reserved (4 items)              | 0 to 0.001  | ---   | 0.001 | F001   | 0                 |
| 625E  | ...Repeated for module number 2               |             |       |       |        |                   |
| 627C  | ...Repeated for module number 3               |             |       |       |        |                   |
| 629A  | ...Repeated for module number 4               |             |       |       |        |                   |
| 62B8  | ...Repeated for module number 5               |             |       |       |        |                   |
| 62D6  | ...Repeated for module number 6               |             |       |       |        |                   |
| <b>Negative Sequence Time Overcurrent (Read/Write Grouped Setting) (2 modules)</b>          |   |             |       |       |        |                   |
| 6300  | Negative Sequence TOC1 Function               | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 6301  | Negative Sequence TOC1 Signal Source          | 0 to 5      | ---   | 1     | F167   | 0 (SRC 1)         |
| 6302  | Negative Sequence TOC1 Pickup                 | 0 to 30     | pu    | 0.001 | F001   | 1000              |
| 6303  | Negative Sequence TOC1 Curve                  | 0 to 16     | ---   | 1     | F103   | 0 (IEEE Mod Inv)  |
| 6304  | Negative Sequence TOC1 Multiplier             | 0 to 600    | ---   | 0.01  | F001   | 100               |
| 6305  | Negative Sequence TOC1 Reset                  | 0 to 1      | ---   | 1     | F104   | 0 (Instantaneous) |
| 6306  | Negative Sequence TOC1 Block                  | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 6307  | Negative Sequence TOC1 Target                 | 0 to 2      | ---   | 1     | F109   | 0 (Self-reset)    |
| 6308  | Negative Sequence TOC1 Events                 | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 6309  | Reserved (7 items)                            | 0 to 1      | ---   | 1     | F001   | 0                 |
| 6310  | ...Repeated for module number 2               |             |       |       |        |                   |
| <b>Negative Sequence Instantaneous Overcurrent (Read/Write Grouped Setting) (2 modules)</b> |   |             |       |       |        |                   |
| 6400  | Negative Sequence IOC1 Function               | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 6401  | Negative Sequence IOC1 Signal Source          | 0 to 5      | ---   | 1     | F167   | 0 (SRC 1)         |
| 6402  | Negative Sequence IOC1 Pickup                 | 0 to 30     | pu    | 0.001 | F001   | 1000              |
| 6403  | Negative Sequence IOC1 Delay                  | 0 to 600    | s     | 0.01  | F001   | 0                 |
| 6404  | Negative Sequence IOC1 Reset Delay            | 0 to 600    | s     | 0.01  | F001   | 0                 |

Table B-9: MODBUS MEMORY MAP (Sheet 18 of 38)

| ADDR  | REGISTER NAME                              | RANGE       | UNITS   | STEP  | FORMAT | DEFAULT        |
|---|--|-------------|---------|-------|--------|----------------|
| 6405  | Negative Sequence IOC1 Block               | 0 to 65535  | ---     | 1     | F300   | 0              |
| 6406  | Negative Sequence IOC1 Target              | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset) |
| 6407  | Negative Sequence IOC1 Events              | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 6408  | Reserved (8 items)                         | 0 to 1      | ---     | 1     | F001   | 0              |
| 6410  | ...Repeated for module number 2            |             |         |       |        |                |
| <b>Negative Sequence Overvoltage (Read/Write Grouped Setting)</b> |  |             |         |       |        |                |
| 64A0  | Negative Sequence Overvoltage Function     | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 64A1  | Negative Sequence Overvoltage Source       | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)      |
| 64A2  | Negative Sequence Overvoltage Pickup       | 0 to 1.25   | pu      | 0.001 | F001   | 300            |
| 64A3  | Negative Sequence Overvoltage Pickup Delay | 0 to 600    | s       | 0.01  | F001   | 50             |
| 64A4  | Negative Sequence Overvoltage Reset Delay  | 0 to 600    | s       | 0.01  | F001   | 50             |
| 64A5  | Negative Sequence Overvoltage Block        | 0 to 65535  | ---     | 1     | F300   | 0              |
| 64A6  | Negative Sequence Overvoltage Target       | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset) |
| 64A7  | Negative Sequence Overvoltage Events       | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| <b>Power Swing Detect (Read/Write Grouped Setting)</b>            |  |             |         |       |        |                |
| 65C0  | Power Swing Detect Function                | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 65C1  | Power Swing Detect Source                  | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)      |
| 65C2  | Power Swing Detect Mode                    | 0 to 1      | ---     | 1     | F513   | 0 (Two Step)   |
| 65C3  | Power Swing Detect Supervision             | 0.05 to 30  | pu      | 0.001 | F001   | 600            |
| 65C4  | Power Swing Detect Forward Reach           | 0.1 to 500  | ohms    | 0.01  | F001   | 5000           |
| 65C5  | Power Swing Detect Forward RCA             | 40 to 90    | degrees | 1     | F001   | 75             |
| 65C6  | Power Swing Detect Reverse Reach           | 0.1 to 500  | ohms    | 0.01  | F001   | 5000           |
| 65C7  | Power Swing Detect Reverse RCA             | 40 to 90    | degrees | 1     | F001   | 75             |
| 65C8  | Power Swing Detect Outer Limit Angle       | 40 to 140   | degrees | 1     | F001   | 120            |
| 65C9  | Power Swing Detect Middle Limit Angle      | 40 to 140   | degrees | 1     | F001   | 90             |
| 65CA  | Power Swing Detect Inner Limit Angle       | 40 to 140   | degrees | 1     | F001   | 60             |
| 65CB  | Power Swing Detect Delay 1 Pickup          | 0 to 65.535 | s       | 0.001 | F001   | 30             |
| 65CC  | Power Swing Detect Delay 1 Reset           | 0 to 65.535 | s       | 0.001 | F001   | 50             |
| 65CD  | Power Swing Detect Delay 2 Pickup          | 0 to 65.535 | s       | 0.001 | F001   | 17             |
| 65CE  | Power Swing Detect Delay 3 Pickup          | 0 to 65.535 | s       | 0.001 | F001   | 9              |
| 65CF  | Power Swing Detect Delay 4 Pickup          | 0 to 65.535 | s       | 0.001 | F001   | 17             |
| 65D0  | Power Swing Detect Seal In Delay           | 0 to 65.535 | s       | 0.001 | F001   | 400            |
| 65D1  | Power Swing Detect Trip Mode               | 0 to 1      | ---     | 1     | F514   | 0 (Delayed)    |
| 65D2  | Power Swing Detect Block                   | 0 to 65535  | ---     | 1     | F300   | 0              |
| 65D3  | Power Swing Detect Target                  | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset) |
| 65D4  | Power Swing Detect Event                   | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 65D5  | Power Swing Detect Shape                   | 0 to 1      | ---     | 1     | F085   | 0 (Mho Shape)  |
| 65D6  | Power Swing Detect Quad Forward Middle     | 0.1 to 500  | ohms    | 0.01  | F001   | 6000           |
| 65D7  | Power Swing Detect Quad Forward Outer      | 0.1 to 500  | ohms    | 0.01  | F001   | 7000           |
| 65D8  | Power Swing Detect Quad Reverse Middle     | 0.1 to 500  | ohms    | 0.01  | F001   | 6000           |
| 65D9  | Power Swing Detect Quad Reverse Outer      | 0.1 to 500  | ohms    | 0.01  | F001   | 7000           |
| 65DA  | Power Swing Detect Outer Right Blinder     | 0.1 to 500  | ohms    | 0.01  | F001   | 10000          |
| 65DB  | Power Swing Detect Outer Left Blinder      | 0.1 to 500  | ohms    | 0.01  | F001   | 10000          |
| 65DC  | Power Swing Detect Middle Right Blinder    | 0.1 to 500  | ohms    | 0.01  | F001   | 10000          |
| 65DD  | Power Swing Detect Middle Left Blinder     | 0.1 to 500  | ohms    | 0.01  | F001   | 10000          |
| 65DE  | Power Swing Detect Inner Right Blinder     | 0.1 to 500  | ohms    | 0.01  | F001   | 10000          |
| 65DF  | Power Swing Detect Inner Left Blinder      | 0.1 to 500  | ohms    | 0.01  | F001   | 10000          |
| <b>Load Encroachment (Read/Write Grouped Setting)</b>             |  |             |         |       |        |                |
| 6700  | Load Encroachment Function                 | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 6701  | Load Encroachment Source                   | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)      |
| 6702  | Load Encroachment Minimum Voltage          | 0 to 3      | pu      | 0.001 | F001   | 250            |
| 6703  | Load Encroachment Reach                    | 0.02 to 250 | ohms    | 0.01  | F001   | 100            |
| 6704  | Load Encroachment Angle                    | 5 to 50     | degrees | 1     | F001   | 30             |
| 6705  | Load Encroachment Pickup Delay             | 0 to 65.535 | s       | 0.001 | F001   | 0              |



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| ADDR   | REGISTER NAME  | RANGE       | UNITS   | STEP  | FORMAT | DEFAULT             |
|--|--|-------------|---------|-------|--------|---------------------|
| 6706   | Load Encroachment Reset Delay                        | 0 to 65.535 | s       | 0.001 | F001   | 0                   |
| 6707   | Load Encroachment Block                              | 0 to 65535  | ---     | 1     | F300   | 0                   |
| 6708   | Load Encroachment Target                             | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset)      |
| 6709   | Load Encroachment Events                             | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 670A   | Load Encroachment Reserved (6 items)                 | 0 to 65535  | ---     | 1     | F001   | 0                   |
| <b>Phase Undervoltage (Read/Write Grouped Setting) (2 modules)</b> |  |             |         |       |        |                     |
| 7000   | Phase UV1 Function                                   | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 7001   | Phase UV1 Signal Source                              | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)           |
| 7002   | Phase UV1 Pickup                                     | 0 to 3      | pu      | 0.001 | F001   | 1000                |
| 7003   | Phase UV1 Curve                                      | 0 to 1      | ---     | 1     | F111   | 0 (Definite Time)   |
| 7004   | Phase UV1 Delay                                      | 0 to 600    | s       | 0.01  | F001   | 100                 |
| 7005   | Phase UV1 Minimum Voltage                            | 0 to 3      | pu      | 0.001 | F001   | 100                 |
| 7006   | Phase UV1 Block                                      | 0 to 65535  | ---     | 1     | F300   | 0                   |
| 7007   | Phase UV1 Target                                     | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset)      |
| 7008   | Phase UV1 Events                                     | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 7009   | Phase UV Measurement Mode                            | 0 to 1      | ---     | 1     | F186   | 0 (Phase to Ground) |
| 700A   | Reserved (6 items)                                   | 0 to 1      | ---     | 1     | F001   | 0                   |
| 7013   | ...Repeated for module number 2                      |             |         |       |        |                     |
| <b>Phase Overvoltage (Read/Write Grouped Setting)</b>              |  |             |         |       |        |                     |
| 7040   | Phase OV1 Function                                   | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 7041   | Phase OV1 Source                                     | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)           |
| 7042   | Phase OV1 Pickup                                     | 0 to 3      | pu      | 0.001 | F001   | 1000                |
| 7043   | Phase OV1 Delay                                      | 0 to 600    | s       | 0.01  | F001   | 100                 |
| 7044   | Phase OV1 Reset Delay                                | 0 to 600    | s       | 0.01  | F001   | 100                 |
| 7045   | Phase OV1 Block                                      | 0 to 65535  | ---     | 1     | F300   | 0                   |
| 7046   | Phase OV1 Target                                     | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset)      |
| 7047   | Phase OV1 Events                                     | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 7048   | Reserved (8 items)                                   | 0 to 1      | ---     | 1     | F001   | 0                   |
| <b>Distance (Read/Write Grouped Setting)</b>                       |  |             |         |       |        |                     |
| 7060   | Distance Signal Source                               | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)           |
| 7061   | Memory Duration                                      | 5 to 25     | cycles  | 1     | F001   | 10                  |
| 7062   | Force Self-Polar                                     | 0 to 65535  | ---     | 1     | F300   | 0                   |
| <b>Phase Distance (Read/Write Grouped Setting) (5 modules)</b>     |  |             |         |       |        |                     |
| 7070   | Phase Distance Zone 1 Function                       | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 7071   | Phase Distance Zone 1 Current Supervision            | 0.05 to 30  | pu      | 0.001 | F001   | 200                 |
| 7072   | Phase Distance Zone 1 Reach                          | 0.02 to 250 | ohms    | 0.01  | F001   | 200                 |
| 7073   | Phase Distance Zone 1 Direction                      | 0 to 2      | ---     | 1     | F154   | 0 (Forward)         |
| 7074   | Phase Distance Zone 1 Comparator Limit               | 30 to 90    | degrees | 1     | F001   | 90                  |
| 7075   | Phase Distance Zone 1 Delay                          | 0 to 65.535 | s       | 0.001 | F001   | 0                   |
| 7076   | Phase Distance Zone 1 Block                          | 0 to 65535  | ---     | 1     | F300   | 0                   |
| 7077   | Phase Distance Zone 1 Target                         | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset)      |
| 7078   | Phase Distance Zone 1 Events                         | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)        |
| 7079   | Phase Distance Zone 1 Shape                          | 0 to 1      | ---     | 1     | F120   | 0 (Mho)             |
| 707A   | Phase Distance Zone 1 RCA                            | 30 to 90    | degrees | 1     | F001   | 85                  |
| 707B   | Phase Distance Zone 1 DIR RCA                        | 30 to 90    | degrees | 1     | F001   | 85                  |
| 707C   | Phase Distance Zone 1 DIR Comp Limit                 | 30 to 90    | degrees | 1     | F001   | 90                  |
| 707D   | Phase Distance Zone 1 Quad Right Blinder             | 0.02 to 500 | ohms    | 0.01  | F001   | 1000                |
| 707E   | Phase Distance Zone 1 Quad Right Blinder RCA         | 60 to 90    | degrees | 1     | F001   | 85                  |
| 707F   | Phase Distance Zone 1 Quad Left Blinder              | 0.02 to 500 | ohms    | 0.01  | F001   | 1000                |
| 7080   | Phase Distance Zone 1 Quad Left Blinder RCA          | 60 to 90    | degrees | 1     | F001   | 85                  |
| 7081   | Phase Distance Zone 1 Volt Limit                     | 0 to 5      | pu      | 0.001 | F001   | 0                   |
| 7082   | Phase Distance Zone 1 Transformer Voltage Connection | 0 to 12     | ---     | 1     | F153   | 0 (None)            |
| 7083   | Phase Distance Zone 1 Transformer Current Connection | 0 to 12     | ---     | 1     | F153   | 0 (None)            |
| 7084   | Phase Distance Zone 1 Rev Reach                      | 0.02 to 250 | ohms    | 0.01  | F001   | 200                 |



Table B-9: MODBUS MEMORY MAP (Sheet 20 of 38)

| ADDR  | REGISTER NAME                                 | RANGE       | UNITS   | STEP  | FORMAT | DEFAULT        |
|---|---|-------------|---------|-------|--------|----------------|
| 7085  | Phase Distance Zone 1 Rev Reach RCA           | 30 to 90    | degrees | 1     | F001   | 85             |
| 7086  | Reserved (10 items)                           | ---         | ---     | ---   | F001   | 0              |
| 7090  | ...Repeated for module number 2               |             |         |       |        |                |
| 70B0  | ...Repeated for module number 3               |             |         |       |        |                |
| <b>Ground Distance (Read/Write Grouped Setting) (5 modules)</b>               |   |             |         |       |        |                |
| 7130  | Ground Distance Zone 1 Function               | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 7131  | Ground Distance Zone 1 Current Supervision    | 0.05 to 30  | pu      | 0.001 | F001   | 200            |
| 7132  | Ground Distance Zone 1 Reach                  | 0.02 to 250 | ohms    | 0.01  | F001   | 200            |
| 7133  | Ground Distance Zone 1 Direction              | 0 to 2      | ---     | 1     | F154   | 0 (Forward)    |
| 7134  | Ground Distance Zone 1 Comparator Limit       | 30 to 90    | degrees | 1     | F001   | 90             |
| 7135  | Ground Distance Zone 1 Delay                  | 0 to 65.535 | s       | 0.001 | F001   | 0              |
| 7136  | Ground Distance Zone 1 Block                  | 0 to 65535  | ---     | 1     | F300   | 0              |
| 7137  | Ground Distance Zone 1 Target                 | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset) |
| 7138  | Ground Distance Zone 1 Events                 | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 7139  | Ground Distance Zone 1 Shape                  | 0 to 1      | ---     | 1     | F120   | 0 (Mho)        |
| 713A  | Ground Distance Zone 1 Z0 Z1 Magnitude        | 0 to 10     | ---     | 0.01  | F001   | 270            |
| 713B  | Ground Distance Zone 1 Z0 Z1 Angle            | -90 to 90   | degrees | 1     | F002   | 0              |
| 713C  | Ground Distance Zone 1 RCA                    | 30 to 90    | degrees | 1     | F001   | 85             |
| 713D  | Ground Distance Zone 1 DIR RCA                | 30 to 90    | degrees | 1     | F001   | 85             |
| 713E  | Ground Distance Zone 1 DIR Comp Limit         | 30 to 90    | degrees | 1     | F001   | 90             |
| 713F  | Ground Distance Zone 1 Quad Right Blinder     | 0.02 to 500 | ohms    | 0.01  | F001   | 1000           |
| 7140  | Ground Distance Zone 1 Quad Right Blinder RCA | 60 to 90    | degrees | 1     | F001   | 85             |
| 7141  | Ground Distance Zone 1 Quad Left Blinder      | 0.02 to 500 | ohms    | 0.01  | F001   | 1000           |
| 7142  | Ground Distance Zone 1 Quad Left Blinder RCA  | 60 to 90    | degrees | 1     | F001   | 85             |
| 7143  | Ground Distance Zone 1 Z0M Z1 Magnitude       | 0 to 7      | ---     | 0.01  | F001   | 0              |
| 7144  | Ground Distance Zone 1 Z0M Z1 Angle           | -90 to 90   | degrees | 1     | F002   | 0              |
| 7145  | Ground Distance Zone 1 Voltage Level          | 0 to 5      | pu      | 0.001 | F001   | 0              |
| 7146  | Ground Distance Zone 1 Non-Homogeneous Angle  | -40 to 40   | degrees | 0.1   | F002   | 0              |
| 7147  | Ground Distance Zone 1 POL Current            | 0 to 1      | ---     | 1     | F521   | 0 (Zero-seq)   |
| 7148  | Ground Distance Zone 1 Reverse Reach          | 0.02 to 250 | ohms    | 0.01  | F001   | 200            |
| 7149  | Ground Distance Zone 1 Reverse Reach RCA      | 30 to 90    | degrees | 1     | F001   | 85             |
| 714A  | Reserved (7 items)                            | 0 to 65535  | ---     | 1     | F001   | 0              |
| 7151  | ...Repeated for module number 2               |             |         |       |        |                |
| 7172  | ...Repeated for module number 3               |             |         |       |        |                |
| 7193  | ...Repeated for module number 4               |             |         |       |        |                |
| <b>Line Pickup (Read/Write Grouped Setting)</b>                               |   |             |         |       |        |                |
| 71F0  | Line Pickup Function                          | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 71F1  | Line Pickup Signal Source                     | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)      |
| 71F2  | Line Pickup Phase IOC Pickup                  | 0 to 30     | pu      | 0.001 | F001   | 1000           |
| 71F3  | Line Pickup UV Pickup                         | 0 to 3      | pu      | 0.001 | F001   | 700            |
| 71F4  | Line End Open Pickup Delay                    | 0 to 65.535 | s       | 0.001 | F001   | 150            |
| 71F5  | Line End Open Reset Delay                     | 0 to 65.535 | s       | 0.001 | F001   | 90             |
| 71F6  | Line Pickup OV Pickup Delay                   | 0 to 65.535 | s       | 0.001 | F001   | 40             |
| 71F7  | Autoreclose Coordination Pickup Delay         | 0 to 65.535 | s       | 0.001 | F001   | 45             |
| 71F8  | Autoreclose Coordination Reset Delay          | 0 to 65.535 | s       | 0.001 | F001   | 5              |
| 71F9  | Autoreclose Coordination Bypass               | 0 to 1      | ---     | 1     | F102   | 1 (Enabled)    |
| 71FA  | Line Pickup Block                             | 0 to 65535  | ---     | 1     | F300   | 0              |
| 71FB  | Line Pickup Target                            | 0 to 2      | ---     | 1     | F109   | 0 (Self-reset) |
| 71FC  | Line Pickup Events                            | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 71FD  | Terminal Open                                 | 0 to 65535  | ---     | 1     | F300   | 0              |
| 71FE  | AR Accelerate                                 | 0 to 65535  | ---     | 1     | F300   | 0              |
| <b>Phase Directional Overcurrent (Read/Write Grouped Setting) (2 modules)</b> |   |             |         |       |        |                |
| 7260  | Phase Directional Overcurrent 1 Function      | 0 to 1      | ---     | 1     | F102   | 0 (Disabled)   |
| 7261  | Phase Directional Overcurrent 1 Source        | 0 to 5      | ---     | 1     | F167   | 0 (SRC 1)      |

Table B-9: MODBUS MEMORY MAP (Sheet 21 of 38)

| ADDR  | REGISTER NAME   | RANGE       | UNITS                | STEP  | FORMAT | DEFAULT            |
|---|---|-------------|----------------------|-------|--------|--------------------|
| 7262  | Phase Directional Overcurrent 1 Block                 | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 7263  | Phase Directional Overcurrent 1 ECA                   | 0 to 359    | ---                  | 1     | F001   | 30                 |
| 7264  | Phase Directional Overcurrent 1 Pol V Threshold       | 0 to 3      | pu                   | 0.001 | F001   | 700                |
| 7265  | Phase Directional Overcurrent 1 Block Overcurrent     | 0 to 1      | ---                  | 1     | F126   | 0 (No)             |
| 7266  | Phase Directional Overcurrent 1 Target                | 0 to 2      | ---                  | 1     | F109   | 0 (Self-reset)     |
| 7267  | Phase Directional Overcurrent 1 Events                | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 7268  | Reserved (8 items)                                    | 0 to 1      | ---                  | 1     | F001   | 0                  |
| 7270  | ...Repeated for module number 2                       |             |                      |       |        |                    |
| <b>Neutral Directional Overcurrent (Read/Write Grouped Setting) (2 modules)</b>           |   |             |                      |       |        |                    |
| 7280  | Neutral Directional Overcurrent 1 Function            | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 7281  | Neutral Directional Overcurrent 1 Source              | 0 to 5      | ---                  | 1     | F167   | 0 (SRC 1)          |
| 7282  | Neutral Directional Overcurrent 1 Polarizing          | 0 to 2      | ---                  | 1     | F230   | 0 (Voltage)        |
| 7283  | Neutral Directional Overcurrent 1 Forward ECA         | -90 to 90   | ° Lag                | 1     | F002   | 75                 |
| 7284  | Neutral Directional Overcurrent 1 Forward Limit Angle | 40 to 90    | degrees              | 1     | F001   | 90                 |
| 7285  | Neutral Directional Overcurrent 1 Forward Pickup      | 0.002 to 30 | pu                   | 0.001 | F001   | 50                 |
| 7286  | Neutral Directional Overcurrent 1 Reverse Limit Angle | 40 to 90    | degrees              | 1     | F001   | 90                 |
| 7287  | Neutral Directional Overcurrent 1 Reverse Pickup      | 0.002 to 30 | pu                   | 0.001 | F001   | 50                 |
| 7288  | Neutral Directional Overcurrent 1 Target              | 0 to 2      | ---                  | 1     | F109   | 0 (Self-reset)     |
| 7289  | Neutral Directional Overcurrent 1 Block               | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 728A  | Neutral Directional Overcurrent 1 Events              | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 728B  | Neutral Directional Overcurrent 1 Polarizing Voltage  | 0 to 1      | ---                  | 1     | F231   | 0 (Calculated V0)  |
| 728C  | Neutral Directional Overcurrent 1 Op Current          | 0 to 1      | ---                  | 1     | F196   | 0 (Calculated 3I0) |
| 728D  | Neutral Directional Overcurrent 1 Offset              | 0 to 250    | ohms                 | 0.01  | F001   | 0                  |
| 728E  | Neutral Directional Overcurrent 1 Pos Seq Restraint   | 0 to 0.5    | ---                  | 0.001 | F001   | 63                 |
| 728F  | Reserved  | 0 to 1      | ---                  | 1     | F001   | 0                  |
| 7290  | ...Repeated for module number 2                       |             |                      |       |        |                    |
| <b>Negative Sequence Directional Overcurrent (Read/Write Grouped Setting) (2 modules)</b> |   |             |                      |       |        |                    |
| 72A0  | Negative Sequence Directional Overcurrent 1 Function  | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 72A1  | Negative Sequence Directional Overcurrent 1 Source    | 0 to 5      | ---                  | 1     | F167   | 0 (SRC 1)          |
| 72A2  | Negative Sequence Directional Overcurrent 1 Type      | 0 to 1      | ---                  | 1     | F179   | 0 (Neg Sequence)   |
| 72A3  | Neg Sequence Directional Overcurrent 1 Forward ECA    | 0 to 90     | ° Lag                | 1     | F002   | 75                 |
| 72A4  | Neg Seq Directional Overcurrent 1 Forward Limit Angle | 40 to 90    | degrees              | 1     | F001   | 90                 |
| 72A5  | Neg Sequence Directional Overcurrent 1 Forward Pickup | 0.05 to 30  | pu                   | 0.01  | F001   | 5                  |
| 72A6  | Neg Seq Directional Overcurrent 1 Reverse Limit Angle | 40 to 90    | degrees              | 1     | F001   | 90                 |
| 72A7  | Neg Sequence Directional Overcurrent 1 Reverse Pickup | 0.05 to 30  | pu                   | 0.01  | F001   | 5                  |
| 72A8  | Negative Sequence Directional Overcurrent 1 Target    | 0 to 2      | ---                  | 1     | F109   | 0 (Self-reset)     |
| 72A9  | Negative Sequence Directional Overcurrent 1 Block     | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 72AA  | Negative Sequence Directional Overcurrent 1 Events    | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 72AB  | Negative Sequence Directional Overcurrent 1 Offset    | 0 to 250    | ohms                 | 0.01  | F001   | 0                  |
| 72AC  | Neg Seq Directional Overcurrent 1 Pos Seq Restraint   | 0 to 0.5    | ---                  | 0.001 | F001   | 63                 |
| 72AD  | Reserved (3 items)                                    | 0 to 1      | ---                  | 1     | F001   | 0                  |
| 72B0  | ...Repeated for module number 2                       |             |                      |       |        |                    |
| <b>Breaker Arcing Current Settings (Read/Write Setting) (2 modules)</b>                   |   |             |                      |       |        |                    |
| 72C0  | Breaker 1 Arcing Current Function                     | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 72C1  | Breaker 1 Arcing Current Source                       | 0 to 5      | ---                  | 1     | F167   | 0 (SRC 1)          |
| 72C2  | Breaker 1 Arcing Current Initiate A                   | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 72C3  | Breaker 1 Arcing Current Initiate B                   | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 72C4  | Breaker 1 Arcing Current Initiate C                   | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 72C5  | Breaker 1 Arcing Current Delay                        | 0 to 65.535 | s                    | 0.001 | F001   | 0                  |
| 72C6  | Breaker 1 Arcing Current Limit                        | 0 to 50000  | kA <sup>2</sup> -cyc | 1     | F001   | 1000               |
| 72C7  | Breaker 1 Arcing Current Block                        | 0 to 65535  | ---                  | 1     | F300   | 0                  |
| 72C8  | Breaker 1 Arcing Current Target                       | 0 to 2      | ---                  | 1     | F109   | 0 (Self-reset)     |
| 72C9  | Breaker 1 Arcing Current Events                       | 0 to 1      | ---                  | 1     | F102   | 0 (Disabled)       |
| 72CA  | ...Repeated for module number 2                       |             |                      |       |        |                    |

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| ADDR   | REGISTER NAME                      | RANGE                 | UNITS | STEP  | FORMAT | DEFAULT              |
|--|------------------------------------|-----------------------|-------|-------|--------|----------------------|
| <b>DCMA Inputs (Read/Write Setting) (24 modules)</b> |                                    |                       |       |       |        |                      |
| 7300   | DCMA Inputs 1 Function             | 0 to 1                | ---   | 1     | F102   | 0 (Disabled)         |
| 7301   | DCMA Inputs 1 ID                   | ---                   | ---   | ---   | F205   | "DCMA I 1"           |
| 7307   | DCMA Inputs 1 Reserved 1 (4 items) | 0 to 65535            | ---   | 1     | F001   | 0                    |
| 730B   | DCMA Inputs 1 Units                | ---                   | ---   | ---   | F206   | "mA"                 |
| 730E   | DCMA Inputs 1 Range                | 0 to 6                | ---   | 1     | F173   | 6 (4 to 20 mA)       |
| 730F   | DCMA Inputs 1 Minimum Value        | -9999.999 to 9999.999 | ---   | 0.001 | F004   | 4000                 |
| 7311   | DCMA Inputs 1 Maximum Value        | -9999.999 to 9999.999 | ---   | 0.001 | F004   | 20000                |
| 7313   | DCMA Inputs 1 Reserved (5 items)   | 0 to 65535            | ---   | 1     | F001   | 0                    |
| 7318   | ...Repeated for module number 2    |                       |       |       |        |                      |
| 7330   | ...Repeated for module number 3    |                       |       |       |        |                      |
| 7348   | ...Repeated for module number 4    |                       |       |       |        |                      |
| 7360   | ...Repeated for module number 5    |                       |       |       |        |                      |
| 7378   | ...Repeated for module number 6    |                       |       |       |        |                      |
| 7390   | ...Repeated for module number 7    |                       |       |       |        |                      |
| 73A8   | ...Repeated for module number 8    |                       |       |       |        |                      |
| 73C0   | ...Repeated for module number 9    |                       |       |       |        |                      |
| 73D8   | ...Repeated for module number 10   |                       |       |       |        |                      |
| 73F0   | ...Repeated for module number 11   |                       |       |       |        |                      |
| 7408   | ...Repeated for module number 12   |                       |       |       |        |                      |
| 7420   | ...Repeated for module number 13   |                       |       |       |        |                      |
| 7438   | ...Repeated for module number 14   |                       |       |       |        |                      |
| 7450   | ...Repeated for module number 15   |                       |       |       |        |                      |
| 7468   | ...Repeated for module number 16   |                       |       |       |        |                      |
| 7480   | ...Repeated for module number 17   |                       |       |       |        |                      |
| 7498   | ...Repeated for module number 18   |                       |       |       |        |                      |
| 74B0   | ...Repeated for module number 19   |                       |       |       |        |                      |
| 74C8   | ...Repeated for module number 20   |                       |       |       |        |                      |
| 74E0   | ...Repeated for module number 21   |                       |       |       |        |                      |
| 74F8   | ...Repeated for module number 22   |                       |       |       |        |                      |
| 7510   | ...Repeated for module number 23   |                       |       |       |        |                      |
| 7528   | ...Repeated for module number 24   |                       |       |       |        |                      |
| <b>RTD Inputs (Read/Write Setting) (48 modules)</b>  |                                    |                       |       |       |        |                      |
| 7540   | RTD Inputs 1 Function              | 0 to 1                | ---   | 1     | F102   | 0 (Disabled)         |
| 7541   | RTD Inputs 1 ID                    | ---                   | ---   | ---   | F205   | "RTD Ip 1"           |
| 7547   | RTD Inputs 1 Reserved 1 (4 items)  | 0 to 65535            | ---   | 1     | F001   | 0                    |
| 754B   | RTD Inputs 1 Type                  | 0 to 3                | ---   | 1     | F174   | 0 (100 Ohm Platinum) |
| 754C   | RTD Inputs 1 Reserved 2 (4 items)  | 0 to 65535            | ---   | 1     | F001   | 0                    |
| 7550   | ...Repeated for module number 2    |                       |       |       |        |                      |
| 7560   | ...Repeated for module number 3    |                       |       |       |        |                      |
| 7570   | ...Repeated for module number 4    |                       |       |       |        |                      |
| 7580   | ...Repeated for module number 5    |                       |       |       |        |                      |
| 7590   | ...Repeated for module number 6    |                       |       |       |        |                      |
| 75A0   | ...Repeated for module number 7    |                       |       |       |        |                      |
| 75B0   | ...Repeated for module number 8    |                       |       |       |        |                      |
| 75C0   | ...Repeated for module number 9    |                       |       |       |        |                      |
| 75D0   | ...Repeated for module number 10   |                       |       |       |        |                      |
| 75E0   | ...Repeated for module number 11   |                       |       |       |        |                      |
| 75F0   | ...Repeated for module number 12   |                       |       |       |        |                      |
| 7600   | ...Repeated for module number 13   |                       |       |       |        |                      |
| 7610   | ...Repeated for module number 14   |                       |       |       |        |                      |
| 7620   | ...Repeated for module number 15   |                       |       |       |        |                      |
| 7630   | ...Repeated for module number 16   |                       |       |       |        |                      |
| 7640   | ...Repeated for module number 17   |                       |       |       |        |                      |

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| ADDR  | REGISTER NAME                              | RANGE      | UNITS | STEP  | FORMAT | DEFAULT        |
|---|--|------------|-------|-------|--------|----------------|
| 7650  | ...Repeated for module number 18           |            |       |       |        |                |
| 7660  | ...Repeated for module number 19           |            |       |       |        |                |
| 7670  | ...Repeated for module number 20           |            |       |       |        |                |
| 7680  | ...Repeated for module number 21           |            |       |       |        |                |
| 7690  | ...Repeated for module number 22           |            |       |       |        |                |
| 76A0  | ...Repeated for module number 23           |            |       |       |        |                |
| 76B0  | ...Repeated for module number 24           |            |       |       |        |                |
| 76C0  | ...Repeated for module number 25           |            |       |       |        |                |
| 76D0  | ...Repeated for module number 26           |            |       |       |        |                |
| 76E0  | ...Repeated for module number 27           |            |       |       |        |                |
| 76F0  | ...Repeated for module number 28           |            |       |       |        |                |
| 7700  | ...Repeated for module number 29           |            |       |       |        |                |
| 7710  | ...Repeated for module number 30           |            |       |       |        |                |
| 7720  | ...Repeated for module number 31           |            |       |       |        |                |
| 7730  | ...Repeated for module number 32           |            |       |       |        |                |
| 7740  | ...Repeated for module number 33           |            |       |       |        |                |
| 7750  | ...Repeated for module number 34           |            |       |       |        |                |
| 7760  | ...Repeated for module number 35           |            |       |       |        |                |
| 7770  | ...Repeated for module number 36           |            |       |       |        |                |
| 7780  | ...Repeated for module number 37           |            |       |       |        |                |
| 7790  | ...Repeated for module number 38           |            |       |       |        |                |
| 77A0  | ...Repeated for module number 39           |            |       |       |        |                |
| 77B0  | ...Repeated for module number 40           |            |       |       |        |                |
| 77C0  | ...Repeated for module number 41           |            |       |       |        |                |
| 77D0  | ...Repeated for module number 42           |            |       |       |        |                |
| 77E0  | ...Repeated for module number 43           |            |       |       |        |                |
| 77F0  | ...Repeated for module number 44           |            |       |       |        |                |
| 7800  | ...Repeated for module number 45           |            |       |       |        |                |
| 7810  | ...Repeated for module number 46           |            |       |       |        |                |
| 7820  | ...Repeated for module number 47           |            |       |       |        |                |
| 7830  | ...Repeated for module number 48           |            |       |       |        |                |
| <b>Neutral Overvoltage (Read/Write Grouped Setting) (3 modules)</b>   |  |            |       |       |        |                |
| 7F00  | Neutral Overvoltage 1 Function             | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)   |
| 7F01  | Neutral Overvoltage 1 Signal Source        | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)      |
| 7F02  | Neutral Overvoltage 1 Pickup               | 0 to 1.25  | pu    | 0.001 | F001   | 300            |
| 7F03  | Neutral Overvoltage 1 Pickup Delay         | 0 to 600   | s     | 0.01  | F001   | 100            |
| 7F04  | Neutral Overvoltage 1 Reset Delay          | 0 to 600   | s     | 0.01  | F001   | 100            |
| 7F05  | Neutral Overvoltage 1 Block                | 0 to 65535 | ---   | 1     | F300   | 0              |
| 7F06  | Neutral Overvoltage 1 Target               | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset) |
| 7F07  | Neutral Overvoltage 1 Events               | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)   |
| 7F08  | Neutral Overvoltage 1 Reserved (8 items)   | 0 to 65535 | ---   | 1     | F001   | 0              |
| 7F10  | ...Repeated for module number 2            |            |       |       |        |                |
| 7F20  | ...Repeated for module number 3            |            |       |       |        |                |
| <b>Auxiliary Overvoltage (Read/Write Grouped Setting) (3 modules)</b> |  |            |       |       |        |                |
| 7F30  | Auxiliary Overvoltage 1 Function           | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)   |
| 7F31  | Auxiliary Overvoltage 1 Signal Source      | 0 to 5     | ---   | 1     | F167   | 0 (SRC 1)      |
| 7F32  | Auxiliary Overvoltage 1 Pickup             | 0 to 3     | pu    | 0.001 | F001   | 300            |
| 7F33  | Auxiliary Overvoltage 1 Pickup Delay       | 0 to 600   | s     | 0.01  | F001   | 100            |
| 7F34  | Auxiliary Overvoltage 1 Reset Delay        | 0 to 600   | s     | 0.01  | F001   | 100            |
| 7F35  | Auxiliary Overvoltage 1 Block              | 0 to 65535 | ---   | 1     | F300   | 0              |
| 7F36  | Auxiliary Overvoltage 1 Target             | 0 to 2     | ---   | 1     | F109   | 0 (Self-reset) |
| 7F37  | Auxiliary Overvoltage 1 Events             | 0 to 1     | ---   | 1     | F102   | 0 (Disabled)   |
| 7F38  | Auxiliary Overvoltage 1 Reserved (8 items) | 0 to 65535 | ---   | 1     | F001   | 0              |
| 7F40  | ...Repeated for module number 2            |            |       |       |        |                |

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| ADDR   | REGISTER NAME                               | RANGE       | UNITS | STEP  | FORMAT | DEFAULT           |
|--|---|-------------|-------|-------|--------|-------------------|
| 7F50   | ...Repeated for module number 3             |             |       |       |        |                   |
| <b>Auxiliary Undervoltage (Read/Write Grouped Setting) (3 modules)</b> |   |             |       |       |        |                   |
| 7F60   | Auxiliary Undervoltage 1 Function           | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 7F61   | Auxiliary Undervoltage 1 Signal Source      | 0 to 5      | ---   | 1     | F167   | 0 (SRC 1)         |
| 7F62   | Auxiliary Undervoltage 1 Pickup             | 0 to 3      | pu    | 0.001 | F001   | 700               |
| 7F63   | Auxiliary Undervoltage 1 Delay              | 0 to 600    | s     | 0.01  | F001   | 100               |
| 7F64   | Auxiliary Undervoltage 1 Curve              | 0 to 1      | ---   | 1     | F111   | 0 (Definite Time) |
| 7F65   | Auxiliary Undervoltage 1 Minimum Voltage    | 0 to 3      | pu    | 0.001 | F001   | 100               |
| 7F66   | Auxiliary Undervoltage 1 Block              | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 7F67   | Auxiliary Undervoltage 1 Target             | 0 to 2      | ---   | 1     | F109   | 0 (Self-reset)    |
| 7F68   | Auxiliary Undervoltage 1 Events             | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 7F69   | Auxiliary Undervoltage 1 Reserved (7 items) | 0 to 65535  | ---   | 1     | F001   | 0                 |
| 7F70   | ...Repeated for module number 2             |             |       |       |        |                   |
| 7F80   | ...Repeated for module number 3             |             |       |       |        |                   |
| <b>Frequency (Read Only)</b>   |   |             |       |       |        |                   |
| 8000   | Tracking Frequency                          | 2 to 90     | Hz    | 0.01  | F001   | 0                 |
| <b>FlexState Settings (Read/Write Setting)</b>                         |   |             |       |       |        |                   |
| 8800   | FlexState Parameters (256 items)            | ---         | ---   | ---   | F300   | 0                 |
| <b>FlexElement (Read/Write Setting) (16 modules)</b>                   |   |             |       |       |        |                   |
| 9000   | FlexElement 1 Function                      | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 9001   | FlexElement 1 Name                          | ---         | ---   | ---   | F206   | "FxE 1 "          |
| 9004   | FlexElement 1 InputP                        | 0 to 65535  | ---   | 1     | F600   | 0                 |
| 9005   | FlexElement 1 InputM                        | 0 to 65535  | ---   | 1     | F600   | 0                 |
| 9006   | FlexElement 1 Compare                       | 0 to 1      | ---   | 1     | F516   | 0 (LEVEL)         |
| 9007   | FlexElement 1 Input                         | 0 to 1      | ---   | 1     | F515   | 0 (SIGNED)        |
| 9008   | FlexElement 1 Direction                     | 0 to 1      | ---   | 1     | F517   | 0 (OVER)          |
| 9009   | FlexElement 1 Hysteresis                    | 0.1 to 50   | %     | 0.1   | F001   | 30                |
| 900A   | FlexElement 1 Pickup                        | -90 to 90   | pu    | 0.001 | F004   | 1000              |
| 900C   | FlexElement 1 DeltaT Units                  | 0 to 2      | ---   | 1     | F518   | 0 (Milliseconds)  |
| 900D   | FlexElement 1 DeltaT                        | 20 to 86400 | ---   | 1     | F003   | 20                |
| 900F   | FlexElement 1 Pickup Delay                  | 0 to 65.535 | s     | 0.001 | F001   | 0                 |
| 9010   | FlexElement 1 Reset Delay                   | 0 to 65.535 | s     | 0.001 | F001   | 0                 |
| 9011   | FlexElement 1 Block                         | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 9012   | FlexElement 1 Target                        | 0 to 2      | ---   | 1     | F109   | 0 (Self-reset)    |
| 9013   | FlexElement 1 Events                        | 0 to 1      | ---   | 1     | F102   | 0 (Disabled)      |
| 9014   | ...Repeated for module number 2             |             |       |       |        |                   |
| 9028   | ...Repeated for module number 3             |             |       |       |        |                   |
| 903C   | ...Repeated for module number 4             |             |       |       |        |                   |
| 9050   | ...Repeated for module number 5             |             |       |       |        |                   |
| 9064   | ...Repeated for module number 6             |             |       |       |        |                   |
| 9078   | ...Repeated for module number 7             |             |       |       |        |                   |
| 908C   | ...Repeated for module number 8             |             |       |       |        |                   |
| 90A0   | ...Repeated for module number 9             |             |       |       |        |                   |
| 90B4   | ...Repeated for module number 10            |             |       |       |        |                   |
| 90C8   | ...Repeated for module number 11            |             |       |       |        |                   |
| 90DC   | ...Repeated for module number 12            |             |       |       |        |                   |
| 90F0   | ...Repeated for module number 13            |             |       |       |        |                   |
| 9104   | ...Repeated for module number 14            |             |       |       |        |                   |
| 9118   | ...Repeated for module number 15            |             |       |       |        |                   |
| 912C   | ...Repeated for module number 16            |             |       |       |        |                   |
| <b>Fault Report Settings (Read/Write Setting) (5 modules)</b>          |   |             |       |       |        |                   |
| 9200   | Fault Report 1 Source                       | 0 to 5      | ---   | 1     | F167   | 0 (SRC 1)         |
| 9201   | Fault Report 1 Trigger                      | 0 to 65535  | ---   | 1     | F300   | 0                 |
| 9202   | Fault Report 1 Z1 Magnitude                 | 0.01 to 250 | ohms  | 0.01  | F001   | 300               |

Table B-9: MODBUS MEMORY MAP (Sheet 25 of 38)

| ADDR  | REGISTER NAME                    | RANGE                       | UNITS   | STEP  | FORMAT | DEFAULT        |
|---|----------------------------------|-----------------------------|---------|-------|--------|----------------|
| 9203  | Fault Report 1 Z1 Angle          | 25 to 90                    | degrees | 1     | F001   | 75             |
| 9204  | Fault Report 1 Z0 Magnitude      | 0.01 to 650                 | ohms    | 0.01  | F001   | 900            |
| 9205  | Fault Report 1 Z0 Angle          | 25 to 90                    | degrees | 1     | F001   | 75             |
| 9206  | Fault Report 1 Line Length Units | 0 to 1                      | ---     | 1     | F147   | 0 (km)         |
| 9207  | Fault Report 1 Line Length       | 0 to 2000                   |         | 0.1   | F001   | 1000           |
| 9208  | ...Repeated for module number 2  |                             |         |       |        |                |
| 9210  | ...Repeated for module number 3  |                             |         |       |        |                |
| 9218  | ...Repeated for module number 4  |                             |         |       |        |                |
| 9220  | ...Repeated for module number 5  |                             |         |       |        |                |
| <b>DCMA Outputs (Read/Write Setting) (24 modules)</b> |                                  |                             |         |       |        |                |
| 9300  | DCMA Outputs 1 Source            | 0 to 65535                  | ---     | 1     | F600   | 0              |
| 9301  | DCMA Outputs 1 Range             | 0 to 2                      | ---     | 1     | F522   | 0 (-1 to 1 mA) |
| 9302  | DCMA Output 1 Minimum            | -90 to 90                   | pu      | 0.001 | F004   | 0              |
| 9304  | DCMA Outputs 1 Maximum           | -90 to 90                   | pu      | 0.001 | F004   | 1000           |
| 9306  | ...Repeated for module number 2  |                             |         |       |        |                |
| 930C  | ...Repeated for module number 3  |                             |         |       |        |                |
| 9312  | ...Repeated for module number 4  |                             |         |       |        |                |
| 9318  | ...Repeated for module number 5  |                             |         |       |        |                |
| 931E  | ...Repeated for module number 6  |                             |         |       |        |                |
| 9324  | ...Repeated for module number 7  |                             |         |       |        |                |
| 932A  | ...Repeated for module number 8  |                             |         |       |        |                |
| 9330  | ...Repeated for module number 9  |                             |         |       |        |                |
| 9336  | ...Repeated for module number 10 |                             |         |       |        |                |
| 933C  | ...Repeated for module number 11 |                             |         |       |        |                |
| 9342  | ...Repeated for module number 12 |                             |         |       |        |                |
| 9348  | ...Repeated for module number 13 |                             |         |       |        |                |
| 934E  | ...Repeated for module number 14 |                             |         |       |        |                |
| 9354  | ...Repeated for module number 15 |                             |         |       |        |                |
| 935A  | ...Repeated for module number 16 |                             |         |       |        |                |
| 9360  | ...Repeated for module number 17 |                             |         |       |        |                |
| 9366  | ...Repeated for module number 18 |                             |         |       |        |                |
| 936C  | ...Repeated for module number 19 |                             |         |       |        |                |
| 9372  | ...Repeated for module number 20 |                             |         |       |        |                |
| 9378  | ...Repeated for module number 21 |                             |         |       |        |                |
| 937E  | ...Repeated for module number 22 |                             |         |       |        |                |
| 9384  | ...Repeated for module number 23 |                             |         |       |        |                |
| 938A  | ...Repeated for module number 24 |                             |         |       |        |                |
| <b>FlexElement Actuals (Read Only) (16 modules)</b>   |                                  |                             |         |       |        |                |
| 9A01  | FlexElement Actual               | -2147483.647 to 2147483.647 | ---     | 0.001 | F004   | 0              |
| 9A03  | ...Repeated for module number 2  |                             |         |       |        |                |
| 9A05  | ...Repeated for module number 3  |                             |         |       |        |                |
| 9A07  | ...Repeated for module number 4  |                             |         |       |        |                |
| 9A09  | ...Repeated for module number 5  |                             |         |       |        |                |
| 9A0B  | ...Repeated for module number 6  |                             |         |       |        |                |
| 9A0D  | ...Repeated for module number 7  |                             |         |       |        |                |
| 9A0F  | ...Repeated for module number 8  |                             |         |       |        |                |
| 9A11  | ...Repeated for module number 9  |                             |         |       |        |                |
| 9A13  | ...Repeated for module number 10 |                             |         |       |        |                |
| 9A15  | ...Repeated for module number 11 |                             |         |       |        |                |
| 9A17  | ...Repeated for module number 12 |                             |         |       |        |                |
| 9A19  | ...Repeated for module number 13 |                             |         |       |        |                |
| 9A1B  | ...Repeated for module number 14 |                             |         |       |        |                |
| 9A1D  | ...Repeated for module number 15 |                             |         |       |        |                |

Table B-9: MODBUS MEMORY MAP (Sheet 26 of 38)

| ADDR  | REGISTER NAME                                      | RANGE      | UNITS | STEP | FORMAT | DEFAULT            |
|---|--|------------|-------|------|--------|--------------------|
| 9A1F  | ...Repeated for module number 16                   |            |       |      |        |                    |
| <b>Setting Groups (Read/Write Setting)</b>                    |  |            |       |      |        |                    |
| A000  | Setting Group for Modbus Comms (0 means group 1)   | 0 to 5     | ---   | 1    | F001   | 0                  |
| A001  | Setting Groups Block                               | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A002  | FlexLogic to Activate Groups 2 through 8 (5 items) | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A009  | Setting Group Function                             | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| A00A  | Setting Group Events                               | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| <b>Setting Groups (Read Only)</b>                             |  |            |       |      |        |                    |
| A00B  | Current Setting Group                              | 0 to 5     | ---   | 1    | F001   | 0                  |
| <b>VT Fuse Failure (Read/Write Setting) (6 modules)</b>       |  |            |       |      |        |                    |
| A040  | VT Fuse Failure Function                           | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| A041  | ...Repeated for module number 2                    |            |       |      |        |                    |
| A042  | ...Repeated for module number 3                    |            |       |      |        |                    |
| A043  | ...Repeated for module number 4                    |            |       |      |        |                    |
| A044  | ...Repeated for module number 5                    |            |       |      |        |                    |
| A045  | ...Repeated for module number 6                    |            |       |      |        |                    |
| <b>Selector Switch Actuals (Read Only)</b>                    |  |            |       |      |        |                    |
| A400  | Selector 1 Position                                | 1 to 7     | ---   | 1    | F001   | 0                  |
| A401  | Selector 2 Position                                | 1 to 7     | ---   | 1    | F001   | 1                  |
| <b>Selector Switch (Read/Write Setting) (2 modules)</b>       |  |            |       |      |        |                    |
| A410  | Selector 1 Function                                | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| A411  | Selector 1 Range                                   | 1 to 7     | ---   | 1    | F001   | 7                  |
| A412  | Selector 1 Timeout                                 | 3 to 60    | s     | 0.1  | F001   | 50                 |
| A413  | Selector 1 Step Up                                 | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A414  | Selector 1 Step Mode                               | 0 to 1     | ---   | 1    | F083   | 0 (Time-out)       |
| A415  | Selector 1 Acknowledge                             | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A416  | Selector 1 Bit0                                    | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A417  | Selector 1 Bit1                                    | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A418  | Selector 1 Bit2                                    | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A419  | Selector 1 Bit Mode                                | 0 to 1     | ---   | 1    | F083   | 0 (Time-out)       |
| A41A  | Selector 1 Bit Acknowledge                         | 0 to 65535 | ---   | 1    | F300   | 0                  |
| A41B  | Selector 1 Power Up Mode                           | 0 to 2     | ---   | 1    | F084   | 0 (Restore)        |
| A41C  | Selector 1 Target                                  | 0 to 2     | ---   | 1    | F109   | 0 (Self-reset)     |
| A41D  | Selector 1 Events                                  | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| A41E  | Selector 1 Reserved (10 items)                     | ---        | ---   | 1    | F001   | 0                  |
| A428  | ...Repeated for module number 2                    |            |       |      |        |                    |
| <b>Flexcurves C and D (Read/Write Setting)</b>                |  |            |       |      |        |                    |
| AC00  | FlexCurve C (120 items)                            | 0 to 65535 | ms    | 1    | F011   | 0                  |
| AC78  | FlexCurve D (120 items)                            | 0 to 65535 | ms    | 1    | F011   | 0                  |
| <b>Non Volatile Latches (Read/Write Setting) (16 modules)</b> |  |            |       |      |        |                    |
| AD00  | Latch 1 Function                                   | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| AD01  | Latch 1 Type                                       | 0 to 1     | ---   | 1    | F519   | 0 (Reset Dominant) |
| AD02  | Latch 1 Set  | 0 to 65535 | ---   | 1    | F300   | 0                  |
| AD03  | Latch 1 Reset                                      | 0 to 65535 | ---   | 1    | F300   | 0                  |
| AD04  | Latch 1 Target                                     | 0 to 2     | ---   | 1    | F109   | 0 (Self-reset)     |
| AD05  | Latch 1 Events                                     | 0 to 1     | ---   | 1    | F102   | 0 (Disabled)       |
| AD06  | Latch 1 Reserved (4 items)                         | ---        | ---   | ---  | F001   | 0                  |
| AD0A  | ...Repeated for module number 2                    |            |       |      |        |                    |
| AD14  | ...Repeated for module number 3                    |            |       |      |        |                    |
| AD1E  | ...Repeated for module number 4                    |            |       |      |        |                    |
| AD28  | ...Repeated for module number 5                    |            |       |      |        |                    |
| AD32  | ...Repeated for module number 6                    |            |       |      |        |                    |
| AD3C  | ...Repeated for module number 7                    |            |       |      |        |                    |
| AD46  | ...Repeated for module number 8                    |            |       |      |        |                    |

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| ADDR  | REGISTER NAME                         | RANGE                     | UNITS | STEP  | FORMAT | DEFAULT          |
|---|---------------------------------------|---------------------------|-------|-------|--------|------------------|
| AD50  | ...Repeated for module number 9       |                           |       |       |        |                  |
| AD5A  | ...Repeated for module number 10      |                           |       |       |        |                  |
| AD64  | ...Repeated for module number 11      |                           |       |       |        |                  |
| AD6E  | ...Repeated for module number 12      |                           |       |       |        |                  |
| AD78  | ...Repeated for module number 13      |                           |       |       |        |                  |
| AD82  | ...Repeated for module number 14      |                           |       |       |        |                  |
| AD8C  | ...Repeated for module number 15      |                           |       |       |        |                  |
| AD96  | ...Repeated for module number 16      |                           |       |       |        |                  |
| <b>Digital Elements (Read/Write Setting) (16 modules)</b> |                                       |                           |       |       |        |                  |
| B000  | Digital Element 1 Function            | 0 to 1                    | ---   | 1     | F102   | 0 (Disabled)     |
| B001  | Digital Element 1 Name                | ---                       | ---   | ---   | F203   | "Dig Element 1 " |
| B015  | Digital Element 1 Input               | 0 to 65535                | ---   | 1     | F300   | 0                |
| B016  | Digital Element 1 Pickup Delay        | 0 to 999999.999           | s     | 0.001 | F003   | 0                |
| B018  | Digital Element 1 Reset Delay         | 0 to 999999.999           | s     | 0.001 | F003   | 0                |
| B01A  | Digital Element 1 Block               | 0 to 65535                | ---   | 1     | F300   | 0                |
| B01B  | Digital Element 1 Target              | 0 to 2                    | ---   | 1     | F109   | 0 (Self-reset)   |
| B01C  | Digital Element 1 Events              | 0 to 1                    | ---   | 1     | F102   | 0 (Disabled)     |
| B01D  | Digital Element 1 Reserved (3 items)  | ---                       | ---   | ---   | F001   | 0                |
| B020  | ...Repeated for module number 2       |                           |       |       |        |                  |
| B040  | ...Repeated for module number 3       |                           |       |       |        |                  |
| B060  | ...Repeated for module number 4       |                           |       |       |        |                  |
| B080  | ...Repeated for module number 5       |                           |       |       |        |                  |
| B0A0  | ...Repeated for module number 6       |                           |       |       |        |                  |
| B0C0  | ...Repeated for module number 7       |                           |       |       |        |                  |
| B0E0  | ...Repeated for module number 8       |                           |       |       |        |                  |
| B100  | ...Repeated for module number 9       |                           |       |       |        |                  |
| B120  | ...Repeated for module number 10      |                           |       |       |        |                  |
| B140  | ...Repeated for module number 11      |                           |       |       |        |                  |
| B160  | ...Repeated for module number 12      |                           |       |       |        |                  |
| B180  | ...Repeated for module number 13      |                           |       |       |        |                  |
| B1A0  | ...Repeated for module number 14      |                           |       |       |        |                  |
| B1C0  | ...Repeated for module number 15      |                           |       |       |        |                  |
| B1E0  | ...Repeated for module number 16      |                           |       |       |        |                  |
| <b>Digital Counter (Read/Write Setting) (8 modules)</b>   |                                       |                           |       |       |        |                  |
| B300  | Digital Counter 1 Function            | 0 to 1                    | ---   | 1     | F102   | 0 (Disabled)     |
| B301  | Digital Counter 1 Name                | ---                       | ---   | ---   | F205   | "Counter 1"      |
| B307  | Digital Counter 1 Units               | ---                       | ---   | ---   | F206   | (none)           |
| B30A  | Digital Counter 1 Block               | 0 to 65535                | ---   | 1     | F300   | 0                |
| B30B  | Digital Counter 1 Up                  | 0 to 65535                | ---   | 1     | F300   | 0                |
| B30C  | Digital Counter 1 Down                | 0 to 65535                | ---   | 1     | F300   | 0                |
| B30D  | Digital Counter 1 Preset              | -2147483647 to 2147483647 | ---   | 1     | F004   | 0                |
| B30F  | Digital Counter 1 Compare             | -2147483647 to 2147483647 | ---   | 1     | F004   | 0                |
| B311  | Digital Counter 1 Reset               | 0 to 65535                | ---   | 1     | F300   | 0                |
| B312  | Digital Counter 1 Freeze/Reset        | 0 to 65535                | ---   | 1     | F300   | 0                |
| B313  | Digital Counter 1 Freeze/Count        | 0 to 65535                | ---   | 1     | F300   | 0                |
| B314  | Digital Counter 1 Set To Preset       | 0 to 65535                | ---   | 1     | F300   | 0                |
| B315  | Digital Counter 1 Reserved (11 items) | ---                       | ---   | ---   | F001   | 0                |
| B320  | ...Repeated for module number 2       |                           |       |       |        |                  |
| B340  | ...Repeated for module number 3       |                           |       |       |        |                  |
| B360  | ...Repeated for module number 4       |                           |       |       |        |                  |
| B380  | ...Repeated for module number 5       |                           |       |       |        |                  |
| B3A0  | ...Repeated for module number 6       |                           |       |       |        |                  |
| B3C0  | ...Repeated for module number 7       |                           |       |       |        |                  |



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| ADDR  | REGISTER NAME                    | RANGE   | UNITS | STEP | FORMAT | DEFAULT      |
|---|----------------------------------|---------|-------|------|--------|--------------|
| B3E0  | ...Repeated for module number 8  |         |       |      |        |              |
| <b>Contact Inputs (Read/Write Setting) (96 modules)</b> |                                  |         |       |      |        |              |
| C000  | Contact Input 1 Name             | ---     | ---   | ---  | F205   | "Cont Ip 1"  |
| C006  | Contact Input 1 Events           | 0 to 1  | ---   | 1    | F102   | 0 (Disabled) |
| C007  | Contact Input 1 Debounce Time    | 0 to 16 | ms    | 0.5  | F001   | 20           |
| C008  | ...Repeated for module number 2  |         |       |      |        |              |
| C010  | ...Repeated for module number 3  |         |       |      |        |              |
| C018  | ...Repeated for module number 4  |         |       |      |        |              |
| C020  | ...Repeated for module number 5  |         |       |      |        |              |
| C028  | ...Repeated for module number 6  |         |       |      |        |              |
| C030  | ...Repeated for module number 7  |         |       |      |        |              |
| C038  | ...Repeated for module number 8  |         |       |      |        |              |
| C040  | ...Repeated for module number 9  |         |       |      |        |              |
| C048  | ...Repeated for module number 10 |         |       |      |        |              |
| C050  | ...Repeated for module number 11 |         |       |      |        |              |
| C058  | ...Repeated for module number 12 |         |       |      |        |              |
| C060  | ...Repeated for module number 13 |         |       |      |        |              |
| C068  | ...Repeated for module number 14 |         |       |      |        |              |
| C070  | ...Repeated for module number 15 |         |       |      |        |              |
| C078  | ...Repeated for module number 16 |         |       |      |        |              |
| C080  | ...Repeated for module number 17 |         |       |      |        |              |
| C088  | ...Repeated for module number 18 |         |       |      |        |              |
| C090  | ...Repeated for module number 19 |         |       |      |        |              |
| C098  | ...Repeated for module number 20 |         |       |      |        |              |
| C0A0  | ...Repeated for module number 21 |         |       |      |        |              |
| C0A8  | ...Repeated for module number 22 |         |       |      |        |              |
| C0B0  | ...Repeated for module number 23 |         |       |      |        |              |
| C0B8  | ...Repeated for module number 24 |         |       |      |        |              |
| C0C0  | ...Repeated for module number 25 |         |       |      |        |              |
| C0C8  | ...Repeated for module number 26 |         |       |      |        |              |
| C0D0  | ...Repeated for module number 27 |         |       |      |        |              |
| C0D8  | ...Repeated for module number 28 |         |       |      |        |              |
| C0E0  | ...Repeated for module number 29 |         |       |      |        |              |
| C0E8  | ...Repeated for module number 30 |         |       |      |        |              |
| C0F0  | ...Repeated for module number 31 |         |       |      |        |              |
| C0F8  | ...Repeated for module number 32 |         |       |      |        |              |
| C100  | ...Repeated for module number 33 |         |       |      |        |              |
| C108  | ...Repeated for module number 34 |         |       |      |        |              |
| C110  | ...Repeated for module number 35 |         |       |      |        |              |
| C118  | ...Repeated for module number 36 |         |       |      |        |              |
| C120  | ...Repeated for module number 37 |         |       |      |        |              |
| C128  | ...Repeated for module number 38 |         |       |      |        |              |
| C130  | ...Repeated for module number 39 |         |       |      |        |              |
| C138  | ...Repeated for module number 40 |         |       |      |        |              |
| C140  | ...Repeated for module number 41 |         |       |      |        |              |
| C148  | ...Repeated for module number 42 |         |       |      |        |              |
| C150  | ...Repeated for module number 43 |         |       |      |        |              |
| C158  | ...Repeated for module number 44 |         |       |      |        |              |
| C160  | ...Repeated for module number 45 |         |       |      |        |              |
| C168  | ...Repeated for module number 46 |         |       |      |        |              |
| C170  | ...Repeated for module number 47 |         |       |      |        |              |
| C178  | ...Repeated for module number 48 |         |       |      |        |              |
| C180  | ...Repeated for module number 49 |         |       |      |        |              |
| C188  | ...Repeated for module number 50 |         |       |      |        |              |

Table B-9: MODBUS MEMORY MAP (Sheet 29 of 38)

| ADDR   | REGISTER NAME                        | RANGE   | UNITS | STEP | FORMAT | DEFAULT      |
|--|--------------------------------------|---------|-------|------|--------|--------------|
| C190   | ...Repeated for module number 51     |         |       |      |        |              |
| C198   | ...Repeated for module number 52     |         |       |      |        |              |
| C1A0   | ...Repeated for module number 53     |         |       |      |        |              |
| C1A8   | ...Repeated for module number 54     |         |       |      |        |              |
| C1B0   | ...Repeated for module number 55     |         |       |      |        |              |
| C1B8   | ...Repeated for module number 56     |         |       |      |        |              |
| C1C0   | ...Repeated for module number 57     |         |       |      |        |              |
| C1C8   | ...Repeated for module number 58     |         |       |      |        |              |
| C1D0   | ...Repeated for module number 59     |         |       |      |        |              |
| C1D8   | ...Repeated for module number 60     |         |       |      |        |              |
| C1E0   | ...Repeated for module number 61     |         |       |      |        |              |
| C1E8   | ...Repeated for module number 62     |         |       |      |        |              |
| C1F0   | ...Repeated for module number 63     |         |       |      |        |              |
| C1F8   | ...Repeated for module number 64     |         |       |      |        |              |
| C200   | ...Repeated for module number 65     |         |       |      |        |              |
| C208   | ...Repeated for module number 66     |         |       |      |        |              |
| C210   | ...Repeated for module number 67     |         |       |      |        |              |
| C218   | ...Repeated for module number 68     |         |       |      |        |              |
| C220   | ...Repeated for module number 69     |         |       |      |        |              |
| C228   | ...Repeated for module number 70     |         |       |      |        |              |
| C230   | ...Repeated for module number 71     |         |       |      |        |              |
| C238   | ...Repeated for module number 72     |         |       |      |        |              |
| C240   | ...Repeated for module number 73     |         |       |      |        |              |
| C248   | ...Repeated for module number 74     |         |       |      |        |              |
| C250   | ...Repeated for module number 75     |         |       |      |        |              |
| C258   | ...Repeated for module number 76     |         |       |      |        |              |
| C260   | ...Repeated for module number 77     |         |       |      |        |              |
| C268   | ...Repeated for module number 78     |         |       |      |        |              |
| C270   | ...Repeated for module number 79     |         |       |      |        |              |
| C278   | ...Repeated for module number 80     |         |       |      |        |              |
| C280   | ...Repeated for module number 81     |         |       |      |        |              |
| C288   | ...Repeated for module number 82     |         |       |      |        |              |
| C290   | ...Repeated for module number 83     |         |       |      |        |              |
| C298   | ...Repeated for module number 84     |         |       |      |        |              |
| C2A0   | ...Repeated for module number 85     |         |       |      |        |              |
| C2A8   | ...Repeated for module number 86     |         |       |      |        |              |
| C2B0   | ...Repeated for module number 87     |         |       |      |        |              |
| C2B8   | ...Repeated for module number 88     |         |       |      |        |              |
| C2C0   | ...Repeated for module number 89     |         |       |      |        |              |
| C2C8   | ...Repeated for module number 90     |         |       |      |        |              |
| C2D0   | ...Repeated for module number 91     |         |       |      |        |              |
| C2D8   | ...Repeated for module number 92     |         |       |      |        |              |
| C2E0   | ...Repeated for module number 93     |         |       |      |        |              |
| C2E8   | ...Repeated for module number 94     |         |       |      |        |              |
| C2F0   | ...Repeated for module number 95     |         |       |      |        |              |
| C2F8   | ...Repeated for module number 96     |         |       |      |        |              |
| <b>Contact Input Thresholds (Read/Write Setting)</b>       |                                      |         |       |      |        |              |
| C600   | Contact Input x Threshold (24 items) | 0 to 3  | ---   | 1    | F128   | 1 (33 Vdc)   |
| <b>Virtual Inputs Global Settings (Read/Write Setting)</b> |                                      |         |       |      |        |              |
| C680   | Virtual Inputs SBO Timeout           | 1 to 60 | s     | 1    | F001   | 30           |
| <b>Virtual Inputs (Read/Write Setting) (32 modules)</b>    |                                      |         |       |      |        |              |
| C690   | Virtual Input 1 Function             | 0 to 1  | ---   | 1    | F102   | 0 (Disabled) |
| C691   | Virtual Input 1 Name                 | ---     | ---   | ---  | F205   | "Virt Ip 1 " |
| C69B   | Virtual Input 1 Programmed Type      | 0 to 1  | ---   | 1    | F127   | 0 (Latched)  |

Table B-9: MODBUS MEMORY MAP (Sheet 30 of 38)

| ADDR   | REGISTER NAME                       | RANGE  | UNITS | STEP | FORMAT | DEFAULT      |
|--|-------------------------------------|--------|-------|------|--------|--------------|
| C69C   | Virtual Input 1 Events              | 0 to 1 | ---   | 1    | F102   | 0 (Disabled) |
| C69D   | Virtual Input 1 IEC 61850 SBOClass  | 1 to 2 | ---   | 1    | F001   | 1            |
| C69E   | Virtual Input 1 IEC 61850 SBOEna    | 0 to 1 | ---   | 1    | F102   | 0 (Disabled) |
| C69F   | Virtual Input 1 Reserved            | ---    | ---   | ---  | F001   | 0            |
| C6A0   | ...Repeated for module number 2     |        |       |      |        |              |
| C6B0   | ...Repeated for module number 3     |        |       |      |        |              |
| C6C0   | ...Repeated for module number 4     |        |       |      |        |              |
| C6D0   | ...Repeated for module number 5     |        |       |      |        |              |
| C6E0   | ...Repeated for module number 6     |        |       |      |        |              |
| C6F0   | ...Repeated for module number 7     |        |       |      |        |              |
| C700   | ...Repeated for module number 8     |        |       |      |        |              |
| C710   | ...Repeated for module number 9     |        |       |      |        |              |
| C720   | ...Repeated for module number 10    |        |       |      |        |              |
| C730   | ...Repeated for module number 11    |        |       |      |        |              |
| C740   | ...Repeated for module number 12    |        |       |      |        |              |
| C750   | ...Repeated for module number 13    |        |       |      |        |              |
| C760   | ...Repeated for module number 14    |        |       |      |        |              |
| C770   | ...Repeated for module number 15    |        |       |      |        |              |
| C780   | ...Repeated for module number 16    |        |       |      |        |              |
| C790   | ...Repeated for module number 17    |        |       |      |        |              |
| C7A0   | ...Repeated for module number 18    |        |       |      |        |              |
| C7B0   | ...Repeated for module number 19    |        |       |      |        |              |
| C7C0   | ...Repeated for module number 20    |        |       |      |        |              |
| C7D0   | ...Repeated for module number 21    |        |       |      |        |              |
| C7E0   | ...Repeated for module number 22    |        |       |      |        |              |
| C7F0   | ...Repeated for module number 23    |        |       |      |        |              |
| C800   | ...Repeated for module number 24    |        |       |      |        |              |
| C810   | ...Repeated for module number 25    |        |       |      |        |              |
| C820   | ...Repeated for module number 26    |        |       |      |        |              |
| C830   | ...Repeated for module number 27    |        |       |      |        |              |
| C840   | ...Repeated for module number 28    |        |       |      |        |              |
| C850   | ...Repeated for module number 29    |        |       |      |        |              |
| C860   | ...Repeated for module number 30    |        |       |      |        |              |
| C870   | ...Repeated for module number 31    |        |       |      |        |              |
| C880   | ...Repeated for module number 32    |        |       |      |        |              |
| <b>Virtual Outputs (Read/Write Setting) (64 modules)</b> |                                     |        |       |      |        |              |
| CC90   | Virtual Output 1 Name               | ---    | ---   | ---  | F205   | "Virt Op 1 " |
| CC9A   | Virtual Output 1 Events             | 0 to 1 | ---   | 1    | F102   | 0 (Disabled) |
| CC9B   | Virtual Output 1 Reserved (5 items) | ---    | ---   | ---  | F001   | 0            |
| CCA0   | ...Repeated for module number 2     |        |       |      |        |              |
| CCB0   | ...Repeated for module number 3     |        |       |      |        |              |
| CCC0   | ...Repeated for module number 4     |        |       |      |        |              |
| CCD0   | ...Repeated for module number 5     |        |       |      |        |              |
| CCE0   | ...Repeated for module number 6     |        |       |      |        |              |
| CCF0   | ...Repeated for module number 7     |        |       |      |        |              |
| CD00   | ...Repeated for module number 8     |        |       |      |        |              |
| CD10   | ...Repeated for module number 9     |        |       |      |        |              |
| CD20   | ...Repeated for module number 10    |        |       |      |        |              |
| CD30   | ...Repeated for module number 11    |        |       |      |        |              |
| CD40   | ...Repeated for module number 12    |        |       |      |        |              |
| CD50   | ...Repeated for module number 13    |        |       |      |        |              |
| CD60   | ...Repeated for module number 14    |        |       |      |        |              |
| CD70   | ...Repeated for module number 15    |        |       |      |        |              |
| CD80   | ...Repeated for module number 16    |        |       |      |        |              |

Table B-9: MODBUS MEMORY MAP (Sheet 31 of 38)

| ADDR                                  | REGISTER NAME                    | RANGE      | UNITS | STEP | FORMAT | DEFAULT      |
|---------------------------------------|----------------------------------|------------|-------|------|--------|--------------|
| CD90                                  | ...Repeated for module number 17 |            |       |      |        |              |
| CDA0                                  | ...Repeated for module number 18 |            |       |      |        |              |
| CDB0                                  | ...Repeated for module number 19 |            |       |      |        |              |
| CDC0                                  | ...Repeated for module number 20 |            |       |      |        |              |
| CDD0                                  | ...Repeated for module number 21 |            |       |      |        |              |
| CDE0                                  | ...Repeated for module number 22 |            |       |      |        |              |
| CDF0                                  | ...Repeated for module number 23 |            |       |      |        |              |
| CE00                                  | ...Repeated for module number 24 |            |       |      |        |              |
| CE10                                  | ...Repeated for module number 25 |            |       |      |        |              |
| CE20                                  | ...Repeated for module number 26 |            |       |      |        |              |
| CE30                                  | ...Repeated for module number 27 |            |       |      |        |              |
| CE40                                  | ...Repeated for module number 28 |            |       |      |        |              |
| CE50                                  | ...Repeated for module number 29 |            |       |      |        |              |
| CE60                                  | ...Repeated for module number 30 |            |       |      |        |              |
| CE70                                  | ...Repeated for module number 31 |            |       |      |        |              |
| CE80                                  | ...Repeated for module number 32 |            |       |      |        |              |
| CE90                                  | ...Repeated for module number 33 |            |       |      |        |              |
| CEA0                                  | ...Repeated for module number 34 |            |       |      |        |              |
| CEB0                                  | ...Repeated for module number 35 |            |       |      |        |              |
| CEC0                                  | ...Repeated for module number 36 |            |       |      |        |              |
| CED0                                  | ...Repeated for module number 37 |            |       |      |        |              |
| CEE0                                  | ...Repeated for module number 38 |            |       |      |        |              |
| CEF0                                  | ...Repeated for module number 39 |            |       |      |        |              |
| CF00                                  | ...Repeated for module number 40 |            |       |      |        |              |
| CF10                                  | ...Repeated for module number 41 |            |       |      |        |              |
| CF20                                  | ...Repeated for module number 42 |            |       |      |        |              |
| CF30                                  | ...Repeated for module number 43 |            |       |      |        |              |
| CF40                                  | ...Repeated for module number 44 |            |       |      |        |              |
| CF50                                  | ...Repeated for module number 45 |            |       |      |        |              |
| CF60                                  | ...Repeated for module number 46 |            |       |      |        |              |
| CF70                                  | ...Repeated for module number 47 |            |       |      |        |              |
| CF80                                  | ...Repeated for module number 48 |            |       |      |        |              |
| CF90                                  | ...Repeated for module number 49 |            |       |      |        |              |
| CFA0                                  | ...Repeated for module number 50 |            |       |      |        |              |
| CFB0                                  | ...Repeated for module number 51 |            |       |      |        |              |
| CFC0                                  | ...Repeated for module number 52 |            |       |      |        |              |
| CFD0                                  | ...Repeated for module number 53 |            |       |      |        |              |
| CFE0                                  | ...Repeated for module number 54 |            |       |      |        |              |
| CFF0                                  | ...Repeated for module number 55 |            |       |      |        |              |
| D000                                  | ...Repeated for module number 56 |            |       |      |        |              |
| D010                                  | ...Repeated for module number 57 |            |       |      |        |              |
| D020                                  | ...Repeated for module number 58 |            |       |      |        |              |
| D030                                  | ...Repeated for module number 59 |            |       |      |        |              |
| D040                                  | ...Repeated for module number 60 |            |       |      |        |              |
| D050                                  | ...Repeated for module number 61 |            |       |      |        |              |
| D060                                  | ...Repeated for module number 62 |            |       |      |        |              |
| D070                                  | ...Repeated for module number 63 |            |       |      |        |              |
| D080                                  | ...Repeated for module number 64 |            |       |      |        |              |
| <b>Mandatory (Read/Write Setting)</b> |                                  |            |       |      |        |              |
| D280                                  | Test Mode Function               | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| <b>Mandatory (Read/Write)</b>         |                                  |            |       |      |        |              |
| D281                                  | Force VFD and LED                | 0 to 1     | ---   | 1    | F126   | 0 (No)       |
| <b>Mandatory (Read/Write Setting)</b> |                                  |            |       |      |        |              |
| D282                                  | Test Mode Initiate               | 0 to 65535 | ---   | 1    | F300   | 1            |

Table B-9: MODBUS MEMORY MAP (Sheet 32 of 38)

| ADDR   | REGISTER NAME                    | RANGE      | UNITS | STEP | FORMAT | DEFAULT              |
|--|----------------------------------|------------|-------|------|--------|----------------------|
| <b>Mandatory (Read/Write Command)</b>                    |                                  |            |       |      |        |                      |
| D283   | Clear All Relay Records Command  | 0 to 1     | ---   | 1    | F126   | 0 (No)               |
| <b>Contact Outputs (Read/Write Setting) (64 modules)</b> |                                  |            |       |      |        |                      |
| D290   | Contact Output 1 Name            | ---        | ---   | ---  | F205   | "Cont Op 1"          |
| D29A   | Contact Output 1 Operation       | 0 to 65535 | ---   | 1    | F300   | 0                    |
| D29B   | Contact Output 1 Seal In         | 0 to 65535 | ---   | 1    | F300   | 0                    |
| D29C   | Latching Output 1 Reset          | 0 to 65535 | ---   | 1    | F300   | 0                    |
| D29D   | Contact Output 1 Events          | 0 to 1     | ---   | 1    | F102   | 1 (Enabled)          |
| D29E   | Latching Output 1 Type           | 0 to 1     | ---   | 1    | F090   | 0 (Operate-dominant) |
| D29F   | Reserved                         | ---        | ---   | ---  | F001   | 0                    |
| D2A0   | ...Repeated for module number 2  |            |       |      |        |                      |
| D2B0   | ...Repeated for module number 3  |            |       |      |        |                      |
| D2C0   | ...Repeated for module number 4  |            |       |      |        |                      |
| D2D0   | ...Repeated for module number 5  |            |       |      |        |                      |
| D2E0   | ...Repeated for module number 6  |            |       |      |        |                      |
| D2F0   | ...Repeated for module number 7  |            |       |      |        |                      |
| D300   | ...Repeated for module number 8  |            |       |      |        |                      |
| D310   | ...Repeated for module number 9  |            |       |      |        |                      |
| D320   | ...Repeated for module number 10 |            |       |      |        |                      |
| D330   | ...Repeated for module number 11 |            |       |      |        |                      |
| D340   | ...Repeated for module number 12 |            |       |      |        |                      |
| D350   | ...Repeated for module number 13 |            |       |      |        |                      |
| D360   | ...Repeated for module number 14 |            |       |      |        |                      |
| D370   | ...Repeated for module number 15 |            |       |      |        |                      |
| D380   | ...Repeated for module number 16 |            |       |      |        |                      |
| D390   | ...Repeated for module number 17 |            |       |      |        |                      |
| D3A0   | ...Repeated for module number 18 |            |       |      |        |                      |
| D3B0   | ...Repeated for module number 19 |            |       |      |        |                      |
| D3C0   | ...Repeated for module number 20 |            |       |      |        |                      |
| D3D0   | ...Repeated for module number 21 |            |       |      |        |                      |
| D3E0   | ...Repeated for module number 22 |            |       |      |        |                      |
| D3F0   | ...Repeated for module number 23 |            |       |      |        |                      |
| D400   | ...Repeated for module number 24 |            |       |      |        |                      |
| D410   | ...Repeated for module number 25 |            |       |      |        |                      |
| D420   | ...Repeated for module number 26 |            |       |      |        |                      |
| D430   | ...Repeated for module number 27 |            |       |      |        |                      |
| D440   | ...Repeated for module number 28 |            |       |      |        |                      |
| D450   | ...Repeated for module number 29 |            |       |      |        |                      |
| D460   | ...Repeated for module number 30 |            |       |      |        |                      |
| D470   | ...Repeated for module number 31 |            |       |      |        |                      |
| D480   | ...Repeated for module number 32 |            |       |      |        |                      |
| D490   | ...Repeated for module number 33 |            |       |      |        |                      |
| D4A0   | ...Repeated for module number 34 |            |       |      |        |                      |
| D4B0   | ...Repeated for module number 35 |            |       |      |        |                      |
| D4C0   | ...Repeated for module number 36 |            |       |      |        |                      |
| D4D0   | ...Repeated for module number 37 |            |       |      |        |                      |
| D4E0   | ...Repeated for module number 38 |            |       |      |        |                      |
| D4F0   | ...Repeated for module number 39 |            |       |      |        |                      |
| D500   | ...Repeated for module number 40 |            |       |      |        |                      |
| D510   | ...Repeated for module number 41 |            |       |      |        |                      |
| D520   | ...Repeated for module number 42 |            |       |      |        |                      |
| D530   | ...Repeated for module number 43 |            |       |      |        |                      |
| D540   | ...Repeated for module number 44 |            |       |      |        |                      |
| D550   | ...Repeated for module number 45 |            |       |      |        |                      |

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| ADDR  | REGISTER NAME   | RANGE      | UNITS | STEP | FORMAT | DEFAULT      |
|---|---|------------|-------|------|--------|--------------|
| D560  | ...Repeated for module number 46                      |            |       |      |        |              |
| D570  | ...Repeated for module number 47                      |            |       |      |        |              |
| D580  | ...Repeated for module number 48                      |            |       |      |        |              |
| D590  | ...Repeated for module number 49                      |            |       |      |        |              |
| D5A0  | ...Repeated for module number 50                      |            |       |      |        |              |
| D5B0  | ...Repeated for module number 51                      |            |       |      |        |              |
| D5C0  | ...Repeated for module number 52                      |            |       |      |        |              |
| D5D0  | ...Repeated for module number 53                      |            |       |      |        |              |
| D5E0  | ...Repeated for module number 54                      |            |       |      |        |              |
| D5F0  | ...Repeated for module number 55                      |            |       |      |        |              |
| D600  | ...Repeated for module number 56                      |            |       |      |        |              |
| D610  | ...Repeated for module number 57                      |            |       |      |        |              |
| D620  | ...Repeated for module number 58                      |            |       |      |        |              |
| D630  | ...Repeated for module number 59                      |            |       |      |        |              |
| D640  | ...Repeated for module number 60                      |            |       |      |        |              |
| D650  | ...Repeated for module number 61                      |            |       |      |        |              |
| D660  | ...Repeated for module number 62                      |            |       |      |        |              |
| D670  | ...Repeated for module number 63                      |            |       |      |        |              |
| D680  | ...Repeated for module number 64                      |            |       |      |        |              |
| <b>Reset (Read/Write Setting)</b>                           |   |            |       |      |        |              |
| D800  | FlexLogic operand which initiates a reset             | 0 to 65535 | ---   | 1    | F300   | 0            |
| <b>Control Pushbuttons (Read/Write Setting) (7 modules)</b> |   |            |       |      |        |              |
| D810  | Control Pushbuttons 1 Function                        | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| D811  | Control Pushbuttons 1 Events                          | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| D812  | ...Repeated for module number 2                       |            |       |      |        |              |
| D814  | ...Repeated for module number 3                       |            |       |      |        |              |
| D816  | ...Repeated for module number 4                       |            |       |      |        |              |
| D818  | ...Repeated for module number 5                       |            |       |      |        |              |
| D81A  | ...Repeated for module number 6                       |            |       |      |        |              |
| D81C  | ...Repeated for module number 7                       |            |       |      |        |              |
| <b>Clear Records (Read/Write Setting)</b>                   |   |            |       |      |        |              |
| D820  | Clear Fault Reports operand                           | 0 to 65535 | ---   | 1    | F300   | 0            |
| D822  | Clear Event Records operand                           | 0 to 65535 | ---   | 1    | F300   | 0            |
| D823  | Clear Oscillography operand                           | 0 to 65535 | ---   | 1    | F300   | 0            |
| D825  | Clear Breaker 1 Arcing Current operand                | 0 to 65535 | ---   | 1    | F300   | 0            |
| D826  | Clear Breaker 2 Arcing Current operand                | 0 to 65535 | ---   | 1    | F300   | 0            |
| D82F  | Clear Unauthorized Access operand                     | 0 to 65535 | ---   | 1    | F300   | 0            |
| D831  | Clear Platform Direct Input/Output Statistics operand | 0 to 65535 | ---   | 1    | F300   | 0            |
| D832  | Clear Relay Records Reserved (18 items)               | ---        | ---   | ---  | F001   | 0            |
| <b>Force Contact Inputs (Read/Write Setting)</b>            |   |            |       |      |        |              |
| D8B0  | Force Contact Input x State (96 items)                | 0 to 2     | ---   | 1    | F144   | 0 (Disabled) |
| <b>Force Contact Outputs (Read/Write Setting)</b>           |   |            |       |      |        |              |
| D910  | Force Contact Output x State (64 items)               | 0 to 3     | ---   | 1    | F131   | 0 (Disabled) |
| <b>Direct Inputs/Outputs (Read/Write Setting)</b>           |   |            |       |      |        |              |
| DB40  | Direct Device ID                                      | 1 to 16    | ---   | 1    | F001   | 1            |
| DB41  | Direct I/O Channel 1 Ring Configuration Function      | 0 to 1     | ---   | 1    | F126   | 0 (No)       |
| DB42  | Platform Direct I/O Data Rate                         | 64 to 128  | kbps  | 64   | F001   | 64           |
| DB43  | Direct I/O Channel 2 Ring Configuration Function      | 0 to 1     | ---   | 1    | F126   | 0 (No)       |
| DB44  | Platform Direct I/O Crossover Function                | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| <b>Direct input/output commands (Read/Write Command)</b>    |   |            |       |      |        |              |
| DB48  | Direct input/output clear counters command            | 0 to 1     | ---   | 1    | F126   | 0 (No)       |
| <b>Direct inputs (Read/Write Setting) (96 modules)</b>      |   |            |       |      |        |              |
| DB50  | Direct Input 1 Device Number                          | 0 to 16    | ---   | 1    | F001   | 0            |
| DB51  | Direct Input 1 Number                                 | 0 to 96    | ---   | 1    | F001   | 0            |

Table B-9: MODBUS MEMORY MAP (Sheet 34 of 38)

| ADDR   | REGISTER NAME                    | RANGE      | UNITS | STEP | FORMAT | DEFAULT      |
|--|----------------------------------|------------|-------|------|--------|--------------|
| DB52   | Direct Input 1 Default State     | 0 to 3     | ---   | 1    | F086   | 0 (Off)      |
| DB53   | Direct Input 1 Events            | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| DB54   | ...Repeated for module number 2  |            |       |      |        |              |
| DB58   | ...Repeated for module number 3  |            |       |      |        |              |
| DB5C   | ...Repeated for module number 4  |            |       |      |        |              |
| DB60   | ...Repeated for module number 5  |            |       |      |        |              |
| DB64   | ...Repeated for module number 6  |            |       |      |        |              |
| DB68   | ...Repeated for module number 7  |            |       |      |        |              |
| DB6C   | ...Repeated for module number 8  |            |       |      |        |              |
| DB70   | ...Repeated for module number 9  |            |       |      |        |              |
| DB74   | ...Repeated for module number 10 |            |       |      |        |              |
| DB78   | ...Repeated for module number 11 |            |       |      |        |              |
| DB7C   | ...Repeated for module number 12 |            |       |      |        |              |
| DB80   | ...Repeated for module number 13 |            |       |      |        |              |
| DB84   | ...Repeated for module number 14 |            |       |      |        |              |
| DB88   | ...Repeated for module number 15 |            |       |      |        |              |
| DB8C   | ...Repeated for module number 16 |            |       |      |        |              |
| DB90   | ...Repeated for module number 17 |            |       |      |        |              |
| DB94   | ...Repeated for module number 18 |            |       |      |        |              |
| DB98   | ...Repeated for module number 19 |            |       |      |        |              |
| DB9C   | ...Repeated for module number 20 |            |       |      |        |              |
| DBA0   | ...Repeated for module number 21 |            |       |      |        |              |
| DBA4   | ...Repeated for module number 22 |            |       |      |        |              |
| DBA8   | ...Repeated for module number 23 |            |       |      |        |              |
| DBAC   | ...Repeated for module number 24 |            |       |      |        |              |
| DBB0   | ...Repeated for module number 25 |            |       |      |        |              |
| DBB4   | ...Repeated for module number 26 |            |       |      |        |              |
| DBB8   | ...Repeated for module number 27 |            |       |      |        |              |
| DBBC   | ...Repeated for module number 28 |            |       |      |        |              |
| DBC0   | ...Repeated for module number 29 |            |       |      |        |              |
| DBC4   | ...Repeated for module number 30 |            |       |      |        |              |
| DBC8   | ...Repeated for module number 31 |            |       |      |        |              |
| DBCC   | ...Repeated for module number 32 |            |       |      |        |              |
| <b>Platform Direct Outputs (Read/Write Setting) (96 modules)</b> |                                  |            |       |      |        |              |
| DD00   | Direct Output 1 Operand          | 0 to 65535 | ---   | 1    | F300   | 0            |
| DD01   | Direct Output 1 Events           | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| DD02   | ...Repeated for module number 2  |            |       |      |        |              |
| DD04   | ...Repeated for module number 3  |            |       |      |        |              |
| DD06   | ...Repeated for module number 4  |            |       |      |        |              |
| DD08   | ...Repeated for module number 5  |            |       |      |        |              |
| DD0A   | ...Repeated for module number 6  |            |       |      |        |              |
| DD0C   | ...Repeated for module number 7  |            |       |      |        |              |
| DD0E   | ...Repeated for module number 8  |            |       |      |        |              |
| DD10   | ...Repeated for module number 9  |            |       |      |        |              |
| DD12   | ...Repeated for module number 10 |            |       |      |        |              |
| DD14   | ...Repeated for module number 11 |            |       |      |        |              |
| DD16   | ...Repeated for module number 12 |            |       |      |        |              |
| DD18   | ...Repeated for module number 13 |            |       |      |        |              |
| DD1A   | ...Repeated for module number 14 |            |       |      |        |              |
| DD1C   | ...Repeated for module number 15 |            |       |      |        |              |
| DD1E   | ...Repeated for module number 16 |            |       |      |        |              |
| DD20   | ...Repeated for module number 17 |            |       |      |        |              |
| DD22   | ...Repeated for module number 18 |            |       |      |        |              |
| DD24   | ...Repeated for module number 19 |            |       |      |        |              |

Table B-9: MODBUS MEMORY MAP (Sheet 35 of 38)

| ADDR  | REGISTER NAME   | RANGE        | UNITS | STEP | FORMAT | DEFAULT            |
|---|---|--------------|-------|------|--------|--------------------|
| DD26  | ...Repeated for module number 20                      |              |       |      |        |                    |
| DD28  | ...Repeated for module number 21                      |              |       |      |        |                    |
| DD2A  | ...Repeated for module number 22                      |              |       |      |        |                    |
| DD2C  | ...Repeated for module number 23                      |              |       |      |        |                    |
| DD2E  | ...Repeated for module number 24                      |              |       |      |        |                    |
| DD30  | ...Repeated for module number 25                      |              |       |      |        |                    |
| DD32  | ...Repeated for module number 26                      |              |       |      |        |                    |
| DD34  | ...Repeated for module number 27                      |              |       |      |        |                    |
| DD36  | ...Repeated for module number 28                      |              |       |      |        |                    |
| DD38  | ...Repeated for module number 29                      |              |       |      |        |                    |
| DD3A  | ...Repeated for module number 30                      |              |       |      |        |                    |
| DD3C  | ...Repeated for module number 31                      |              |       |      |        |                    |
| DD3E  | ...Repeated for module number 32                      |              |       |      |        |                    |
| <b>Direct Input/Output Alarms (Read/Write Setting)</b>  |   |              |       |      |        |                    |
| DE00  | Direct Input/Output Channel 1 CRC Alarm Function      | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE01  | Direct I/O Channel 1 CRC Alarm Message Count          | 100 to 10000 | ---   | 1    | F001   | 600                |
| DE02  | Direct Input/Output Channel 1 CRC Alarm Threshold     | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE03  | Direct Input/Output Channel 1 CRC Alarm Events        | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE04  | Reserved (4 items)                                    | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE08  | Direct Input/Output Channel 2 CRC Alarm Function      | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE09  | Direct I/O Channel 2 CRC Alarm Message Count          | 100 to 10000 | ---   | 1    | F001   | 600                |
| DE0A  | Direct Input/Output Channel 2 CRC Alarm Threshold     | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE0B  | Direct Input/Output Channel 2 CRC Alarm Events        | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE0C  | Reserved (4 items)                                    | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE10  | Direct I/O Ch 1 Unreturned Messages Alarm Function    | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE11  | Direct I/O Ch 1 Unreturned Messages Alarm Msg Count   | 100 to 10000 | ---   | 1    | F001   | 600                |
| DE12  | Direct I/O Ch 1 Unreturned Messages Alarm Threshold   | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE13  | Direct I/O Ch 1 Unreturned Messages Alarm Events      | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE14  | Reserved (4 items)                                    | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE18  | Direct IO Ch 2 Unreturned Messages Alarm Function     | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE19  | Direct I/O Ch 2 Unreturned Messages Alarm Msg Count   | 100 to 10000 | ---   | 1    | F001   | 600                |
| DE1A  | Direct I/O Ch 2 Unreturned Messages Alarm Threshold   | 1 to 1000    | ---   | 1    | F001   | 10                 |
| DE1B  | Direct I/O Channel 2 Unreturned Messages Alarm Events | 0 to 1       | ---   | 1    | F102   | 0 (Disabled)       |
| DE1C  | Reserved (4 items)                                    | 1 to 1000    | ---   | 1    | F001   | 10                 |
| <b>Remote Devices (Read/Write Setting) (16 modules)</b> |   |              |       |      |        |                    |
| E000  | Remote Device 1 ID                                    | ---          | ---   | ---  | F202   | "Remote Device 1 " |
| E00A  | ...Repeated for module number 2                       |              |       |      |        |                    |
| E014  | ...Repeated for module number 3                       |              |       |      |        |                    |
| E01E  | ...Repeated for module number 4                       |              |       |      |        |                    |
| E028  | ...Repeated for module number 5                       |              |       |      |        |                    |
| E032  | ...Repeated for module number 6                       |              |       |      |        |                    |
| E03C  | ...Repeated for module number 7                       |              |       |      |        |                    |
| E046  | ...Repeated for module number 8                       |              |       |      |        |                    |
| E050  | ...Repeated for module number 9                       |              |       |      |        |                    |
| E05A  | ...Repeated for module number 10                      |              |       |      |        |                    |
| E064  | ...Repeated for module number 11                      |              |       |      |        |                    |
| E06E  | ...Repeated for module number 12                      |              |       |      |        |                    |
| E078  | ...Repeated for module number 13                      |              |       |      |        |                    |
| E082  | ...Repeated for module number 14                      |              |       |      |        |                    |
| E08C  | ...Repeated for module number 15                      |              |       |      |        |                    |
| E096  | ...Repeated for module number 16                      |              |       |      |        |                    |
| <b>Remote Inputs (Read/Write Setting) (64 modules)</b>  |   |              |       |      |        |                    |
| E100  | Remote Input 1 Device                                 | 1 to 16      | ---   | 1    | F001   | 1                  |
| E101  | Remote Input 1 Bit Pair                               | 0 to 64      | ---   | 1    | F156   | 0 (None)           |



Table B-9: MODBUS MEMORY MAP (Sheet 36 of 38)

| ADDR | REGISTER NAME                    | RANGE  | UNITS | STEP | FORMAT | DEFAULT      |
|------|----------------------------------|--------|-------|------|--------|--------------|
| E102 | Remote Input 1 Default State     | 0 to 3 | ---   | 1    | F086   | 0 (Off)      |
| E103 | Remote Input 1 Events            | 0 to 1 | ---   | 1    | F102   | 0 (Disabled) |
| E104 | ...Repeated for module number 2  |        |       |      |        |              |
| E108 | ...Repeated for module number 3  |        |       |      |        |              |
| E10C | ...Repeated for module number 4  |        |       |      |        |              |
| E110 | ...Repeated for module number 5  |        |       |      |        |              |
| E114 | ...Repeated for module number 6  |        |       |      |        |              |
| E118 | ...Repeated for module number 7  |        |       |      |        |              |
| E11C | ...Repeated for module number 8  |        |       |      |        |              |
| E120 | ...Repeated for module number 9  |        |       |      |        |              |
| E124 | ...Repeated for module number 10 |        |       |      |        |              |
| E128 | ...Repeated for module number 11 |        |       |      |        |              |
| E12C | ...Repeated for module number 12 |        |       |      |        |              |
| E130 | ...Repeated for module number 13 |        |       |      |        |              |
| E134 | ...Repeated for module number 14 |        |       |      |        |              |
| E138 | ...Repeated for module number 15 |        |       |      |        |              |
| E13C | ...Repeated for module number 16 |        |       |      |        |              |
| E140 | ...Repeated for module number 17 |        |       |      |        |              |
| E144 | ...Repeated for module number 18 |        |       |      |        |              |
| E148 | ...Repeated for module number 19 |        |       |      |        |              |
| E14C | ...Repeated for module number 20 |        |       |      |        |              |
| E150 | ...Repeated for module number 21 |        |       |      |        |              |
| E154 | ...Repeated for module number 22 |        |       |      |        |              |
| E158 | ...Repeated for module number 23 |        |       |      |        |              |
| E15C | ...Repeated for module number 24 |        |       |      |        |              |
| E160 | ...Repeated for module number 25 |        |       |      |        |              |
| E164 | ...Repeated for module number 26 |        |       |      |        |              |
| E168 | ...Repeated for module number 27 |        |       |      |        |              |
| E16C | ...Repeated for module number 28 |        |       |      |        |              |
| E170 | ...Repeated for module number 29 |        |       |      |        |              |
| E174 | ...Repeated for module number 30 |        |       |      |        |              |
| E178 | ...Repeated for module number 31 |        |       |      |        |              |
| E17C | ...Repeated for module number 32 |        |       |      |        |              |
| E180 | ...Repeated for module number 33 |        |       |      |        |              |
| E184 | ...Repeated for module number 34 |        |       |      |        |              |
| E188 | ...Repeated for module number 35 |        |       |      |        |              |
| E18C | ...Repeated for module number 36 |        |       |      |        |              |
| E190 | ...Repeated for module number 37 |        |       |      |        |              |
| E194 | ...Repeated for module number 38 |        |       |      |        |              |
| E198 | ...Repeated for module number 39 |        |       |      |        |              |
| E19C | ...Repeated for module number 40 |        |       |      |        |              |
| E1A0 | ...Repeated for module number 41 |        |       |      |        |              |
| E1A4 | ...Repeated for module number 42 |        |       |      |        |              |
| E1A8 | ...Repeated for module number 43 |        |       |      |        |              |
| E1AC | ...Repeated for module number 44 |        |       |      |        |              |
| E1B0 | ...Repeated for module number 45 |        |       |      |        |              |
| E1B4 | ...Repeated for module number 46 |        |       |      |        |              |
| E1B8 | ...Repeated for module number 47 |        |       |      |        |              |
| E1BC | ...Repeated for module number 48 |        |       |      |        |              |
| E1C0 | ...Repeated for module number 49 |        |       |      |        |              |
| E1C4 | ...Repeated for module number 50 |        |       |      |        |              |
| E1C8 | ...Repeated for module number 51 |        |       |      |        |              |
| E1CC | ...Repeated for module number 52 |        |       |      |        |              |
| E1D0 | ...Repeated for module number 53 |        |       |      |        |              |

Table B-9: MODBUS MEMORY MAP (Sheet 37 of 38)

| ADDR  | REGISTER NAME                             | RANGE      | UNITS | STEP | FORMAT | DEFAULT      |
|---|---|------------|-------|------|--------|--------------|
| E1D4  | ...Repeated for module number 54          |            |       |      |        |              |
| E1D8  | ...Repeated for module number 55          |            |       |      |        |              |
| E1DC  | ...Repeated for module number 56          |            |       |      |        |              |
| E1E0  | ...Repeated for module number 57          |            |       |      |        |              |
| E1E4  | ...Repeated for module number 58          |            |       |      |        |              |
| E1E8  | ...Repeated for module number 59          |            |       |      |        |              |
| E1EC  | ...Repeated for module number 60          |            |       |      |        |              |
| E1F0  | ...Repeated for module number 61          |            |       |      |        |              |
| E1F4  | ...Repeated for module number 62          |            |       |      |        |              |
| E1F8  | ...Repeated for module number 63          |            |       |      |        |              |
| E1FC  | ...Repeated for module number 64          |            |       |      |        |              |
| <b>Remote Output DNA Pairs (Read/Write Setting) (32 modules)</b>    |   |            |       |      |        |              |
| E600  | Remote Output DNA 1 Operand               | 0 to 65535 | ---   | 1    | F300   | 0            |
| E601  | Remote Output DNA 1 Events                | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| E602  | Remote Output DNA 1 Reserved (2 items)    | 0 to 1     | ---   | 1    | F001   | 0            |
| E604  | ...Repeated for module number 2           |            |       |      |        |              |
| E608  | ...Repeated for module number 3           |            |       |      |        |              |
| E60C  | ...Repeated for module number 4           |            |       |      |        |              |
| E610  | ...Repeated for module number 5           |            |       |      |        |              |
| E614  | ...Repeated for module number 6           |            |       |      |        |              |
| E618  | ...Repeated for module number 7           |            |       |      |        |              |
| E61C  | ...Repeated for module number 8           |            |       |      |        |              |
| E620  | ...Repeated for module number 9           |            |       |      |        |              |
| E624  | ...Repeated for module number 10          |            |       |      |        |              |
| E628  | ...Repeated for module number 11          |            |       |      |        |              |
| E62C  | ...Repeated for module number 12          |            |       |      |        |              |
| E630  | ...Repeated for module number 13          |            |       |      |        |              |
| E634  | ...Repeated for module number 14          |            |       |      |        |              |
| E638  | ...Repeated for module number 15          |            |       |      |        |              |
| E63C  | ...Repeated for module number 16          |            |       |      |        |              |
| E640  | ...Repeated for module number 17          |            |       |      |        |              |
| E644  | ...Repeated for module number 18          |            |       |      |        |              |
| E648  | ...Repeated for module number 19          |            |       |      |        |              |
| E64C  | ...Repeated for module number 20          |            |       |      |        |              |
| E650  | ...Repeated for module number 21          |            |       |      |        |              |
| E654  | ...Repeated for module number 22          |            |       |      |        |              |
| E658  | ...Repeated for module number 23          |            |       |      |        |              |
| E65C  | ...Repeated for module number 24          |            |       |      |        |              |
| E660  | ...Repeated for module number 25          |            |       |      |        |              |
| E664  | ...Repeated for module number 26          |            |       |      |        |              |
| E668  | ...Repeated for module number 27          |            |       |      |        |              |
| E66C  | ...Repeated for module number 28          |            |       |      |        |              |
| E670  | ...Repeated for module number 29          |            |       |      |        |              |
| E674  | ...Repeated for module number 30          |            |       |      |        |              |
| E678  | ...Repeated for module number 31          |            |       |      |        |              |
| E67C  | ...Repeated for module number 32          |            |       |      |        |              |
| <b>Remote Output UserSt Pairs (Read/Write Setting) (32 modules)</b> |   |            |       |      |        |              |
| E680  | Remote Output UserSt 1 Operand            | 0 to 65535 | ---   | 1    | F300   | 0            |
| E681  | Remote Output UserSt 1 Events             | 0 to 1     | ---   | 1    | F102   | 0 (Disabled) |
| E682  | Remote Output UserSt 1 Reserved (2 items) | 0 to 1     | ---   | 1    | F001   | 0            |
| E684  | ...Repeated for module number 2           |            |       |      |        |              |
| E688  | ...Repeated for module number 3           |            |       |      |        |              |
| E68C  | ...Repeated for module number 4           |            |       |      |        |              |
| E690  | ...Repeated for module number 5           |            |       |      |        |              |

Table B-9: MODBUS MEMORY MAP (Sheet 38 of 38)

| ADDR | REGISTER NAME                    | RANGE | UNITS | STEP | FORMAT | DEFAULT |
|------|----------------------------------|-------|-------|------|--------|---------|
| E694 | ...Repeated for module number 6  |       |       |      |        |         |
| E698 | ...Repeated for module number 7  |       |       |      |        |         |
| E69C | ...Repeated for module number 8  |       |       |      |        |         |
| E6A0 | ...Repeated for module number 9  |       |       |      |        |         |
| E6A4 | ...Repeated for module number 10 |       |       |      |        |         |
| E6A8 | ...Repeated for module number 11 |       |       |      |        |         |
| E6AC | ...Repeated for module number 12 |       |       |      |        |         |
| E6B0 | ...Repeated for module number 13 |       |       |      |        |         |
| E6B4 | ...Repeated for module number 14 |       |       |      |        |         |
| E6B8 | ...Repeated for module number 15 |       |       |      |        |         |
| E6BC | ...Repeated for module number 16 |       |       |      |        |         |
| E6C0 | ...Repeated for module number 17 |       |       |      |        |         |
| E6C4 | ...Repeated for module number 18 |       |       |      |        |         |
| E6C8 | ...Repeated for module number 19 |       |       |      |        |         |
| E6CC | ...Repeated for module number 20 |       |       |      |        |         |
| E6D0 | ...Repeated for module number 21 |       |       |      |        |         |
| E6D4 | ...Repeated for module number 22 |       |       |      |        |         |
| E6D8 | ...Repeated for module number 23 |       |       |      |        |         |
| E6DC | ...Repeated for module number 24 |       |       |      |        |         |
| E6E0 | ...Repeated for module number 25 |       |       |      |        |         |
| E6E4 | ...Repeated for module number 26 |       |       |      |        |         |
| E6E8 | ...Repeated for module number 27 |       |       |      |        |         |
| E6EC | ...Repeated for module number 28 |       |       |      |        |         |
| E6F0 | ...Repeated for module number 29 |       |       |      |        |         |
| E6F4 | ...Repeated for module number 30 |       |       |      |        |         |
| E6F8 | ...Repeated for module number 31 |       |       |      |        |         |
| E6FC | ...Repeated for module number 32 |       |       |      |        |         |

## B.4.2 DATA FORMATS

B

**F001**  
**UR\_UINT16 UNSIGNED 16 BIT INTEGER**

**F002**  
**UR\_SINT16 SIGNED 16 BIT INTEGER**

**F003**  
**UR\_UINT32 UNSIGNED 32 BIT INTEGER (2 registers)**

High order word is stored in the first register.  
Low order word is stored in the second register.

**F004**  
**UR\_SINT32 SIGNED 32 BIT INTEGER (2 registers)**

High order word is stored in the first register/  
Low order word is stored in the second register.

**F005**  
**UR\_UINT8 UNSIGNED 8 BIT INTEGER**

**F006**  
**UR\_SINT8 SIGNED 8 BIT INTEGER**

**F011**  
**UR\_UINT16 FLEXCURVE DATA (120 points)**

A FlexCurve is an array of 120 consecutive data points (x, y) which are interpolated to generate a smooth curve. The y-axis is the user defined trip or operation time setting; the x-axis is the pickup ratio and is pre-defined. Refer to format F119 for a listing of the pickup ratios; the enumeration value for the pickup ratio indicates the offset into the FlexCurve base address where the corresponding time value is stored.

**F012**  
**DISPLAY\_SCALE DISPLAY SCALING**  
**(unsigned 16-bit integer)**

MSB indicates the SI units as a power of ten. LSB indicates the number of decimal points to display.

Example: Current values are stored as 32 bit numbers with three decimal places and base units in Amps. If the retrieved value is 12345.678 A and the display scale equals 0x0302 then the displayed value on the unit is 12.35 kA.

**F013**  
**POWER\_FACTOR (SIGNED 16 BIT INTEGER)**

Positive values indicate lagging power factor; negative values indicate leading.

**F040**  
**UR\_UINT48 48-BIT UNSIGNED INTEGER**

**F050**  
**UR\_UINT32 TIME and DATE (UNSIGNED 32 BIT INTEGER)**

Gives the current time in seconds elapsed since 00:00:00 January 1, 1970.

**F051**  
**UR\_UINT32 DATE in SR format (alternate format for F050)**

First 16 bits are Month/Day (MM/DD/xxxx). Month: 1=January, 2=February,...,12=December; Day: 1 to 31 in steps of 1  
Last 16 bits are Year (xx/xx/YYYY): 1970 to 2106 in steps of 1

**F052**  
**UR\_UINT32 TIME in SR format (alternate format for F050)**

First 16 bits are Hours/Minutes (HH:MM:xx.xxx).  
Hours: 0=12am, 1=1am,...,12=12pm,...23=11pm;  
Minutes: 0 to 59 in steps of 1

Last 16 bits are Seconds (xx:xx:SS.SSS): 0=00.000s, 1=00.001,...,59999=59.999s)

**F060**  
**FLOATING\_POINT IEEE FLOATING POINT (32 bits)**

**F070**  
**HEX2 2 BYTES - 4 ASCII DIGITS**

**F071**  
**HEX4 4 BYTES - 8 ASCII DIGITS**

**F072**  
**HEX6 6 BYTES - 12 ASCII DIGITS**

**F073**  
**HEX8 8 BYTES - 16 ASCII DIGITS**

**F074**  
**HEX20 20 BYTES - 40 ASCII DIGITS**

**F080**  
**ENUMERATION: AUTORECLOSE MODE**

0 = 1 & 3 Pole, 1 = 1 Pole, 2 = 3 Pole-A, 3 = 3 Pole-B

**F083**  
**ENUMERATION: SELECTOR MODES**

0 = Time-Out, 1 = Acknowledge

**F084****ENUMERATION: SELECTOR POWER UP**

0 = Restore, 1 = Synchronize, 2 = Sync/Restore

**F085****ENUMERATION: POWER SWING SHAPE**

0 = Mho Shape, 1 = Quad Shape

**F086****ENUMERATION: DIGITAL INPUT DEFAULT STATE**

0 = Off, 1 = On, 2 = Latest/Off, 3 = Latest/On

**F090****ENUMERATION: LATCHING OUTPUT TYPE**

0 = Operate-dominant, 1 = Reset-dominant

**F100****ENUMERATION: VT CONNECTION TYPE**

0 = Wye; 1 = Delta

**F101****ENUMERATION: MESSAGE DISPLAY INTENSITY**

0 = 25%, 1 = 50%, 2 = 75%, 3 = 100%

**F102****ENUMERATION: DISABLED/ENABLED**

0 = Disabled; 1 = Enabled

**F103****ENUMERATION: CURVE SHAPES**

| bitmask | curve shape   |
|---------|---------------|
| 0       | IEEE Mod Inv  |
| 1       | IEEE Very Inv |
| 2       | IEEE Ext Inv  |
| 3       | IEC Curve A   |
| 4       | IEC Curve B   |
| 5       | IEC Curve C   |
| 6       | IEC Short Inv |
| 7       | IAC Ext Inv   |
| 8       | IAC Very Inv  |

| bitmask | curve shape   |
|---------|---------------|
| 9       | IAC Inverse   |
| 10      | IAC Short Inv |
| 11      | I2t           |
| 12      | Definite Time |
| 13      | FlexCurve™ A  |
| 14      | FlexCurve™ B  |
| 15      | FlexCurve™ C  |
| 16      | FlexCurve™ D  |

**F104****ENUMERATION: RESET TYPE**

0 = Instantaneous, 1 = Timed, 2 = Linear

**F105****ENUMERATION: LOGIC INPUT**

0 = Disabled, 1 = Input 1, 2 = Input 2

**F106****ENUMERATION: PHASE ROTATION**

0 = ABC, 1 = ACB

**F108****ENUMERATION: OFF/ON**

0 = Off, 1 = On

**F109****ENUMERATION: CONTACT OUTPUT OPERATION**

0 = Self-reset, 1 = Latched, 2 = Disabled

**F110****ENUMERATION: CONTACT OUTPUT LED CONTROL**

0 = Trip, 1 = Alarm, 2 = None

**F111****ENUMERATION: UNDERVOLTAGE CURVE SHAPES**

0 = Definite Time, 1 = Inverse Time

**F112****ENUMERATION: RS485 BAUD RATES**

| bitmask | value |
|---------|-------|
| 0       | 300   |
| 1       | 1200  |
| 2       | 2400  |
| 3       | 4800  |

| bitmask | value |
|---------|-------|
| 4       | 9600  |
| 5       | 19200 |
| 6       | 38400 |
| 7       | 57600 |

| bitmask | value  |
|---------|--------|
| 8       | 115200 |
| 9       | 14400  |
| 10      | 28800  |
| 11      | 33600  |

**F113****ENUMERATION: PARITY**

0 = None, 1 = Odd, 2 = Even

**F114****ENUMERATION: IRIG-B SIGNAL TYPE**

0 = None, 1 = DC Shift, 2 = Amplitude Modulated

**F115****ENUMERATION: BREAKER STATUS**

0 = Auxiliary A, 1 = Auxiliary B

**F117****ENUMERATION: NUMBER OF OSCILLOGRAPHY RECORDS**

0 = 1×72 cycles, 1 = 3×36 cycles, 2 = 7×18 cycles, 3 = 15×9 cycles

**F118****ENUMERATION: OSCILLOGRAPHY MODE**

0 = Automatic Overwrite, 1 = Protected

**F119****ENUMERATION: FLEXCURVE™ PICKUP RATIOS**

| mask | value | mask | value | mask | value | mask | value |
|------|-------|------|-------|------|-------|------|-------|
| 0    | 0.00  | 30   | 0.88  | 60   | 2.90  | 90   | 5.90  |
| 1    | 0.05  | 31   | 0.90  | 61   | 3.00  | 91   | 6.00  |
| 2    | 0.10  | 32   | 0.91  | 62   | 3.10  | 92   | 6.50  |
| 3    | 0.15  | 33   | 0.92  | 63   | 3.20  | 93   | 7.00  |
| 4    | 0.20  | 34   | 0.93  | 64   | 3.30  | 94   | 7.50  |
| 5    | 0.25  | 35   | 0.94  | 65   | 3.40  | 95   | 8.00  |
| 6    | 0.30  | 36   | 0.95  | 66   | 3.50  | 96   | 8.50  |
| 7    | 0.35  | 37   | 0.96  | 67   | 3.60  | 97   | 9.00  |
| 8    | 0.40  | 38   | 0.97  | 68   | 3.70  | 98   | 9.50  |
| 9    | 0.45  | 39   | 0.98  | 69   | 3.80  | 99   | 10.00 |
| 10   | 0.48  | 40   | 1.03  | 70   | 3.90  | 100  | 10.50 |
| 11   | 0.50  | 41   | 1.05  | 71   | 4.00  | 101  | 11.00 |
| 12   | 0.52  | 42   | 1.10  | 72   | 4.10  | 102  | 11.50 |
| 13   | 0.54  | 43   | 1.20  | 73   | 4.20  | 103  | 12.00 |
| 14   | 0.56  | 44   | 1.30  | 74   | 4.30  | 104  | 12.50 |
| 15   | 0.58  | 45   | 1.40  | 75   | 4.40  | 105  | 13.00 |
| 16   | 0.60  | 46   | 1.50  | 76   | 4.50  | 106  | 13.50 |
| 17   | 0.62  | 47   | 1.60  | 77   | 4.60  | 107  | 14.00 |
| 18   | 0.64  | 48   | 1.70  | 78   | 4.70  | 108  | 14.50 |
| 19   | 0.66  | 49   | 1.80  | 79   | 4.80  | 109  | 15.00 |
| 20   | 0.68  | 50   | 1.90  | 80   | 4.90  | 110  | 15.50 |
| 21   | 0.70  | 51   | 2.00  | 81   | 5.00  | 111  | 16.00 |
| 22   | 0.72  | 52   | 2.10  | 82   | 5.10  | 112  | 16.50 |
| 23   | 0.74  | 53   | 2.20  | 83   | 5.20  | 113  | 17.00 |
| 24   | 0.76  | 54   | 2.30  | 84   | 5.30  | 114  | 17.50 |
| 25   | 0.78  | 55   | 2.40  | 85   | 5.40  | 115  | 18.00 |
| 26   | 0.80  | 56   | 2.50  | 86   | 5.50  | 116  | 18.50 |
| 27   | 0.82  | 57   | 2.60  | 87   | 5.60  | 117  | 19.00 |
| 28   | 0.84  | 58   | 2.70  | 88   | 5.70  | 118  | 19.50 |
| 29   | 0.86  | 59   | 2.80  | 89   | 5.80  | 119  | 20.00 |

**F120****ENUMERATION: DISTANCE SHAPE**

0 = Mho, 1 = Quad

**F122****ENUMERATION: ELEMENT INPUT SIGNAL TYPE**

0 = Phasor, 1 = RMS

**F123****ENUMERATION: CT SECONDARY**

0 = 1 A, 1 = 5 A

**F124****ENUMERATION: LIST OF ELEMENTS**

| bitmask | element                                       |
|---------|---|
| 0       | Phase Instantaneous Overcurrent 1             |
| 1       | Phase Instantaneous Overcurrent 2             |
| 16      | Phase Time Overcurrent 1                      |
| 17      | Phase Time Overcurrent 2                      |
| 24      | Phase Directional Overcurrent 1               |
| 25      | Phase Directional Overcurrent 2               |
| 32      | Neutral Instantaneous Overcurrent 1           |
| 33      | Neutral Instantaneous Overcurrent 2           |
| 48      | Neutral Time Overcurrent 1                    |
| 49      | Neutral Time Overcurrent 2                    |
| 56      | Neutral Directional Overcurrent 1             |
| 57      | Neutral Directional Overcurrent 2             |
| 60      | Negative Sequence Directional Overcurrent 1   |
| 61      | Negative Sequence Directional Overcurrent 2   |
| 64      | Ground Instantaneous Overcurrent 1            |
| 65      | Ground Instantaneous Overcurrent 2            |
| 80      | Ground Time Overcurrent 1                     |
| 81      | Ground Time Overcurrent 2                     |
| 96      | Negative Sequence Instantaneous Overcurrent 1 |
| 97      | Negative Sequence Instantaneous Overcurrent 2 |
| 112     | Negative Sequence Time Overcurrent 1          |
| 113     | Negative Sequence Time Overcurrent 2          |
| 120     | Negative Sequence Overvoltage                 |
| 140     | Auxiliary Undervoltage 1                      |
| 144     | Phase Undervoltage 1                          |
| 145     | Phase Undervoltage 2                          |
| 148     | Auxiliary Overvoltage 1                       |
| 152     | Phase Overvoltage 1                           |
| 156     | Neutral Overvoltage 1                         |
| 160     | Phase Distance Zone 1                         |
| 161     | Phase Distance Zone 2                         |
| 162     | Phase Distance Zone 3                         |
| 168     | Line Pickup                                   |
| 172     | Ground Distance Zone 1                        |
| 173     | Ground Distance Zone 2                        |
| 174     | Ground Distance Zone 3                        |
| 180     | Load Enchroachment                            |
| 190     | Power Swing Detect                            |
| 224     | SRC1 VT Fuse Failure                          |
| 225     | SRC2 VT Fuse Failure                          |
| 226     | SRC3 VT Fuse Failure                          |
| 227     | SRC4 VT Fuse Failure                          |
| 228     | SRC5 VT Fuse Failure                          |
| 229     | SRC6 VT Fuse Failure                          |
| 232     | SRC1 50DD (Disturbance Detection)             |
| 233     | SRC2 50DD (Disturbance Detection)             |
| 234     | SRC3 50DD (Disturbance Detection)             |
| 235     | SRC4 50DD (Disturbance Detection)             |
| 236     | SRC5 50DD (Disturbance Detection)             |

| bitmask | element                           |
|---------|-----------------------------------|
| 237     | SRC6 50DD (Disturbance Detection) |
| 272     | Breaker 1                         |
| 273     | Breaker 2                         |
| 288     | Breaker Arcing Current 1          |
| 289     | Breaker Arcing Current 2          |
| 290     | Breaker Arcing Current 3          |
| 291     | Breaker Arcing Current 4          |
| 292     | Breaker Arcing Current 5          |
| 293     | Breaker Arcing Current 6          |
| 304     | Autoreclose 1                     |
| 305     | Autoreclose 2                     |
| 312     | Synchrocheck 1                    |
| 313     | Synchrocheck 2                    |
| 336     | Setting Group                     |
| 337     | Reset                             |
| 375     | Autoreclose                       |
| 385     | Selector 1                        |
| 386     | Selector 2                        |
| 390     | Control Pushbutton 1              |
| 391     | Control Pushbutton 2              |
| 392     | Control Pushbutton 3              |
| 393     | Control Pushbutton 4              |
| 394     | Control Pushbutton 5              |
| 395     | Control Pushbutton 6              |
| 396     | Control Pushbutton 7              |
| 400     | FlexElement™ 1                    |
| 401     | FlexElement™ 2                    |
| 402     | FlexElement™ 3                    |
| 403     | FlexElement™ 4                    |
| 404     | FlexElement™ 5                    |
| 405     | FlexElement™ 6                    |
| 406     | FlexElement™ 7                    |
| 407     | FlexElement™ 8                    |
| 420     | Non-volatile Latch 1              |
| 421     | Non-volatile Latch 2              |
| 422     | Non-volatile Latch 3              |
| 423     | Non-volatile Latch 4              |
| 424     | Non-volatile Latch 5              |
| 425     | Non-volatile Latch 6              |
| 426     | Non-volatile Latch 7              |
| 427     | Non-volatile Latch 8              |
| 428     | Non-volatile Latch 9              |
| 429     | Non-volatile Latch 10             |
| 430     | Non-volatile Latch 11             |
| 431     | Non-volatile Latch 12             |
| 432     | Non-volatile Latch 13             |
| 433     | Non-volatile Latch 14             |
| 434     | Non-volatile Latch 15             |
| 435     | Non-volatile Latch 16             |
| 512     | Digital Element 1                 |
| 513     | Digital Element 2                 |
| 514     | Digital Element 3                 |

| bitmask | element                         |
|---------|---------------------------------|
| 515     | Digital Element 4               |
| 516     | Digital Element 5               |
| 517     | Digital Element 6               |
| 518     | Digital Element 7               |
| 519     | Digital Element 8               |
| 520     | Digital Element 9               |
| 521     | Digital Element 10              |
| 522     | Digital Element 11              |
| 523     | Digital Element 12              |
| 524     | Digital Element 13              |
| 525     | Digital Element 14              |
| 526     | Digital Element 15              |
| 527     | Digital Element 16              |
| 544     | Digital Counter 1               |
| 545     | Digital Counter 2               |
| 546     | Digital Counter 3               |
| 547     | Digital Counter 4               |
| 548     | Digital Counter 5               |
| 549     | Digital Counter 6               |
| 550     | Digital Counter 7               |
| 551     | Digital Counter 8               |
| 680     | User-Programmable Pushbutton 1  |
| 681     | User-Programmable Pushbutton 2  |
| 682     | User-Programmable Pushbutton 3  |
| 683     | User-Programmable Pushbutton 4  |
| 684     | User-Programmable Pushbutton 5  |
| 685     | User-Programmable Pushbutton 6  |
| 686     | User-Programmable Pushbutton 7  |
| 687     | User-Programmable Pushbutton 8  |
| 688     | User-Programmable Pushbutton 9  |
| 689     | User-Programmable Pushbutton 10 |
| 690     | User-Programmable Pushbutton 11 |
| 691     | User-Programmable Pushbutton 12 |

#### F125 ENUMERATION: ACCESS LEVEL

0 = Restricted; 1 = Command, 2 = Setting, 3 = Factory Service

#### F126 ENUMERATION: NO/YES CHOICE

0 = No, 1 = Yes

#### F127 ENUMERATION: LATCHED OR SELF-RESETTING

0 = Latched, 1 = Self-Reset

#### F128 ENUMERATION: CONTACT INPUT THRESHOLD

0 = 17 V DC, 1 = 33 V DC, 2 = 84 V DC, 3 = 166 V DC

**F129****ENUMERATION: FLEXLOGIC TIMER TYPE**

0 = millisecond, 1 = second, 2 = minute

**F130****ENUMERATION: SIMULATION MODE**

0 = Off, 1 = Pre-Fault, 2 = Fault, 3 = Post-Fault

**F131****ENUMERATION: FORCED CONTACT OUTPUT STATE**

0 = Disabled, 1 = Energized, 2 = De-energized, 3 = Freeze

**F133****ENUMERATION: PROGRAM STATE**

0 = Not Programmed, 1 = Programmed

**F134****ENUMERATION: PASS/FAIL**

0 = Fail, 1 = OK, 2 = n/a

**F135****ENUMERATION: GAIN CALIBRATION**

0 = 0x1, 1 = 1x16

**F136****ENUMERATION: NUMBER OF OSCILLOGRAPHY RECORDS**

0 = 31 x 8 cycles, 1 = 15 x 16 cycles, 2 = 7 x 32 cycles  
3 = 3 x 64 cycles, 4 = 1 x 128 cycles

**F138****ENUMERATION: OSCILLOGRAPHY FILE TYPE**

0 = Data File, 1 = Configuration File, 2 = Header File

**F140****ENUMERATION: CURRENT, SENS CURRENT, VOLTAGE, DISABLED**

0 = Disabled, 1 = Current 46 A, 2 = Voltage 280 V, 3 = Current 4.6 A, 4 = Current 2 A, 5 = Notched 4.6 A, 6 = Notched 2 A

**F141****ENUMERATION: SELF TEST ERROR**

| bitmask | error             |
|---------|-------------------|
| 0       | Any Self Tests    |
| 1       | IRIG-B Failure    |
| 2       | DSP Error         |
| 4       | No DSP Interrupts |

| bitmask | error                      |
|---------|----------------------------|
| 5       | Unit Not Calibrated        |
| 9       | Prototype Firmware         |
| 10      | Flexlogic Error Token      |
| 11      | Equipment Mismatch         |
| 13      | Unit Not Programmed        |
| 14      | System Exception           |
| 15      | Latching Out Error         |
| 18      | SNTP Failure               |
| 19      | Battery Failure            |
| 20      | Primary Ethernet Failure   |
| 21      | Secondary Ethernet Failure |
| 22      | EEPROM Data Error          |
| 23      | SRAM Data Error            |
| 24      | Program Memory             |
| 25      | Watchdog Error             |
| 26      | Low On Memory              |
| 27      | Remote Device Off          |
| 28      | Direct Device Off          |
| 29      | Direct Ring Break          |
| 30      | Any Minor Error            |
| 31      | Any Major Error            |

**F142****ENUMERATION: EVENT RECORDER ACCESS FILE TYPE**

0 = All Record Data, 1 = Headers Only, 2 = Numeric Event Cause

**F143****UR\_UINT32: 32 BIT ERROR CODE (F141 specifies bit number)**

A bit value of 0 = no error, 1 = error

**F144****ENUMERATION: FORCED CONTACT INPUT STATE**

0 = Disabled, 1 = Open, 2 = Closed

**F145****ENUMERATION: ALPHABET LETTER**

| bitmask | type | bitmask | type | bitmask | type | bitmask | type |
|---------|------|---------|------|---------|------|---------|------|
| 0       | null | 7       | G    | 14      | N    | 21      | U    |
| 1       | A    | 8       | H    | 15      | O    | 22      | V    |
| 2       | B    | 9       | I    | 16      | P    | 23      | W    |
| 3       | C    | 10      | J    | 17      | Q    | 24      | X    |
| 4       | D    | 11      | K    | 18      | R    | 25      | Y    |
| 5       | E    | 12      | L    | 19      | S    | 26      | Z    |
| 6       | F    | 13      | M    | 20      | T    |         |      |



**F146****ENUMERATION: MISC. EVENT CAUSES**

| bitmask | definition                             |
|---------|--|
| 0       | Events Cleared                         |
| 1       | Oscillography Triggered                |
| 2       | Date/time Changed                      |
| 3       | Default Settings Loaded                |
| 4       | Test Mode On                           |
| 5       | Test Mode Off                          |
| 6       | Power On                               |
| 7       | Power Off                              |
| 8       | Relay In Service                       |
| 9       | Relay Out Of Service                   |
| 10      | Watchdog Reset                         |
| 11      | Oscillography Clear                    |
| 12      | Reboot Command                         |
| 13      | Led Test Initiated                     |
| 14      | Flash Programming                      |
| 15      | Fault Report Trigger                   |
| 16      | User Programmable Fault Report Trigger |

**F147****ENUMERATION: LINE LENGTH UNITS**

0 = km, 1 = miles

**F148****ENUMERATION: FAULT TYPE**

| bitmask | fault type | bitmask | fault type |
|---------|------------|---------|------------|
| 0       | NA         | 6       | AC         |
| 1       | AG         | 7       | ABG        |
| 2       | BG         | 8       | BCG        |
| 3       | CG         | 9       | ACG        |
| 4       | AB         | 10      | ABC        |
| 5       | BC         | 11      | ABCG       |

**F151****ENUMERATION: RTD SELECTION**

| bitmask | RTD#   | bitmask | RTD#   | bitmask | RTD#   |
|---------|--------|---------|--------|---------|--------|
| 0       | NONE   | 17      | RTD 17 | 33      | RTD 33 |
| 1       | RTD 1  | 18      | RTD 18 | 34      | RTD 34 |
| 2       | RTD 2  | 19      | RTD 19 | 35      | RTD 35 |
| 3       | RTD 3  | 20      | RTD 20 | 36      | RTD 36 |
| 4       | RTD 4  | 21      | RTD 21 | 37      | RTD 37 |
| 5       | RTD 5  | 22      | RTD 22 | 38      | RTD 38 |
| 6       | RTD 6  | 23      | RTD 23 | 39      | RTD 39 |
| 7       | RTD 7  | 24      | RTD 24 | 40      | RTD 40 |
| 8       | RTD 8  | 25      | RTD 25 | 41      | RTD 41 |
| 9       | RTD 9  | 26      | RTD 26 | 42      | RTD 42 |
| 10      | RTD 10 | 27      | RTD 27 | 43      | RTD 43 |
| 11      | RTD 11 | 28      | RTD 28 | 44      | RTD 44 |
| 12      | RTD 12 | 29      | RTD 29 | 45      | RTD 45 |
| 13      | RTD 13 | 30      | RTD 30 | 46      | RTD 46 |
| 14      | RTD 14 | 31      | RTD 31 | 47      | RTD 47 |
| 15      | RTD 15 | 32      | RTD 32 | 48      | RTD 48 |
| 16      | RTD 16 |         |        |         |        |

**F152****ENUMERATION: SETTING GROUP**

0 = Active Group, 1 = Group 1, 2 = Group 2, 3 = Group 3  
4 = Group 4, 5 = Group 5, 6 = Group 6

**F154****ENUMERATION: DISTANCE DIRECTION**

0 = Forward, 1 = Reverse, 2 = Non-Directional

**F155****ENUMERATION: REMOTE DEVICE STATE**

0 = Offline, 1 = Online

**F156****ENUMERATION: REMOTE INPUT BIT PAIRS**

| bitmask | RTD#   | bitmask | RTD#      | bitmask | RTD#      |
|---------|--------|---------|-----------|---------|-----------|
| 0       | NONE   | 22      | DNA-22    | 44      | UserSt-12 |
| 1       | DNA-1  | 23      | DNA-23    | 45      | UserSt-13 |
| 2       | DNA-2  | 24      | DNA-24    | 46      | UserSt-14 |
| 3       | DNA-3  | 25      | DNA-25    | 47      | UserSt-15 |
| 4       | DNA-4  | 26      | DNA-26    | 48      | UserSt-16 |
| 5       | DNA-5  | 27      | DNA-27    | 49      | UserSt-17 |
| 6       | DNA-6  | 28      | DNA-28    | 50      | UserSt-18 |
| 7       | DNA-7  | 29      | DNA-29    | 51      | UserSt-19 |
| 8       | DNA-8  | 30      | DNA-30    | 52      | UserSt-20 |
| 9       | DNA-9  | 31      | DNA-31    | 53      | UserSt-21 |
| 10      | DNA-10 | 32      | DNA-32    | 54      | UserSt-22 |
| 11      | DNA-11 | 33      | UserSt-1  | 55      | UserSt-23 |
| 12      | DNA-12 | 34      | UserSt-2  | 56      | UserSt-24 |
| 13      | DNA-13 | 35      | UserSt-3  | 57      | UserSt-25 |
| 14      | DNA-14 | 36      | UserSt-4  | 58      | UserSt-26 |
| 15      | DNA-15 | 37      | UserSt-5  | 59      | UserSt-27 |
| 16      | DNA-16 | 38      | UserSt-6  | 60      | UserSt-28 |
| 17      | DNA-17 | 39      | UserSt-7  | 61      | UserSt-29 |
| 18      | DNA-18 | 40      | UserSt-8  | 62      | UserSt-30 |
| 19      | DNA-19 | 41      | UserSt-9  | 63      | UserSt-31 |
| 20      | DNA-20 | 42      | UserSt-10 | 64      | UserSt-32 |
| 21      | DNA-21 | 43      | UserSt-11 |         |           |

**F157****ENUMERATION: BREAKER MODE**

0 = 3-Pole, 1 = 1-Pole

**F159****ENUMERATION: BREAKER AUX CONTACT KEYING**

0 = 52a, 1 = 52b, 2 = None

**F166****ENUMERATION: AUXILIARY VT CONNECTION TYPE**

0 = Vn, 1 = Vag, 2 = Vbg, 3 = Vcg, 4 = Vab, 5 = Vbc, 6 = Vca

**F167****ENUMERATION: SIGNAL SOURCE**

0 = SRC 1, 1 = SRC 2, 2 = SRC 3, 3 = SRC 4, 4 = SRC 5, 5 = SRC 6

**F168****ENUMERATION: INRUSH INHIBIT FUNCTION**

0 = Disabled, 1 = Adapt. 2nd, 2 = Trad. 2nd

**F170****ENUMERATION: LOW/HIGH OFFSET and GAIN  
TRANSDUCER INPUT/OUTPUT SELECTION**

0 = LOW, 1 = HIGH

**F171****ENUMERATION: TRANSDUCER CHANNEL INPUT TYPE**

0 = dcmA IN, 1 = Ohms IN, 2 = RTD IN, 3 = dcmA OUT

**F172****ENUMERATION: SLOT LETTERS**

| bitmask | slot | bitmask | slot | bitmask | slot | bitmask | slot |
|---------|------|---------|------|---------|------|---------|------|
| 0       | F    | 4       | K    | 8       | P    | 12      | U    |
| 1       | G    | 5       | L    | 9       | R    | 13      | V    |
| 2       | H    | 6       | M    | 10      | S    | 14      | W    |
| 3       | J    | 7       | N    | 11      | T    | 15      | X    |

**F173****ENUMERATION: TRANSDUCER DCMA I/O RANGE**

| bitmask | dcmA I/O range |
|---------|----------------|
| 0       | 0 to -1 mA     |
| 1       | 0 to 1 mA      |
| 2       | -1 to 1 mA     |
| 3       | 0 to 5 mA      |
| 4       | 0 to 10 mA     |
| 5       | 0 to 20 mA     |
| 6       | 4 to 20 mA     |

**F174****ENUMERATION: TRANSDUCER RTD INPUT TYPE**

0 = 100 Ohm Platinum, 1 = 120 Ohm Nickel, 2 = 100 Ohm Nickel, 3 = 10 Ohm Copper

**F175****ENUMERATION: PHASE LETTERS**

0 = A, 1 = B, 2 = C

**F176****ENUMERATION: SYNCHROCHECK DEAD SOURCE SELECT**

| bitmask | synchrocheck dead source |
|---------|--------------------------|
| 0       | None                     |
| 1       | LV1 and DV2              |
| 2       | DV1 and LV2              |
| 3       | DV1 or DV2               |
| 4       | DV1 Xor DV2              |
| 5       | DV1 and DV2              |

**F177****ENUMERATION: COMMUNICATION PORT**

0 = None, 1 = COM1-RS485, 2 = COM2-RS485,  
3 = Front Panel-RS232, 4 = Network

**F179****ENUMERATION: NEGATIVE SEQUENCE DIRECTIONAL OVERCURRENT TYPE**

0 = Neg Sequence, 1 = Zero Sequence

**F180****ENUMERATION: PHASE/GROUND**

0 = PHASE, 1 = GROUND

**F181****ENUMERATION: ODD/EVEN/NONE**

0 = ODD, 1 = EVEN, 2 = NONE

**F183****ENUMERATION: AC INPUT WAVEFORMS**

| bitmask | definition       |
|---------|------------------|
| 0       | Off              |
| 1       | 8 samples/cycle  |
| 2       | 16 samples/cycle |
| 3       | 32 samples/cycle |
| 4       | 64 samples/cycle |

**F185****ENUMERATION: PHASE A,B,C, GROUND SELECTOR**

0 = A, 1 = B, 2 = C, 3 = G

**F186****ENUMERATION: MEASUREMENT MODE**

0 = Phase to Ground, 1 = Phase to Phase

**F190****ENUMERATION: SIMULATED KEYPRESS**

| bitmsk | keypress                     | bitmsk | keypress                    |
|--------|------------------------------|--------|-----------------------------|
| 0      | ---<br>use between real keys | 21     | Escape                      |
| 1      | 1                            | 22     | Enter                       |
| 2      | 2                            | 23     | Reset                       |
| 3      | 3                            | 24     | User 1                      |
| 4      | 4                            | 25     | User 2                      |
| 5      | 5                            | 26     | User 3                      |
| 6      | 6                            | 27     | User-programmable key 1     |
| 7      | 7                            | 28     | User-programmable key 2     |
| 8      | 8                            | 29     | User-programmable key 3     |
| 9      | 9                            | 30     | User-programmable key 4     |
| 10     | 0                            | 31     | User-programmable key 5     |
| 11     | Decimal Pt                   | 32     | User-programmable key 6     |
| 12     | Plus/Minus                   | 33     | User-programmable key 7     |
| 13     | Value Up                     | 34     | User-programmable key 8     |
| 14     | Value Down                   | 35     | User-programmable key 9     |
| 15     | Message Up                   | 36     | User-programmable key 10    |
| 16     | Message Down                 | 37     | User-programmable key 11    |
| 17     | Message Left                 | 38     | User-programmable key 12    |
| 18     | Message Right                | 39     | User 4 (control pushbutton) |
| 19     | Menu                         | 40     | User 5 (control pushbutton) |
| 20     | Help                         | 41     | User 6 (control pushbutton) |
|        |                              | 42     | User 7 (control pushbutton) |

**F192****ENUMERATION: ETHERNET OPERATION MODE**

0 = Half-Duplex, 1 = Full-Duplex

**F194****ENUMERATION: DNP SCALE**

A bitmask of 0 = 0.01, 1 = 0.1, 2 = 1, 3 = 10, 4 = 100, 5 = 1000,  
6 = 10000, 7 = 100000, 8 = 0.001

**F196****ENUMERATION: NEUTRAL DIRECTIONAL OVERCURRENT OPERATING CURRENT**

0 = Calculated 3I0, 1 = Measured IG

**F197****ENUMERATION: DNP BINARY INPUT POINT BLOCK**

| bitmask | Input Point Block        |
|---------|--------------------------|
| 0       | Not Used                 |
| 1       | Virtual Inputs 1 to 16   |
| 2       | Virtual Inputs 17 to 32  |
| 3       | Virtual Outputs 1 to 16  |
| 4       | Virtual Outputs 17 to 32 |
| 5       | Virtual Outputs 33 to 48 |
| 6       | Virtual Outputs 49 to 64 |

| bitmask | Input Point Block        |
|---------|--------------------------|
| 7       | Contact Inputs 1 to 16   |
| 8       | Contact Inputs 17 to 32  |
| 9       | Contact Inputs 33 to 48  |
| 10      | Contact Inputs 49 to 64  |
| 11      | Contact Inputs 65 to 80  |
| 12      | Contact Inputs 81 to 96  |
| 13      | Contact Outputs 1 to 16  |
| 14      | Contact Outputs 17 to 32 |
| 15      | Contact Outputs 33 to 48 |
| 16      | Contact Outputs 49 to 64 |
| 17      | Remote Inputs 1 to 16    |
| 18      | Remote Inputs 17 to 32   |
| 19      | Remote Devs 1 to 16      |
| 20      | Elements 1 to 16         |
| 21      | Elements 17 to 32        |
| 22      | Elements 33 to 48        |
| 23      | Elements 49 to 64        |
| 24      | Elements 65 to 80        |
| 25      | Elements 81 to 96        |
| 26      | Elements 97 to 112       |
| 27      | Elements 113 to 128      |
| 28      | Elements 129 to 144      |
| 29      | Elements 145 to 160      |
| 30      | Elements 161 to 176      |
| 31      | Elements 177 to 192      |
| 32      | Elements 193 to 208      |
| 33      | Elements 209 to 224      |
| 34      | Elements 225 to 240      |
| 35      | Elements 241 to 256      |
| 36      | Elements 257 to 272      |
| 37      | Elements 273 to 288      |
| 38      | Elements 289 to 304      |
| 39      | Elements 305 to 320      |
| 40      | Elements 321 to 336      |
| 41      | Elements 337 to 352      |
| 42      | Elements 353 to 368      |
| 43      | Elements 369 to 384      |
| 44      | Elements 385 to 400      |
| 45      | Elements 401 to 406      |
| 46      | Elements 417 to 432      |
| 47      | Elements 433 to 448      |
| 48      | Elements 449 to 464      |
| 49      | Elements 465 to 480      |
| 50      | Elements 481 to 496      |
| 51      | Elements 497 to 512      |
| 52      | Elements 513 to 528      |
| 53      | Elements 529 to 544      |
| 54      | Elements 545 to 560      |
| 55      | LED States 1 to 16       |
| 56      | LED States 17 to 32      |
| 57      | Self Tests 1 to 16       |
| 58      | Self Tests 17 to 32      |

**F199****ENUMERATION: DISABLED/ENABLED/CUSTOM**

0 = Disabled, 1 = Enabled, 2 = Custom

**F200****TEXT40: 40-CHARACTER ASCII TEXT**

20 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

**F201****TEXT8: 8-CHARACTER ASCII PASSCODE**

4 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

**F202****TEXT20: 20-CHARACTER ASCII TEXT**

10 registers, 16 Bits: 1st Char MSB, 2nd Char. LSB

**F203****TEXT16: 16-CHARACTER ASCII TEXT****F204****TEXT80: 80-CHARACTER ASCII TEXT****F205****TEXT12: 12-CHARACTER ASCII TEXT****F206****TEXT6: 6-CHARACTER ASCII TEXT****F207****TEXT4: 4-CHARACTER ASCII TEXT****F208****TEXT2: 2-CHARACTER ASCII TEXT****F222****ENUMERATION: TEST ENUMERATION**

0 = Test Enumeration 0, 1 = Test Enumeration 1

**F230****ENUMERATION: DIRECTIONAL POLARIZING**

0 = Voltage, 1 = Current, 2 = Dual

**F231****ENUMERATION: POLARIZING VOLTAGE**

0 = Calculated V0, 1 = Measured VX

**F300****UR\_UINT16: FLEXLOGIC™ BASE TYPE (6-bit type)**

The FlexLogic™ BASE type is 6 bits and is combined with a 9 bit descriptor and 1 bit for protection element to form a 16 bit value. The combined bits are of the form: PTTTTTDDDDDDDDDD, where P bit if set, indicates that the FlexLogic™ type is associated with a protection element state and T represents bits for the BASE type, and D represents bits for the descriptor.

The values in square brackets indicate the base type with P prefix [PTTTTTT] and the values in round brackets indicate the descriptor range.

[0] Off(0) this is boolean FALSE value  
 [0] On (1) This is boolean TRUE value  
 [2] CONTACT INPUTS (1 - 96)  
 [3] CONTACT INPUTS OFF (1-96)  
 [4] VIRTUAL INPUTS (1-64)  
 [6] VIRTUAL OUTPUTS (1-64)  
 [10] CONTACT OUTPUTS VOLTAGE DETECTED (1-64)  
 [11] CONTACT OUTPUTS VOLTAGE OFF DETECTED (1-64)  
 [12] CONTACT OUTPUTS CURRENT DETECTED (1-64)  
 [13] CONTACT OUTPUTS CURRENT OFF DETECTED (1-64)  
 [14] REMOTE INPUTS (1-32)  
 [28] INSERT (Via Keypad only)  
 [32] END  
 [34] NOT (1 INPUT)  
 [36] 2 INPUT XOR (0)  
 [38] LATCH SET/RESET (2 inputs)  
 [40] OR (2 to 16 inputs)  
 [42] AND (2 to 16 inputs)  
 [44] NOR (2 to 16 inputs)  
 [46] NAND (2 to 16 inputs)  
 [48] TIMER (1 to 32)  
 [50] ASSIGN VIRTUAL OUTPUT (1 to 64)  
 [52] SELF-TEST ERROR (see F141 for range)  
 [56] ACTIVE SETTING GROUP (1 to 6)  
 [62] MISCELLANEOUS EVENTS (see F146 for range)  
 [64 to 127] ELEMENT STATES

**F400****UR\_UINT16: CT/VT BANK SELECTION**

| bitmask | bank selection        |
|---------|-----------------------|
| 0       | Card 1 Contact 1 to 4 |
| 1       | Card 1 Contact 5 to 8 |
| 2       | Card 2 Contact 1 to 4 |
| 3       | Card 2 Contact 5 to 8 |
| 4       | Card 3 Contact 1 to 4 |
| 5       | Card 3 Contact 5 to 8 |

**F500****UR\_UINT16: PACKED BITFIELD**

First register indicates input/output state with bits 0(MSB)-15(LSB) corresponding to input/output state 1-16. The second register indicates input/output state with bits 0-15 corresponding to input/output state 17-32 (if required). The third register indicates input/output state with bits 0-15 corresponding to input/output state 33-48 (if required). The fourth register indicates input/output state with bits 0-15 corresponding to input/output state 49-64 (if required).

The number of registers required is determined by the specific data item. A bit value of 0 = Off, 1 = On

**F501****UR\_UINT16: LED STATUS**

Low byte of register indicates LED status with bit 0 representing the top LED and bit 7 the bottom LED. A bit value of 1 indicates the LED is on, 0 indicates the LED is off.

**F502****BITFIELD: ELEMENT OPERATE STATES**

Each bit contains the operate state for an element. See the F124 format code for a list of element IDs. The operate bit for element ID X is bit [X mod 16] in register [X/16].

**F504****BITFIELD: 3-PHASE ELEMENT STATE**

| bitmask | element state   |
|---------|-----------------|
| 0       | Pickup          |
| 1       | Operate         |
| 2       | Pickup Phase A  |
| 3       | Pickup Phase B  |
| 4       | Pickup Phase C  |
| 5       | Operate Phase A |
| 6       | Operate Phase B |
| 7       | Operate Phase C |

**F505****BITFIELD: CONTACT OUTPUT STATE**

0 = Contact State, 1 = Voltage Detected, 2 = Current Detected

**F506|****BITFIELD: 1 PHASE ELEMENT STATE**

0 = Pickup, 1 = Operate

**F507****BITFIELD: COUNTER ELEMENT STATE**

0 = Count Greater Than, 1 = Count Equal To, 2 = Count Less Than

**F508****BITFIELD: DISTANCE ELEMENT STATE**

| bitmask | distance element state |
|---------|------------------------|
| 0       | Pickup                 |
| 1       | Operate                |
| 2       | Pickup AB              |
| 3       | Pickup BC              |
| 4       | Pickup CA              |
| 5       | Operate AB             |
| 6       | Operate BC             |
| 7       | Operate CA             |
| 8       | Timed                  |
| 9       | Operate IAB            |
| 10      | Operate IBC            |
| 11      | Operate ICA            |

**F509****BITFIELD: SIMPLE ELEMENT STATE**

0 = Operate

**F511****BITFIELD: 3-PHASE SIMPLE ELEMENT STATE**

0 = Operate, 1 = Operate A, 2 = Operate B, 3 = Operate C

**F513****ENUMERATION: POWER SWING MODE**

0 = Two Step, 1 = Three Step

**F514****ENUMERATION: POWER SWING TRIP MODE**

0 = Delayed, 1 = Early

**F515****ENUMERATION ELEMENT INPUT MODE**

0 = SIGNED, 1 = ABSOLUTE

**F516****ENUMERATION ELEMENT COMPARE MODE**

0 = LEVEL, 1 = DELTA

**F517****ENUMERATION: ELEMENT DIRECTION OPERATION**

0 = OVER, 1 = UNDER

**F518****ENUMERATION: FLEXELEMENT™ UNITS**

0 = Milliseconds, 1 = Seconds, 2 = Minutes

**F519****ENUMERATION: NON-VOLATILE LATCH**

0 = Reset-Dominant, 1 = Set-Dominant

**F521****ENUMERATION: GROUND DISTANCE POLARIZING CURRENT**

0 = Zero-Sequence; 1 = Negative-Sequence

**F522****ENUMERATION: TRANSDUCER DCMA OUTPUT RANGE**

0 = -1 to 1 mA; 1 = 0 to 1 mA; 2 = 4 to 20 mA

**F523****ENUMERATION: DNP OBJECTS 20, 22, AND 23 DEFAULT VARIATION**

| bitmask | Default Variation |
|---------|-------------------|
| 0       | 1                 |
| 1       | 2                 |
| 2       | 5                 |
| 3       | 6                 |

**F524****ENUMERATION: DNP OBJECT 21 DEFAULT VARIATION**

| bitmask | Default Variation |
|---------|-------------------|
| 0       | 1                 |
| 1       | 2                 |
| 2       | 9                 |
| 3       | 10                |

**F525****ENUMERATION: DNP OBJECT 32 DEFAULT VARIATION**

| bitmask | Default Variation |
|---------|-------------------|
| 0       | 1                 |
| 1       | 2                 |
| 2       | 3                 |
| 3       | 4                 |
| 4       | 5                 |
| 5       | 7                 |

**F530****ENUMERATION: FRONT PANEL INTERFACE KEYPRESS**

| bitmask | keypress      | bitmask | keypress   |
|---------|---------------|---------|------------|
| 0       | None          | 22      | Value Down |
| 1       | Menu          | 23      | Reset      |
| 2       | Message Up    | 24      | User 1     |
| 3       | 7             | 25      | User 2     |
| 4       | 8             | 26      | User 3     |
| 5       | 9             | 31      | User PB 1  |
| 6       | Help          | 32      | User PB 2  |
| 7       | Message Left  | 33      | User PB 3  |
| 8       | 4             | 34      | User PB 4  |
| 9       | 5             | 35      | User PB 5  |
| 10      | 6             | 36      | User PB 6  |
| 11      | Escape        | 37      | User PB 7  |
| 12      | Message Right | 38      | User PB 8  |
| 13      | 1             | 39      | User PB 9  |
| 14      | 2             | 40      | User PB 10 |
| 15      | 3             | 41      | User PB 11 |
| 16      | Enter         | 42      | User PB 12 |
| 17      | Message Down  | 44      | User 4     |
| 18      | 0             | 45      | User 5     |
| 19      | Decimal       | 46      | User 6     |
| 20      | +/-           | 47      | User 7     |
| 21      | Value Up      |         |            |

**F600****UR\_UINT16: FLEXANALOG PARAMETER**

Corresponds to the modbus address of the value used when this parameter is selected. Only certain values may be used as Flex-Analogs (basically all metering quantities used in protection)

**B**



## C.1.1 INTEROPERABILITY

This document is adapted from the IEC 60870-5-104 standard. For this section the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ☐ – cannot be selected in IEC 60870-5-104 standard.

## 1. SYSTEM OR DEVICE:

- ☐ System Definition  
☐ Controlling Station Definition (Master)  
☒ Controlled Station Definition (Slave)

## 2. NETWORK CONFIGURATION:

- ☐ Point to Point ☐ Multipoint  
☐ Multiple Point to Point ☐ Multipoint Star

## 3. PHYSICAL LAYER

Transmission Speed (control direction):

| Unbalanced Interchange Circuit V.24/V.28 Standard:  | Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s:   | Balanced Interchange Circuit X.24/X.27:   |
|---|---|---|
| <input type="checkbox"/> 100 bits/sec.<br><input type="checkbox"/> 200 bits/sec.<br><input type="checkbox"/> 300 bits/sec.<br><input type="checkbox"/> 600 bits/sec.<br><input type="checkbox"/> 1200 bits/sec. | <input type="checkbox"/> 2400 bits/sec.<br><input type="checkbox"/> 4800 bits/sec.<br><input type="checkbox"/> 9600 bits/sec. | <input type="checkbox"/> 2400 bits/sec.<br><input type="checkbox"/> 4800 bits/sec.<br><input type="checkbox"/> 9600 bits/sec.<br><input type="checkbox"/> 19200 bits/sec.<br><input type="checkbox"/> 38400 bits/sec.<br><input type="checkbox"/> 56000 bits/sec.<br><input type="checkbox"/> 64000 bits/sec. |

Transmission Speed (monitor direction):

| Unbalanced Interchange Circuit V.24/V.28 Standard:  | Unbalanced Interchange Circuit V.24/V.28 Recommended if >1200 bits/s:   | Balanced Interchange Circuit X.24/X.27:   |
|---|---|---|
| <input type="checkbox"/> 100 bits/sec.<br><input type="checkbox"/> 200 bits/sec.<br><input type="checkbox"/> 300 bits/sec.<br><input type="checkbox"/> 600 bits/sec.<br><input type="checkbox"/> 1200 bits/sec. | <input type="checkbox"/> 2400 bits/sec.<br><input type="checkbox"/> 4800 bits/sec.<br><input type="checkbox"/> 9600 bits/sec. | <input type="checkbox"/> 2400 bits/sec.<br><input type="checkbox"/> 4800 bits/sec.<br><input type="checkbox"/> 9600 bits/sec.<br><input type="checkbox"/> 19200 bits/sec.<br><input type="checkbox"/> 38400 bits/sec.<br><input type="checkbox"/> 56000 bits/sec.<br><input type="checkbox"/> 64000 bits/sec. |

## 4. LINK LAYER

| Link Transmission Procedure:  | Address Field of the Link:   |
|---|--|
| <input type="checkbox"/> Balanced Transmission<br><input type="checkbox"/> Unbalanced Transmission    | <input type="checkbox"/> Not Present (Balanced Transmission Only)<br><input type="checkbox"/> One Octet<br><input type="checkbox"/> Two Octets<br><input type="checkbox"/> Structured<br><input type="checkbox"/> Unstructured |
| Frame Length (maximum length, number of octets): Not selectable in companion IEC 60870-5-104 standard |  |

When using an unbalanced link layer, the following ADSU types are returned in class 2 messages (low priority) with the indicated causes of transmission:

■ The standard assignment of ADSUs to class 2 messages is used as follows:

■ A special assignment of ADSUs to class 2 messages is used as follows:

## 5. APPLICATION LAYER

### Transmission Mode for Application Data:

Mode 1 (least significant octet first), as defined in Clause 4.10 of IEC 60870-5-4, is used exclusively in this companion standard.

### Common Address of ADSU:

■ One Octet

☒ Two Octets

### Information Object Address:

■ One Octet

☒ Structured

■ Two Octets

☒ Unstructured

☒ Three Octets

### Cause of Transmission:

■ One Octet

☒ Two Octets (with originator address). Originator address is set to zero if not used.

**Maximum Length of APDU:** 253 (the maximum length may be reduced by the system).

### Selection of standard ASDUs:

For the following lists, the boxes indicate the following: ☒ – used in standard direction; ☐ – not used; ■ – cannot be selected in IEC 60870-5-104 standard.

#### Process information in monitor direction

|   |           |
|---|-----------|
| <input checked="" type="checkbox"/> <1> := Single-point information                           | M_SP_NA_1 |
| ■ <2> := Single-point information with time tag   | M_SP_TA_1 |
| <input type="checkbox"/> <3> := Double-point information                                      | M_DP_NA_1 |
| ■ <4> := Double-point information with time tag   | M_DP_TA_1 |
| <input type="checkbox"/> <5> := Step position information                                     | M_ST_NA_1 |
| ■ <6> := Step position information with time tag  | M_ST_TA_1 |
| <input type="checkbox"/> <7> := Bitstring of 32 bits  | M_BO_NA_1 |
| ■ <8> := Bitstring of 32 bits with time tag   | M_BO_TA_1 |
| <input type="checkbox"/> <9> := Measured value, normalized value                              | M_ME_NA_1 |
| ■ <10> := Measured value, normalized value with time tag                                      | M_ME_TA_1 |
| <input type="checkbox"/> <11> := Measured value, scaled value                                 | M_ME_NB_1 |
| ■ <12> := Measured value, scaled value with time tag  | M_ME_TB_1 |
| <input checked="" type="checkbox"/> <13> := Measured value, short floating point value        | M_ME_NC_1 |
| ■ <14> := Measured value, short floating point value with time tag                            | M_ME_TC_1 |
| <input checked="" type="checkbox"/> <15> := Integrated totals                                 | M_IT_NA_1 |
| ■ <16> := Integrated totals with time tag   | M_IT_TA_1 |
| ■ <17> := Event of protection equipment with time tag   | M_EP_TA_1 |
| ■ <18> := Packed start events of protection equipment with time tag                           | M_EP_TB_1 |
| ■ <19> := Packed output circuit information of protection equipment with time tag             | M_EP_TC_1 |
| <input type="checkbox"/> <20> := Packed single-point information with status change detection | M_SP_NA_1 |

|   |           |
|---|-----------|
| <input type="checkbox"/> <21> := Measured value, normalized value without quantity descriptor                       | M_ME_ND_1 |
| <input checked="" type="checkbox"/> <30> := Single-point information with time tag CP56Time2a                       | M_SP_TB_1 |
| <input type="checkbox"/> <31> := Double-point information with time tag CP56Time2a                                  | M_DP_TB_1 |
| <input type="checkbox"/> <32> := Step position information with time tag CP56Time2a                                 | M_ST_TB_1 |
| <input type="checkbox"/> <33> := Bitstring of 32 bits with time tag CP56Time2a                                      | M_BO_TB_1 |
| <input type="checkbox"/> <34> := Measured value, normalized value with time tag CP56Time2a                          | M_ME_TD_1 |
| <input type="checkbox"/> <35> := Measured value, scaled value with time tag CP56Time2a                              | M_ME_TE_1 |
| <input type="checkbox"/> <36> := Measured value, short floating point value with time tag CP56Time2a                | M_ME_TF_1 |
| <input checked="" type="checkbox"/> <37> := Integrated totals with time tag CP56Time2a                              | M_IT_TB_1 |
| <input type="checkbox"/> <38> := Event of protection equipment with time tag CP56Time2a                             | M_EP_TD_1 |
| <input type="checkbox"/> <39> := Packed start events of protection equipment with time tag CP56Time2a               | M_EP_TE_1 |
| <input type="checkbox"/> <40> := Packed output circuit information of protection equipment with time tag CP56Time2a | M_EP_TF_1 |

Either the ASDUs of the set <2>, <4>, <6>, <8>, <10>, <12>, <14>, <16>, <17>, <18>, and <19> or of the set <30> to <40> are used.

#### Process information in control direction

|   |           |
|---|-----------|
| <input checked="" type="checkbox"/> <45> := Single command  | C_SC_NA_1 |
| <input type="checkbox"/> <46> := Double command   | C_DC_NA_1 |
| <input type="checkbox"/> <47> := Regulating step command  | C_RC_NA_1 |
| <input type="checkbox"/> <48> := Set point command, normalized value                                    | C_SE_NA_1 |
| <input type="checkbox"/> <49> := Set point command, scaled value  | C_SE_NB_1 |
| <input type="checkbox"/> <50> := Set point command, short floating point value                          | C_SE_NC_1 |
| <input type="checkbox"/> <51> := Bitstring of 32 bits   | C_BO_NA_1 |
| <input checked="" type="checkbox"/> <58> := Single command with time tag CP56Time2a                     | C_SC_TA_1 |
| <input type="checkbox"/> <59> := Double command with time tag CP56Time2a                                | C_DC_TA_1 |
| <input type="checkbox"/> <60> := Regulating step command with time tag CP56Time2a                       | C_RC_TA_1 |
| <input type="checkbox"/> <61> := Set point command, normalized value with time tag CP56Time2a           | C_SE_TA_1 |
| <input type="checkbox"/> <62> := Set point command, scaled value with time tag CP56Time2a               | C_SE_TB_1 |
| <input type="checkbox"/> <63> := Set point command, short floating point value with time tag CP56Time2a | C_SE_TC_1 |
| <input type="checkbox"/> <64> := Bitstring of 32 bits with time tag CP56Time2a                          | C_BO_TA_1 |

Either the ASDUs of the set <45> to <51> or of the set <58> to <64> are used.

#### System information in monitor direction

|   |           |
|---|-----------|
| <input checked="" type="checkbox"/> <70> := End of initialization | M_EI_NA_1 |
|---|-----------|

#### System information in control direction

|   |           |
|---|-----------|
| <input checked="" type="checkbox"/> <100> := Interrogation command                                      | C_IC_NA_1 |
| <input checked="" type="checkbox"/> <101> := Counter interrogation command                              | C_CI_NA_1 |
| <input checked="" type="checkbox"/> <102> := Read command   | C_RD_NA_1 |
| <input checked="" type="checkbox"/> <103> := Clock synchronization command (see Clause 7.6 in standard) | C_CS_NA_1 |
| <input checked="" type="checkbox"/> <104> := Test command   | C_TS_NA_1 |
| <input checked="" type="checkbox"/> <105> := Reset process command                                      | C_RP_NA_1 |
| <input checked="" type="checkbox"/> <106> := Delay acquisition command                                  | C_CD_NA_1 |
| <input checked="" type="checkbox"/> <107> := Test command with time tag CP56Time2a                      | C_TS_TA_1 |

**Parameter in control direction**

|  |            |
|--|------------|
| <input type="checkbox"/> <110> := Parameter of measured value, normalized value                      | PE_ME_NA_1 |
| <input type="checkbox"/> <111> := Parameter of measured value, scaled value                          | PE_ME_NB_1 |
| <input checked="" type="checkbox"/> <112> := Parameter of measured value, short floating point value | PE_ME_NC_1 |
| <input type="checkbox"/> <113> := Parameter activation   | PE_AC_NA_1 |

**File transfer**

|  |           |
|--|-----------|
| <input type="checkbox"/> <120> := File Ready   | F_FR_NA_1 |
| <input type="checkbox"/> <121> := Section Ready  | F_SR_NA_1 |
| <input type="checkbox"/> <122> := Call directory, select file, call file, call section                   | F_SC_NA_1 |
| <input type="checkbox"/> <123> := Last section, last segment   | F_LS_NA_1 |
| <input type="checkbox"/> <124> := Ack file, ack section  | F_AF_NA_1 |
| <input type="checkbox"/> <125> := Segment  | F_SG_NA_1 |
| <input type="checkbox"/> <126> := Directory (blank or X, available only in monitor [standard] direction) | C_CD_NA_1 |

**Type identifier and cause of transmission assignments**  
 (station-specific parameters)

In the following table:

- Shaded boxes are not required.
- Black boxes are not permitted in this companion standard.
- Blank boxes indicate functions or ASDU not used.
- 'X' if only used in the standard direction

| TYPE IDENTIFICATION |           | CAUSE OF TRANSMISSION |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
|---------------------|-----------|-----------------------|-----------------|-------------|-------------|----------------------|------------|-------------------------|--------------|---------------------------|------------------------|---------------------------------|---------------|--------------------------------|----------------------------------|-----------------------------|-------------------------------|--------------------------------|---------------------------------|---------------------------------|
|                     |           | PERIODIC, CYCLIC      | BACKGROUND SCAN | SPONTANEOUS | INITIALIZED | REQUEST OR REQUESTED | ACTIVATION | ACTIVATION CONFIRMATION | DEACTIVATION | DEACTIVATION CONFIRMATION | ACTIVATION TERMINATION | RETURN INFO CAUSED BY LOCAL CMD | FILE TRANSFER | INTERROGATED BY GROUP <NUMBER> | REQUEST BY GROUP <N> COUNTER REQ | UNKNOWN TYPE IDENTIFICATION | UNKNOWN CAUSE OF TRANSMISSION | UNKNOWN COMMON ADDRESS OF ADSU | UNKNOWN INFORMATION OBJECT ADDR | UNKNOWN INFORMATION OBJECT ADDR |
| NO.                 | MNEMONIC  | 1                     | 2               | 3           | 4           | 5                    | 6          | 7                       | 8            | 9                         | 10                     | 11                              | 12            | 13                             | 20 to 36                         | 37 to 41                    | 44                            | 45                             | 46                              | 47                              |
| <1>                 | M_SP_NA_1 |                       |                 | X           |             | X                    |            |                         |              |                           |                        | X                               | X             |                                | X                                |                             |                               |                                |                                 |                                 |
| <2>                 | M_SP_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <3>                 | M_DP_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <4>                 | M_DP_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <5>                 | M_ST_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <6>                 | M_ST_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <7>                 | M_BO_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <8>                 | M_BO_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |

| TYPE IDENTIFICATION |           | CAUSE OF TRANSMISSION |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
|---------------------|-----------|-----------------------|-----------------|-------------|-------------|----------------------|------------|-------------------------|--------------|---------------------------|------------------------|---------------------------------|---------------|--------------------------------|----------------------------------|-----------------------------|-------------------------------|--------------------------------|
|                     |           | PERIODIC, CYCLIC      | BACKGROUND SCAN | SPONTANEOUS | INITIALIZED | REQUEST OR REQUESTED | ACTIVATION | ACTIVATION CONFIRMATION | DEACTIVATION | DEACTIVATION CONFIRMATION | ACTIVATION TERMINATION | RETURN INFO CAUSED BY LOCAL CMD | FILE TRANSFER | INTERROGATED BY GROUP <NUMBER> | REQUEST BY GROUP <N> COUNTER REQ | UNKNOWN TYPE IDENTIFICATION | UNKNOWN CAUSE OF TRANSMISSION | UNKNOWN COMMON ADDRESS OF ADSU |
| NO.                 | MNEMONIC  | 1                     | 2               | 3           | 4           | 5                    | 6          | 7                       | 8            | 9                         | 10                     | 11                              | 12            | 13                             | 20 to 36                         | 37 to 41                    | 44                            | 45                             |
| <9>                 | M_ME_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <10>                | M_ME_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <11>                | M_ME_NB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <12>                | M_ME_TB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <13>                | M_ME_NC_1 | X                     |                 | X           |             | X                    |            |                         |              |                           |                        |                                 |               |                                | X                                |                             |                               |                                |
| <14>                | M_ME_TC_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <15>                | M_IT_NA_1 |                       |                 | X           |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  | X                           |                               |                                |
| <16>                | M_IT_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <17>                | M_EP_TA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <18>                | M_EP_TB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <19>                | M_EP_TC_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <20>                | M_PS_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <21>                | M_ME_ND_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <30>                | M_SP_TB_1 |                       |                 | X           |             |                      |            |                         |              |                           |                        | X                               | X             |                                |                                  |                             |                               |                                |
| <31>                | M_DP_TB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <32>                | M_ST_TB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <33>                | M_BO_TB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <34>                | M_ME_TD_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <35>                | M_ME_TE_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <36>                | M_ME_TF_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <37>                | M_IT_TB_1 |                       |                 | X           |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  | X                           |                               |                                |
| <38>                | M_EP_TD_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <39>                | M_EP_TE_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <40>                | M_EP_TF_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <45>                | C_SC_NA_1 |                       |                 |             |             |                      | X          | X                       | X            | X                         | X                      |                                 |               |                                |                                  |                             |                               |                                |
| <46>                | C_DC_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <47>                | C_RC_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <48>                | C_SE_NA_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |
| <49>                | C_SE_NB_1 |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |

| TYPE IDENTIFICATION |             | CAUSE OF TRANSMISSION |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
|---------------------|-------------|-----------------------|-----------------|-------------|-------------|----------------------|------------|-------------------------|--------------|---------------------------|------------------------|---------------------------------|---------------|--------------------------------|----------------------------------|-----------------------------|-------------------------------|--------------------------------|---------------------------------|---------------------------------|
|                     |             | PERIODIC, CYCLIC      | BACKGROUND SCAN | SPONTANEOUS | INITIALIZED | REQUEST OR REQUESTED | ACTIVATION | ACTIVATION CONFIRMATION | DEACTIVATION | DEACTIVATION CONFIRMATION | ACTIVATION TERMINATION | RETURN INFO CAUSED BY LOCAL CMD | FILE TRANSFER | INTERROGATED BY GROUP <NUMBER> | REQUEST BY GROUP <N> COUNTER REQ | UNKNOWN TYPE IDENTIFICATION | UNKNOWN CAUSE OF TRANSMISSION | UNKNOWN COMMON ADDRESS OF ADSU | UNKNOWN INFORMATION OBJECT ADDR | UNKNOWN INFORMATION OBJECT ADDR |
| NO.                 | MNEMONIC    | 1                     | 2               | 3           | 4           | 5                    | 6          | 7                       | 8            | 9                         | 10                     | 11                              | 12            | 13                             | 20 to 36                         | 37 to 41                    | 44                            | 45                             | 46                              | 47                              |
| <50>                | C_SE_NC_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <51>                | C_BO_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <58>                | C_SC_TA_1   |                       |                 |             |             |                      | X          | X                       | X            | X                         | X                      |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <59>                | C_DC_TA_1   |                       |                 |             |             |                      | X          |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <60>                | C_RC_TA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <61>                | C_SE_TA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <62>                | C_SE_TB_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <63>                | C_SE_TC_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <64>                | C_BO_TA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <70>                | M_EI_NA_1*) |                       |                 |             | X           |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <100>               | C_IC_NA_1   |                       |                 |             |             |                      | X          | X                       | X            | X                         | X                      |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <101>               | C_CI_NA_1   |                       |                 |             |             |                      | X          | X                       |              |                           | X                      |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <102>               | C_RD_NA_1   |                       |                 |             |             | X                    |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <103>               | C_CS_NA_1   |                       |                 | X           |             |                      | X          | X                       |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <104>               | C_TS_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <105>               | C_RP_NA_1   |                       |                 |             |             |                      | X          | X                       |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <106>               | C_CD_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <107>               | C_TS_TA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <110>               | P_ME_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <111>               | P_ME_NB_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <112>               | P_ME_NC_1   |                       |                 |             |             |                      | X          | X                       |              |                           |                        |                                 |               |                                | X                                |                             |                               |                                |                                 |                                 |
| <113>               | P_AC_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <120>               | F_FR_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <121>               | F_SR_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <122>               | F_SC_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <123>               | F_LS_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <124>               | F_AF_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <125>               | F_SG_NA_1   |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |
| <126>               | F_DR_TA_1*) |                       |                 |             |             |                      |            |                         |              |                           |                        |                                 |               |                                |                                  |                             |                               |                                |                                 |                                 |

## 6. BASIC APPLICATION FUNCTIONS

### Station Initialization:

- ☒ Remote initialization

### Cyclic Data Transmission:

- ☒ Cyclic data transmission

### Read Procedure:

- ☒ Read procedure

### Spontaneous Transmission:

- ☒ Spontaneous transmission

### Double transmission of information objects with cause of transmission spontaneous:

The following type identifications may be transmitted in succession caused by a single status change of an information object. The particular information object addresses for which double transmission is enabled are defined in a project-specific list.

- ☐ Single point information: M\_SP\_NA\_1, M\_SP\_TA\_1, M\_SP\_TB\_1, and M\_PS\_NA\_1
- ☐ Double point information: M\_DP\_NA\_1, M\_DP\_TA\_1, and M\_DP\_TB\_1
- ☐ Step position information: M\_ST\_NA\_1, M\_ST\_TA\_1, and M\_ST\_TB\_1
- ☐ Bitstring of 32 bits: M\_BO\_NA\_1, M\_BO\_TA\_1, and M\_BO\_TB\_1 (if defined for a specific project)
- ☐ Measured value, normalized value: M\_ME\_NA\_1, M\_ME\_TA\_1, M\_ME\_ND\_1, and M\_ME\_TD\_1
- ☐ Measured value, scaled value: M\_ME\_NB\_1, M\_ME\_TB\_1, and M\_ME\_TE\_1
- ☐ Measured value, short floating point number: M\_ME\_NC\_1, M\_ME\_TC\_1, and M\_ME\_TF\_1

### Station interrogation:

- |   |   |  |  |
|---|---|--|--|
| <input checked="" type="checkbox"/> Global  |   |  |  |
| <input checked="" type="checkbox"/> Group 1 | <input checked="" type="checkbox"/> Group 5 | <input checked="" type="checkbox"/> Group 9  | <input checked="" type="checkbox"/> Group 13 |
| <input checked="" type="checkbox"/> Group 2 | <input checked="" type="checkbox"/> Group 6 | <input checked="" type="checkbox"/> Group 10 | <input checked="" type="checkbox"/> Group 14 |
| <input checked="" type="checkbox"/> Group 3 | <input checked="" type="checkbox"/> Group 7 | <input checked="" type="checkbox"/> Group 11 | <input checked="" type="checkbox"/> Group 15 |
| <input checked="" type="checkbox"/> Group 4 | <input checked="" type="checkbox"/> Group 8 | <input checked="" type="checkbox"/> Group 12 | <input checked="" type="checkbox"/> Group 16 |

### Clock synchronization:

- ☒ Clock synchronization (optional, see Clause 7.6)

### Command transmission:

- ☒ Direct command transmission
- ☐ Direct setpoint command transmission
- ☒ Select and execute command
- ☐ Select and execute setpoint command
- ☒ C\_SE ACTTERM used
- ☒ No additional definition
- ☒ Short pulse duration (duration determined by a system parameter in the outstation)
- ☒ Long pulse duration (duration determined by a system parameter in the outstation)
- ☒ Persistent output

- ☒ Supervision of maximum delay in command direction of commands and setpoint commands

Maximum allowable delay of commands and setpoint commands: **10 s**

**Transmission of integrated totals:**

- ☒ Mode A: Local freeze with spontaneous transmission
- ☒ Mode B: Local freeze with counter interrogation
- ☒ Mode C: Freeze and transmit by counter-interrogation commands
- ☒ Mode D: Freeze by counter-interrogation command, frozen values reported simultaneously
  
- ☒ Counter read
- ☒ Counter freeze without reset
- ☒ Counter freeze with reset
- ☒ Counter reset
  
- ☒ General request counter
- ☒ Request counter group 1
- ☒ Request counter group 2
- ☒ Request counter group 3
- ☒ Request counter group 4

**Parameter loading:**

- ☒ Threshold value
- ☐ Smoothing factor
- ☐ Low limit for transmission of measured values
- ☐ High limit for transmission of measured values

**Parameter activation:**

- ☐ Activation/deactivation of persistent cyclic or periodic transmission of the addressed object

**Test procedure:**

- ☐ Test procedure

**File transfer:**

File transfer in monitor direction:

- ☐ Transparent file
- ☐ Transmission of disturbance data of protection equipment
- ☐ Transmission of sequences of events
- ☐ Transmission of sequences of recorded analog values

File transfer in control direction:

- ☐ Transparent file

**Background scan:**

- ☐ Background scan

**Acquisition of transmission delay:**

- ☒ Acquisition of transmission delay



**Definition of time outs:**

| PARAMETER | DEFAULT VALUE | REMARKS  | SELECTED VALUE |
|-----------|---------------|--|----------------|
| $t_0$     | 30 s          | Timeout of connection establishment                                  | 120 s          |
| $t_1$     | 15 s          | Timeout of send or test APDUs  | 15 s           |
| $t_2$     | 10 s          | Timeout for acknowledgements in case of no data messages $t_2 < t_1$ | 10 s           |
| $t_3$     | 20 s          | Timeout for sending test frames in case of a long idle state         | 20 s           |

Maximum range of values for all time outs: 1 to 255 s, accuracy 1 s

**Maximum number of outstanding I-format APDUs  $k$  and latest acknowledge APDUs ( $w$ ):**

| PARAMETER | DEFAULT VALUE | REMARKS   | SELECTED VALUE |
|-----------|---------------|---|----------------|
| $k$       | 12 APDUs      | Maximum difference receive sequence number to send state variable | 12 APDUs       |
| $w$       | 8 APDUs       | Latest acknowledge after receiving $w$ I-format APDUs             | 8 APDUs        |

Maximum range of values  $k$ : 1 to 32767 ( $2^{15} - 1$ ) APDUs, accuracy 1 APDU

Maximum range of values  $w$ : 1 to 32767 APDUs, accuracy 1 APDU

Recommendation:  $w$  should not exceed two-thirds of  $k$ .

**Portnumber:**

| PARAMETER  | VALUE | REMARKS      |
|------------|-------|--------------|
| Portnumber | 2404  | In all cases |

**RFC 2200 suite:**

RFC 2200 is an official Internet Standard which describes the state of standardization of protocols used in the Internet as determined by the Internet Architecture Board (IAB). It offers a broad spectrum of actual standards used in the Internet. The suitable selection of documents from RFC 2200 defined in this standard for given projects has to be chosen by the user of this standard.

- ☒ Ethernet 802.3
- ☐ Serial X.21 interface
- ☐ Other selection(s) from RFC 2200 (list below if selected)

## C.1.2 POINT LIST

Only Source 1 data points are shown in the following table. If the **NUMBER OF SOURCES IN MMENC LIST** setting is increased, data points for subsequent sources will be added to the list immediately following the Source 1 data points.

Table C–1: IEC 60870-5-104 POINTS (Sheet 1 of 4)

| POINT                   | DESCRIPTION                                 | UNITS   |
|-------------------------|---|---------|
| <b>M_ME_NC_1 Points</b> |   |         |
| 2000                    | SRC 1 Phase A Current RMS                   | A       |
| 2001                    | SRC 1 Phase B Current RMS                   | A       |
| 2002                    | SRC 1 Phase C Current RMS                   | A       |
| 2003                    | SRC 1 Neutral Current RMS                   | A       |
| 2004                    | SRC 1 Phase A Current Magnitude             | A       |
| 2005                    | SRC 1 Phase A Current Angle                 | degrees |
| 2006                    | SRC 1 Phase B Current Magnitude             | A       |
| 2007                    | SRC 1 Phase B Current Angle                 | degrees |
| 2008                    | SRC 1 Phase C Current Magnitude             | A       |
| 2009                    | SRC 1 Phase C Current Angle                 | degrees |
| 2010                    | SRC 1 Neutral Current Magnitude             | A       |
| 2011                    | SRC 1 Neutral Current Angle                 | degrees |
| 2012                    | SRC 1 Ground Current RMS                    | A       |
| 2013                    | SRC 1 Ground Current Magnitude              | A       |
| 2014                    | SRC 1 Ground Current Angle                  | degrees |
| 2015                    | SRC 1 Zero Sequence Current Magnitude       | A       |
| 2016                    | SRC 1 Zero Sequence Current Angle           | degrees |
| 2017                    | SRC 1 Positive Sequence Current Magnitude   | A       |
| 2018                    | SRC 1 Positive Sequence Current Angle       | degrees |
| 2019                    | SRC 1 Negative Sequence Current Magnitude   | A       |
| 2020                    | SRC 1 Negative Sequence Current Angle       | degrees |
| 2021                    | SRC 1 Differential Ground Current Magnitude | A       |
| 2022                    | SRC 1 Differential Ground Current Angle     | degrees |
| 2023                    | SRC 1 Phase AG Voltage RMS                  | V       |
| 2024                    | SRC 1 Phase BG Voltage RMS                  | V       |
| 2025                    | SRC 1 Phase CG Voltage RMS                  | V       |
| 2026                    | SRC 1 Phase AG Voltage Magnitude            | V       |
| 2027                    | SRC 1 Phase AG Voltage Angle                | degrees |
| 2028                    | SRC 1 Phase BG Voltage Magnitude            | V       |
| 2029                    | SRC 1 Phase BG Voltage Angle                | degrees |
| 2030                    | SRC 1 Phase CG Voltage Magnitude            | V       |
| 2031                    | SRC 1 Phase CG Voltage Angle                | degrees |
| 2032                    | SRC 1 Phase AB Voltage RMS                  | V       |
| 2033                    | SRC 1 Phase BC Voltage RMS                  | V       |
| 2034                    | SRC 1 Phase CA Voltage RMS                  | V       |
| 2035                    | SRC 1 Phase AB Voltage Magnitude            | V       |
| 2036                    | SRC 1 Phase AB Voltage Angle                | degrees |
| 2037                    | SRC 1 Phase BC Voltage Magnitude            | V       |
| 2038                    | SRC 1 Phase BC Voltage Angle                | degrees |
| 2039                    | SRC 1 Phase CA Voltage Magnitude            | V       |
| 2040                    | SRC 1 Phase CA Voltage Angle                | degrees |
| 2041                    | SRC 1 Auxiliary Voltage RMS                 | V       |
| 2042                    | SRC 1 Auxiliary Voltage Magnitude           | V       |
| 2043                    | SRC 1 Auxiliary Voltage Angle               | degrees |
| 2044                    | SRC 1 Zero Sequence Voltage Magnitude       | V       |

Table C–1: IEC 60870-5-104 POINTS (Sheet 2 of 4)

| POINT | DESCRIPTION                                 | UNITS   |
|-------|---|---------|
| 2045  | SRC 1 Zero Sequence Voltage Angle           | degrees |
| 2046  | SRC 1 Positive Sequence Voltage Magnitude   | V       |
| 2047  | SRC 1 Positive Sequence Voltage Angle       | degrees |
| 2048  | SRC 1 Negative Sequence Voltage Magnitude   | V       |
| 2049  | SRC 1 Negative Sequence Voltage Angle       | degrees |
| 2050  | SRC 1 Three Phase Real Power                | W       |
| 2051  | SRC 1 Phase A Real Power                    | W       |
| 2052  | SRC 1 Phase B Real Power                    | W       |
| 2053  | SRC 1 Phase C Real Power                    | W       |
| 2054  | SRC 1 Three Phase Reactive Power            | var     |
| 2055  | SRC 1 Phase A Reactive Power                | var     |
| 2056  | SRC 1 Phase B Reactive Power                | var     |
| 2057  | SRC 1 Phase C Reactive Power                | var     |
| 2058  | SRC 1 Three Phase Apparent Power            | VA      |
| 2059  | SRC 1 Phase A Apparent Power                | VA      |
| 2060  | SRC 1 Phase B Apparent Power                | VA      |
| 2061  | SRC 1 Phase C Apparent Power                | VA      |
| 2062  | SRC 1 Three Phase Power Factor              | none    |
| 2063  | SRC 1 Phase A Power Factor                  | none    |
| 2064  | SRC 1 Phase B Power Factor                  | none    |
| 2065  | SRC 1 Phase C Power Factor                  | none    |
| 2066  | SRC 1 Frequency                             | Hz      |
| 2067  | SRC 1 Ia THD                                | %       |
| 2068  | SRC 1 Ib THD                                | %       |
| 2069  | SRC 1 Ic THD                                | none    |
| 2070  | SRC 1 In THD                                | none    |
| 2071  | Breaker 1 Arcing Amp Phase A                | kA2-cyc |
| 2072  | Breaker 1 Arcing Amp Phase B                | kA2-cyc |
| 2073  | Breaker 1 Arcing Amp Phase C                | kA2-cyc |
| 2074  | Breaker 2 Arcing Amp Phase A                | kA2-cyc |
| 2075  | Breaker 2 Arcing Amp Phase B                | kA2-cyc |
| 2076  | Breaker 2 Arcing Amp Phase C                | kA2-cyc |
| 2077  | Fault 1 Prefault Phase A Current Magnitude  | A       |
| 2078  | Fault 1 Prefault Phase A Current Angle      | degrees |
| 2079  | Fault 1 Prefault Phase B Current Magnitude  | A       |
| 2080  | Fault 1 Prefault Phase B Current Angle      | degrees |
| 2081  | Fault 1 Prefault Phase C Current Magnitude  | A       |
| 2082  | Fault 1 Prefault Phase C Current Angle      | degrees |
| 2083  | Fault 1 Prefault Phase A Voltage Magnitude  | V       |
| 2084  | Fault 1 Prefault Phase A Voltage Angle      | degrees |
| 2085  | Fault 1 Prefault Phase B Voltage Magnitude  | V       |
| 2086  | Fault 1 Prefault Phase B Voltage Angle      | degrees |
| 2087  | Fault 1 Prefault Phase C Voltage Magnitude  | V       |
| 2088  | Fault 1 Prefault Phase C Voltage Angle      | degrees |
| 2089  | Fault 1 Postfault Phase A Current Magnitude | A       |
| 2090  | Fault 1 Postfault Phase A Current Angle     | degrees |

Table C–1: IEC 60870-5-104 POINTS (Sheet 3 of 4)

| POINT                   | DESCRIPTION                                 | UNITS    |
|-------------------------|---|----------|
| 2091                    | Fault 1 Postfault Phase B Current Magnitude | A        |
| 2092                    | Fault 1 Postfault Phase B Current Angle     | degrees  |
| 2093                    | Fault 1 Postfault Phase C Current Magnitude | A        |
| 2094                    | Fault 1 Postfault Phase C Current Angle     | degrees  |
| 2095                    | Fault 1 Postfault Phase A Voltage Magnitude | V        |
| 2096                    | Fault 1 Postfault Phase A Voltage Angle     | degrees  |
| 2097                    | Fault 1 Postfault Phase B Voltage Magnitude | V        |
| 2098                    | Fault 1 Postfault Phase B Voltage Angle     | degrees  |
| 2099                    | Fault 1 Postfault Phase C Voltage Magnitude | V        |
| 2100                    | Fault 1 Postfault Phase C Voltage Angle     | degrees  |
| 2101                    | Fault 1 Type                                | none     |
| 2102                    | Fault 1 Location                            | none     |
| 2103                    | Synchrocheck 1 Delta Voltage                | V        |
| 2104                    | Synchrocheck 1 Delta Frequency              | Hz       |
| 2105                    | Synchrocheck 1 Delta Phase                  | degrees  |
| 2106                    | Synchrocheck 2 Delta Voltage                | V        |
| 2107                    | Synchrocheck 2 Delta Frequency              | Hz       |
| 2108                    | Synchrocheck 2 Delta Phase                  | degrees  |
| 2109                    | DCMA Inputs 1 Value                         | none     |
| 2110                    | DCMA Inputs 2 Value                         | none     |
| 2111                    | DCMA Inputs 3 Value                         | none     |
| 2112                    | DCMA Inputs 4 Value                         | none     |
| 2113                    | RTD Inputs 1 Value                          | degreesC |
| 2114                    | RTD Inputs 2 Value                          | degreesC |
| 2115                    | RTD Inputs 3 Value                          | degreesC |
| 2116                    | RTD Inputs 4 Value                          | degreesC |
| 2117                    | Tracking Frequency                          | Hz       |
| 2118                    | FlexElement 1 Actual                        | none     |
| 2119                    | FlexElement 2 Actual                        | none     |
| 2120                    | FlexElement 3 Actual                        | none     |
| 2121                    | FlexElement 4 Actual                        | none     |
| 2122                    | FlexElement 5 Actual                        | none     |
| 2123                    | FlexElement 6 Actual                        | none     |
| 2124                    | FlexElement 7 Actual                        | none     |
| 2125                    | FlexElement 8 Actual                        | none     |
| 2126                    | Current Setting Group                       | none     |
| <b>P_ME_NC_1 Points</b> |   |          |
| 5000 - 5125             | Threshold values for M_ME_NC_1 points       | -        |
| <b>M_SP_NA_1 Points</b> |   |          |
| 100 - 115               | Virtual Input States[0]                     | -        |
| 116 - 131               | Virtual Input States[1]                     | -        |
| 132 - 147               | Virtual Output States[0]                    | -        |
| 148 - 163               | Virtual Output States[1]                    | -        |
| 164 - 179               | Virtual Output States[2]                    | -        |
| 180 - 195               | Virtual Output States[3]                    | -        |
| 196 - 211               | Contact Input States[0]                     | -        |
| 212 - 227               | Contact Input States[1]                     | -        |
| 228 - 243               | Contact Input States[2]                     | -        |
| 244 - 259               | Contact Input States[3]                     | -        |
| 260 - 275               | Contact Input States[4]                     | -        |
| 276 - 291               | Contact Input States[5]                     | -        |

Table C–1: IEC 60870-5-104 POINTS (Sheet 4 of 4)

| POINT                   | DESCRIPTION                                  | UNITS |
|-------------------------|--|-------|
| 292 - 307               | Contact Output States[0]                     | -     |
| 308 - 323               | Contact Output States[1]                     | -     |
| 324 - 339               | Contact Output States[2]                     | -     |
| 340 - 355               | Contact Output States[3]                     | -     |
| 356 - 371               | Remote Input 1 States[0]                     | -     |
| 372 - 387               | Remote Input 1 States[1]                     | -     |
| 388 - 403               | Remote Device 1 States                       | -     |
| 404 - 419               | LED Column 1 State[0]                        | -     |
| 420 - 435               | LED Column 1 State[1]                        | -     |
| <b>C_SC_NA_1 Points</b> |  |       |
| 1100 - 1115             | Virtual Input States[0] - No Select Required | -     |
| 1116 - 1131             | Virtual Input States[1] - Select Required    | -     |
| <b>M_IT_NA_1 Points</b> |  |       |
| 4000                    | Digital Counter 1 Value                      | -     |
| 4001                    | Digital Counter 2 Value                      | -     |
| 4002                    | Digital Counter 3 Value                      | -     |
| 4003                    | Digital Counter 4 Value                      | -     |
| 4004                    | Digital Counter 5 Value                      | -     |
| 4005                    | Digital Counter 6 Value                      | -     |
| 4006                    | Digital Counter 7 Value                      | -     |
| 4007                    | Digital Counter 8 Value                      | -     |

## C

## D.1.1 DEVICE PROFILE DOCUMENT

The following table provides a 'Device Profile Document' in the standard format defined in the DNP 3.0 Subset Definitions Document.

**Table D–1: DNP V3.00 DEVICE PROFILE (Sheet 1 of 3)**

|   |   |
|---|---|
| (Also see the IMPLEMENTATION TABLE in the following section)  |   |
| Vendor Name: <b>General Electric Multilin</b>   |   |
| Device Name: <b>UR Series Relay</b>   |   |
| <b>Highest DNP Level Supported:</b><br>For Requests: <b>Level 2</b><br>For Responses: <b>Level 2</b>  | <b>Device Function:</b><br><input type="checkbox"/> Master<br><input checked="" type="checkbox"/> <b>Slave</b>                  |
| Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):<br><b>Binary Inputs (Object 1)</b><br><b>Binary Input Changes (Object 2)</b><br><b>Binary Outputs (Object 10)</b><br><b>Binary Counters (Object 20)</b><br><b>Frozen Counters (Object 21)</b><br><b>Counter Change Event (Object 22)</b><br><b>Frozen Counter Event (Object 23)</b><br><b>Analog Inputs (Object 30)</b><br><b>Analog Input Changes (Object 32)</b><br><b>Analog Deadbands (Object 34)</b> |   |
| <b>Maximum Data Link Frame Size (octets):</b><br>Transmitted: <b>292</b><br>Received: <b>292</b>  | <b>Maximum Application Fragment Size (octets):</b><br>Transmitted: <b>240</b><br>Received: <b>2048</b>                          |
| <b>Maximum Data Link Re-tries:</b><br><input type="checkbox"/> None<br><input checked="" type="checkbox"/> Fixed at 2<br><input type="checkbox"/> Configurable  | <b>Maximum Application Layer Re-tries:</b><br><input checked="" type="checkbox"/> None<br><input type="checkbox"/> Configurable |
| <b>Requires Data Link Layer Confirmation:</b><br><input checked="" type="checkbox"/> Never<br><input type="checkbox"/> Always<br><input type="checkbox"/> Sometimes<br><input type="checkbox"/> Configurable  |   |

Table D–1: DNP V3.00 DEVICE PROFILE (Sheet 2 of 3)

|   |   |  |   |                                       |
|---|---|--|---|---------------------------------------|
| <b>Requires Application Layer Confirmation:</b>   |   |  |   |                                       |
| <input type="checkbox"/> Never<br><input type="checkbox"/> Always<br><input checked="" type="checkbox"/> When reporting Event Data<br><input checked="" type="checkbox"/> When sending multi-fragment responses<br><input type="checkbox"/> Sometimes<br><input type="checkbox"/> Configurable  |   |  |   |                                       |
| <b>Timeouts while waiting for:</b>  |   |  |   |                                       |
| Data Link Confirm:  | <input type="checkbox"/> None             | <input checked="" type="checkbox"/> Fixed at 3 s | <input type="checkbox"/> Variable             | <input type="checkbox"/> Configurable |
| Complete Appl. Fragment:  | <input checked="" type="checkbox"/> None  | <input type="checkbox"/> Fixed at ____           | <input type="checkbox"/> Variable             | <input type="checkbox"/> Configurable |
| Application Confirm:  | <input type="checkbox"/> None             | <input checked="" type="checkbox"/> Fixed at 4 s | <input type="checkbox"/> Variable             | <input type="checkbox"/> Configurable |
| Complete Appl. Response:  | <input checked="" type="checkbox"/> None  | <input type="checkbox"/> Fixed at ____           | <input type="checkbox"/> Variable             | <input type="checkbox"/> Configurable |
| <b>Others:</b>  |   |  |   |                                       |
| Transmission Delay:   | No intentional delay                      |  |   |                                       |
| Inter-character Timeout:  | 50 ms                                     |  |   |                                       |
| Need Time Delay:  | Configurable (default = 24 hrs.)          |  |   |                                       |
| Select/Operate Arm Timeout:   | 10 s                                      |  |   |                                       |
| Binary input change scanning period:  | 8 times per power system cycle            |  |   |                                       |
| Packed binary change process period:  | 1 s                                       |  |   |                                       |
| Analog input change scanning period:  | 500 ms                                    |  |   |                                       |
| Counter change scanning period:   | 500 ms                                    |  |   |                                       |
| Frozen counter event scanning period:   | 500 ms                                    |  |   |                                       |
| Unsolicited response notification delay:  | 500 ms                                    |  |   |                                       |
| Unsolicited response retry delay  | configurable 0 to 60 sec.                 |  |   |                                       |
| <b>Sends/Executes Control Operations:</b>   |   |  |   |                                       |
| WRITE Binary Outputs  | <input checked="" type="checkbox"/> Never | <input type="checkbox"/> Always                  | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| SELECT/OPERATE  | <input type="checkbox"/> Never            | <input checked="" type="checkbox"/> Always       | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| DIRECT OPERATE  | <input type="checkbox"/> Never            | <input checked="" type="checkbox"/> Always       | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| DIRECT OPERATE – NO ACK   | <input type="checkbox"/> Never            | <input checked="" type="checkbox"/> Always       | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| Count > 1   | <input checked="" type="checkbox"/> Never | <input type="checkbox"/> Always                  | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| Pulse On  | <input type="checkbox"/> Never            | <input type="checkbox"/> Always                  | <input checked="" type="checkbox"/> Sometimes | <input type="checkbox"/> Configurable |
| Pulse Off   | <input type="checkbox"/> Never            | <input type="checkbox"/> Always                  | <input checked="" type="checkbox"/> Sometimes | <input type="checkbox"/> Configurable |
| Latch On  | <input type="checkbox"/> Never            | <input type="checkbox"/> Always                  | <input checked="" type="checkbox"/> Sometimes | <input type="checkbox"/> Configurable |
| Latch Off   | <input type="checkbox"/> Never            | <input type="checkbox"/> Always                  | <input checked="" type="checkbox"/> Sometimes | <input type="checkbox"/> Configurable |
| Queue   | <input checked="" type="checkbox"/> Never | <input type="checkbox"/> Always                  | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| Clear Queue   | <input checked="" type="checkbox"/> Never | <input type="checkbox"/> Always                  | <input type="checkbox"/> Sometimes            | <input type="checkbox"/> Configurable |
| <b>Explanation of ‘Sometimes’:</b> Object 12 points are mapped to UR Virtual Inputs. The persistence of Virtual Inputs is determined by the <b>VIRTUAL INPUT X TYPE</b> settings. Both “Pulse On” and “Latch On” operations perform the same function in the UR; that is, the appropriate Virtual Input is put into the “On” state. If the Virtual Input is set to “Self-Reset”, it will reset after one pass of FlexLogic™. The On/Off times and Count value are ignored. “Pulse Off” and “Latch Off” operations put the appropriate Virtual Input into the “Off” state. “Trip” and “Close” operations both put the appropriate Virtual Input into the “On” state. |   |  |   |                                       |

Table D-1: DNP V3.00 DEVICE PROFILE (Sheet 3 of 3)

|   |  |
|---|--|
| <b>Reports Binary Input Change Events when no specific variation requested:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> Never</li> <li><input checked="" type="checkbox"/> <b>Only time-tagged</b></li> <li><input type="checkbox"/> Only non-time-tagged</li> <li><input type="checkbox"/> Configurable</li> </ul>   | <b>Reports time-tagged Binary Input Change Events when no specific variation requested:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> Never</li> <li><input checked="" type="checkbox"/> Binary Input Change With Time</li> <li><input type="checkbox"/> Binary Input Change With Relative Time</li> <li><input type="checkbox"/> Configurable (attach explanation)</li> </ul>   |
| <b>Sends Unsolicited Responses:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> <b>Never</b></li> <li><input checked="" type="checkbox"/> Configurable</li> <li><input type="checkbox"/> Only certain objects</li> <li><input type="checkbox"/> Sometimes (attach explanation)</li> <li><input checked="" type="checkbox"/> ENABLE/DISABLE unsolicited Function codes supported</li> </ul>                                | <b>Sends Static Data in Unsolicited Responses:</b> <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Never</li> <li><input type="checkbox"/> When Device Restarts</li> <li><input type="checkbox"/> When Status Flags Change</li> </ul> <p>No other options are permitted.</p>  |
| <b>Default Counter Object/Variation:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> No Counters Reported</li> <li><input type="checkbox"/> Configurable (attach explanation)</li> <li><input checked="" type="checkbox"/> <b>Default Object: 20</b></li> <li><input checked="" type="checkbox"/> <b>Default Variation: 1</b></li> <li><input checked="" type="checkbox"/> <b>Point-by-point list attached</b></li> </ul> | <b>Counters Roll Over at:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> No Counters Reported</li> <li><input type="checkbox"/> Configurable (attach explanation)</li> <li><input checked="" type="checkbox"/> <b>16 Bits (Counter 8)</b></li> <li><input checked="" type="checkbox"/> <b>32 Bits (Counters 0 to 7, 9)</b></li> <li><input type="checkbox"/> Other Value: _____</li> <li><input checked="" type="checkbox"/> <b>Point-by-point list attached</b></li> </ul> |
| <b>Sends Multi-Fragment Responses:</b> <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Yes</li> <li><input type="checkbox"/> No</li> </ul>   |  |

## D.1.2 DNP IMPLEMENTATION

The following table identifies the variations, function codes, and qualifiers supported by the D30 in both request messages and in response messages. For static (non-change-event) objects, requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01. Static object requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28. For change-event objects, qualifiers 17 or 28 are always responded.

Table D–2: IMPLEMENTATION TABLE (Sheet 1 of 4)

| OBJECT     |                   |   | REQUEST  |   | RESPONSE                             |   |
|------------|-------------------|---|--|---|--------------------------------------|---|
| OBJECT NO. | VARIATION NO.     | DESCRIPTION   | FUNCTION CODES (DEC)   | QUALIFIER CODES (HEX)   | FUNCTION CODES (DEC)                 | QUALIFIER CODES (HEX)                                 |
| 1          | 0                 | Binary Input (Variation 0 is used to request default variation)         | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) |                                      |   |
|            | 1                 | Binary Input  | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|            | 2                 | Binary Input with Status  | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 2          | 0                 | Binary Input Change (Variation 0 is used to request default variation)  | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  |                                      |   |
|            | 1                 | Binary Input Change without Time  | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|            | 2                 | Binary Input Change with Time   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|            | 3<br>(parse only) | Binary Input Change with Relative Time                                  | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  |                                      |   |
| 10         | 0                 | Binary Output Status (Variation 0 is used to request default variation) | 1 (read)   | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) |                                      |   |
|            | 2                 | Binary Output Status  | 1 (read)   | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 12         | 1                 | Control Relay Output Block  | 3 (select)<br>4 (operate)<br>5 (direct op)<br>6 (dir. op, noack)   | 00, 01 (start-stop)<br>07, 08 (limited quantity)<br>17, 28 (index)                          | 129 (response)                       | echo of request                                       |
| 20         | 0                 | Binary Counter<br>(Variation 0 is used to request default variation)    | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) |                                      |   |
|            | 1                 | 32-Bit Binary Counter   | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the *Communications* section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the D30 is not restarted, but the DNP process is restarted.



Table D–2: IMPLEMENTATION TABLE (Sheet 2 of 4)

| OBJECT       |               |   | REQUEST  |   | RESPONSE                             |   |
|--------------|---------------|---|--|---|--------------------------------------|---|
| OBJECT NO.   | VARIATION NO. | DESCRIPTION   | FUNCTION CODES (DEC)   | QUALIFIER CODES (HEX)   | FUNCTION CODES (DEC)                 | QUALIFIER CODES (HEX)                                 |
| 20<br>cont'd | 2             | 16-Bit Binary Counter   | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 5             | 32-Bit Binary Counter without Flag                                      | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 6             | 16-Bit Binary Counter without Flag                                      | 1 (read)<br>7 (freeze)<br>8 (freeze noack)<br>9 (freeze clear)<br>10 (frz. cl. noack)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 21           | 0             | Frozen Counter<br>(Variation 0 is used to request default variation)    | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) |                                      |   |
|              | 1             | 32-Bit Frozen Counter   | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 2             | 16-Bit Frozen Counter   | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 9             | 32-Bit Frozen Counter without Flag                                      | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 10            | 16-Bit Frozen Counter without Flag                                      | 1 (read)<br>22 (assign class)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 22           | 0             | Counter Change Event (Variation 0 is used to request default variation) | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  |                                      |   |
|              | 1             | 32-Bit Counter Change Event   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 2             | 16-Bit Counter Change Event   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 5             | 32-Bit Counter Change Event with Time                                   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 6             | 16-Bit Counter Change Event with Time                                   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
| 23           | 0             | Frozen Counter Event (Variation 0 is used to request default variation) | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  |                                      |   |
|              | 1             | 32-Bit Frozen Counter Event   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 2             | 16-Bit Frozen Counter Event   | 1 (read)   | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the *Communications* section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the D30 is not restarted, but the DNP process is restarted.

Table D–2: IMPLEMENTATION TABLE (Sheet 3 of 4)

| OBJECT       |               |  | REQUEST                       |   | RESPONSE                             |   |
|--------------|---------------|--|-------------------------------|---|--------------------------------------|---|
| OBJECT NO.   | VARIATION NO. | DESCRIPTION  | FUNCTION CODES (DEC)          | QUALIFIER CODES (HEX)   | FUNCTION CODES (DEC)                 | QUALIFIER CODES (HEX)                                 |
| 23<br>cont'd | 5             | 32-Bit Frozen Counter Event with Time  | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 6             | 16-Bit Frozen Counter Event with Time  | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
| 30           | 0             | Analog Input (Variation 0 is used to request default variation)                    | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) |                                      |   |
|              | 1             | 32-Bit Analog Input  | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 2             | 16-Bit Analog Input  | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 3             | 32-Bit Analog Input without Flag   | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 4             | 16-Bit Analog Input without Flag   | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 5             | short floating point   | 1 (read)<br>22 (assign class) | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 32           | 0             | Analog Change Event (Variation 0 is used to request default variation)             | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  |                                      |   |
|              | 1             | 32-Bit Analog Change Event without Time  | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 2             | 16-Bit Analog Change Event without Time  | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 3             | 32-Bit Analog Change Event with Time   | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 4             | 16-Bit Analog Change Event with Time   | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 5             | short floating point Analog Change Event without Time                              | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
|              | 7             | short floating point Analog Change Event with Time                                 | 1 (read)                      | 06 (no range, or all)<br>07, 08 (limited quantity)  | 129 (response)<br>130 (unsol. resp.) | 17, 28 (index)  |
| 34           | 0             | Analog Input Reporting Deadband (Variation 0 is used to request default variation) | 1 (read)                      | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) |                                      |   |
|              | 1             | 16-bit Analog Input Reporting Deadband (default – see Note 1)                      | 1 (read)                      | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index) | 129 (response)                       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              |               |  | 2 (write)                     | 00, 01 (start-stop)<br>07, 08 (limited quantity)<br>17, 28 (index)                          |                                      |   |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the *Communications* section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the D30 is not restarted, but the DNP process is restarted.

Table D–2: IMPLEMENTATION TABLE (Sheet 4 of 4)

| OBJECT       |               |  | REQUEST  |   | RESPONSE             |   |
|--------------|---------------|--|--|---|----------------------|---|
| OBJECT NO.   | VARIATION NO. | DESCRIPTION  | FUNCTION CODES (DEC)   | QUALIFIER CODES (HEX)   | FUNCTION CODES (DEC) | QUALIFIER CODES (HEX)                                 |
| 34<br>cont'd | 2             | 32-bit Analog Input Reporting Deadband               | 1 (read)   | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index)                   | 129 (response)       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              |               |  | 2 (write)  | 00, 01 (start-stop)<br>07, 08 (limited quantity)<br>17, 28 (index)  |                      |   |
|              | 3             | Short floating point Analog Input Reporting Deadband | 1 (read)   | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index)                   | 129 (response)       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 50           | 0             | Time and Date  | 1 (read)   | 00, 01 (start-stop)<br>06 (no range, or all)<br>07, 08 (limited quantity)<br>17, 28 (index)                   | 129 (response)       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
|              | 1             | Time and Date<br>(default – see Note 1)              | 1 (read)<br>2 (write)  | 00, 01 (start-stop)<br>06 (no range, or all)<br>07 (limited qty=1)<br>08 (limited quantity)<br>17, 28 (index) | 129 (response)       | 00, 01 (start-stop)<br>17, 28 (index)<br>(see Note 2) |
| 52           | 2             | Time Delay Fine                                      |  |   | 129 (response)       | 07 (limited quantity)<br>(quantity = 1)               |
| 60           | 0             | Class 0, 1, 2, and 3 Data                            | 1 (read)<br>20 (enable unsol)<br>21 (disable unsol)<br>22 (assign class) | 06 (no range, or all)   |                      |   |
|              | 1             | Class 0 Data   | 1 (read)<br>22 (assign class)  | 06 (no range, or all)   |                      |   |
|              | 2             | Class 1 Data   | 1 (read)<br>20 (enable unsol)<br>21 (disable unsol)<br>22 (assign class) | 06 (no range, or all)<br>07, 08 (limited quantity)  |                      |   |
|              | 3             | Class 2 Data   | 1 (read)<br>20 (enable unsol)<br>21 (disable unsol)<br>22 (assign class) | 06 (no range, or all)<br>07, 08 (limited quantity)  |                      |   |
|              | 4             | Class 3 Data   | 1 (read)<br>20 (enable unsol)<br>21 (disable unsol)<br>22 (assign class) | 06 (no range, or all)<br>07, 08 (limited quantity)  |                      |   |
| 80           | 1             | Internal Indications                                 | 2 (write)  | 00 (start-stop)<br>(index must =7)  |                      |   |
| ---          |               | No Object (function code only)<br>see Note 3         | 13 (cold restart)  |   |                      |   |
| ---          |               | No Object (function code only)                       | 14 (warm restart)  |   |                      |   |
| ---          |               | No Object (function code only)                       | 23 (delay meas.)   |   |                      |   |

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans. The default variations for object types 1, 2, 20, 21, 22, 23, 30, and 32 are selected via relay settings. Refer to the *Communications* section in Chapter 5 for details. This optimizes the class 0 poll data size.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded.)

Note 3: Cold restarts are implemented the same as warm restarts – the D30 is not restarted, but the DNP process is restarted.

## D.2.1 BINARY INPUTS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

**BINARY INPUT POINTS**

Static (Steady-State) Object Number: **1**

Change Event Object Number: **2**

Request Function Codes supported: **1 (read), 22 (assign class)**

Static Variation reported when variation 0 requested: **2 (Binary Input with status)**

Change Event Variation reported when variation 0 requested: **2 (Binary Input Change with Time)**

Change Event Scan Rate: **8 times per power system cycle**

Change Event Buffer Size: **1000**

D

Table D-3: BINARY INPUTS (Sheet 1 of 10)

| point | name/description | change event class |
|-------|------------------|--------------------|
| 0     | Virtual Input 1  | 2                  |
| 1     | Virtual Input 2  | 2                  |
| 2     | Virtual Input 3  | 2                  |
| 3     | Virtual Input 4  | 2                  |
| 4     | Virtual Input 5  | 2                  |
| 5     | Virtual Input 6  | 2                  |
| 6     | Virtual Input 7  | 2                  |
| 7     | Virtual Input 8  | 2                  |
| 8     | Virtual Input 9  | 2                  |
| 9     | Virtual Input 10 | 2                  |
| 10    | Virtual Input 11 | 2                  |
| 11    | Virtual Input 12 | 2                  |
| 12    | Virtual Input 13 | 2                  |
| 13    | Virtual Input 14 | 2                  |
| 14    | Virtual Input 15 | 2                  |
| 15    | Virtual Input 16 | 2                  |
| 16    | Virtual Input 17 | 2                  |
| 17    | Virtual Input 18 | 2                  |
| 18    | Virtual Input 19 | 2                  |
| 19    | Virtual Input 20 | 2                  |
| 20    | Virtual Input 21 | 2                  |
| 21    | Virtual Input 22 | 2                  |
| 22    | Virtual Input 23 | 2                  |
| 23    | Virtual Input 24 | 2                  |
| 24    | Virtual Input 25 | 2                  |
| 25    | Virtual Input 26 | 2                  |
| 26    | Virtual Input 27 | 2                  |
| 27    | Virtual Input 28 | 2                  |
| 28    | Virtual Input 29 | 2                  |
| 29    | Virtual Input 30 | 2                  |

Table D-3: BINARY INPUTS (Sheet 2 of 10)

| point | name/description  | change event class |
|-------|-------------------|--------------------|
| 30    | Virtual Input 31  | 2                  |
| 31    | Virtual Input 32  | 2                  |
| 32    | Virtual Output 1  | 2                  |
| 33    | Virtual Output 2  | 2                  |
| 34    | Virtual Output 3  | 2                  |
| 35    | Virtual Output 4  | 2                  |
| 36    | Virtual Output 5  | 2                  |
| 37    | Virtual Output 6  | 2                  |
| 38    | Virtual Output 7  | 2                  |
| 39    | Virtual Output 8  | 2                  |
| 40    | Virtual Output 9  | 2                  |
| 41    | Virtual Output 10 | 2                  |
| 42    | Virtual Output 11 | 2                  |
| 43    | Virtual Output 12 | 2                  |
| 44    | Virtual Output 13 | 2                  |
| 45    | Virtual Output 14 | 2                  |
| 46    | Virtual Output 15 | 2                  |
| 47    | Virtual Output 16 | 2                  |
| 48    | Virtual Output 17 | 2                  |
| 49    | Virtual Output 18 | 2                  |
| 50    | Virtual Output 19 | 2                  |
| 51    | Virtual Output 20 | 2                  |
| 52    | Virtual Output 21 | 2                  |
| 53    | Virtual Output 22 | 2                  |
| 54    | Virtual Output 23 | 2                  |
| 55    | Virtual Output 24 | 2                  |
| 56    | Virtual Output 25 | 2                  |
| 57    | Virtual Output 26 | 2                  |
| 58    | Virtual Output 27 | 2                  |
| 59    | Virtual Output 28 | 2                  |

Table D-3: BINARY INPUTS (Sheet 3 of 10)

| point | name/description  | change event class |
|-------|-------------------|--------------------|
| 60    | Virtual Output 29 | 2                  |
| 61    | Virtual Output 30 | 2                  |
| 62    | Virtual Output 31 | 2                  |
| 63    | Virtual Output 32 | 2                  |
| 64    | Virtual Output 33 | 2                  |
| 65    | Virtual Output 34 | 2                  |
| 66    | Virtual Output 35 | 2                  |
| 67    | Virtual Output 36 | 2                  |
| 68    | Virtual Output 37 | 2                  |
| 69    | Virtual Output 38 | 2                  |
| 70    | Virtual Output 39 | 2                  |
| 71    | Virtual Output 40 | 2                  |
| 72    | Virtual Output 41 | 2                  |
| 73    | Virtual Output 42 | 2                  |
| 74    | Virtual Output 43 | 2                  |
| 75    | Virtual Output 44 | 2                  |
| 76    | Virtual Output 45 | 2                  |
| 77    | Virtual Output 46 | 2                  |
| 78    | Virtual Output 47 | 2                  |
| 79    | Virtual Output 48 | 2                  |
| 80    | Virtual Output 49 | 2                  |
| 81    | Virtual Output 50 | 2                  |
| 82    | Virtual Output 51 | 2                  |
| 83    | Virtual Output 52 | 2                  |
| 84    | Virtual Output 53 | 2                  |
| 85    | Virtual Output 54 | 2                  |
| 86    | Virtual Output 55 | 2                  |
| 87    | Virtual Output 56 | 2                  |
| 88    | Virtual Output 57 | 2                  |
| 89    | Virtual Output 58 | 2                  |
| 90    | Virtual Output 59 | 2                  |
| 91    | Virtual Output 60 | 2                  |
| 92    | Virtual Output 61 | 2                  |
| 93    | Virtual Output 62 | 2                  |
| 94    | Virtual Output 63 | 2                  |
| 95    | Virtual Output 64 | 2                  |
| 96    | Contact Input 1   | 1                  |
| 97    | Contact Input 2   | 1                  |
| 98    | Contact Input 3   | 1                  |
| 99    | Contact Input 4   | 1                  |
| 100   | Contact Input 5   | 1                  |
| 101   | Contact Input 6   | 1                  |
| 102   | Contact Input 7   | 1                  |
| 103   | Contact Input 8   | 1                  |
| 104   | Contact Input 9   | 1                  |
| 105   | Contact Input 10  | 1                  |
| 106   | Contact Input 11  | 1                  |

Table D-3: BINARY INPUTS (Sheet 4 of 10)

| point | name/description | change event class |
|-------|------------------|--------------------|
| 107   | Contact Input 12 | 1                  |
| 108   | Contact Input 13 | 1                  |
| 109   | Contact Input 14 | 1                  |
| 110   | Contact Input 15 | 1                  |
| 111   | Contact Input 16 | 1                  |
| 112   | Contact Input 17 | 1                  |
| 113   | Contact Input 18 | 1                  |
| 114   | Contact Input 19 | 1                  |
| 115   | Contact Input 20 | 1                  |
| 116   | Contact Input 21 | 1                  |
| 117   | Contact Input 22 | 1                  |
| 118   | Contact Input 23 | 1                  |
| 119   | Contact Input 24 | 1                  |
| 120   | Contact Input 25 | 1                  |
| 121   | Contact Input 26 | 1                  |
| 122   | Contact Input 27 | 1                  |
| 123   | Contact Input 28 | 1                  |
| 124   | Contact Input 29 | 1                  |
| 125   | Contact Input 30 | 1                  |
| 126   | Contact Input 31 | 1                  |
| 127   | Contact Input 32 | 1                  |
| 128   | Contact Input 33 | 1                  |
| 129   | Contact Input 34 | 1                  |
| 130   | Contact Input 35 | 1                  |
| 131   | Contact Input 36 | 1                  |
| 132   | Contact Input 37 | 1                  |
| 133   | Contact Input 38 | 1                  |
| 134   | Contact Input 39 | 1                  |
| 135   | Contact Input 40 | 1                  |
| 136   | Contact Input 41 | 1                  |
| 137   | Contact Input 42 | 1                  |
| 138   | Contact Input 43 | 1                  |
| 139   | Contact Input 44 | 1                  |
| 140   | Contact Input 45 | 1                  |
| 141   | Contact Input 46 | 1                  |
| 142   | Contact Input 47 | 1                  |
| 143   | Contact Input 48 | 1                  |
| 144   | Contact Input 49 | 1                  |
| 145   | Contact Input 50 | 1                  |
| 146   | Contact Input 51 | 1                  |
| 147   | Contact Input 52 | 1                  |
| 148   | Contact Input 53 | 1                  |
| 149   | Contact Input 54 | 1                  |
| 150   | Contact Input 55 | 1                  |
| 151   | Contact Input 56 | 1                  |
| 152   | Contact Input 57 | 1                  |
| 153   | Contact Input 58 | 1                  |

Table D–3: BINARY INPUTS (Sheet 5 of 10)

| point | name/description | change event class |
|-------|------------------|--------------------|
| 154   | Contact Input 59 | 1                  |
| 155   | Contact Input 60 | 1                  |
| 156   | Contact Input 61 | 1                  |
| 157   | Contact Input 62 | 1                  |
| 158   | Contact Input 63 | 1                  |
| 159   | Contact Input 64 | 1                  |
| 160   | Contact Input 65 | 1                  |
| 161   | Contact Input 66 | 1                  |
| 162   | Contact Input 67 | 1                  |
| 163   | Contact Input 68 | 1                  |
| 164   | Contact Input 69 | 1                  |
| 165   | Contact Input 70 | 1                  |
| 166   | Contact Input 71 | 1                  |
| 167   | Contact Input 72 | 1                  |
| 168   | Contact Input 73 | 1                  |
| 169   | Contact Input 74 | 1                  |
| 170   | Contact Input 75 | 1                  |
| 171   | Contact Input 76 | 1                  |
| 172   | Contact Input 77 | 1                  |
| 173   | Contact Input 78 | 1                  |
| 174   | Contact Input 79 | 1                  |
| 175   | Contact Input 80 | 1                  |
| 176   | Contact Input 81 | 1                  |
| 177   | Contact Input 82 | 1                  |
| 178   | Contact Input 83 | 1                  |
| 179   | Contact Input 84 | 1                  |
| 180   | Contact Input 85 | 1                  |
| 181   | Contact Input 86 | 1                  |
| 182   | Contact Input 87 | 1                  |
| 183   | Contact Input 88 | 1                  |
| 184   | Contact Input 89 | 1                  |
| 185   | Contact Input 90 | 1                  |
| 186   | Contact Input 91 | 1                  |
| 187   | Contact Input 92 | 1                  |
| 188   | Contact Input 93 | 1                  |
| 189   | Contact Input 94 | 1                  |
| 190   | Contact Input 95 | 1                  |
| 191   | Contact Input 96 | 1                  |
| 192   | Contact Output 1 | 1                  |
| 193   | Contact Output 2 | 1                  |
| 194   | Contact Output 3 | 1                  |
| 195   | Contact Output 4 | 1                  |
| 196   | Contact Output 5 | 1                  |
| 197   | Contact Output 6 | 1                  |
| 198   | Contact Output 7 | 1                  |
| 199   | Contact Output 8 | 1                  |
| 200   | Contact Output 9 | 1                  |

Table D–3: BINARY INPUTS (Sheet 6 of 10)

| point | name/description  | change event class |
|-------|-------------------|--------------------|
| 201   | Contact Output 10 | 1                  |
| 202   | Contact Output 11 | 1                  |
| 203   | Contact Output 12 | 1                  |
| 204   | Contact Output 13 | 1                  |
| 205   | Contact Output 14 | 1                  |
| 206   | Contact Output 15 | 1                  |
| 207   | Contact Output 16 | 1                  |
| 208   | Contact Output 17 | 1                  |
| 209   | Contact Output 18 | 1                  |
| 210   | Contact Output 19 | 1                  |
| 211   | Contact Output 20 | 1                  |
| 212   | Contact Output 21 | 1                  |
| 213   | Contact Output 22 | 1                  |
| 214   | Contact Output 23 | 1                  |
| 215   | Contact Output 24 | 1                  |
| 216   | Contact Output 25 | 1                  |
| 217   | Contact Output 26 | 1                  |
| 218   | Contact Output 27 | 1                  |
| 219   | Contact Output 28 | 1                  |
| 220   | Contact Output 29 | 1                  |
| 221   | Contact Output 30 | 1                  |
| 222   | Contact Output 31 | 1                  |
| 223   | Contact Output 32 | 1                  |
| 224   | Contact Output 33 | 1                  |
| 225   | Contact Output 34 | 1                  |
| 226   | Contact Output 35 | 1                  |
| 227   | Contact Output 36 | 1                  |
| 228   | Contact Output 37 | 1                  |
| 229   | Contact Output 38 | 1                  |
| 230   | Contact Output 39 | 1                  |
| 231   | Contact Output 40 | 1                  |
| 232   | Contact Output 41 | 1                  |
| 233   | Contact Output 42 | 1                  |
| 234   | Contact Output 43 | 1                  |
| 235   | Contact Output 44 | 1                  |
| 236   | Contact Output 45 | 1                  |
| 237   | Contact Output 46 | 1                  |
| 238   | Contact Output 47 | 1                  |
| 239   | Contact Output 48 | 1                  |
| 240   | Contact Output 49 | 1                  |
| 241   | Contact Output 50 | 1                  |
| 242   | Contact Output 51 | 1                  |
| 243   | Contact Output 52 | 1                  |
| 244   | Contact Output 53 | 1                  |
| 245   | Contact Output 54 | 1                  |
| 246   | Contact Output 55 | 1                  |
| 247   | Contact Output 56 | 1                  |

Table D-3: BINARY INPUTS (Sheet 7 of 10)

| point | name/description  | change event class |
|-------|-------------------|--------------------|
| 248   | Contact Output 57 | 1                  |
| 249   | Contact Output 58 | 1                  |
| 250   | Contact Output 59 | 1                  |
| 251   | Contact Output 60 | 1                  |
| 252   | Contact Output 61 | 1                  |
| 253   | Contact Output 62 | 1                  |
| 254   | Contact Output 63 | 1                  |
| 255   | Contact Output 64 | 1                  |
| 256   | Remote Input 1    | 1                  |
| 257   | Remote Input 2    | 1                  |
| 258   | Remote Input 3    | 1                  |
| 259   | Remote Input 4    | 1                  |
| 260   | Remote Input 5    | 1                  |
| 261   | Remote Input 6    | 1                  |
| 262   | Remote Input 7    | 1                  |
| 263   | Remote Input 8    | 1                  |
| 264   | Remote Input 9    | 1                  |
| 265   | Remote Input 10   | 1                  |
| 266   | Remote Input 11   | 1                  |
| 267   | Remote Input 12   | 1                  |
| 268   | Remote Input 13   | 1                  |
| 269   | Remote Input 14   | 1                  |
| 270   | Remote Input 15   | 1                  |
| 271   | Remote Input 16   | 1                  |
| 272   | Remote Input 17   | 1                  |
| 273   | Remote Input 18   | 1                  |
| 274   | Remote Input 19   | 1                  |
| 275   | Remote Input 20   | 1                  |
| 276   | Remote Input 21   | 1                  |
| 277   | Remote Input 22   | 1                  |
| 278   | Remote Input 23   | 1                  |
| 279   | Remote Input 24   | 1                  |
| 280   | Remote Input 25   | 1                  |
| 281   | Remote Input 26   | 1                  |
| 282   | Remote Input 27   | 1                  |
| 283   | Remote Input 28   | 1                  |
| 284   | Remote Input 29   | 1                  |
| 285   | Remote Input 30   | 1                  |
| 286   | Remote Input 31   | 1                  |
| 287   | Remote Input 32   | 1                  |
| 288   | Remote Device 1   | 1                  |
| 289   | Remote Device 2   | 1                  |
| 290   | Remote Device 3   | 1                  |
| 291   | Remote Device 4   | 1                  |
| 292   | Remote Device 5   | 1                  |
| 293   | Remote Device 6   | 1                  |
| 294   | Remote Device 7   | 1                  |

Table D-3: BINARY INPUTS (Sheet 8 of 10)

| point | name/description                            | change event class |
|-------|---|--------------------|
| 295   | Remote Device 8                             | 1                  |
| 296   | Remote Device 9                             | 1                  |
| 297   | Remote Device 10                            | 1                  |
| 298   | Remote Device 11                            | 1                  |
| 299   | Remote Device 12                            | 1                  |
| 300   | Remote Device 13                            | 1                  |
| 301   | Remote Device 14                            | 1                  |
| 302   | Remote Device 15                            | 1                  |
| 303   | Remote Device 16                            | 1                  |
| 364   | Negative-Sequence Directional Overcurrent 1 | 1                  |
| 364   | Negative-Sequence Directional Overcurrent 2 | 1                  |
| 464   | Phase Distance Zone 1                       | 1                  |
| 465   | Phase Distance Zone 2                       | 1                  |
| 466   | Phase Distance Zone 3                       | 1                  |
| 476   | Ground Distance Zone 1                      | 1                  |
| 477   | Ground Distance Zone 2                      | 1                  |
| 478   | Ground Distance Zone 3                      | 1                  |
| 536   | 50DD Disturbance Detector 1                 | 1                  |
| 537   | 50DD Disturbance Detector 2                 | 1                  |
| 592   | Breaker Arcing Current 1                    | 1                  |
| 593   | Breaker Arcing Current 2                    | 1                  |
| 608   | Autoreclose 1                               | 1                  |
| 609   | Autoreclose 2                               | 1                  |
| 610   | Autoreclose 3                               | 1                  |
| 611   | Autoreclose 4                               | 1                  |
| 612   | Autoreclose 5                               | 1                  |
| 613   | Autoreclose 6                               | 1                  |
| 640   | Setting Group                               | 1                  |
| 641   | Reset                                       | 1                  |
| 689   | Selector Switch 1                           | 1                  |
| 690   | Selector Switch 2                           | 1                  |
| 694   | Control Pushbutton 1                        | 1                  |
| 695   | Control Pushbutton 2                        | 1                  |
| 696   | Control Pushbutton 3                        | 1                  |
| 697   | Control Pushbutton 4                        | 1                  |
| 698   | Control Pushbutton 5                        | 1                  |
| 699   | Control Pushbutton 6                        | 1                  |
| 700   | Control Pushbutton 7                        | 1                  |
| 704   | FlexElement™ 1                              | 1                  |
| 705   | FlexElement™ 2                              | 1                  |
| 706   | FlexElement™ 3                              | 1                  |
| 707   | FlexElement™ 4                              | 1                  |
| 708   | FlexElement™ 5                              | 1                  |
| 709   | FlexElement™ 6                              | 1                  |
| 710   | FlexElement™ 7                              | 1                  |
| 711   | FlexElement™ 8                              | 1                  |

Table D-3: BINARY INPUTS (Sheet 9 of 10)

| point | name/description         | change event class |
|-------|--------------------------|--------------------|
| 724   | Non-Volatile Latch 1     | 1                  |
| 725   | Non-Volatile Latch 2     | 1                  |
| 726   | Non-Volatile Latch 3     | 1                  |
| 727   | Non-Volatile Latch 4     | 1                  |
| 728   | Non-Volatile Latch 5     | 1                  |
| 729   | Non-Volatile Latch 6     | 1                  |
| 730   | Non-Volatile Latch 7     | 1                  |
| 731   | Non-Volatile Latch 8     | 1                  |
| 732   | Non-Volatile Latch 9     | 1                  |
| 733   | Non-Volatile Latch 10    | 1                  |
| 734   | Non-Volatile Latch 11    | 1                  |
| 735   | Non-Volatile Latch 12    | 1                  |
| 736   | Non-Volatile Latch 13    | 1                  |
| 737   | Non-Volatile Latch 14    | 1                  |
| 738   | Non-Volatile Latch 15    | 1                  |
| 739   | Non-Volatile Latch 16    | 1                  |
| 816   | Digital Element 1        | 1                  |
| 817   | Digital Element 2        | 1                  |
| 818   | Digital Element 3        | 1                  |
| 819   | Digital Element 4        | 1                  |
| 820   | Digital Element 5        | 1                  |
| 821   | Digital Element 6        | 1                  |
| 822   | Digital Element 7        | 1                  |
| 823   | Digital Element 8        | 1                  |
| 824   | Digital Element 9        | 1                  |
| 825   | Digital Element 10       | 1                  |
| 826   | Digital Element 11       | 1                  |
| 827   | Digital Element 12       | 1                  |
| 828   | Digital Element 13       | 1                  |
| 829   | Digital Element 14       | 1                  |
| 830   | Digital Element 15       | 1                  |
| 831   | Digital Element 16       | 1                  |
| 848   | Digital Counter 1        | 1                  |
| 849   | Digital Counter 2        | 1                  |
| 850   | Digital Counter 3        | 1                  |
| 851   | Digital Counter 4        | 1                  |
| 852   | Digital Counter 5        | 1                  |
| 853   | Digital Counter 6        | 1                  |
| 854   | Digital Counter 7        | 1                  |
| 855   | Digital Counter 8        | 1                  |
| 864   | LED State 1 (IN SERVICE) | 1                  |
| 865   | LED State 2 (TROUBLE)    | 1                  |
| 866   | LED State 3 (TEST MODE)  | 1                  |
| 867   | LED State 4 (TRIP)       | 1                  |
| 868   | LED State 5 (ALARM)      | 1                  |
| 869   | LED State 6 (PICKUP)     | 1                  |
| 880   | LED State 9 (VOLTAGE)    | 1                  |

Table D-3: BINARY INPUTS (Sheet 10 of 10)

| point | name/description                | change event class |
|-------|---------------------------------|--------------------|
| 881   | LED State 10 (CURRENT)          | 1                  |
| 882   | LED State 11 (FREQUENCY)        | 1                  |
| 883   | LED State 12 (OTHER)            | 1                  |
| 884   | LED State 13 (PHASE A)          | 1                  |
| 885   | LED State 14 (PHASE B)          | 1                  |
| 886   | LED State 15 (PHASE C)          | 1                  |
| 887   | LED State 16 (NTL/GROUND)       | 1                  |
| 898   | SNTP FAILURE                    | 1                  |
| 899   | BATTERY FAIL                    | 1                  |
| 900   | PRI ETHERNET FAIL               | 1                  |
| 901   | SEC ETHERNET FAIL               | 1                  |
| 902   | EEPROM DATA ERROR               | 1                  |
| 903   | SRAM DATA ERROR                 | 1                  |
| 904   | PROGRAM MEMORY                  | 1                  |
| 905   | WATCHDOG ERROR                  | 1                  |
| 906   | LOW ON MEMORY                   | 1                  |
| 907   | REMOTE DEVICE OFF               | 1                  |
| 908   | DIRECT DEVICE OFF               |                    |
| 909   | DIRECT RING BREAK               |                    |
| 910   | ANY MINOR ERROR                 | 1                  |
| 911   | ANY MAJOR ERROR                 | 1                  |
| 912   | ANY SELF-TESTS                  | 1                  |
| 913   | IRIG-B FAILURE                  | 1                  |
| 914   | DSP ERROR                       | 1                  |
| 916   | NO DSP INTERRUPTS               | 1                  |
| 917   | UNIT NOT CALIBRATED             | 1                  |
| 921   | PROTOTYPE FIRMWARE              | 1                  |
| 922   | FLEXLOGIC ERR TOKEN             | 1                  |
| 923   | EQUIPMENT MISMATCH              | 1                  |
| 925   | UNIT NOT PROGRAMMED             | 1                  |
| 926   | SYSTEM EXCEPTION                | 1                  |
| 927   | LATCHING OUT ERROR              | 1                  |
| 984   | User-Programmable Pushbutton 1  | 1                  |
| 985   | User-Programmable Pushbutton 2  | 1                  |
| 986   | User-Programmable Pushbutton 3  | 1                  |
| 987   | User-Programmable Pushbutton 4  | 1                  |
| 988   | User-Programmable Pushbutton 5  | 1                  |
| 989   | User-Programmable Pushbutton 6  | 1                  |
| 990   | User-Programmable Pushbutton 7  | 1                  |
| 991   | User-Programmable Pushbutton 8  | 1                  |
| 992   | User-Programmable Pushbutton 9  | 1                  |
| 993   | User-Programmable Pushbutton 10 | 1                  |
| 994   | User-Programmable Pushbutton 11 | 1                  |
| 995   | User-Programmable Pushbutton 12 | 1                  |



## D.2.2 BINARY AND CONTROL RELAY OUTPUTS

Supported Control Relay Output Block fields: Pulse On, Pulse Off, Latch On, Latch Off, Paired Trip, Paired Close.

**BINARY OUTPUT STATUS POINTS**

Object Number: **10**

Request Function Codes supported: **1 (read)**

Default Variation reported when Variation 0 requested: **2 (Binary Output Status)**

**CONTROL RELAY OUTPUT BLOCKS**

Object Number: **12**

Request Function Codes supported: **3 (select), 4 (operate), 5 (direct operate), 6 (direct operate, noack)**

**Table D–4: BINARY/CONTROL OUTPUTS**

| POINT | NAME/DESCRIPTION |
|-------|------------------|
| 0     | Virtual Input 1  |
| 1     | Virtual Input 2  |
| 2     | Virtual Input 3  |
| 3     | Virtual Input 4  |
| 4     | Virtual Input 5  |
| 5     | Virtual Input 6  |
| 6     | Virtual Input 7  |
| 7     | Virtual Input 8  |
| 8     | Virtual Input 9  |
| 9     | Virtual Input 10 |
| 10    | Virtual Input 11 |
| 11    | Virtual Input 12 |
| 12    | Virtual Input 13 |
| 13    | Virtual Input 14 |
| 14    | Virtual Input 15 |
| 15    | Virtual Input 16 |
| 16    | Virtual Input 17 |
| 17    | Virtual Input 18 |
| 18    | Virtual Input 19 |
| 19    | Virtual Input 20 |
| 20    | Virtual Input 21 |
| 21    | Virtual Input 22 |
| 22    | Virtual Input 23 |
| 23    | Virtual Input 24 |
| 24    | Virtual Input 25 |
| 25    | Virtual Input 26 |
| 26    | Virtual Input 27 |
| 27    | Virtual Input 28 |
| 28    | Virtual Input 29 |
| 29    | Virtual Input 30 |
| 30    | Virtual Input 31 |
| 31    | Virtual Input 32 |

## D.2.3 COUNTERS

The following table lists both Binary Counters (Object 20) and Frozen Counters (Object 21). When a freeze function is performed on a Binary Counter point, the frozen value is available in the corresponding Frozen Counter point.

**BINARY COUNTERS**

Static (Steady-State) Object Number: **20**

Change Event Object Number: **22**

Request Function Codes supported: **1 (read), 7 (freeze), 8 (freeze noack), 9 (freeze and clear), 10 (freeze and clear, noack), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Binary Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Counter Change Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **2**

**FROZEN COUNTERS**

Static (Steady-State) Object Number: **21**

Change Event Object Number: **23**

Request Function Codes supported: **1 (read)**

Static Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter with Flag)**

Change Event Variation reported when variation 0 requested: **1 (32-Bit Frozen Counter Event without time)**

Change Event Buffer Size: **10**

Default Class for all points: **2**

**Table D-5: BINARY AND FROZEN COUNTERS**

| POINT INDEX | NAME/DESCRIPTION            |
|-------------|-----------------------------|
| 0           | Digital Counter 1           |
| 1           | Digital Counter 2           |
| 2           | Digital Counter 3           |
| 3           | Digital Counter 4           |
| 4           | Digital Counter 5           |
| 5           | Digital Counter 6           |
| 6           | Digital Counter 7           |
| 7           | Digital Counter 8           |
| 8           | Oscillography Trigger Count |
| 9           | Events Since Last Clear     |

A counter freeze command has no meaning for counters 8 and 9. D30 Digital Counter values are represented as 32-bit integers. The DNP 3.0 protocol defines counters to be unsigned integers. Care should be taken when interpreting negative counter values.

## D.2.4 ANALOG INPUTS

The following table lists Analog Inputs (Object 30). It is important to note that 16-bit and 32-bit variations of analog inputs are transmitted through DNP as signed numbers. Even for analog input points that are not valid as negative values, the maximum positive representation is 32767 for 16-bit values and 2147483647 for 32-bit values. This is a DNP requirement.

The deadbands for all Analog Input points are in the same units as the Analog Input quantity. For example, an Analog Input quantity measured in volts has a corresponding deadband in units of volts. This is in conformance with DNP Technical Bulletin 9809-001 Analog Input Reporting Deadband. Relay settings are available to set default deadband values according to data type. Deadbands for individual Analog Input Points can be set using DNP Object 34.

When using the D30 in DNP systems with limited memory, the Analog Input Points below may be replaced with a user-definable list. This user-definable list uses the same settings as the Modbus User Map and can be configured with the Modbus User Map settings. When used with DNP, each entry in the Modbus User Map represents the starting Modbus address of a data item available as a DNP Analog Input point. To enable use of the Modbus User Map for DNP Analog Input points, set the **USER MAP FOR DNP ANALOGS** setting to Enabled (this setting is in the **PRODUCT SETUP** ⇌ **COMMUNICATIONS** ⇌ **DNP PROTOCOL** menu). The new DNP Analog points list can be checked via the “DNP Analog Input Points List” webpage, accessible from the “Device Information menu” webpage.



After changing the **USER MAP FOR DNP ANALOGS** setting, the relay must be powered off and then back on for the setting to take effect.

Only Source 1 data points are shown in the following table. If the **NUMBER OF SOURCES IN ANALOG LIST** setting is increased, data points for subsequent sources will be added to the list immediately following the Source 1 data points.

Units for Analog Input points are as follows:

- |                   |                                  |              |                      |
|-------------------|----------------------------------|--------------|----------------------|
| • Current:        | A (amps)                         | • Frequency: | Hz (hertz)           |
| • Voltage:        | V (volts)                        | • Angle:     | degrees              |
| • Real Power:     | W (watts)                        | • Ohm Input: | ohms                 |
| • Reactive Power: | var (vars)                       | • RTD Input: | °C (degrees Celsius) |
| • Apparent Power: | VA (volt-amps)                   |              |                      |
| • Energy          | Wh, varh (watt-hours, var-hours) |              |                      |

Static (Steady-State) Object Number: **30**

Change Event Object Number: **32**

Request Function Codes supported: **1 (read), 2 (write, deadbands only), 22 (assign class)**

Static Variation reported when variation 0 requested: **1 (32-Bit Analog Input)**

Change Event Variation reported when variation 0 requested: **1 (Analog Change Event without Time)**

Change Event Scan Rate: defaults to **500 ms**

Change Event Buffer Size: **800**

Default Class for all Points: **1**

Table D-6: ANALOG INPUT POINTS (Sheet 1 of 3)

| POINT | DESCRIPTION                                 |
|-------|---|
| 0     | SRC 1 Phase A Current RMS                   |
| 1     | SRC 1 Phase B Current RMS                   |
| 2     | SRC 1 Phase C Current RMS                   |
| 3     | SRC 1 Neutral Current RMS                   |
| 4     | SRC 1 Phase A Current Magnitude             |
| 5     | SRC 1 Phase A Current Angle                 |
| 6     | SRC 1 Phase B Current Magnitude             |
| 7     | SRC 1 Phase B Current Angle                 |
| 8     | SRC 1 Phase C Current Magnitude             |
| 9     | SRC 1 Phase C Current Angle                 |
| 10    | SRC 1 Neutral Current Magnitude             |
| 11    | SRC 1 Neutral Current Angle                 |
| 12    | SRC 1 Ground Current RMS                    |
| 13    | SRC 1 Ground Current Magnitude              |
| 14    | SRC 1 Ground Current Angle                  |
| 15    | SRC 1 Zero Sequence Current Magnitude       |
| 16    | SRC 1 Zero Sequence Current Angle           |
| 17    | SRC 1 Positive Sequence Current Magnitude   |
| 18    | SRC 1 Positive Sequence Current Angle       |
| 19    | SRC 1 Negative Sequence Current Magnitude   |
| 20    | SRC 1 Negative Sequence Current Angle       |
| 21    | SRC 1 Differential Ground Current Magnitude |
| 22    | SRC 1 Differential Ground Current Angle     |
| 23    | SRC 1 Phase AG Voltage RMS                  |
| 24    | SRC 1 Phase BG Voltage RMS                  |
| 25    | SRC 1 Phase CG Voltage RMS                  |
| 26    | SRC 1 Phase AG Voltage Magnitude            |
| 27    | SRC 1 Phase AG Voltage Angle                |
| 28    | SRC 1 Phase BG Voltage Magnitude            |
| 29    | SRC 1 Phase BG Voltage Angle                |
| 30    | SRC 1 Phase CG Voltage Magnitude            |
| 31    | SRC 1 Phase CG Voltage Angle                |
| 32    | SRC 1 Phase AB Voltage RMS                  |
| 33    | SRC 1 Phase BC Voltage RMS                  |
| 34    | SRC 1 Phase CA Voltage RMS                  |
| 35    | SRC 1 Phase AB Voltage Magnitude            |
| 36    | SRC 1 Phase AB Voltage Angle                |
| 37    | SRC 1 Phase BC Voltage Magnitude            |
| 38    | SRC 1 Phase BC Voltage Angle                |
| 39    | SRC 1 Phase CA Voltage Magnitude            |
| 40    | SRC 1 Phase CA Voltage Angle                |
| 41    | SRC 1 Auxiliary Voltage RMS                 |
| 42    | SRC 1 Auxiliary Voltage Magnitude           |
| 43    | SRC 1 Auxiliary Voltage Angle               |
| 44    | SRC 1 Zero Sequence Voltage Magnitude       |
| 45    | SRC 1 Zero Sequence Voltage Angle           |
| 46    | SRC 1 Positive Sequence Voltage Magnitude   |
| 47    | SRC 1 Positive Sequence Voltage Angle       |
| 48    | SRC 1 Negative Sequence Voltage Magnitude   |
| 49    | SRC 1 Negative Sequence Voltage Angle       |
| 50    | SRC 1 Three Phase Real Power                |
| 51    | SRC 1 Phase A Real Power                    |

Table D-6: ANALOG INPUT POINTS (Sheet 2 of 3)

| POINT | DESCRIPTION                                 |
|-------|---|
| 52    | SRC 1 Phase B Real Power                    |
| 53    | SRC 1 Phase C Real Power                    |
| 54    | SRC 1 Three Phase Reactive Power            |
| 55    | SRC 1 Phase A Reactive Power                |
| 56    | SRC 1 Phase B Reactive Power                |
| 57    | SRC 1 Phase C Reactive Power                |
| 58    | SRC 1 Three Phase Apparent Power            |
| 59    | SRC 1 Phase A Apparent Power                |
| 60    | SRC 1 Phase B Apparent Power                |
| 61    | SRC 1 Phase C Apparent Power                |
| 62    | SRC 1 Three Phase Power Factor              |
| 63    | SRC 1 Phase A Power Factor                  |
| 64    | SRC 1 Phase B Power Factor                  |
| 65    | SRC 1 Phase C Power Factor                  |
| 66    | SRC 1 Frequency                             |
| 67    | SRC 1 Ia THD                                |
| 68    | SRC 1 Ib THD                                |
| 69    | SRC 1 Ic THD                                |
| 70    | SRC 1 In THD                                |
| 71    | Breaker 1 Arcing Amp Phase A                |
| 72    | Breaker 1 Arcing Amp Phase B                |
| 73    | Breaker 1 Arcing Amp Phase C                |
| 74    | Breaker 2 Arcing Amp Phase A                |
| 75    | Breaker 2 Arcing Amp Phase B                |
| 76    | Breaker 2 Arcing Amp Phase C                |
| 77    | Fault 1 Prefault Phase A Current Magnitude  |
| 78    | Fault 1 Prefault Phase A Current Angle      |
| 79    | Fault 1 Prefault Phase B Current Magnitude  |
| 80    | Fault 1 Prefault Phase B Current Angle      |
| 81    | Fault 1 Prefault Phase C Current Magnitude  |
| 82    | Fault 1 Prefault Phase C Current Angle      |
| 83    | Fault 1 Prefault Phase A Voltage Magnitude  |
| 84    | Fault 1 Prefault Phase A Voltage Angle      |
| 85    | Fault 1 Prefault Phase B Voltage Magnitude  |
| 86    | Fault 1 Prefault Phase B Voltage Angle      |
| 87    | Fault 1 Prefault Phase C Voltage Magnitude  |
| 88    | Fault 1 Prefault Phase C Voltage Angle      |
| 89    | Fault 1 Postfault Phase A Current Magnitude |
| 90    | Fault 1 Postfault Phase A Current Angle     |
| 91    | Fault 1 Postfault Phase B Current Magnitude |
| 92    | Fault 1 Postfault Phase B Current Angle     |
| 93    | Fault 1 Postfault Phase C Current Magnitude |
| 94    | Fault 1 Postfault Phase C Current Angle     |
| 95    | Fault 1 Postfault Phase A Voltage Magnitude |
| 96    | Fault 1 Postfault Phase A Voltage Angle     |
| 97    | Fault 1 Postfault Phase B Voltage Magnitude |
| 98    | Fault 1 Postfault Phase B Voltage Angle     |
| 99    | Fault 1 Postfault Phase C Voltage Magnitude |
| 100   | Fault 1 Postfault Phase C Voltage Angle     |
| 101   | Fault 1 Type                                |
| 102   | Fault 1 Location                            |
| 103   | Synchrocheck 1 Delta Voltage                |

Table D-6: ANALOG INPUT POINTS (Sheet 3 of 3)

| POINT | DESCRIPTION                    |
|-------|--------------------------------|
| 104   | Synchrocheck 1 Delta Frequency |
| 105   | Synchrocheck 1 Delta Phase     |
| 106   | Synchrocheck 2 Delta Voltage   |
| 107   | Synchrocheck 2 Delta Frequency |
| 108   | Synchrocheck 2 Delta Phase     |
| 109   | DCMA Inputs 1 Value            |
| 110   | DCMA Inputs 2 Value            |
| 111   | DCMA Inputs 3 Value            |
| 112   | DCMA Inputs 4 Value            |
| 113   | RTD Inputs 1 Value             |
| 114   | RTD Inputs 2 Value             |
| 115   | RTD Inputs 3 Value             |
| 116   | RTD Inputs 4 Value             |
| 117   | Tracking Frequency             |
| 118   | FlexElement 1 Actual           |
| 119   | FlexElement 2 Actual           |
| 120   | FlexElement 3 Actual           |
| 121   | FlexElement 4 Actual           |
| 122   | FlexElement 5 Actual           |
| 123   | FlexElement 6 Actual           |
| 124   | FlexElement 7 Actual           |
| 125   | FlexElement 8 Actual           |
| 126   | Current Setting Group          |

## D

## E.1.1 REVISION HISTORY

Table E-1: REVISION HISTORY

| MANUAL P/N   | D30 REVISION | RELEASE DATE      | ECO     |
|--------------|--------------|-------------------|---------|
| 1601-0116-C1 | 3.0x         | 15 July 2002      | URD-011 |
| 1601-0116-C2 | 3.1x         | 30 August 2002    | URD-013 |
| 1601-0116-C3 | 3.0x         | 18 November 2002  | URD-014 |
| 1601-0116-C4 | 3.1x         | 18 November 2002  | URD-015 |
| 1601-0116-C5 | 3.0x         | 11 February 2003  | URD-018 |
| 1601-0116-C6 | 3.1x         | 11 February 2003  | URD-019 |
| 1601-0116-D1 | 3.2x         | 11 February 2003  | URD-022 |
| 1601-0116-D2 | 3.2x         | 02 June 2003      | URX-084 |
| 1601-0116-E1 | 3.3x         | 01 May 2003       | URX-080 |
| 1601-0116-E2 | 3.3x         | 29 May 2003       | URX-083 |
| 1601-0116-F1 | 3.4x         | 10 December 2003  | URX-111 |
| 1601-0116-F2 | 3.4x         | 09 February 2004  | URX-115 |
| 1601-0116-G1 | 4.0x         | 23 March 2004     | URX-123 |
| 1601-0116-G2 | 4.0x         | 17 May 2004       | URX-136 |
| 1601-0116-H1 | 4.2x         | 30 June 2004      | URX-145 |
| 1601-0116-H2 | 4.2x         | 23 July 2004      | URX-151 |
| 1601-0116-J1 | 4.4x         | 15 September 2004 | URX-156 |
| 1601-0116-J2 | 4.4x         | 05 January 2005   | URX-173 |

## E.1.2 CHANGES TO THE MANUAL

Table E-2: MAJOR UPDATES FOR D30 MANUAL REVISION J2

| PAGE (J1) | PAGE (J2) | CHANGE | DESCRIPTION   |
|-----------|-----------|--------|---|
| Title     | Title     | Update | Manual part number to 1601-0116-J2                  |
| 3-18      | 3-18      | Update | Updated RS485 SERIAL CONNECTION diagram to 827757A7 |

Table E-3: MAJOR UPDATES FOR D30 MANUAL REVISION J1

| PAGE (H2) | PAGE (J1) | CHANGE | DESCRIPTION  |
|-----------|-----------|--------|--|
| Title     | Title     | Update | Manual part number to 1601-0116-J1                   |
| 5-15      | ---       | Remove | Removed UCA/MMS PROTOCOL sub-section                 |
| ---       | 5-15      | Add    | Added IEC 61850 PROTOCOL sub-section                 |
| 5-41      | 5-41      | Update | Updated BREAKERS sub-section                         |
| 5-157     | 5-157     | Update | Updated VIRTUAL INPUTS sub-section                   |
| B-8       | B-8       | Update | Updated MODBUS MEMORY MAP for firmware revision 4.4x |
| C-1       | ---       | Remove | Removed UCA/MMS COMMUNICATIONS appendix              |

Table E-4: MAJOR UPDATES FOR D30 MANUAL REVISION H2

| PAGE (H1) | PAGE (H2) | CHANGE | DESCRIPTION                                 |
|-----------|-----------|--------|---|
| Title     | Title     | Update | Manual part number to 1601-0116-H2          |
| 3-21      | 3-21      | Update | Updated CHANNEL COMMUNICATION OPTIONS table |

Table E-5: MAJOR UPDATES FOR D30 MANUAL REVISION H1

| PAGE (G2) | PAGE (H1) | CHANGE | DESCRIPTION  |
|-----------|-----------|--------|--|
| Title     | Title     | Update | Manual part number to 1601-0116-H1                       |
| 1-12      | 1-13      | Update | Updated COMMISSIONING section                            |
| 2-3       | 2-3       | Update | Updated D30 ORDER CODES table                            |
| 3-9       | 3-9       | Update | Updated FORM-A CONTACT FUNCTIONS diagram to 827821A5     |
| 5-13      | 5-13      | Update | Updated DNP PROTOCOL sub-section to reflect new settings |
| 5-18      | 5-19      | Update | Updated FAULT REPORTS section                            |
| B-8       | B-8       | Update | Updated MODBUS MEMORY MAP for firmware release 4.2x      |

Table E-6: MAJOR UPDATES FOR D30 MANUAL REVISION G2

| PAGE (G1) | PAGE (G2) | CHANGE | DESCRIPTION                                |
|-----------|-----------|--------|--|
| Title     | Title     | Update | Manual part number to 1601-0116-G2         |
| 3-6       | 3-6       | Update | Updated TYPICAL WIRING DIAGRAM to 837772A2 |

Table E-7: MAJOR UPDATES FOR D30 MANUAL REVISION G1 (Sheet 1 of 2)

| PAGE (F2) | PAGE (G1) | CHANGE | DESCRIPTION  |
|-----------|-----------|--------|--|
| Title     | Title     | Update | Manual part number to 1601-0116-G1   |
| 2-3       | 2-3       | Update | Updated D30 ORDER CODES table  |
| 2-4       | 2-4       | Update | Updated ORDER CODES FOR REPLACEMENT MODULES table  |
| 2-5       | 2-5       | Update | Updated phase distance and ground distance specifications for non-directional protection |
| 2-12      | 2-12      | Add    | Added dcmA outputs specifications to OUTPUTS section                                     |
| 2-12      | 2-12      | Add    | Added IRIG-B outputs specifications to OUTPUTS section                                   |
| 3-4       | 3-4       | Update | Updated MODULE WITHDRAWAL AND INSERTION section to reflect new hardware                  |
| 3-7       | 3-7       | Update | Updated DIELECTRIC STRENGTH section  |
| 3-8       | 3-8       | Update | Updated CT/VT MODULES section for new hardware   |
| 3-15      | 3-15      | Update | Updated drawings and description in TRANSDUCER INPUTS/OUTPUTS section                    |
| 3-16      | 3-17      | Update | Updated drawings and description in CPU COMMUNICATIONS PORTS section                     |
| 3-18      | 3-19      | Update | Updated IRIG-B section to indicate updated functionality                                 |
| 5-17      | 5-18      | Update | Updated REAL TIME CLOCK section  |
| 5-18      | 5-18      | Update | Updated FAULT REPORTS section to indicate settings moved from deleted LINE section       |
| 5-39      | ---       | Remove | Removed LINE section. These settings are now part of the FAULT REPORTS section           |
| 5-52      | 5-52      | Update | Updated FLEXLOGIC™ OPERANDS table  |



Table E-7: MAJOR UPDATES FOR D30 MANUAL REVISION G1 (Sheet 2 of 2)

| PAGE (F2) | PAGE (G1) | CHANGE | DESCRIPTION  |
|-----------|-----------|--------|--|
| 5-65      | 5-65      | Update | Updated FLEXELEMENT™ SCHEME LOGIC diagram to 842004A3  |
| 5-66      | 5-66      | Update | Updated FLEXELEMENT™ INPUT MODE SETTING diagram to 842706A2  |
| 5-73      | 5-73      | Update | Updated PHASE DISTANCE section and logic diagrams for non-directional protection                     |
| 5-80      | 5-81      | Update | Updated GROUND DISTANCE section and logic diagrams for non-directional protection                    |
| 5-107     | 5-111     | Update | Updated NEUTRAL DIRECTIONAL OVERCURRENT sub-section  |
| 5-164     | 5-169     | Add    | Added DCMA OUTPUTS section   |
| 6-14      | 6-14      | Update | Updated FAULT REPORTS section  |
| 8-2       | 8-2       | Update | Updated DISTANCE CHARACTERISTICS section for non-directional protection                              |
| 9-3       | 9-3       | Add    | Added POLARIZING CURRENT AND NON-HOMOGENEITY CORRECTION ANGLE OF THE QUAD CHARACTERISTIC sub-section |
| B-8       | B-8       | Update | Updated MODBUS MEMORY MAP for firmware release 4.0x  |

Table E-8: MAJOR UPDATES FOR D30 MANUAL REVISION F2

| PAGE (F1) | PAGE (F2) | CHANGE | DESCRIPTION  |
|-----------|-----------|--------|--|
| Title     | Title     | Update | Manual part number to 1601-0116-F2.                            |
| 3-15      | 3-15      | Update | Updated TRANSDUCER I/O MODULE WIRING diagram to 827831A9-X1.   |
| 5-8       | 5-8       | Update | Updated DISPLAY PROPERTIES section.                            |
| 5-41      | 5-42      | Update | Updated DUAL BREAKER CONTROL SCHEME LOGIC diagram to 827061AM. |
| 5-99      | 5-100     | Update | Updated PHASE TOC1 SCHEME LOGIC diagram to 827072A4.           |
| 5-100     | 5-101     | Update | Updated PHASE IOC1 SCHEME LOGIC diagram to 827033A6.           |
| 5-119     | 5-120     | Update | Updated PHASE UNDERVOLTAGE1 SCHEME LOGIC diagram to 827039AB.  |
| 5-120     | 5-121     | Update | Updated PHASE OVERVOLTAGE SCHEME LOGIC diagram to 827066A5.    |

Table E-9: MAJOR UPDATES FOR D30 MANUAL REVISION F1

| PAGE (E2) | PAGE (F1) | CHANGE | DESCRIPTION  |
|-----------|-----------|--------|--|
| Title     | Title     | Update | Manual part number to 1601-0116-F1.  |
| 1-5       | 1-5       | Update | Updated software installation procedure.   |
| 2-3       | 2-3       | Update | Updated ORDER CODES table to add the 67 Digital I/O option.                      |
| 2-4       | 2-4       | Update | Updated ORDER CODES FOR REPLACEMENT MODULES table to add the 67 Module option.   |
| 3-10      | 3-10      | Update | Updated DIGITAL I/O MODULE ASSIGNMENTS table to add the 67 module.               |
| 3-12      | 3-12      | Update | Updated the DIGITAL I/O MODULE WIRING diagram to show the 67 module.             |
| 5-71      | 5-71      | Update | Updated DISTANCE OVERVIEW section to reflect new <b>FORCE SELF-POLAR</b> setting |
| 5-71      | 5-72      | Update | Updated MEMORY VOLTAGE LOGIC diagram to 827842A5                                 |
| 5-148     | 5-148     | Update | Updated VT FUSE FAIL SCHEME LOGIC diagram to 827093AF                            |
| B-8       | B-8       | Update | Updated MODBUS MEMORY MAP to reflect new firmware 3.4x.                          |

## E.2.1 STANDARD ABBREVIATIONS

|                |   |                      |  |
|----------------|---|----------------------|--|
| A.....         | Ampere                                      | FREQ.....            | Frequency  |
| AC.....        | Alternating Current                         | FSK.....             | Frequency-Shift Keying                           |
| A/D.....       | Analog to Digital                           | FTP.....             | File Transfer Protocol                           |
| AE.....        | Accidental Energization, Application Entity | FxE.....             | FlexElement™                                     |
| AMP.....       | Ampere                                      | FWD.....             | Forward  |
| ANG.....       | Angle                                       |                      |  |
| ANSI.....      | American National Standards Institute       | G.....               | Generator  |
| AR.....        | Automatic Reclosure                         | GE.....              | General Electric                                 |
| ASDU.....      | Application-layer Service Data Unit         | GND.....             | Ground   |
| ASYM.....      | Asymmetry                                   | GNTR.....            | Generator  |
| AUTO.....      | Automatic                                   | GOOSE.....           | General Object Oriented Substation Event         |
| AUX.....       | Auxiliary                                   | GPS.....             | Global Positioning System                        |
| AVG.....       | Average                                     |                      |  |
|                |   | HARM.....            | Harmonic / Harmonics                             |
| BER.....       | Bit Error Rate                              | HCT.....             | High Current Time                                |
| BF.....        | Breaker Fail                                | HGF.....             | High-Impedance Ground Fault (CT)                 |
| BFI.....       | Breaker Failure Initiate                    | HIZ.....             | High-Impedance and Arcing Ground                 |
| BKR.....       | Breaker                                     | HMI.....             | Human-Machine Interface                          |
| BLK.....       | Block                                       | HTTP.....            | Hyper Text Transfer Protocol                     |
| BLKG.....      | Blocking                                    | HYB.....             | Hybrid   |
| BPNT.....      | Breakpoint of a characteristic              |                      |  |
| BRKR.....      | Breaker                                     | I.....               | Instantaneous                                    |
|                |   | I <sub>0</sub> ..... | Zero Sequence current                            |
| CAP.....       | Capacitor                                   | I <sub>1</sub> ..... | Positive Sequence current                        |
| CC.....        | Coupling Capacitor                          | I <sub>2</sub> ..... | Negative Sequence current                        |
| CCVT.....      | Coupling Capacitor Voltage Transformer      | IA.....              | Phase A current                                  |
| CFG.....       | Configure / Configurable                    | IAB.....             | Phase A minus B current                          |
| .CFG.....      | Filename extension for oscillography files  | IB.....              | Phase B current                                  |
| CHK.....       | Check                                       | IBC.....             | Phase B minus C current                          |
| CHNL.....      | Channel                                     | IC.....              | Phase C current                                  |
| CLS.....       | Close                                       | ICA.....             | Phase C minus A current                          |
| CLSD.....      | Closed                                      | ID.....              | Identification                                   |
| CMND.....      | Command                                     | IED.....             | Intelligent Electronic Device                    |
| CMPSN.....     | Comparison                                  | IEC.....             | International Electrotechnical Commission        |
| CO.....        | Contact Output                              | IEEE.....            | Institute of Electrical and Electronic Engineers |
| COM.....       | Communication                               | IG.....              | Ground (not residual) current                    |
| COMM.....      | Communications                              | Igd.....             | Differential Ground current                      |
| COMP.....      | Compensated, Comparison                     | IN.....              | CT Residual Current (3Io) or Input               |
| CONN.....      | Connection                                  | INC SEQ.....         | Incomplete Sequence                              |
| CONT.....      | Continuous, Contact                         | INIT.....            | Initiate   |
| CO-ORD.....    | Coordination                                | INST.....            | Instantaneous                                    |
| CPU.....       | Central Processing Unit                     | INV.....             | Inverse  |
| CRC.....       | Cyclic Redundancy Code                      | I/O.....             | Input/Output                                     |
| CRT, CRNT..... | Current                                     | IOC.....             | Instantaneous Overcurrent                        |
| CSA.....       | Canadian Standards Association              | IOV.....             | Instantaneous Overvoltage                        |
| CT.....        | Current Transformer                         | IRIG.....            | Inter-Range Instrumentation Group                |
| CVT.....       | Capacitive Voltage Transformer              | ISO.....             | International Standards Organization             |
|                |   | IUV.....             | Instantaneous Undervoltage                       |
| D/A.....       | Digital to Analog                           |                      |  |
| DC (dc).....   | Direct Current                              | K0.....              | Zero Sequence Current Compensation               |
| DD.....        | Disturbance Detector                        | kA.....              | kiloAmpere                                       |
| DFLT.....      | Default                                     | kV.....              | kiloVolt   |
| DGNST.....     | Diagnostics                                 |                      |  |
| DI.....        | Digital Input                               | LED.....             | Light Emitting Diode                             |
| DIFF.....      | Differential                                | LEO.....             | Line End Open                                    |
| DIR.....       | Directional                                 | LFT BLD.....         | Left Blinder                                     |
| DISCREP.....   | Discrepancy                                 | LOOP.....            | Loopback   |
| DIST.....      | Distance                                    | LPU.....             | Line Pickup                                      |
| DMD.....       | Demand                                      | LRA.....             | Locked-Rotor Current                             |
| DNP.....       | Distributed Network Protocol                | LTC.....             | Load Tap-Changer                                 |
| DPO.....       | Dropout                                     |                      |  |
| DSP.....       | Digital Signal Processor                    | M.....               | Machine  |
| dt.....        | Rate of Change                              | mA.....              | MilliAmpere                                      |
| DTT.....       | Direct Transfer Trip                        | MAG.....             | Magnitude  |
| DUTT.....      | Direct Under-reaching Transfer Trip         | MAN.....             | Manual / Manually                                |
|                |   | MAX.....             | Maximum  |
| ENCRMNT.....   | Encroachment                                | MIC.....             | Model Implementation Conformance                 |
| EPRI.....      | Electric Power Research Institute           | MIN.....             | Minimum, Minutes                                 |
| .EVT.....      | Filename extension for event recorder files | MMI.....             | Man Machine Interface                            |
| EXT.....       | Extension, External                         | MMS.....             | Manufacturing Message Specification              |
|                |   | MRT.....             | Minimum Response Time                            |
| F.....         | Field                                       | MSG.....             | Message  |
| FAIL.....      | Failure                                     | MTA.....             | Maximum Torque Angle                             |
| FD.....        | Fault Detector                              | MTR.....             | Motor  |
| FDH.....       | Fault Detector high-set                     | MVA.....             | MegaVolt-Ampere (total 3-phase)                  |
| FDL.....       | Fault Detector low-set                      | MVA_A.....           | MegaVolt-Ampere (phase A)                        |
| FLA.....       | Full Load Current                           | MVA_B.....           | MegaVolt-Ampere (phase B)                        |
| FO.....        | Fiber Optic                                 | MVA_C.....           | MegaVolt-Ampere (phase C)                        |

|               |   |               |  |
|---------------|---|---------------|--|
| MVAR.....     | MegaVar (total 3-phase)                         | SAT.....      | CT Saturation                            |
| MVAR_A.....   | MegaVar (phase A)                               | SBO.....      | Select Before Operate                    |
| MVAR_B.....   | MegaVar (phase B)                               | SCADA.....    | Supervisory Control and Data Acquisition |
| MVAR_C.....   | MegaVar (phase C)                               | SEC.....      | Secondary                                |
| MVARH.....    | MegaVar-Hour                                    | SEL.....      | Select / Selector / Selection            |
| MW.....       | MegaWatt (total 3-phase)                        | SENS.....     | Sensitive                                |
| MW_A.....     | MegaWatt (phase A)                              | SEQ.....      | Sequence                                 |
| MW_B.....     | MegaWatt (phase B)                              | SIR.....      | Source Impedance Ratio                   |
| MW_C.....     | MegaWatt (phase C)                              | SNTP.....     | Simple Network Time Protocol             |
| MWH.....      | MegaWatt-Hour                                   | SRC.....      | Source                                   |
| N.....        | Neutral   | SSB.....      | Single Side Band                         |
| N/A, n/a..... | Not Applicable                                  | SSEL.....     | Session Selector                         |
| NEG.....      | Negative  | STATS.....    | Statistics                               |
| NMPLT.....    | Nameplate                                       | SUPN.....     | Supervision                              |
| NOM.....      | Nominal   | SUPV.....     | Supervise / Supervision                  |
| NSAP.....     | Network Service Access Protocol                 | SV.....       | Supervision, Service                     |
| NTR.....      | Neutral   | SYNC.....     | Synchrocheck                             |
|               |   | SYNCHCHK..... | Synchrocheck                             |
| O.....        | Over  | T.....        | Time, transformer                        |
| OC, O/C.....  | Overcurrent                                     | TC.....       | Thermal Capacity                         |
| O/P, Op.....  | Output  | TCP.....      | Transmission Control Protocol            |
| OP.....       | Operate   | TCU.....      | Thermal Capacity Used                    |
| OPER.....     | Operate   | TD MULT.....  | Time Dial Multiplier                     |
| OPERATG.....  | Operating                                       | TEMP.....     | Temperature                              |
| O/S.....      | Operating System                                | TFTP.....     | Trivial File Transfer Protocol           |
| OSI.....      | Open Systems Interconnect                       | THD.....      | Total Harmonic Distortion                |
| OSB.....      | Out-of-Step Blocking                            | TMR.....      | Timer                                    |
| OUT.....      | Output  | TOC.....      | Time Overcurrent                         |
| OV.....       | Overvoltage                                     | TOV.....      | Time Overvoltage                         |
| OVERFREQ..... | Overfrequency                                   | TRANS.....    | Transient                                |
| OVL.....      | Overload  | TRANSF.....   | Transfer                                 |
| P.....        | Phase   | TSEL.....     | Transport Selector                       |
| PC.....       | Phase Comparison, Personal Computer             | TUC.....      | Time Undercurrent                        |
| PCNT.....     | Percent   | TUV.....      | Time Undervoltage                        |
| PF.....       | Power Factor (total 3-phase)                    | TX (Tx).....  | Transmit, Transmitter                    |
| PF_A.....     | Power Factor (phase A)                          | U.....        | Under                                    |
| PF_B.....     | Power Factor (phase B)                          | UC.....       | Undercurrent                             |
| PF_C.....     | Power Factor (phase C)                          | UCA.....      | Utility Communications Architecture      |
| PFL.....      | Phase and Frequency Lock Loop                   | UDP.....      | User Datagram Protocol                   |
| PHS.....      | Phase   | UL.....       | Underwriters Laboratories                |
| PICS.....     | Protocol Implementation & Conformance Statement | UNBAL.....    | Unbalance                                |
| PKP.....      | Pickup  | UR.....       | Universal Relay                          |
| PLC.....      | Power Line Carrier                              | URC.....      | Universal Recloser Control               |
| POS.....      | Positive  | .URS.....     | Filename extension for settings files    |
| POTT.....     | Permissive Over-reaching Transfer Trip          | UV.....       | Undervoltage                             |
| PRESS.....    | Pressure  | V/Hz.....     | Volts per Hertz                          |
| PRI.....      | Primary   | V_0.....      | Zero Sequence voltage                    |
| PROT.....     | Protection                                      | V_1.....      | Positive Sequence voltage                |
| PSEL.....     | Presentation Selector                           | V_2.....      | Negative Sequence voltage                |
| pu.....       | Per Unit  | VA.....       | Phase A voltage                          |
| PUIB.....     | Pickup Current Block                            | VAB.....      | Phase A to B voltage                     |
| PUIT.....     | Pickup Current Trip                             | VAG.....      | Phase A to Ground voltage                |
| PUSHBTN.....  | Pushbutton                                      | VARH.....     | Var-hour voltage                         |
| PUTT.....     | Permissive Under-reaching Transfer Trip         | VB.....       | Phase B voltage                          |
| PWM.....      | Pulse Width Modulated                           | VBA.....      | Phase B to A voltage                     |
| PWR.....      | Power   | VBG.....      | Phase B to Ground voltage                |
| QUAD.....     | Quadrilateral                                   | VC.....       | Phase C voltage                          |
| R.....        | Rate, Reverse                                   | VCA.....      | Phase C to A voltage                     |
| RCA.....      | Reach Characteristic Angle                      | VCG.....      | Phase C to Ground voltage                |
| REF.....      | Reference                                       | VF.....       | Variable Frequency                       |
| REM.....      | Remote  | VIBR.....     | Vibration                                |
| REV.....      | Reverse   | VT.....       | Voltage Transformer                      |
| RI.....       | Reclose Initiate                                | VTFF.....     | Voltage Transformer Fuse Failure         |
| RIP.....      | Reclose In Progress                             | VTLOS.....    | Voltage Transformer Loss Of Signal       |
| RGT BLD.....  | Right Blinder                                   | WDG.....      | Winding                                  |
| ROD.....      | Remote Open Detector                            | WH.....       | Watt-hour                                |
| RST.....      | Reset   | w/ opt.....   | With Option                              |
| RSTR.....     | Restrained                                      | WRT.....      | With Respect To                          |
| RTD.....      | Resistance Temperature Detector                 | X.....        | Reactance                                |
| RTU.....      | Remote Terminal Unit                            | XDUCER.....   | Transducer                               |
| RX (Rx).....  | Receive, Receiver                               | XFMR.....     | Transformer                              |
| s.....        | second  | Z.....        | Impedance, Zone                          |
| S.....        | Sensitive                                       |               |  |

## GE MULTILIN RELAY WARRANTY

General Electric Multilin Inc. (GE Multilin) warrants each relay it manufactures to be free from defects in material and workmanship under normal use and service for a period of 24 months from date of shipment from factory.

In the event of a failure covered by warranty, GE Multilin will undertake to repair or replace the relay providing the warrantor determined that it is defective and it is returned with all transportation charges prepaid to an authorized service centre or the factory. Repairs or replacement under warranty will be made without charge.

Warranty shall not apply to any relay which has been subject to misuse, negligence, accident, incorrect installation or use not in accordance with instructions nor any unit that has been altered outside a GE Multilin authorized factory outlet.

GE Multilin is not liable for special, indirect or consequential damages or for loss of profit or for expenses sustained as a result of a relay malfunction, incorrect application or adjustment.

For complete text of Warranty (including limitations and disclaimers), refer to GE Multilin Standard Conditions of Sale.

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