GE Industrial Systems

750/760

Feedback Management Relay®

Instruction Manual

Firmware Rev.: 501.00

Manual P/N: 1601-0044-AM (GEK-106293B)

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ISO9001 REGISTERED

Manufactured under an ISO9001 Registered system.

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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 MANUAL ORGANIZATION

Reading a lengthy instruction manual on a new product is not a task most people enjoy. To speed things up, this introductory chapter provides a step-by-step tutorial for a simple feeder application. Important wiring considerations and precautions discussed in Chapter 3: Installation should be observed for reliable operation. Detailed information regarding accuracy, output relay contact ratings, and so forth are detailed in Section 2.2: Specifications. The remainder of this manual should be read and kept for reference to ensure maximum benefit from the 750 and 760. For further information, please consult your local sales representative or the factory. Comments about new features or modifications for your specific requirements are welcome and encouraged.

Setpoints and actual values are indicated as follows in the manual:

A2 METERING ⇨⇩ DMND ⇨ PHASE A CURRENT ⇨ LAST PHASE A CURRENT DMND

This “path representation” shows how to navigate menus and sub-menus to get to a specific setpoint or value (in the example above, **LAST PHASE A CURRENT DMND**). The forward arrows indicate entering a new sub-menu to arrive at a message; the down arrows indicate scrolling through a sub-menu to arrive at a message. See 1.2.1: Menu Navigation on page 1–2 for an example of how to navigate setpoints and actual values messages from the relay front panel.

1.1.3 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.
- Ensure that the following items are included:
  - Instruction Manual
  - GE Multilin Products CD (includes the 750/760PC software and manuals in PDF format)
  - mounting screws
  - registration card (attached as the last page of the manual)
- Fill out the registration form and mail it back 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 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:**

GE Multilin
215 Anderson Avenue
Markham, Ontario
Canada L6E 1B3

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 MENU NAVIGATION

The relay has five types of display messages: actual value, setpoint, diagnostic, flash, and help. Actual values are values that are measured by the relay such as current and voltage. Setpoints are programmable settings entered by the user. These types of messages are located within a menu structure that groups the information into categories. Navigating the menu structure is described below. A summary of the menu structure for setpoints and actual values can be found in Sections 5.1.1: Setpoints Message Map on page 5–1 and 6.1.1: Actual Values Main Menu on page 6–1, respectively.

1. Press the ACTUAL key to display the header for the first actual values page. The actual values pages are numbered, have an 'A' prefix for easy identification and have a name which gives a general idea of the information available in that page. Repeatedly pressing the ACTUAL key will scroll through all the available actual values page headers.

```
■■ ACTUAL VALUES
■■ A1 STATUS
```

2. Press the SETPOINT key to display the header for the first setpoints page. The setpoint pages are numbered, have an 'S' prefix for easy identification and have a name which gives a general idea of the settings available in that page. Repeatedly pressing the SETPOINT key will scroll through all the available setpoint page headers.

```
■■ SETPOINTS
■■ S1 RELAY SETUP
```

3. Press the ACTUAL key until the **A2 METERING** page appears. Now press the MESSAGE ▼ key and the first sub-page heading for Page 2 of actual values appears. Pressing the MESSAGE ▲ and MESSAGE ▼ keys will scroll the display up and down through the sub-page headers.

```
■ CURRENT
■ [ENTER] for more
```

4. Press the MESSAGE ▼ key until the **DMND** sub-page heading appears. Press ENTER to display the messages in this sub-page.

```
■ DMND
■ [ENTER] for more
```

5. Note that all heading messages have the ■ symbol preceding them and that only some sub-pages have a subsequent second sub-page.

```
■ PHASE A CURRENT
■ [ENTER] for more
```

6. Press the ENTER key to display the actual values of this second sub-page. Actual values messages and setpoints always have a colon separating the name of the value and the actual value or setpoint. This particular message displays the last Phase A current demand as measured by the relay. The menu path to this particular message is referred to as **A2 METERING ⇨⇩ DMND ⇨ PHASE A CURRENT ⇨ LAST PHASE A CURRENT DMND**. Messages are referred to in this manner throughout the manual.

```
LAST PHASE A CURRENT
DMND:      0 A
```

7. Press the MESSAGE ▼ key and the next actual value display message will appear. Pressing the MESSAGE ▲ and MESSAGE ▼ keys will scroll the display up and down through all the actual value displays in this second sub-page.

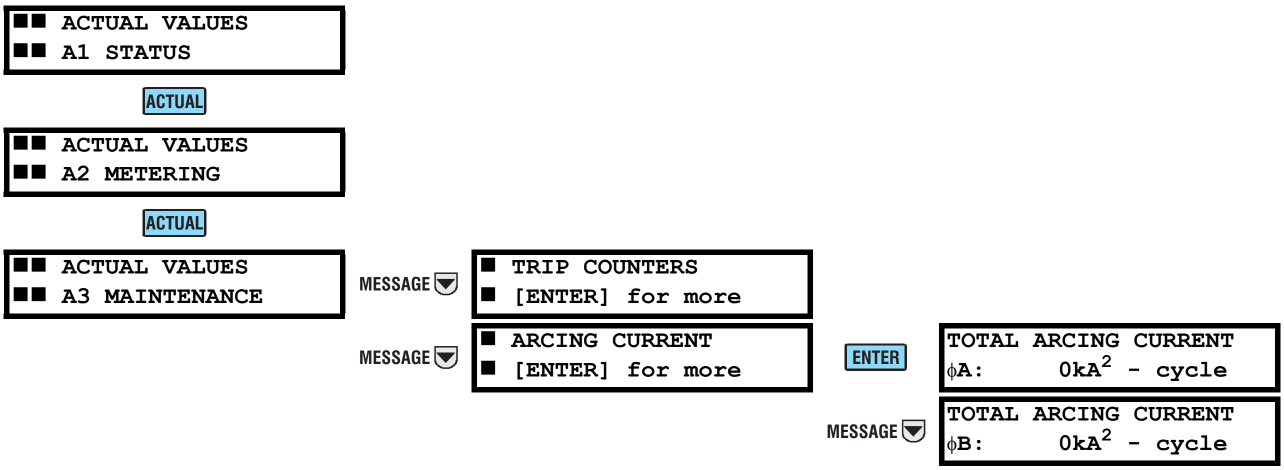
```
MAX PHASE A CURRENT
DMND:      0 A
```

8. Pressing the ESCAPE key reverses the process described above and returns the display to the previous level. Press the ESCAPE key twice to return to the **A2 METERING ⇨⇩ DMND** sub-page header.

```
■ PHASE A CURRENT
■ [ENTER] for more
```

1.2.2 PANEL KEYING EXAMPLE

The following figure gives a specific example of the keypad is used to navigate through the menu structure. Specific locations are referred to throughout this manual by using a path. The example shown in the figure gives the key presses required to reach the point given by the path **A3 MAINTENANCE ⇨⇩ ARCING CURRENT ⇨⇩ TOTAL ARCING CURRENT ∅B**.



1.2.3 CHANGING SETPOINTS

a) INTRODUCTION

There are several classes of setpoints, each distinguished by the way their values are displayed and edited. Now that we have become more familiar with maneuvering through messages, we can learn how to edit the values used by all setpoint classes.

Hardware and passcode security features are designed to provide protection against unauthorized setpoint changes. Since we will be programming new setpoints using the front panel keys, a hardware jumper must be installed across the setpoint access terminals (C10 and C11) on the back of the relay case. Attempts to enter a new setpoint without this electrical connection will result in an error message.

b) THE HELP KEY

Pressing the HELP key displays context sensitive information about setpoints such as the range of values and the method of changing the setpoint. Help messages will automatically scroll through all messages currently appropriate.

c) NUMERICAL SETPOINTS

Each numerical setpoint has its own minimum, maximum, and step value associated with it. These parameters define what is acceptable for the setpoint. Two methods of editing and storing a numerical setpoint value are available.

The 750/760 numeric keypad works the same as any electronic calculator. A number is entered one digit at a time with the 0 to 9 and decimal keys. The leftmost digit is entered first and the rightmost digit is entered last. Pressing the ESCAPE key before the ENTER key returns the original value to the display.

The VALUE ▲ key increments the displayed value by the step value, up to a maximum allowed and then wraps around to the minimum value. The VALUE ▼ key decrements the displayed value by the step value, down to a minimum value and then wraps around to the maximum value.

1. Move to the **S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING ⇨⇩ NOMINAL VT SECONDARY VOLTAGE** setpoint message.

```
NOMINAL VT SECONDARY
VOLTAGE: 120.0 V
```

2. Press the 6, 3, decimal, and 9 keys. The display message will change as shown.

```
NOMINAL VT SECONDARY
VOLTAGE: 63.9 V
```

3. Until the ENTER key is pressed, editing changes are not registered by the relay. Therefore, press the ENTER key to store the new value in memory. This flash message will momentarily appear as confirmation of the storing process. If 69.28 were entered, it would be automatically rounded to 69.3.

```
■ NEW SETPOINT
■ STORED
```

d) ENUMERATION SETPOINTS

Enumeration setpoints 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. Enumeration values are changed using the VALUE ▲ and VALUE ▼ keys.

1. Move to the **S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING ⇨ VT CONNECTION TYPE** setpoint message.

```
VT CONNECTION TYPE:
Wye
```

2. Press the VALUE ▲ key until the "Delta" value is displayed as shown (in this manual, setpoint values are always shown in double quotation marks).

```
VT CONNECTION TYPE:
Delta
```

3. Press the ENTER key to store this change into memory. As before, confirmation of this action will momentarily flash on the display.

```
■ NEW SETPOINT
■ STORED
```

e) OUTPUT RELAY SETPOINTS

Each output relay setpoint has the Auxiliary Output Relays 3 to 7 associated with it. Each can be toggled on or off individually, so that any combination of relays can be activated upon detection of the initiating condition. Output relay configuration type values are changed by using the 3 to 7 keys. Each key toggles the display between the corresponding number and a hyphen.

1. Move to the **S5 PROTECTION ⇨⇩ PHASE CURRENT ⇨ PHASE TIME O/C 1 ⇨⇩ PHASE TIME O/C 1 RELAYS (3-7)** setpoint message.

```
PHASE TIME O/C 1
RELAYS (3-7): -----
```

2. If an application requires the Phase TOC protection element to operate the 3 Auxiliary output relay, select this output relay by pressing the 3 key.

```
PHASE TIME O/C 1
RELAYS (3-7): 3----
```

3. Press the ENTER key to store this change into memory. As before, confirmation of this action will momentarily flash on the display.

```
■ NEW SETPOINT
■ STORED
```

The output relay setpoint values are represented by a 1-row, 5-column matrix. For example, a value of "3---7" activates Auxiliary Relays 3 and 7, while a value of "34567" activates all five Auxiliary relays.

f) TEXT SETPOINTS

Text setpoints 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. The editing and storing of a text value is accomplished with the use of the ENTER, VALUE ▼, VALUE ▲, and ESCAPE keys.

1. Move to message **S3 LOGIC INPUTS ⇨ USER INPUT A ⇨ USER INPUT A NAME** setpoint message. The name of this user defined input is going to be changed in this section.

```
USER INPUT A NAME:
User Input A
```

2. If an application is to be using the relay as a substation monitor, it is more informative to rename this input ‘Substation Monitor’. Press the ENTER key and a solid cursor (■) will appear in the first character position.

```
USER INPUT A NAME:
■ser Input A
```

3. Press the VALUE ▼ or VALUE ▲ key until the character "S" is displayed in the first position. Now press the ENTER key to store the character and advance the cursor to the next position. Change the second character to a "u" in the same manner. Continue entering characters in this way until all characters the text "Substation Monitor" are entered. Note that a space is selected like a character. If a character is entered incorrectly, press the ENTER key repeatedly until the cursor returns to the position of the error. Re-enter the character as required. Once complete, press the ESCAPE key to remove the solid cursor and view the result.

```
USER INPUT A NAME:
Substation Monitor
```

1.2.4 APPLICATION EXAMPLE

a) DESCRIPTION

The 750 and 760 relays contain many features designed to accommodate a wide range of applications. This chapter is provided to guide you, the first time user, through a real-world application. The following step-by-step installation example, provides you with a quick and convenient way of becoming familiar with the relay. To start, simply power on the unit, and follow the instructions in this tutorial. The example assumes the following system characteristics. It also assumes that relay setpoints are unaltered from their factory default values.

- **Power System Data**

  System: 3Φ, 4 wire

  Frequency: 60 Hz

  Line Voltage: 13.8 kV

  Maximum Current: 600 A

- **Control System Requirements**

  All protection elements used are to trip the breaker.

  Breaker position monitoring via 52b contact only.

  Only current metering is required.

  Contact Inputs: Remote open and close contacts from RTU. Remote/local selection from panel hand switch. Reset from RTU. Alarm after 100 second delay from substation monitor

  Contact Outputs: Trip and close to breaker control circuit (trip and close relays). Relay failure alarm to RTU (self-test warning relay, no programming required). Alarm contact to RTU (setup in User Function for “Substation Monitor”)

  No data communications to other equipment.

- **Instrument Transformer Data**

  Bus VTs: 3 × Wye connected, ratio = 14.4 kV:120 V

  Phase CTs: 3 × Wye connected, ratio = 600:5 A

- **Phase Protection Settings**

  Time Overcurrent 1: Curve Shape = Moderately Inverse; Pickup = 840 A; Multiplier = 20.2

  Instantaneous Overcurrent 1: Pickup = 840 A; Phases Required = Any Two; Delay = 0 seconds

  Instantaneous Overcurrent 2: Pickup = 10100 A; Phases Required = Any Two; Delay = 0 seconds

- **Neutral Protection Settings**

  Time Overcurrent 1: curve shape = Moderately Inverse; pickup = 120 A; multiplier = 10

  Instantaneous Overcurrent 1: Pickup = 120 A; Delay = 0 seconds

  Instantaneous Overcurrent 2: Pickup = 2000 A; Delay = 0 seconds

You should now be familiar with maneuvering through and editing setpoint messages. As such, we will now limit our discussion to just the values that must be programmed, in order to meet the requirements of the example application. Any setpoints not explicitly mentioned should be left at the factory default value.

b) S2 SYSTEM SETPOINTS

The S2 setpoints page contains setpoints for entering the characteristics of the equipment on the feeder electrical system. In our example, these characteristics are specified under **POWER SYSTEM DATA** and **INSTRUMENT TRANSFORMER DATA**. From this information and the resulting calculations, program S2 setpoints as indicated.

For current transformers, make the following change in the **S2 SYSTEM SETUP ⇨ CURRENT SENSING** setpoints page:

> **PHASE CT PRIMARY:** "600 A"

For voltage transformers, make the following changes in the **S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING** setpoints page:

> **VT CONNECTION TYPE:** "Wye"
> **NOMINAL VT SECONDARY VOLTAGE:** "66.4 V" (13.8kV ø-ø ≡ 7.97kV ø-N; 7.97kV / 120 = 66.4 V)
> **VT RATIO:** "120:1" (14.4 kV VT_{pri} / 120V VT_{sec})

Make the following change in the **S2 SYSTEM SETUP ⇨⇩ POWER SYSTEM** setpoints page to reflect the power system:

> **NOMINAL FREQ:** “60 Hz”

c) S3 LOGIC INPUTS SETPOINTS

The S3 setpoints page is for entering the characteristics of the logic inputs. In our example, these characteristics are specified under the Control System Requirements heading. Program S3 setpoints as indicated.

For breaker position monitoring, enter the following values in the **S3 LOGIC INPUTS ⇨ LOGIC INPUTS SETUP** setpoints page:

> **INPUT 2 NAME:** "Brkr Position (52b)"
> **INPUT 2 ASSERTED LOGIC:** "Contact Close"

then enter the following value in the **S3 LOGIC INPUTS ⇨⇩ BRKR FUNCTIONS** setpoint page:

> **52B CONTACT:** "Input 2"

For the Remote Open/Close and Reset RTU contacts, enter the following values in the **S3 LOGIC INPUTS ⇨ LOGIC INPUTS SETUP** setpoints page:

> **INPUT 3 NAME:** "Local Mode"
> **INPUT 3 ASSERTED LOGIC:** "Contact Close"
> **INPUT 4 NAME:** "Remote Open"
> **INPUT 4 ASSERTED LOGIC:** "Contact Close"
> **INPUT 5 NAME:** "Remote Close"
> **INPUT 5 ASSERTED LOGIC:** "Contact Close"
> **INPUT 6 NAME:** "Reset"
> **INPUT 6 ASSERTED LOGIC:** "Contact Close"

then enter the following values in the **S3 LOGIC INPUTS ⇨⇩ CONTROL FUNCTIONS** setpoint page:

> **LOCAL MODE:** "Input 3"
> **RESET:** "Input 6"
> **REMOTE OPEN:** "Input 4"
> **REMOTE CLOSE:** "Input 5"

To setup an Alarm-after-Delay Input. make the following changes to the **S3 LOGIC INPUTS ⇨⇩ USER INPUT A** setpoints page:

USER INPUT A NAME: "Substation Monitor"
USER INPUT A SOURCE: "Input 1"
USER INPUT A FUNCTION: "Alarm"
USER INPUT A RELAYS (3-7): "3----"
USER INPUT A DELAY: "100.00 s"

d) S5 PROTECTION SETPOINTS

The S5 Protection setpoints page contains setpoints for entering protection element characteristics. In our example, these characteristics are specified under **PHASE CURRENT** and **NEUTRAL CURRENT**. From this data and the resulting calculations, program the S5 setpoints as indicated.

For the Phase Time Overcurrent 1 element, enter the following values in the **S5 PROTECTION ⇨ PHASE CURRENT ⇨⇩ PHASE TIME OC 1** setpoints page:

PHASE TIME OC 1 FUNCTION: "Trip"
PHASE TIME OC 1 PICKUP: "1.40 x CT" (840 A pickup / 600 A CT primary)
PHASE TIME OC 1 CURVE: "Mod Inverse"
PHASE TIME OC 1 MULTIPLIER: "20.20"
PHASE TIME OC 1 RESET: "Instantaneous"

For the Phase Instantaneous Overcurrent 1 element, enter the following values in the **S5 PROTECTION ⇨ PHASE CURRENT ⇨⇩ PHASE INST OC 1** setpoints page:

PHASE INST OC 1 FUNCTION: "Trip"
PHASE INST OC 1 PICKUP: "1.40 x CT" (840 A pickup / 600 A CT primary)
PHASE INST OC 1 DELAY: "0.00 s"
PHASES REQUIRED FOR OPERATION: "Any Two"

For the Phase Instantaneous Overcurrent 2 element, enter the following values in the **S5 PROTECTION ⇨ PHASE CURRENT ⇨⇩ PHASE INST OC 2** setpoints page:

PHASE INST OC 2 FUNCTION: "Trip"
PHASE INST OC 2 PICKUP: "16.83 x CT" (10100 A pickup / 600 A primary)
PHASE INST OC 2 DELAY: "0.00 s"
PHASES REQUIRED FOR OPERATION: "Any Two"

For the Neutral Time Overcurrent 1 element, enter the following values in the **S5 PROTECTION ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL TIME OC 1** setpoints page:

NEUTRAL TIME OC 1 FUNCTION: "Trip"
NEUTRAL TIME OC 1 PICKUP: "0.20 x CT" (120 A pickup / 600 A primary)
NEUTRAL TIME OC 1 CURVE: "Mod Inverse"
NEUTRAL TIME OC 1 MULTIPLIER: "10.00"
NEUTRAL TIME OC 1 RESET: "Instantaneous"

For the Neutral Instantaneous Overcurrent 1 element, enter the following values in the **S5 PROTECTION ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL INST OC 1** setpoints page:

NEUTRAL INST OC 1 FUNCTION: "Trip"
NEUTRAL INST OC 1 PICKUP: "0.20 x CT" (120 A pickup / 600 A primary)
NEUTRAL INST OC 1 DELAY: "0.00 s"

For the Neutral Instantaneous Overcurrent 2 element, enter the following values in the **S5 PROTECTION ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL INST OC 2** setpoints page:

NEUTRAL INST OC 2 FUNCTION: "Trip"
NEUTRAL INST OC 2 PICKUP: "3.33 x CT" (2000 A pickup / 600 A primary)
NEUTRAL INST OC 2 DELAY: "0.00 s"

The Ground and Negative Sequence Overcurrent elements are disabled as follows:

S5 PROTECTION ⇨⇩ GROUND CURRENT ⇨ GROUND TIME OC ⇨ GROUND TIME O/C FUNCTION: "Disabled"
S5 PROTECTION ⇨⇩ GROUND CURRENT ⇨⇩ GROUND INST OC ⇨ GROUND INST O/C FUNCTION: "Disabled"
S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE ⇨ NEG SEQ TIME OC ⇨ NEG SEQ TIME OC FUNCTION: "Disabled"
S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE ⇨⇩ NEG SEQ INST OC ⇨ NEG SEQ INST O/C FUNCTION: "Disabled"

e) INSTALLATION

Now that programming for the sample application is complete, the relay should be put in the Ready state. Note that the relay is defaulted to the Not Ready state before it leaves the factory. This minor self-test warning, diagnostic message, warns that the 750/760 has not been programmed for its intended application. If this warning is ignored, protection is active and will be using factory default setpoints. The Relay In Service LED Indicator will be on.

The following message indicates that the relay is in the Not Ready state:

```
■ SELF-TEST WARNING
■ Relay Not Ready
```

Move to the **S1 RELAY SETUP ⇨⇩ INSTALLATION ⇨⇩ 750 OPERATION** setpoint message. To put the relay in the Ready state, press the VALUE ▲ key until the **READY** message is displayed and press ENTER. Enter "Yes" at the **ARE YOU SURE?** prompt. The Relay In Service LED Indicator will now turn on and the **Relay Not Ready** diagnostic message will disappear.

1.2.5 COMMISSIONING

Extensive commissioning tests are available in Chapter 8: Commissioning Tests. Commissioning tables for recording required settings are available in Microsoft Excel format from the GE Multilin website at http://www.GEindustrial.com/multilin. The website also contains additional technical papers and FAQs relevant to the 750/760 Feeder Management Relay.

2.1.1 DESCRIPTION

The 750/760 Feeder Management Relays are microprocessor-based units intended for the management and primary protection of distribution feeders, as well as for the management and backup protection of buses, transformers, and transmission lines. The 760 relay is particularly suited to overhead feeders, where automatic reclosing is normally applied.

Each relay provides protection, control, and monitoring functions with both local and remote human interfaces. They also display the present trip/alarm conditions, and most of the more than 35 measured system parameters. Recording of past trip, alarm or control events, maximum demand levels, and energy consumption is also performed.

These relays contain many innovative features. To meet diverse utility standards and industry requirements, these features have the flexibility to be programmed to meet specific user needs. This flexibility will naturally make a piece of equipment difficult to learn. To aid new users in getting basic protection operating quickly, setpoints are set to typical default values and advanced features are disabled. These settings can be reprogrammed at any time.

Programming can be accomplished with the front panel keys and display. Due to the numerous settings, this manual method can be somewhat laborious. To simplify programming and provide a more intuitive interface, setpoints can be entered with a PC running the 750/760PC software provided with the relay. Even with minimal computer knowledge, this menu-driven software provides easy access to all front panel functions. Actual values and setpoints can be displayed, altered, stored, and printed. If settings are stored in a setpoint file, they can be downloaded at any time to the front panel program port of the relay via a computer cable connected to the serial port of any personal computer.

A summary of the available functions and a single-line diagram of protection and control features is shown below. For a complete understanding of each features operation, refer to Chapter 5: Setpoints. The logic diagrams include a reference to every setpoint related to a feature and show all logic signals passed between individual features. Information related to the selection of settings for each setpoint is also provided.

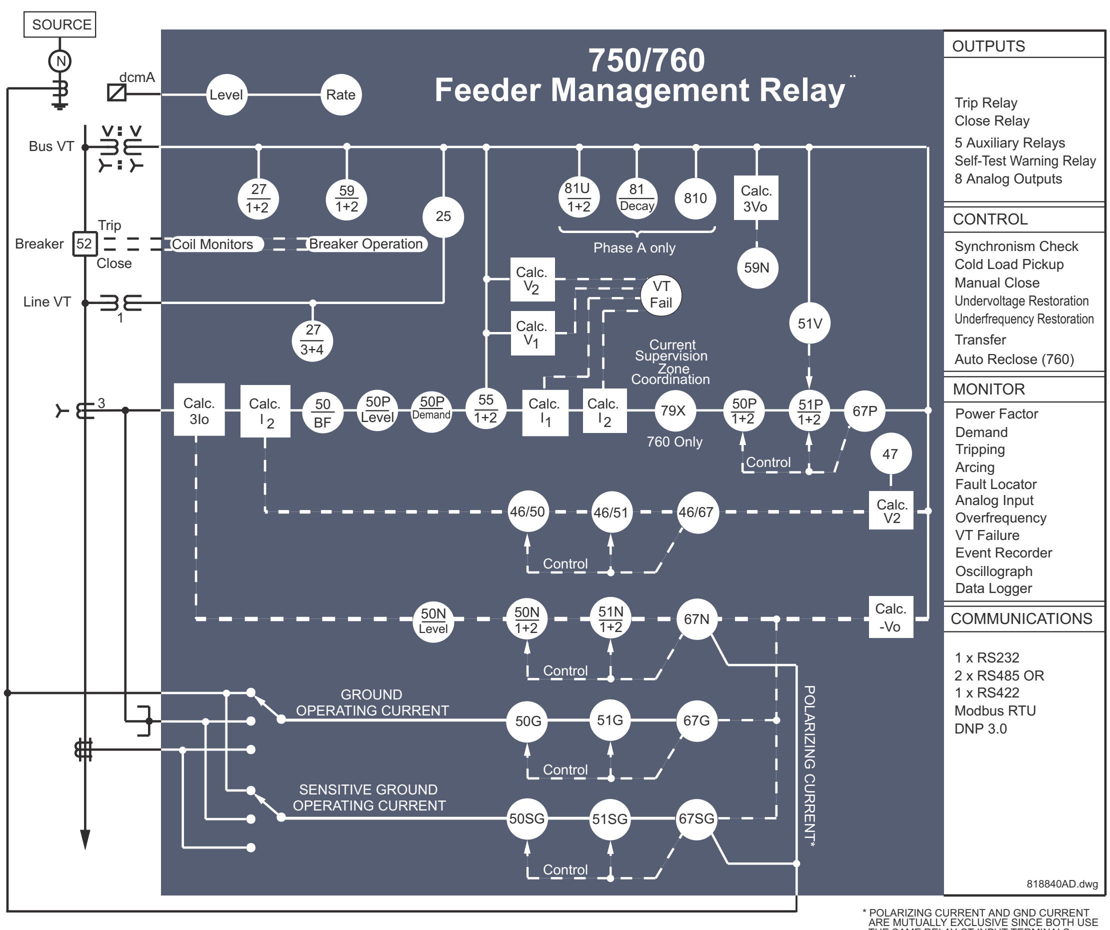


Figure 2–1: FUNCTIONAL BLOCK DIAGRAM

ANSI	PROTECTION / CONTROL	FEEDER			BUS		TRANSFORMER	LINE
		Capacitor	Radial	Two-ended	Backup	Transfer	Backup	Backup
27	Bus / Line Undervoltage	●	●	●	●	●		●
47	Negative Sequence Voltage	●	●	●	●		●	●
50	Phase/Neutral/Gnd/Neg Seq/Sens Gnd Inst O/C	●	●	●			●	●
51	Phase/Neutral/Gnd/Neg Seq/Sens Gnd Time O/C	●	●	●	●	●	●	●
59	Bus Overvoltage/Neutral Displacement	●	●	●	●		●	●
67	Phase/Neutral/Neg Seq/Sens Gnd/Gnd Directional Control			●	●		●	●
81	Bus Underfrequency/Rate of Change				●		●	●
	Undervoltage Automatic Restoration	●	●	●	●		●	
	Underfrequency Automatic Restoration	●	●	●	●		●	
	Breaker Failure with Current Superv.	●	●	●	●	●	●	●
	Bus Transfer					●		
	Programmable Logic Inputs	●	●	●	●	●	●	●
	Multiple Setpoint Groups	●	●	●	●	●	●	●

ANSI	MONITORING / CONTROL	FEEDER			BUS		TRANSFORMER	LINE
		Capacitor	Radial	Two-ended	Backup	Transfer	Backup	Backup
25	Synchrocheck			●		●		●
50	Phase/Neutral Current Level	●	●	●	●	●	●	●
55	Power Factor	●	●					
79	Autoreclose (760 only)		●	●				●
81	Overfrequency							●
	Breaker Open/Close	●	●	●	●	●	●	●
	Manual Close Feature Blocking	●	●	●		●	●	
	Cold Load Pickup Feature Blocking		●	●	●		●	
	Breaker Operation Failure	●	●	●	●	●	●	●
	Trip/Close Circuit Failure	●	●	●	●	●	●	●
	Total Breaker Arcing Current	●	●	●	●	●	●	●
	VT Failure	●	●	●				●
	Demand (A, MW, Mvar, MVA)	●	●	●	●	●	●	●
	Analog Input	●	●	●	●	●	●	●
	Event Recording	●	●	●	●	●	●	●
	Analog Output	●	●	●				●
	Fault Locator		●	●				●
	Trip Counter	●	●	●	●	●	●	●

FEATUR60/50.AI

Figure 2–2: SUMMARY OF FEATURES

2.1.2 THEORY OF OPERATION

Relay functions are controlled by two processors: a Motorola 68332 32-bit microprocessor measures all analog signals and logic inputs, outputs all analog signals, and controls all output relays; an Intel 80C186 16-bit microprocessor reads all user input including communications, and outputs to the faceplate display and LEDs. The processors pass information to each other via an RS485 serial communications channel. The remainder of this section describes the algorithms and operations that are critical to protection elements.

CURRENT AND VOLTAGE WAVEFORM CAPTURE:

Current and voltage transformers (CTs and VTs) are used to scale-down the incoming current and voltage signals from the source instrument transformers. The current and voltage signals are then passed through a 400 Hz low pass anti-aliasing filter. All signals are then simultaneously captured by sample and hold buffers to ensure there are no phase shifts. The signals are converted to digital values by a 12-bit A/D converter before finally being passed on to the 68332 CPU for analysis.

Both current and voltage are sampled sixteen times per power frequency cycle with frequency tracking control. These ‘raw’ samples are calibrated in software and then placed into the waveform capture buffer thus emulating a fault recorder. The waveforms can be retrieved from the relay via the 750/760PC software for display and diagnostics.

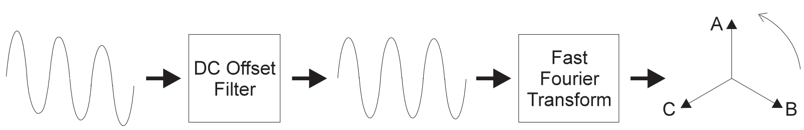
FREQUENCY TRACKING:

Frequency measurement is done by measuring the time between zero crossings of the Bus VT A and Line VT voltage inputs. Both signals are passed through a 72 Hz low pass filter to prevent false zero crossings. Frequency readings are discarded if the rate of change between two successive cycles is greater than 10 Hz/second. This prevents momentary false frequency readings due to noise, phase reversals, or faults.

Frequency tracking utilizes the measured frequency to set the sampling rate for current and voltage which results in better accuracy for the FFT algorithm for off-nominal frequencies. Also, sampling is synchronized to the Va-x voltage zero crossing which results in better co-ordination for multiple 750/760 relays on the same bus. If a stable frequency signal is not available then the sampling rate defaults to the nominal system frequency.

PHASORS, TRANSIENTS, AND HARMONICS:

Current waveforms are processed once every cycle with a DC Offset Filter and a Fast Fourier Transform (FFT) to yield phasors at the fundamental power system frequency. The resulting phasors have fault current transients and all harmonics removed. This results in an overcurrent relay that is extremely secure and reliable and one that will not overreach. The following diagram illustrates the signal processing performed on the AC current inputs:



PROCESSING OF AC CURRENT INPUTS:

The DC Offset Filter is an infinite impulse response (IIR) digital filter which removes the DC component from the asymmetrical current present at the moment a fault occurs. This is done for all current signals used for overcurrent protection; voltage signals bypass the DC Offset Filter. The filter results in no overreach of the overcurrent protection; unfortunately, the filter also causes slower overcurrent response times (0 to 50 ms) for faults marginally over the pickup level.

The Fast Fourier Transform (FFT) uses exactly one cycle of samples to calculate a phasor quantity which represents the signal at the fundamental frequency only; all harmonic components are removed. Further explanation of the FFT is beyond the scope of this discussion but can be found in any text on signal analysis. All subsequent calculations (e.g. RMS, power, demand, etc.) are based upon the current and voltage phasors so the resulting values do not have any harmonic components either.

PROTECTION ELEMENTS:

All protection elements are processed once every cycle to determine if a pickup has occurred or a timer has expired. The protection elements use RMS current/voltage based on the magnitude of the phasor; hence, protection is impervious to both harmonics and DC transients. Timing is not affected by system frequency.

LOGIC INPUTS:

Contact inputs are debounced to eliminate false operations due to noise. The inputs must be in the same state for three consecutive readings spaced evenly over one power frequency cycle before a new state is recognized.

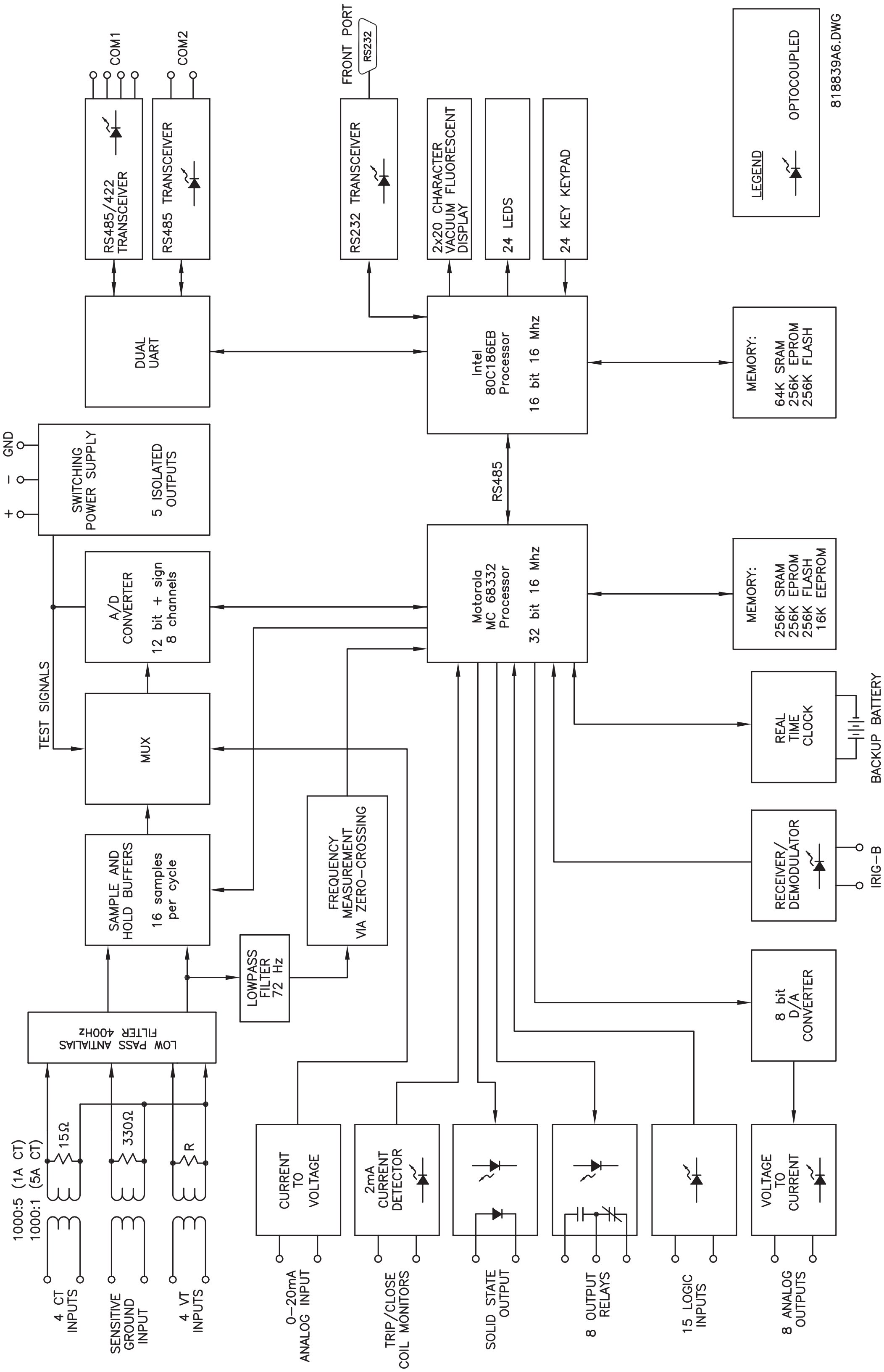


Figure 2–3: HARDWARE BLOCK DIAGRAM

2.1.3 ORDERING

The relay model number will be indicated on the side of the drawout unit. This identification label can be interpreted with the following order code.

Table 2–1: 750/760 ORDER CODES

	750	**– * –**	*** –**	*** –**	*** –**	*** –**	*****	750 Feeder Management Relay
	760	**– * –**	*** –**	*** –**	*** –**	*** –**	*****	760 Feeder Management Relay
Base Unit	750	|	|	|	|	|	|	750 Feeder Management Relay
	760	|	|	|	|	|	|	760 Feeder Management Relay with Autoreclose
Phase Current Inputs		P1	|	|	|	|	|	1 A Phase Current Inputs
		P5	|	|	|	|	|	5 A Phase Current Inputs
Zero-Sequence Current Inputs			G1	|	|	|	|	1 A Zero-Sequence Current Inputs
			G5	|	|	|	|	5 A Zero-Sequence Current Inputs
Sensitive Ground Current Input				S1	|	|	|	1 A Sensitive Ground Current Input
				S5	|	|	|	5 A Sensitive Ground Current Input
Control Power					LO		|	25 to 60 V DC; 20 to 48 V AC at 48 to 62 Hz
					HI		|	88 to 300 V DC; 70 to 265 V AC at 48 to 62 Hz
Analog Outputs						A1	|	Eight (8) 0 to 1 mA Analog Outputs
						A5	|	Eight (8) 0 to 5 mA Analog Outputs
						A10	|	Eight (8) 0 to 10 mA Analog Outputs
						A20	|	Eight (8) 4 to 20 mA Analog Outputs
Breaker Closed LED							R	Red LED for Breaker Closed indicator
							G	Green LED for Breaker Closed Indicator

Examples: the 750-P1-G1-S1-LO-A10-R specifies a 750 Feeder Management Relay with 1 A Phase, Zero-Sequence, and Sensitive Ground Current Inputs, low control power, eight 0 to 10 mA Analog Outputs and a red LED for the Breaker Closed indicator; the 760-P5-G5-S5-HI-A20-G specifies a 760 Feeder Management Relay with Autoreclose, 5 A Phase, Zero-Sequence, and Sensitive Ground Current Inputs, high control power, eight 4 to 20 mA Analog Outputs and a green LED for the Breaker Closed indicator.

The following accessories are also available:

- **DEMO:** Metal carry case in which the 750/760 can be mounted
- **SR19-1 or SR19-2 PANEL:** Single or double cutout 19" panels
- **RS-232/485:** RS232 to RS485 converter box for harsh industrial environments
- **5 A PHASE CT:** 50, 75, 100, 150, 200, 250, 300, 350, 400, 500, 600, 750, 1000 ratios
- **1 A PHASE CT:** 50, 75, 100, 150, 200, 250, 300, 350, 400, 500, 600, 750, 1000 ratios
- **SR 1 3/8" COLLAR:** For shallow switchgear, the collar reduces the depth of the relay by 1 3/8"
- **SR 3" COLLAR:** For shallow switchgear, the collar reduces the depth of the relay by 3"

2.2.1 APPLICABILITY

APPLICABILITY

Systems:	3 or 4 wire, 600 kV maximum 5000 A maximum
Frequency:	25 to 60 Hz nominal (frequency tracking allows operation from 16 to 65 Hz)

2.2.2 INPUTS

CONTROL POWER

Options:	LO/HI (specified when ordering)
LO range:	DC = 20 to 60 V AC = 20 to 48 V at 48 to 62 Hz.
HI range:	DC = 88 to 300 V AC = 70 to 265 V at 48 to 62 Hz.
Power:	25 VA nominal, 35 VA maximum

Voltage loss hold-up time: 30 ms

PHASE CURRENT

Source CT:	1 to 50000 A primary, 1 or 5 A secondary
Relay input:	1 A or 5 A (specified when ordering)
Burden:	Less than 0.2 VA at 1 or 5 A
Conversion range:	0.01 to 20 × CT (fundamental frequency only)
Accuracy:	at < 2 × CT: ±0.5% of 2 × CT at ≥ 2 × CT: ±1% of 20 × CT
Overload withstand:	1 second at 80 × rated current continuous at 3 × rated current

Calculated neutral current errors: 3 × phase inputs

GROUND CURRENT

Source CT:	1 to 50000 A primary, 1 or 5 A secondary
Relay input:	1 A or 5 A (specified when ordering)
Burden:	Less than 0.2 VA at 1 or 5 A
Conversion range:	0.01 to 20 × CT (fundamental frequency only)
Accuracy:	at < 2 × CT: ±0.5% of 2 × CT at ≥ 2 × CT: ±1% of 20 × CT
Overload withstand:	1 second at 80 × rated current continuous at 3 × rated current

SENSITIVE GROUND CURRENT

Source CT:	1 to 50000 A primary, 1 or 5 A secondary
Relay input:	1 A or 5 A (specified when ordering)
Burden:	Less than 0.2 VA at 1 or 5 A
Conversion range:	Low end: 0.005 × CT Maximum: 500 A primary (fundamental frequency only)
Accuracy:	at < 0.1 × CT: ±0.2% of 1 × CT at ≥ 0.1 × CT: ±1% of 1 × CT
Overload withstand:	1 second at 80 × rated current continuous at 3 × rated current

BUS AND LINE VOLTAGE

Source VT:	0.12 to 600 kV / 50 to 240 V
Source VT ratio:	1 to 5000 in steps of 0.1
Relay input:	50 to 240 V phase-neutral
Burden:	Less than 0.025 VA at 120 V or > 576 KW
Maximum continuous:	273 V phase-neutral (full-scale) CT (fundamental frequency only)
Accuracy (0 to 40°C):	±0.25% of full scale (10 to 130 V); ±0.8% of full scale (130 to 273 V) (For open delta, the calculated phase has errors 2 times those shown above)

LOGIC INPUTS

Inputs:	14 contact and / or virtual inputs, 6 virtual only (functions assigned to logic inputs)
Dry contacts:	1000 Ω maximum ON resistance (32 V DC at 2 mA provided by relay)
Wet contacts:	30 to 300 V DC at 2.0 mA (External DC voltage only)

ANALOG INPUTS

Current Input:	0 to 1 mA, 0 to 5 mA, 0 to 10 mA, 0 to 20 mA, or 4 to 20 mA (programmable)
Input Impedance:	375 Ω ± 10%
Conversion Range:	0 to 21 mA
Accuracy:	±1% of full scale

TRIP AND CLOSE COIL MONITORING

Acceptable voltage range: 20 to 250 V DC

Trickle current:	2 to 5 mA

IRIG-B

Amplitude modulated:	2.5 to 6 Vpk-pk at 3:1 signal ratio
DC shift:	TTL
Input impedance:	20 kΩ ±10%
Error:	±1.0 ms

2.2.3 MEASURED PARAMETERS

NOTE: In the following specifications, accuracies based on less than 2 × CT and 50 to 130 V inputs. The full-scale is defined as follows: Full Scale = 2 × CT at 1 × $VT_{Full\ Scale}$ × $\sqrt{3}$.

The harmonic components of current and voltage are removed from the input voltage and current parameters, so all relay measurements based on these quantities respond to the fundamental component only. To minimize errors, the A/D process utilizes a sampling rate that is automatically adjusted to be 16 samples per power frequency cycle when a measurable voltage is available. To prevent overreaching of overcurrent elements, a digital filter removes the transient DC component of currents.

CURRENT

Phasors: Phase A RMS current
Phase B RMS current
Phase C RMS current

% of load-to-trip accuracy: ±0.5% of full scale

VOLTAGE

Phasors: Phase A-N (A-B) voltage
Phase B-N (B-C) voltage
Phase C-N (C-A) voltage

Accuracy: ±0.25% of full scale

FREQUENCY

Measured: A-N (A-B) bus and line voltage

Range: 16 to 90 Hz

Accuracy: ±0.02 Hz

SYMMETRICAL COMPONENTS

Current level accuracy: ±1.5% of full scale

Voltage level accuracy: ±0.75% of full scale

Current and voltage angle accuracy: ±2°

3Φ POWER FACTOR

Range: 0.00 Lag to 1.00 to 0.00 Lead

Accuracy: ±0.02

3Φ REAL POWER

Range: –3000.0 to 3000.0 MW

Accuracy: ±1% of full scale

3Φ REACTIVE POWER

Range: –3000.0 to 3000.0 Mvar

Accuracy: ±1% of full scale (see note above)

3Φ APPARENT POWER

Range: –3000.0 to 3000.0 MVA

Accuracy: ±1% of full scale (see note above)

WATT-HOURS

Range: –2.1 × 108 to 2.1 × 108 MWh

Accuracy: ±2% of full scale (see note above) per hr

VAR-HOURS

Range: –2.1 × 108 to 2.1 × 108 Mvarh

Accuracy: ±2% of full scale (see note above) per hr

DEMAND

Phase A/B/C current range: 0 to 65535 A

3Φ real power range: –3000.0 to 3000.0 MW

3Φ reactive power range: –3000.0 to 3000.0 Mvar

3Φ apparent power range: –3000.0 to 3000.0 MVA

Measurement type:
Thermal Exponential, 90% response time (programmed):
5, 10, 15, 20, 30, or 60 min.
Block Interval / Rolling Demand, time interval (programmed):
5, 10, 15, 20, 30, or 60 min.

Accuracy: ±2% of full scale (see note above)

2.2.4 PROTECTION ELEMENTS

PHASE / NEUTRAL / GROUND / NEG SEQ TOC

Pickup level: 0.05 to 20.00 × CT in steps of 0.01

Dropout level: 97 to 98% of pickup

Curve shapes: ANSI Extremely/Very/Moderately/Normally Inverse, Definite Time (0.1 s base curve), IEC Curve A/B/C and Short, FlexCurve™ A/B (programmable curves), IAC Extreme/Very/Inverse/Short

Curve multiplier: 0.00 to 100.00 in steps of 0.01

Reset type: Instantaneous/Linear

Level accuracy: per current input (I_2 is 3 × input error)

Timing accuracy: ±3% of trip time or ±40 ms (whichever is greater) at ≥ 1.03 × PU

SENSITIVE GROUND TOC

Pickup level: 0.005 to 1.000 × CT in steps of 0.001

Dropout level: 97 to 98% of Pickup

Curve shapes: ANSI Extremely/Very/Moderately/Normally Inverse, Definite Time (0.1 s base curve), IEC Curve A/B/C and Short, FlexCurve™ A/B (programmable curves), IAC Extreme/Very/Inverse/Short

Curve multiplier: 0.00 to 100.00 in steps of 0.01

Reset type: Instantaneous/Linear

Level accuracy: per current input (I_2 is 3 × input error)

Timing accuracy: ±3% of trip time or ±40 ms (whichever is greater) at ≥ 1.03 × PU

VOLTAGE RESTRAINED PHASE TOC

Pickup adjustment: Modifies pickup from 0.10 to 0.90 × VT nominal in a fixed line relationship

PHASE / NEUTRAL / GROUND / NEG SEQ IOC

Pickup level: 0.05 to 20.00 × CT in steps of 0.01
Dropout level: 97 to 98% of pickup
Time delay: 0.00 to 600.00 s in steps of 0.01
Level accuracy: per phase / neutral / ground current input (I_2 is 3 × phase input error)
Timing accuracy at 0 ms time delay (no intentional delay):
relay contacts = 50 ms max.
solid state output = 45 ms max.
Timing accuracy at non-zero time delay:
delay accuracy = 0 to 20 ms
Phases: Any one, any two, or all three (programmable) phases must operate for output (not for I_2)

SENSITIVE GROUND IOC

Pickup level: 0.005 to 1.000 × CT in steps of 0.00
Dropout level: 97 to 98% of pickup
Time delay: 0.00 to 600.00 s in steps of 0.01
Level accuracy: per phase / neutral / ground current input (I_2 is 3 × phase input error)
Timing accuracy at 0 ms time delay (no intentional delay):
relay contacts = 50 ms max.
solid state output = 45 ms max.
Timing accuracy at non-zero time delay:
delay accuracy = 0 to 20 ms
Phases: Any one, any two, or all three (programmable) phases must operate for output (not for I_2)

PHASE DIRECTIONAL

Relay Connection: 90° (quadrature)
Polarizing Voltage: Phase A: Vbc; Phase B: Vca; Phase C: Vab
MTA: 0 to 359° in steps of 1
Angle Accuracy: ±2°
Operation Delay: 25 to 40 ms

NEUTRAL DIRECTIONAL

NOTE: Polarized by voltage, current, or both voltage and current. For voltage element polarizing, the source VTs must be connected in Wye.

Polarizing voltage: –Vo
Polarizing current: Ig
MTA: 0 to 359° in steps of 1
Angle accuracy: ±2°
Operation delay: 25 to 40 ms

GROUND / SENSITIVE GROUND DIRECTIONAL

NOTE: Polarized by voltage, current, or both voltage and current. For voltage element polarizing, the source VTs must be connected in Wye.

Polarizing voltage: –Vo
Polarizing current: Ig
MTA: 0 to 359° in steps of 1
Angle accuracy: ±2°
Operation delay: 25 to 40 ms

BUS / LINE UNDERVOLTAGE

Minimum voltage: > programmable threshold from 0.00 to 1.25 × VT in steps of 0.01
Pickup level: 0.00 to 1.25 × VT in steps of 0.01
Dropout level: 102 to 103% of pickup
Curve: Definite Time or Inverse Time
Time delay: 0.0 to 6000.0 s in steps of 0.1
Phases: Any one, any two, or all three (programmable) phases must operate for output (Bus Undervoltage only)
Level accuracy: per voltage input
Timing accuracy: ±100 ms

OVERVOLTAGE

Pickup level: 0.00 to 1.25 × VT in steps of 0.01
Dropout level: 97 to 98% of pickup
Time delay: 0.0 to 6000.0 s in steps of 0.1 (Definite Time)
Phases: Any one, any two, or all three (programmable) phases must operate for output
Level accuracy: per voltage input
Timing accuracy: ±100 ms

NEGATIVE SEQUENCE VOLTAGE

Pickup level: 0.00 to 1.25 × VT in steps of 0.01
Dropout level: 97 to 98% of pickup
Time delay: 0 to 6000.0 s in steps of 0.1 (Definite Time or Inverse Time)
Level accuracy: 3 × voltage input error
Timing accuracy: ±100 ms

UNDERFREQUENCY

Minimum voltage: 0.00 to 1.25 × VT in steps of 0.01 in Phase A
Pickup level: 20.00 to 65.00 Hz in steps of 0.01
Dropout level: Pickup + 0.03 Hz
Time delay: 0 to 600.00 s in steps of 0.01 (Definite Time)
Level accuracy: ±0.02 Hz
Timing accuracy: ±25 ms at 60 Hz; ±30 ms at 50 Hz

BREAKER FAILURE

Pickup level: 0.05 to 20.0 × CT in steps of 0.01
Dropout level: 97 to 98% of pickup
Time delay: 0.03 to 1.00 s in steps of 10
Timing accuracy: ±20 ms error
Level accuracy: per CT input

NEUTRAL DISPLACEMENT

Pickup level: 0.00 to 1.25 × VT in steps of 0.01
Dropout level: 97 to 98% of pickup
Curve shapes: ANSI Extremely/Very/Moderately/Normally Inverse, Definite Time (0.1 s base curve), IEC Curve A/B/C and Short, FlexCurve™ A/B (programmable curves), IAC Extreme/Very/Inverse/Short
Curve multiplier: 0.00 to 100.00 in steps of 0.01
Reset type: Instantaneous/Linear
Level accuracy: 3 × voltage input error
Timing accuracy: ±50 ms

REVERSE POWER (IF ENABLED)

Pickup level:	0.015 to 0.600 × rated power
Dropout level:	94 to 95% of pickup
Reset time:	less than 100 ms
Time delay:	see 3F Real Power metering
Timing accuracy:	±200 ms (includes Reverse Power pickup time)

2.2.5 MONITORING ELEMENTS

PHASE/NEUTRAL CURRENT

Pickup level:	0.05 to 20.00 × CT in steps of 0.01
Dropout level:	97 to 98% of pickup
Time delay:	0 to 60000 s in steps of 1 (Definite Time)
Level accuracy:	per current input
Timing accuracy:	±100 ms

POWER FACTOR

Required voltage:	>30% of nominal in all phases
Pickup level:	0.50 lag to 0.50 lead in steps of 0.01
Dropout level:	0.50 lag to 0.50 lead in steps of 0.01
Time delay:	0 to 60000 s in steps of 1 (Definite Time)
Level accuracy:	±0.02
Timing accuracy:	±100 ms

ANALOG IN THRESHOLD

Pickup level:	0 to 65535 units in steps of 1
Dropout level:	2 to 20% of Pickup (programmable, under or over)
Time delay:	0 to 60000 s in steps of 1
Level accuracy:	±1%
Timing accuracy:	±100 ms

ANALOG IN RATE

Pickup level:	–1000 to 1000 mA/hr in steps of 0.1
Dropout level:	97 to 98% of Pickup
Time delay:	0 to 60000.0 s in steps of 1
Level accuracy:	±1%
Timing accuracy:	±100 ms

OVERFREQUENCY

Required voltage:	>30% of nominal in Phase A
Pickup level:	20.01 to 65.00 Hz in steps of 0.01
Dropout level:	Pickup – 0.03 Hz
Time delay:	0.0 to 6000.0 s in steps of 0.1
Level accuracy:	±0.02 Hz
Timing accuracy:	±34 ms at 60 Hz; ±40 ms at 50 Hz

FAULT LOCATOR

Range:	–327.68 to 327.66 km/miles 0 to 65534 ohms
Memory:	stores the 10 most recent faults

DATA LOGGER

Data channels:	8 channels; same parameters as for analog outputs available
Sample rate:	per cycle / per second / per minute / every 5, 10, 15, 20, 30, or 60 minutes
Trigger source:	pickup/trip/dropout, control/alarm event, logic input, manual command, or continuous
Trigger position:	0 to 100%
Storage capacity:	2 to 16 events with 2048 to 256 samples of data respectively (4096 if continuous)

TRIP COUNTERS

Accumulates all ground, sensitive ground, neutral, negative sequence, and phase overcurrent trips.

DEMAND

NOTE: Demand accuracies are based on less than 2 × CT and 50 to 130 V inputs.

Measured values: Phase A/B/C current (A), 3Φ real power (MW), 3Φ reactive power (Mvar), 3Φ apparent power (MVA)

Measurement type:
- Thermal Exponential, 90% response time (programmed): 5, 10, 15, 20, 30, or 60 min.
- Block Interval / Rolling Demand, time interval (programmed): 5, 10, 15, 20, 30, or 60 min.
- Block Interval with Start Demand Interval Logic Input pulses

Amps pickup level:	10 to 10000 in steps of 1
MW pickup level:	0.1 to 3000.0 in steps of 0.1
Mvar pickup level:	0.1 to 3000.0 in steps of 0.1
MVA pickup level:	0.1 to 3000.0 in steps of 0.1
Level accuracy:	±2%

VT FAILURE

Programmable to inhibit dependent features.

BREAKER FAILURE TO OPERATE

Time delay:	30 to 1000 ms in steps of 10
Timing accuracy:	0 to 20 ms error

ACCUMULATED ARCING CURRENT

Pickup level:	1 to 50000 kA^2-seconds in steps of 1
Start delay:	0 to 100 ms in steps of 1

TRIP / CLOSE COIL MONITORS

Detect open trip and close circuits.

PULSED OUTPUT

Pulsed output is 1 second on time and one second off time after the programmed interval.

2

WAVEFORM CAPTURE

Data channels:	4 currents, 3 voltages, 14 logic input states and 8 output relays
Sample rate:	16 per cycle
Trigger source:	Element pickup/trip/dropout, control/alarm event, logic input or manual command
Trigger position:	0 to 100%
Storage capacity:	2 to 16 events with 2048 to 256 samples of data respectively

EVENT RECORDER

Number of events:	128
Content:	event cause, 3 phase current phasors, 1 ground current phasor, sensitive ground current phasors, 3 voltage phasors, system frequency, synchronizing voltage, synchronizing frequency, and analog input level with a 1 ms time stamp.

LAST TRIP DATA

Records cause of most recent trip, 4 RMS currents, and 3 RMS voltages with a 1 ms time stamp.

2.2.6 CONTROL ELEMENTS

SYNCHROCHECK

Voltage difference:	0.01 to 100.00 kV in steps of 0.01
Phase difference:	0 to 100° in steps of 2
Frequency difference:	0.00 to 5.00 Hz in steps of 0.02
Bypass permissives:	DB & DL (dead bus and dead line) LL & DB (live line and dead bus) DL & LB (dead line and live bus) DL | DB (dead line or dead bus) DL X DB (either dead line or dead bus)

SETPOINT GROUPS

Number of groups:	4
Accessibility:	Can be changed from logic input or through communications
Included features:	TOC Curves, Phase TOC and IOC, Neutral TOC and IOC, Ground TOC and IOC, Negative Sequence OC and Voltage, Phase Directional, Ground Directional, Overvoltage, Undervoltage, Underfrequency, Breaker Failure

UNDERVOLTAGE RESTORATION

Initiated by:	Trip from Undervoltage 1, 2, 3 or 4
Minimum voltage level:	0.00 to 1.25 × VT in steps of 0.01
Time delay:	0.1 to 100.0 s in steps of 0.1
Incomplete seq. time:	1 to 10000 min. in steps of 1
Phases:	Any one, any two, or all three (programmable) phases must operate for output
Level accuracy:	per voltage input
Timing accuracy:	±100 ms

UNDERFREQUENCY RESTORATION

Initiated by:	Trip from Underfrequency 1 or 2
Minimum voltage level:	0.00 to 1.25 × VT in steps of 0.01
Minimum freq. level:	20.00 to 60.00 Hz in steps of 0.01
Time delay:	0.1 to 100.0 s in steps of 0.1
Incomplete seq. time:	1 to 10000 min in steps of 1
Level accuracy:	Per voltage and frequency input
Timing accuracy:	±100 ms

MANUAL CLOSE FEATURE BLOCKING

Operated by:	manual close command.
Programmability:	Block IOC for a selected period. Raise TOC pickup for a selected period.

COLD LOAD PICKUP FEATURE BLOCKING

Operated by:	logic input command or automatically
Programmability:	Block IOC for a selected period. Raise TOC pickup for a selected period.

TRANSFER SCHEME

Applicability:	Used for double-bus system with two normally-closed incoming and one normally-open bus tie circuit breaker.
Closing:	Automatic closing of the bus tie breaker after a loss of one source, with bus decayed voltage permissive.
Trip:	Trips a pre-selected breaker after the third breaker is manually closed (prevent-parallel operation).

AUTORECLOSE (760 ONLY)

Reclose attempts:	Up to four (4) before lockout.
Blocking:	Each reclose shot can block IOC and raise TOC Pickup.
Adjustability:	Current supervision can adjust the maximum number of shots to be attempted.

2.2.7 OUTPUTS

ANALOG OUTPUTS

Type:	Active
Outputs:	8 Channels; specify one of the following output ranges when ordering:
Output ranges:	0 to 1 mA, 0 to 5 mA, 0 to 10 mA, 4 to 20 mA
Maximum load:	12 kΩ for 0 to 1 mA output, 2.4 kΩ for 0 to 5 mA output, 1.2 kΩ for 0 to 10 mA output, 600 kΩ for 4 to 20 mA output
Isolation:	Fully isolated
Accuracy:	±1% of full scale
Response time:	100% indication in less than 6 power system cycles (100 ms at 60 Hz)

SOLID STATE TRIP

Make and carry:	15 A at 250 V DC for 500 ms

2.2.8 OUTPUT RELAYS

WARNING

Relay contacts must be considered unsafe to touch when the 750/760 is energized! If the output relay contacts are required for low voltage accessible applications, it is the customer's responsibility to ensure proper insulation levels.

CONFIGURATION

Number:	8
Type:	Trip (1) and Close (2) Relays: Form A Auxiliary Relays 3 to 7: Form C Self-Test Warning Relay 8: Form C
Contact material:	silver alloy
Contact durability:	100 000 operations (at 1800 operations/ hour) at rated load

FORM A CONTACT RATINGS

Applicability:	Trip and Close Relays (Relays 1 and 2)
Make:	30 A (per ANSI/IEEE C37.90)
Carry:	20 A continuous
Break (DC):	300 W resistive, 150 W inductive (L/R = 40 ms)
Break (AC):	5000 VA resistive 5000 VA inductive (PF = 0.4)

FORM C CONTACT RATINGS

Applicability:	Auxiliary Relays 3 to 7 Self-Test Warning Relay (Relay 8)
Make:	30 A (per ANSI/IEEE C37.90)
Carry:	10 A continuous for 15 seconds 5 A continuous
Break (DC):	150 W resistive, 90 W inductive (L/R = 40 ms)
Break (AC):	1250 VA resistive 500 VA inductive (PF = 0.4)

2.2.9 CPU

COMMUNICATIONS

Baud rate:	300 to 19200 baud
Parity:	programmable
Protocol:	Modbus RTU or DNP 3.0 protocol

EEPROM

100000 program/erase cycles max.

CLOCK

Resolution:	1 ms
Accuracy with IRIG-B:	±1 ms
Accuracy without IRIG-B:	±1 minute/month
Backup battery life:	10 years continuous use

2.2.10 PHYSICAL

TEMPERATURE

Operating range:	–40°C to +60°C
Ambient storage:	–40°C to +80°C
Ambient shipping	–40°C to +80°C

NOTE: At temperatures below –20°C, the LCD contrast may become impaired

ENVIRONMENTAL

Humidity:	up to 90% non-condensing
Pollution degree:	2
IP Rating:	40-X

CASE

Type:	Fully drawout unit (automatic CT shorts)
Approvals:	Meets CE drawout specifications
Seal:	Seal provision
Door:	Dust tight door
Mounting:	Panel or 19" rack mount
Weight:	7.9 kg (case and relay) 9.4 kg (shipping weight)

2.2.11 TESTING

SIMULATION

Simulation modes:	Programmable prefault, fault, and post-fault parameters. Simulation of circuit breaker and selection of whether or not to operate outputs relays.

TYPE TESTING

Fast transient:	per ANSI/IEEE C37.90.1 and IEC 801.4 Level 4 (5 kV at 5 × 50 ns, Ri = 50 Ω)
Insulation resistance:	per IEC 255-5 (500 V DC, 2000 MW)
Dielectric strength:	per IEC 255-5 and ANSI/IEEE C37.90 (2 kV at 60 Hz for 1 minute)
Surge withstand:	per IEC 255-22-1 and IEC 255-4 Class 3 (fast transient common mode 2.5 kV, differential modes 1 kV); per IEC 255-4 and ANSI/IEEE C37.90.1 (2.5 kV at 1 MHz, 400/second for 2 seconds, Ri = 200 Ω)
Electrostatic discharge:	per IEC 801.2 Class 4 (15 kV, 150 pF, 150 W)
Impulse voltage:	per IEC 255-5, 0.5 Joule 5kV (5 kV at 1.2 × 50 ms, 0.5 J, Ri = 500 Ω common and differential modes)
Current withstand:	per ANSI/IEEE C37.90 (40 × rated A for 2 sec., 80 × I_r for 1 sec.)
RFI:	per Ontario Hydro (150/450 MHz, 5 W transmitter at 25 cm and 50 MHz, 15 W mobile transmitter at 25 cm)
EMI:	per ANSI/IEEE C37.90.2 Electromagnetic Interference at 150 MHz and 450 MHz, 10V/m
Static:	per IEC 801-2 Static Discharge
Stress vibration:	per IEC 68-2-6 and IEC 255-21-1

PRODUCTION TESTS

Thermal cycling:	Operational test at ambient, reducing to –40°C and then increasing to 60°C
Dielectric strength:	On CT inputs, VT inputs, Control Power inputs, Switch inputs, Coil Supervision outputs, and Relay outputs (2 kV AC for 1 minute) to Safety Ground.

2.2.12 APPROVALS

UL
Recognized under E83849

CSA
Approved under LR 41286-56

CE
Conforms to IEC 947-1, IEC 1010-1

ISO
Manufactured to an ISO9001 registered program.

NOTE: **Specifications subject to change without notice.**

NOTE: **It is recommended that all relays must be powered up at least once per year to avoid deterioration of electrolytic capacitors and subsequent relay failure.**

3.1.1 DRAWOUT CASE

The 750/760 is packaged in the standard SR series arrangement which consists of a drawout relay and a companion case. The case provides mechanical protection for the drawout portion and is used to make permanent electrical connections to external equipment. Where required, case connectors are fitted with mechanisms, such as automatic CT shorting, to allow the safe removal of the relay from an energized panel. There are no electronic components in the case.

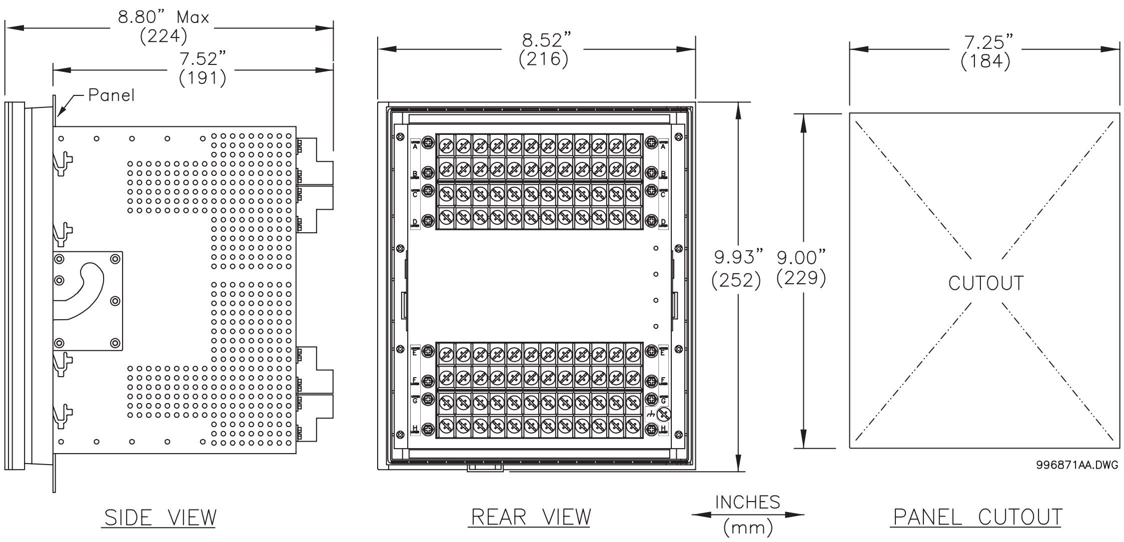


Figure 3–1: CASE DIMENSIONS

To prevent unauthorized removal of the drawout relay, a wire lead seal can be installed through the slot provided in the middle of the locking latch. With this seal in place, the relay cannot be removed from the case. Even though a passcode or setpoint access jumper can be used to prevent entry of setpoints and still allow monitoring of actual values, access to the front panel controls may still need to be restricted. As such, a separate seal can be installed on the outside of the door to prevent it from being opened.

Figure 3–2: DRAWOUT CASE SEAL

3.1.2 INSTALLATION

The 750/760 can be mounted alone or adjacent to another SR series unit on a standard 19” rack panel. Panel cutout dimensions for both conditions shown below. When planning the location of your panel cutout, ensure provision is made for the front door to swing open without interference to or from adjacent equipment.

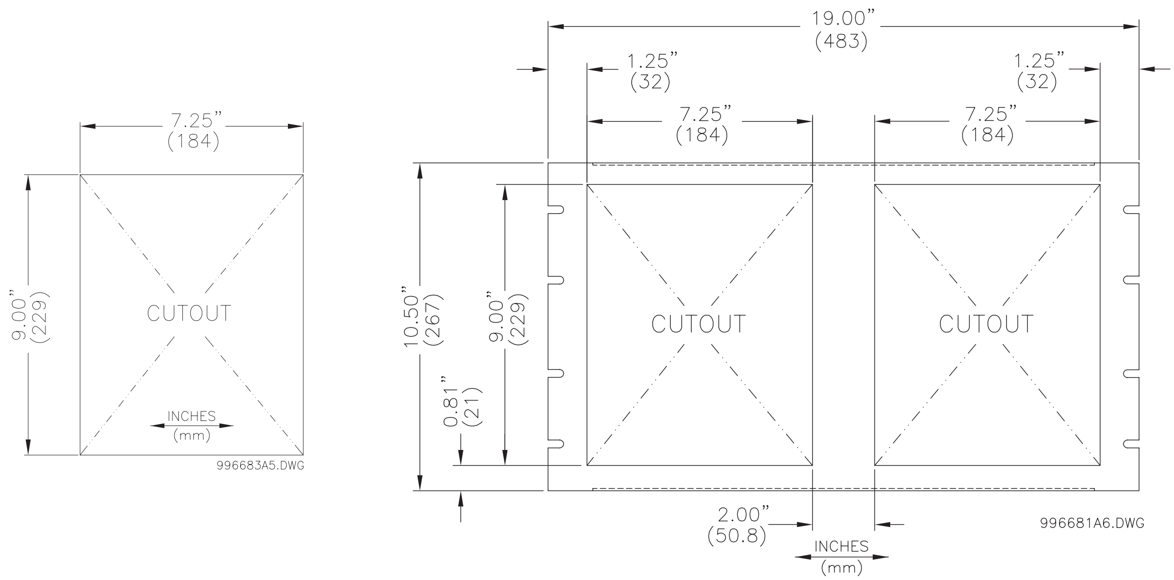


Figure 3–3: SINGLE AND DOUBLE UNIT PANEL CUTOUTS

Before mounting the SR unit in the supporting panel, remove the unit from the case. From the front of the panel, slide the empty case into the cutout. To ensure the case’s front bezel sits flush with the panel, apply pressure to the bezel’s front while bending the retaining tabs 90°. These tabs are located on the sides and bottom of the case and appear as shown in the illustration. After bending all tabs, the case will be securely mounted so that its relay can be inserted. The SR unit is now ready for panel wiring.

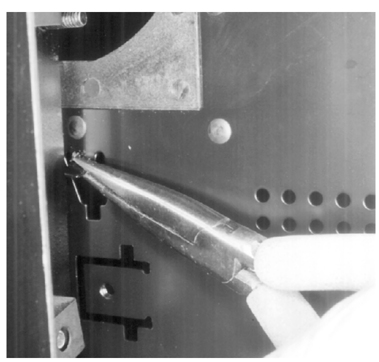


Figure 3–4: MOUNTING TABS

3.1.3 UNIT WITHDRAWAL AND INSERTION

CAUTION

TURN OFF CONTROL POWER BEFORE DRAWING OUT OR RE-INSERTING THE RELAY TO PREVENT MAL-OPERATION!

CAUTION

If an attempt is made to install a relay into a non-matching case, the case's configuration pin will prevent full insertion. Applying a strong force in this instance will result in damage to the relay and case.

To remove the unit from the case:

1. Open the door by pulling from the top or bottom of its right side. It will rotate to the left about its hinges.
2. Press upward on the locking latch, which is located below the handle, and hold in its raised position. The tip of a small screwdriver may prove helpful in this operation.

Figure 3–5: PRESS LATCH UP AND PULL HANDLE

3. With the latch raised, pull the center of the handle outward. Once disengaged, continue rotating the handle up to the stop position.

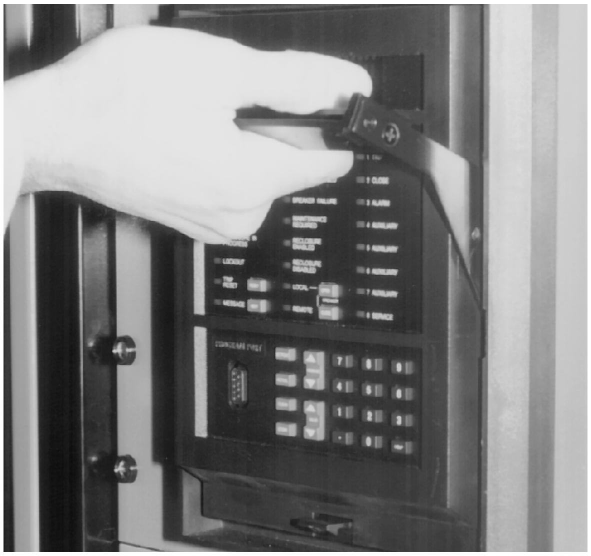


Figure 3–6: ROTATING HANDLE TO STOP POSITION

4. When the stop position is reached, the locking mechanism will release. The relay will now slide out of the case when pulled from its handle. To free the relay, it may sometimes be necessary to adjust the handle position slightly.

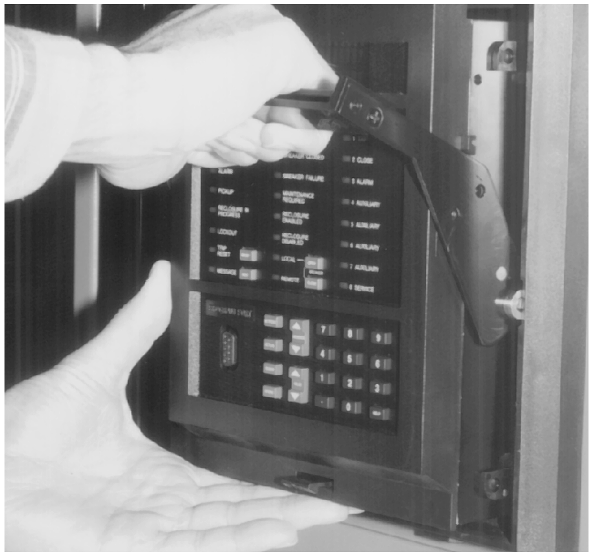


Figure 3–7: SLIDING THE UNIT OUT OF THE CASE

To insert the unit into the case:

1. Ensure that the model number on the left side of the relay matches the requirements of the installation.
2. Raise the locking handle to the highest position.
3. Hold the unit immediately in front of the case and align the rolling guide pins (near the hinges of the relay's handle) with the case's guide slots.
4. Slide the unit into the case until the guide pins on the unit have engaged the guide slots on either side of the case.
5. Once fully inserted, grasp the handle from its center and rotate it down from the raised position towards the bottom of the relay.
6. Once the unit is fully inserted the latch will be heard to click, locking the handle in the final position. The unit is mechanically held in the case by the handle's rolling pins, which cannot be fully lowered to the locked position until the electrical connections are completely mated.

NOTE **No special ventilation requirements need to be observed during the installation of the unit.**

NOTE **The unit does not require cleaning.**

3.1.4 REAR TERMINAL LAYOUT

Due to the many features built into the 750/760 relays, a broad range of applications are available to the user. As such, it is not possible to present typical connections for all possible schemes. The information in this section will cover the important aspects of interconnections, in the general areas of instrument transformer inputs, other inputs, outputs, communications and grounding. The figure below shows the rear terminal layout of the 750/760.

WARNING **Relay contacts must be considered unsafe to touch when system is energized! If the customer requires the relay contacts for low voltage accessible applications, it is their responsibility to ensure proper insulation levels!**

WARNING **HAZARD may result if the product is not used for its intended purposes.**

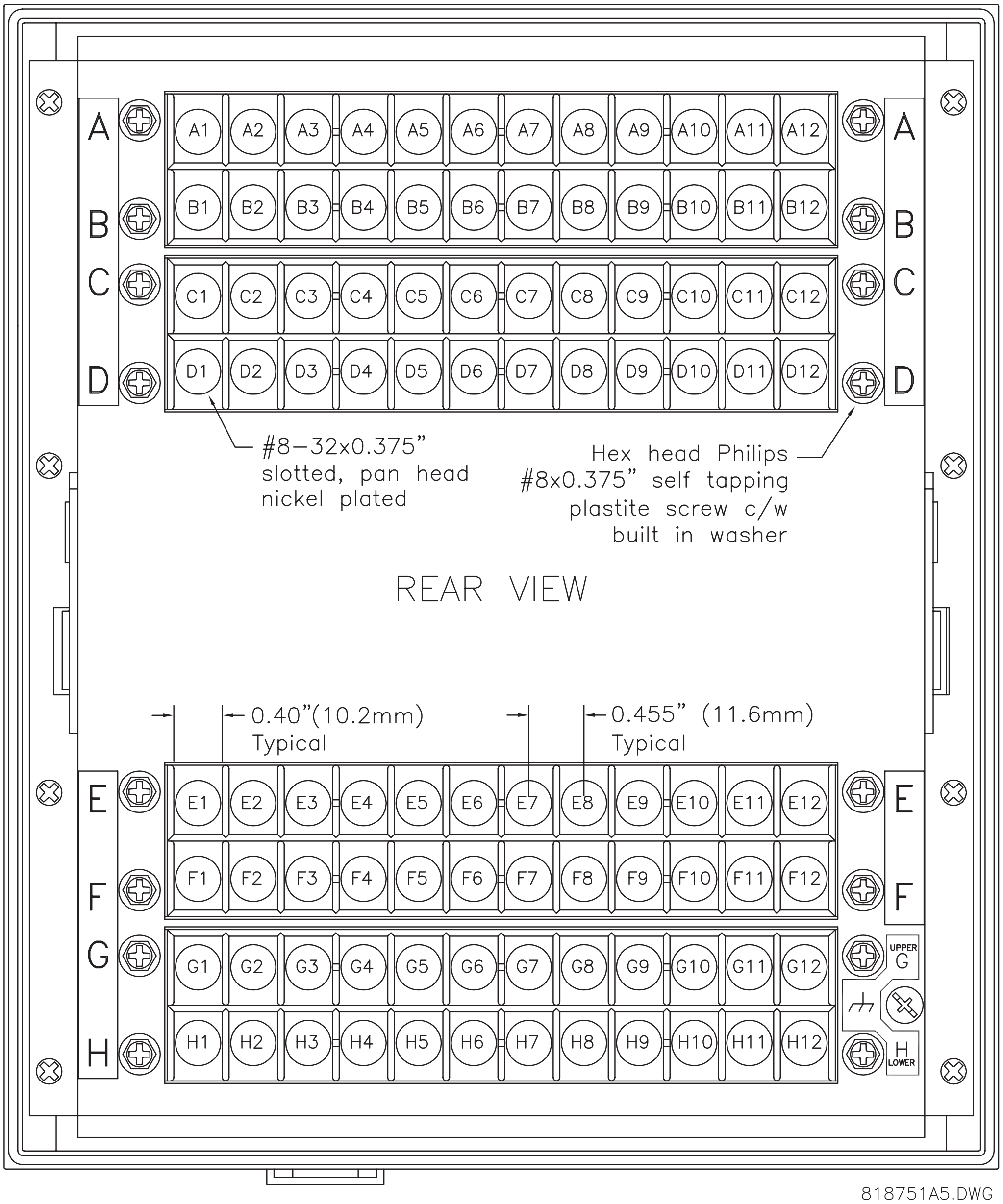


Figure 3–8: REAR TERMINAL LAYOUT

Table 3–1: REAR TERMINAL ASSIGNMENTS

TERMINAL	DESCRIPTION
ANALOG INPUT / OUTPUTS	
A1	ANALOG INPUT +
A2	ANALOG INPUT -
A3	SHIELD (GROUND)
A4	ANALOG OUTPUT -
A5	ANALOG OUTPUT 1 +
A6	ANALOG OUTPUT 2 +
A7	ANALOG OUTPUT 3 +
A8	ANALOG OUTPUT 4 +
A9	ANALOG OUTPUT 5 +
A10	ANALOG OUTPUT 6 +
A11	ANALOG OUTPUT 7 +
A12	ANALOG OUTPUT 8 +
COMMUNICATION	
B1	COM1 RS485 +
B2	COM1 RS485 -
B3	COM1 RS485 COM
B4	COM1 RS422 TX +
B5	COM1 RS422 TX -
B6	COM2 RS485 +
B7	COM2 RS485 -
B8	COM2 RS485 COM
B9	SHIELD (GROUND)
B10	IRIG-B +
B11	IRIG-B -
B12	RESERVED
LOGIC INPUTS	
C1	LOGIC INPUT 1
C2	LOGIC INPUT 2
C3	LOGIC INPUT 3
C4	LOGIC INPUT 4
C5	LOGIC INPUT 5
C6	LOGIC INPUT 6
C7	LOGIC INPUT 7
C8	RESERVED
C9	RESERVED
C10	SETPOINT ACCESS –
C11	SETPOINT ACCESS +
C12	+32 VDC
LOGIC INPUTS	
D1	LOGIC INPUT 8
D2	LOGIC INPUT 9
D3	LOGIC INPUT 10
D4	LOGIC INPUT 11
D5	LOGIC INPUT 12
D6	LOGIC INPUT 13
D7	LOGIC INPUT 14
D8	RESERVED
D9	RESERVED
D10	RESERVED
D11	RESERVED
D12	DC NEGATIVE

TERMINAL	DESCRIPTION
OUTPUT RELAYS	
E1	SOLID STATE TRIP OUT +
E2	1 TRIP RELAY NO
E3	2 CLOSE RELAY NO
E4	3 AUXILIARY RELAY NO
E5	3 AUXILIARY RELAY NC
E6	4 AUXILIARY RELAY NC
E7	5 AUXILIARY RELAY NC
E8	5 AUXILIARY RELAY NO
E9	6 AUXILIARY RELAY NC
E10	7 AUXILIARY RELAY NC
E11	7 AUXILIARY RELAY NO
E12	8 SELF-TEST WARNING RELAY NC
OUTPUT RELAYS	
F1	SOLID STATE TRIP OUT -
F2	1 TRIP RELAY COM
F3	2 CLOSE RELAY COM
F4	3 AUXILIARY RELAY COM
F5	4 AUXILIARY RELAY NO
F6	4 AUXILIARY RELAY COM
F7	5 AUXILIARY RELAY COM
F8	6 AUXILIARY RELAY NO
F9	6 AUXILIARY RELAY COM
F10	7 AUXILIARY RELAY COM
F11	8 SELF-TEST WARNING RELAY NO
F12	8 SELF-TEST WARNG RELAY COM
CT and VT INPUTS / GROUND	
G1	COIL MONITOR 1 +
G2	COIL MONITOR 2 +
G3	SENSITIVE GROUND CT ■
G4	SYNCHRO VT ■ *(LINE)*
G5	PHASE A VT ■ *(BUS)*
G6	PHASE C VT ■ *(BUS)*
G7	PHASE A CT ■
G8	PHASE B CT ■
G9	PHASE C CT ■
G10	GROUND CT ■
G11	FILTER GROUND
G12	SAFETY GROUND
CT and VT INPUTS / POWER	
H1	COIL MONITOR 1 -
H2	COIL MONITOR 2 -
H3	SENSITIVE GROUND CT
H4	SYNCHRO VT *(LINE)*
H5	PHASE B VT ■ *(BUS)*
H6	PHASE VT NEUTRAL *(BUS)*
H7	PHASE A CT
H8	PHASE B CT
H9	PHASE C CT
H10	GROUND CT
H11	CONTROL POWER -
H12	CONTROL POWER +

3.2.1 TYPICAL WIRING

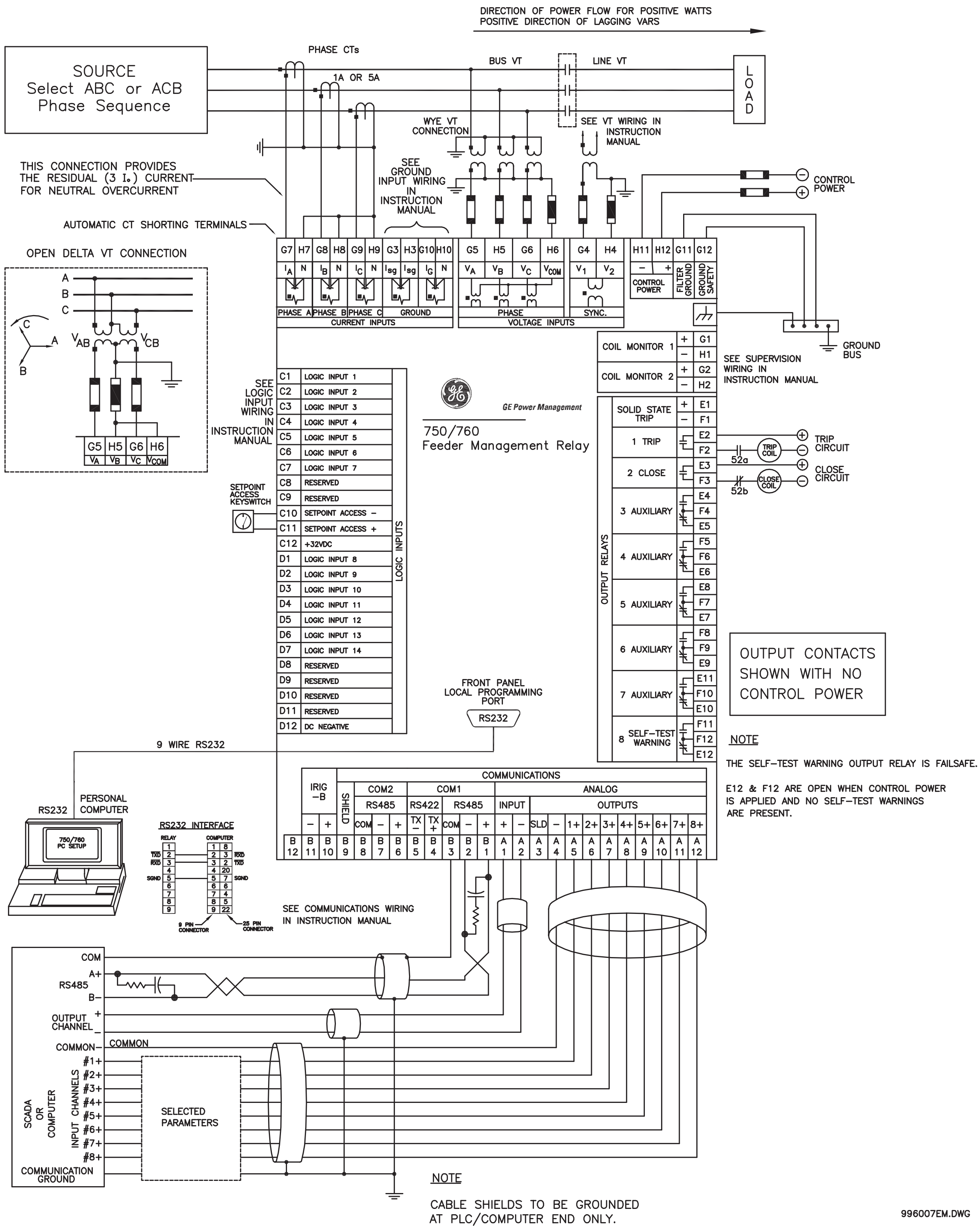


Figure 3–9: TYPICAL WIRING DIAGRAM

3.2.2 PHASE SEQUENCE AND TRANSFORMER POLARITY

For the correct operation of many relay features, the instrument transformer polarities shown above in Figure 3–9: Typical Wiring Diagram on page 3–7 must be followed. Note the solid square markings shown with all instrument transformer connections. When the connections adhere to this drawing, the arrow shows the direction of power flow for positive watts and the positive direction of lagging vars. The phase sequence is user programmable to be either ABC or ACB rotation.

3.2.3 CURRENT INPUTS

a) DESCRIPTION

The 750/760 relays have five (5) channels for AC current inputs, each with an isolating transformer and an automatic shorting mechanism that acts when the relay is withdrawn from its case. There are no internal ground connections on the current inputs. Current transformers with 1 to 50000 A primaries may be used.

3

CAUTION **Verify that the relay's nominal input 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.**

CAUTION **IMPORTANT: The phase and ground current inputs will correctly measure to 20 times the current input's nominal rating. Time overcurrent curves become horizontal lines for currents above the 20 × CT rating. This becomes apparent if the pickup level is set above the nominal CT rating.**

b) GROUND AND SENSITIVE GROUND CT INPUTS

There are two dedicated ground inputs referred throughout this manual as the Ground Current and the Sensitive Ground Current inputs. Before making ground connections, consider that the relay automatically calculates the neutral (residual) current from the sum of the three phase current phasors. The following figures show three possible ground connections using the ground current input (Terminals G10 and H10) and three possible sensitive ground connections using the sensitive ground current input (Terminals G3 and H3).

The ground input (Terminals G10 and H10) is used in conjunction with a Zero Sequence CT as source, or in the neutral of wye-connected source CTs. The ground current input can be used to polarize both the neutral and sensitive ground directional elements. When using the residual connection set the **GROUND CT PRIMARY** setpoint to a value equal to the **PHASE CT PRIMARY** setpoint.

The sensitive ground current input is intended for use either with a CT in a source neutral of a high-impedance grounded system, or on ungrounded systems. On ungrounded systems it is connected residually with the phase current inputs. In this case, the **SENSTV GND CT PRIMARY** setpoint should be programmed to a value equal to the **PHASE CT PRIMARY** setpoint. The sensitive ground current input can be connected to a Zero Sequence CT for increased sensitivity and accuracy when physically possible in the system.

NOTE Units that do not have the Sensitive Ground input (such as older units which have been upgraded with new firmware) use the G3 and H3 terminals as the polarizing input. The G10 and H10 terminals are used for the Ground input. These connections will be shown on the terminal assignment label on the back of the relay's case.

NOTE The Sensitive Ground input (G3 and H3 terminals) must only be used on systems where the maximum ground current does not exceed 500 A.

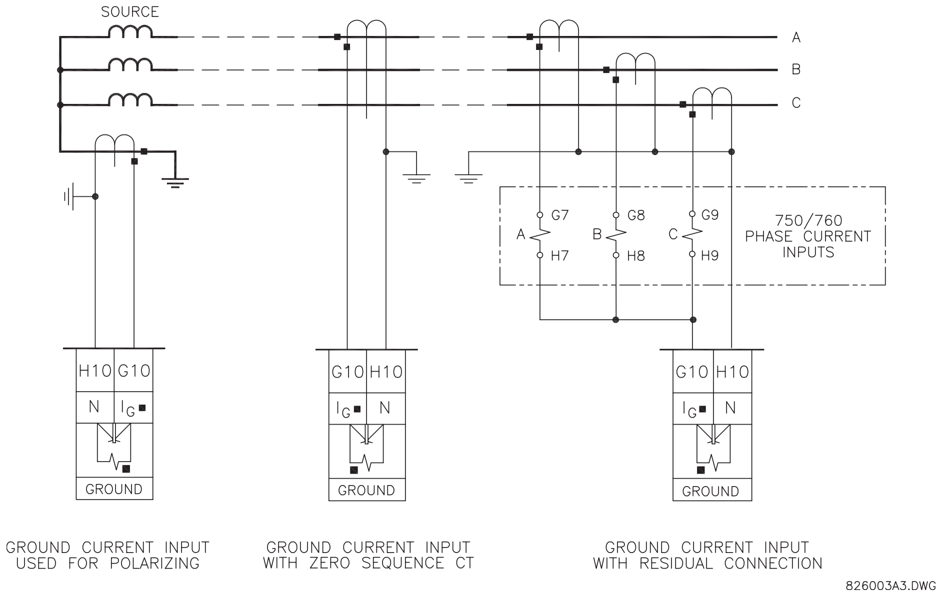


Figure 3–10: GROUND INPUTS

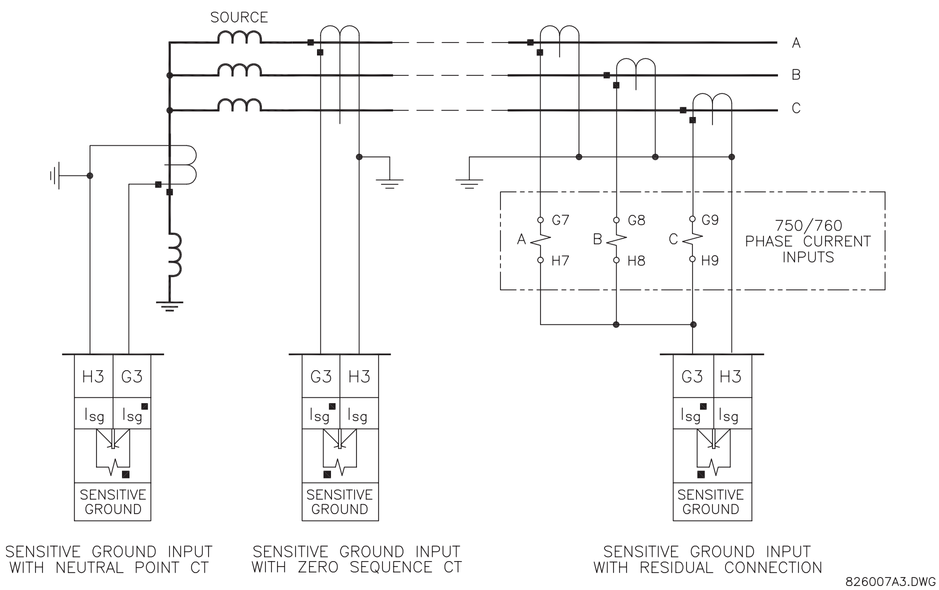


Figure 3–11: SENSITIVE GROUND INPUTS

c) RESTRICTED EARTH FAULT INPUTS

Restricted Earth Fault protection is often applied to transformers having grounded wye windings to provide sensitive ground fault detection for faults near the transformer neutral. The Sensitive Ground input (Terminals G3 and H3) can be used.

NOTE: Although the 750/760 is designed for feeder protection, it can provide Restricted Earth Fault protection on transformers that do not have dedicated protection. To use the 750/760 for this type of protection, a stabilizing resistor and possibly a non-linear resistor will be required. For more details see page 5–54.

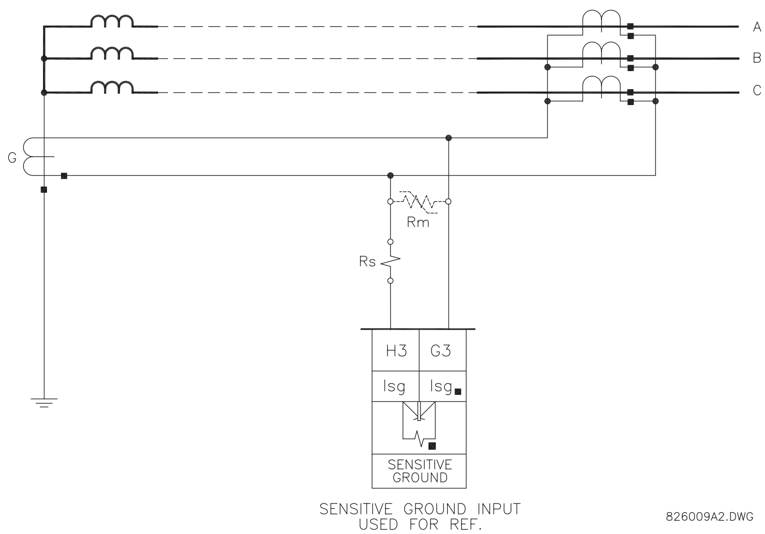


Figure 3–12: RESTRICTED EARTH FAULT INPUTS

d) ZERO SEQUENCE CT INSTALLATION

The various CT connections and the exact placement of a Zero Sequence CT, so that ground fault current will be detected, are shown in the figure below. Twisted pair cabling on the Zero Sequence CT is recommended.

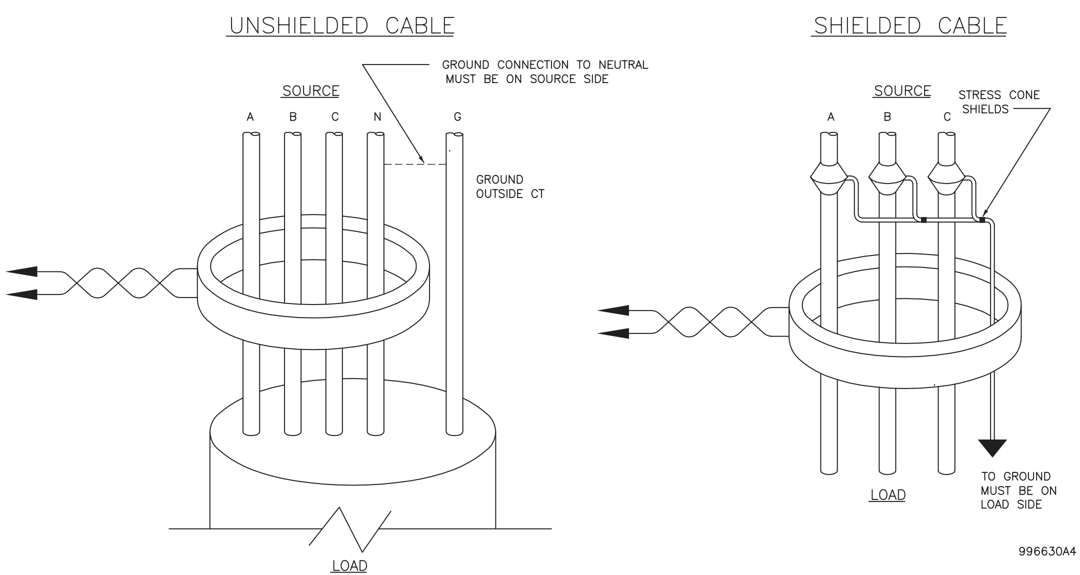


Figure 3–13: ZERO SEQUENCE (CORE BALANCE) CT INSTALLATION

3.2.4 VOLTAGE INPUTS

The 750/760 relays have four channels for AC voltage inputs, each with an isolating transformer. Voltage transformers up to a maximum 5000:1 ratio may be used. The nominal secondary voltage must be in the 50 to 240 V range.

The three phase inputs are designated as the “bus voltage”. The Bus VT connections most commonly used, wye and delta (or open delta), are shown in the typical wiring diagram. Be aware that these voltage channels are internally connected as wye. This is why the jumper between the phase B terminal and the Vcom terminal must be installed with a delta connection.

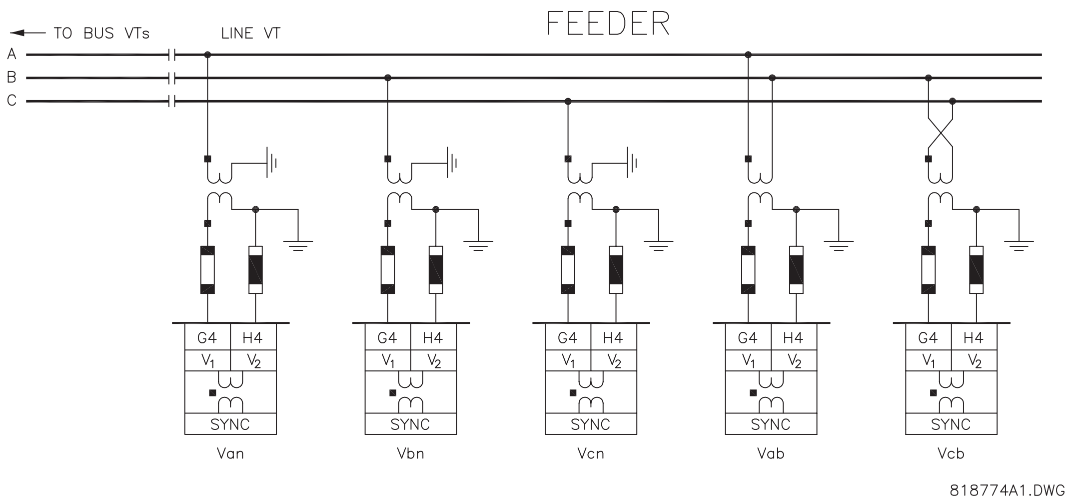


Figure 3–14: LINE VT CONNECTIONS

NOTE

If Delta VTs are used, the zero sequence voltage (V_0) and neutral/sensitive ground polarizing voltage ($-V_0$) will be zero. Also, with this Delta VT connection, the phase-neutral voltage cannot be measured and will not be displayed.

The single phase input is designated as the “line voltage”. The line VT input channel, used for the synchrocheck feature, can be connected for phase-neutral voltages V_{an}, V_{bn}, or V_{cn}; or for phase-phase voltages V_{ab} or V_{cb} as shown below.

3.2.5 CONTROL POWER

CAUTION **Control power supplied to the relay must match the installed power supply range. If the applied voltage does not match, damage to the unit may occur. All grounds MUST be connected for normal operation regardless of control power supply type.**

The label found on the left side of the relay specifies its order code or model number. The installed power supply's operating range will be one of the following.

LO: 20 to 60 V DC or 20 to 48 V AC
HI: 88 to 300 V DC or 70 to 265 V AC

CAUTION **The relay should be connected directly to the ground bus, using the shortest practical path. A tinned copper, braided, shielding and bonding cable should be used. As a minimum, 96 strands of number 34 AWG should be used. Belden catalog number 8660 is suitable.**

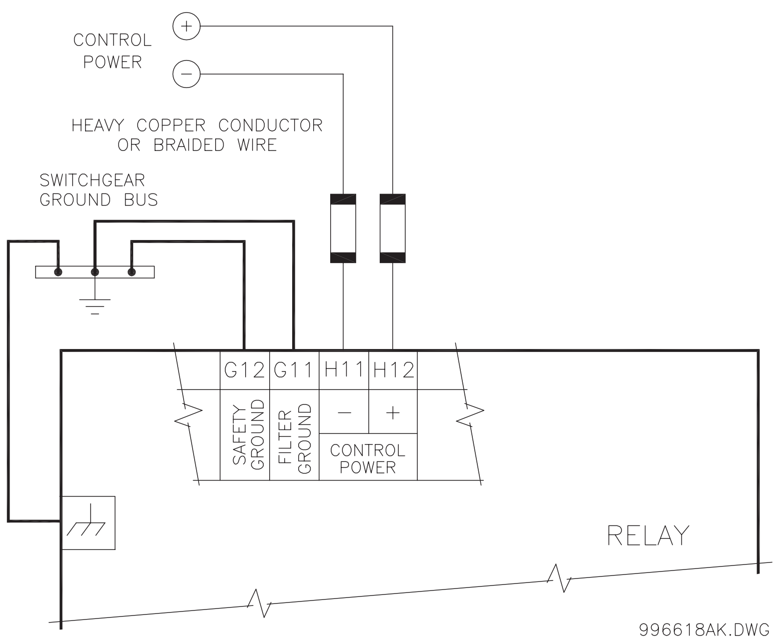


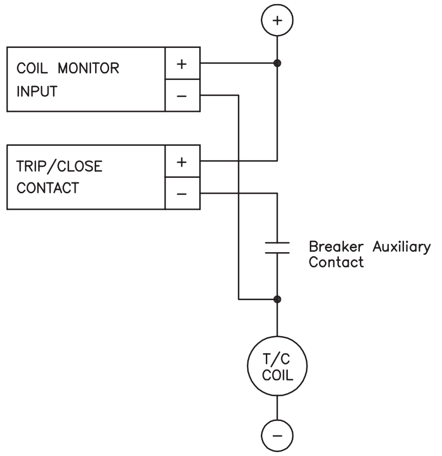
Figure 3–15: CONTROL POWER CONNECTION

3.2.6 TRIP/CLOSE COIL SUPERVISION

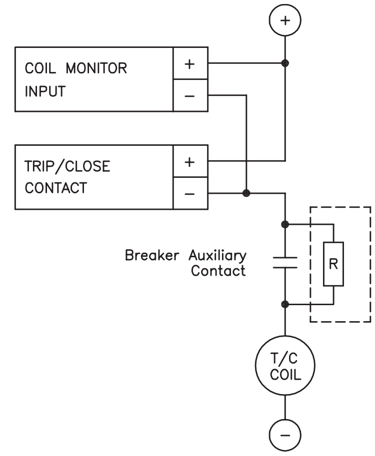
Supervision of a breaker trip coil requires the relay supervision circuit to be wired in parallel with the Trip contact. Likewise, supervision of the close coil requires the supervision circuit to be wired in parallel with the Close contact. Each connection places an impedance across the associated contact, which allows a small trickle current to flow through the related trip and close coil supervision circuitry. For external supply voltages in the 30 to 250 V DC range, this current draw will be between 2 to 5 mA. If either the trip or close coil supervision circuitry ceases to detect this trickle current, the appropriate failure will be declared by the relay.

When the **BRKR STATE BYPASS** setpoint is "Disabled", the logic only allows a trip circuit to be monitored when the breaker is closed and a close circuit to be monitored when the breaker is open.

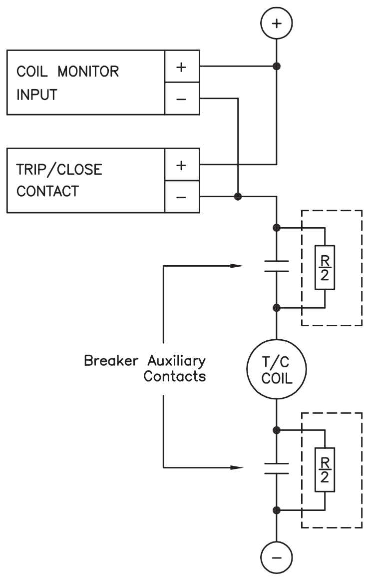
Circuit breakers equipped with standard control circuits have a 52a auxiliary contact which only allows tripping of the breaker when it is closed. In this breaker state, the 52a contact is closed and a trickle current will flow through the trip circuitry. When the breaker is open, the 52a auxiliary contact is also open and no trickle current will flow. When the breaker position monitoring inputs detect an open breaker, the trip coil supervision monitoring function will be disabled.



DRAWING A: CONNECTION WHERE ACCESS TO BREAKER COIL IS AVAILABLE ('BREAKER STATE BYPASS' SETPOINT SHOULD BE ENABLED FOR THIS TYPE OF CONNECTION.)*



DRAWING B: ALTERNATE PATH WITH ONE BREAKER AUXILIARY CONTACT.



DRAWING C: ALTERNATE PATH WITH TWO BREAKER AUXILIARY CONTACTS

VALUE OF RESISTOR 'R'

SUPPLY	OHMS	WATTS
48 VDC	10 K	2
125 VDC	25 K	5
250 VDC	50 K	5

RESISTER CONNECTED	BREAKER STATE BYPASS SETPOINT*
YES	ENABLED
NO	DISABLED

* SEE S6 MONITORING FOR ADDITIONAL SETPOINTS

Figure 3–16: TRIP/CLOSE COIL SUPERVISION

In a similar manner, the 52b auxiliary contact only allows closing of the breaker when it is open. In this breaker state, the 52b contact is shorted and a trickle current will flow through the breaker's close circuitry. When the breaker is closed, the 52b auxiliary contact is open and no trickle current will flow. When the breaker position monitoring inputs detect a closed breaker, the close coil supervision monitoring function will be disabled.

When the **BRKR STATE BYPASS** setpoint is "Enabled", the trip and close coil supervision circuits can be arranged to monitor the trip and close circuits continuously, unaffected by breaker state. This application requires that an alternate path around the 52a or 52b contacts in series with the operating coils be provided, with modifications to the standard wiring as shown on drawing 818730. With these connections, trickle current can flow at all times. If access to the breaker coil is available, as shown in drawing A above, continuous coil monitoring regardless of breaker state is possible without using a resistor to bypass the 52a/b contact.

A high speed solid state (SCR) output is also provided. This output is intended for applications where it is required to key a communications channel.

3.2.7 LOGIC INPUTS

CAUTION

Ensure correct polarity on logic input connections and do not connect any logic input circuits to ground or else relay hardware may be damaged.

External contacts can be connected to the relay's fourteen (14) logic inputs. As shown, these contacts can be either dry or wet. It is also possible to use a combination of both contact types.

A dry contact has one side connected to Terminal C12. This is the +32 V DC voltage rail. The other side of the dry contact is connected to the required logic input terminal. When a dry contact closes, a current of approximately 2 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 logic input terminal. In addition, the negative side of the external source must be connected to the relay's DC negative rail at Terminal D12. The maximum external source voltage for this arrangement is 300 V DC.

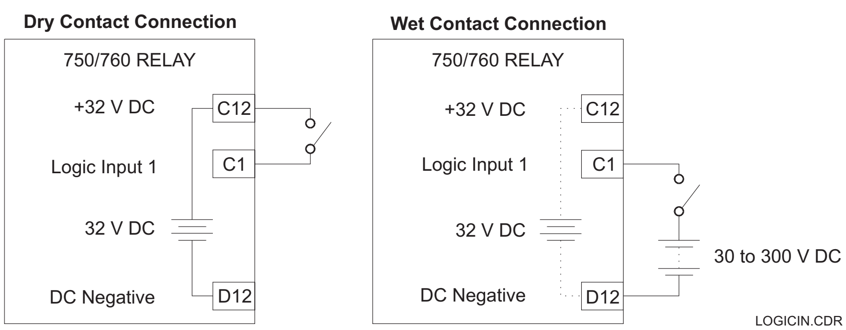


Figure 3–17: DRY AND WET CONTACT CONNECTIONS

3.2.8 ANALOG INPUT

Terminals A1 (+) and A2 (–) are provided for the input of a current signal from a wide variety of transducer outputs - refer to technical specifications for complete listing. This current signal can represent any external quantity, such as transformer winding temperature, bus voltage, battery voltage, station service voltage, or transformer tap position. Be sure to observe polarity markings for correct operation. Both terminals are clamped to within 36 V of ground with surge protection. As such, common mode voltages should not exceed this limit. Shielded wire, with only one end of the shield grounded, is recommended to minimize noise effects.

3.2.9 ANALOG OUTPUTS

The 750/760 relays provide eight (8) analog output channels whose full scale range was specified at the time of ordering. Refer to Section 2.2.7: Outputs on page 2–11 the for complete listing.

Each analog output channel can be programmed to represent one of the parameters measured by the relay. For details, see Section 5.9.3: Analog Outputs on page 5–129.

As shown in the Typical Wiring Diagram, the analog output signals originate from Terminals A5 to A12 and share A4 as a common return. Output signals are internally isolated and allow connection to devices which sit at a different ground potential. Each analog output terminal is clamped to within 36 V of ground. To minimize the affect of noise, external connections should be made with shielded cable and only one end of the shield should be grounded.

If a voltage output is required, a burden resistor must be connected at the input of the external measuring device. Ignoring the input impedance, we have

$$R_{LOAD} = \frac{V_{FULL\ SCALE}}{I_{MAX}} \quad \text{(EQ 3.1)}$$

If a 5V full scale output is required with a 0 to 1 mA output channel:

$$R_{LOAD} = \frac{V_{FULL\ SCALE}}{I_{MAX}} = \frac{5\text{ V}}{0.001\text{ A}} = 5\text{ k}\Omega \quad \text{(EQ 3.2)}$$

For a 0 to 5 mA channel this resistor would be 1 kW and for a 4 to 20 mA channel this resistor would be 250 Ω. The Analog Output connection diagram is shown below.

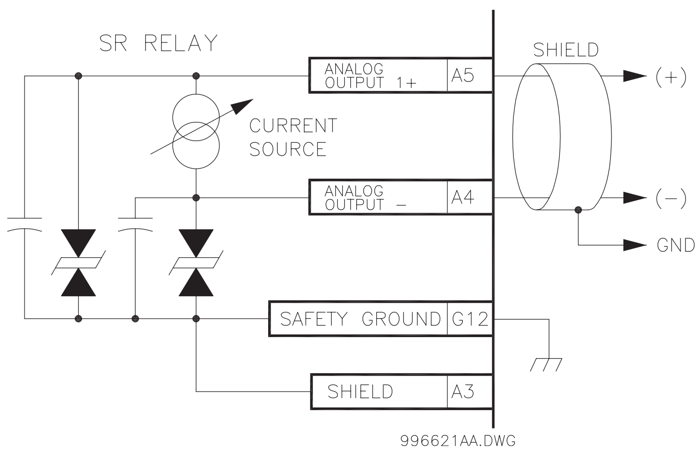


Figure 3–18: ANALOG OUTPUT CONNECTION

3.2.10 RS485 AND RS422 COMMUNICATIONS

The 750/760 relays provide the user with two rear communication ports which may be used simultaneously. Both support a subset of the AEG Modicon Modbus protocol as well as the Harris Distributed Network Protocol (DNP) as discussed in the communications chapter. Through the use of these ports, continuous monitoring and control from a remote computer, SCADA system or PLC is possible.

The first port, COM1, can be used in a two wire RS485 mode or a four wire RS422 mode, but will not operate in both modes at the same time. In the RS485 mode, data transmission and reception are accomplished over a single twisted pair with transmit and receive data alternating over the same two wires. These wires should be connected to the terminals marked RS485. The RS422 mode uses the COM1 terminals designated as RS485 for receive lines, and the COM1 terminals designated as RS422 for transmit lines. The second port, COM2, is intended for the two wire RS485 mode only.

To minimize errors from noise, the use of shielded twisted-pair wire is recommended. Correct polarity should also be observed. For instance, SR type relays must be connected with all B1 terminals (labeled COM1 RS485+) connected together, and all B2 terminals (labeled COM1 RS485–) connected together. Terminal B3 (COM1 RS485 COM) should be connected to the common wire inside the shield. 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 devices 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 add more than 32 relays on a single channel. 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.

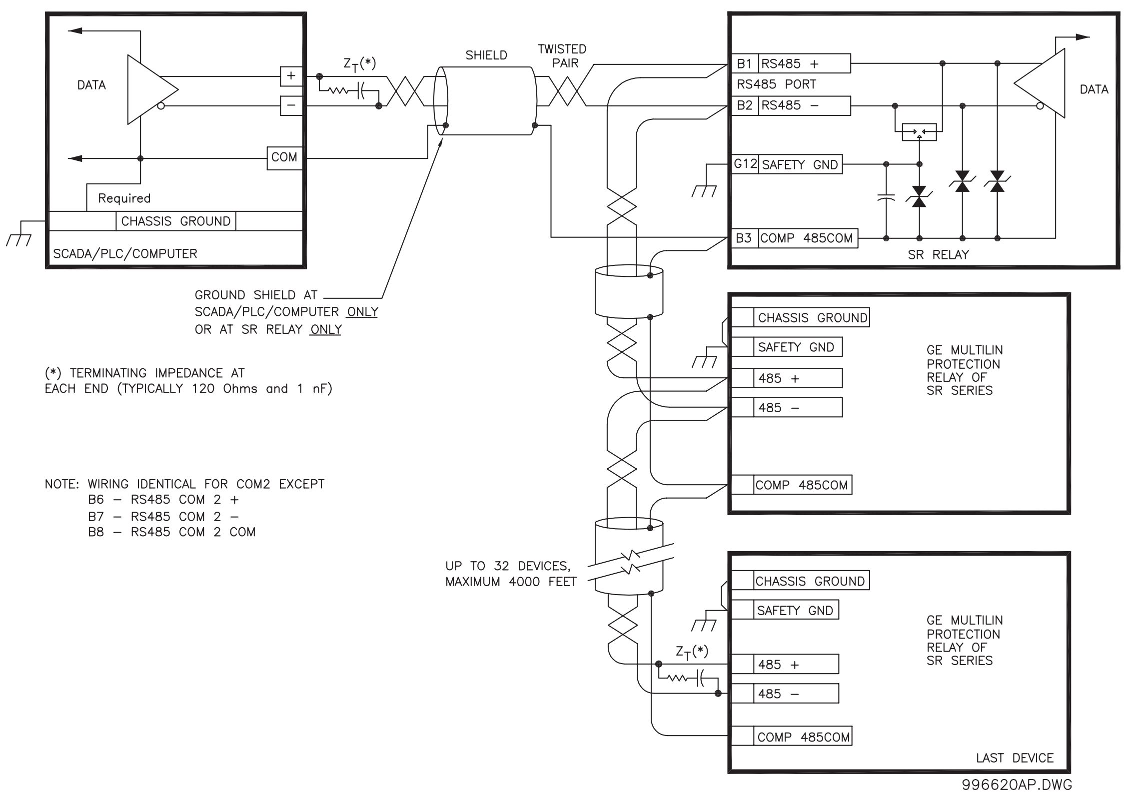


Figure 3–19: RS485 WIRING DIAGRAM

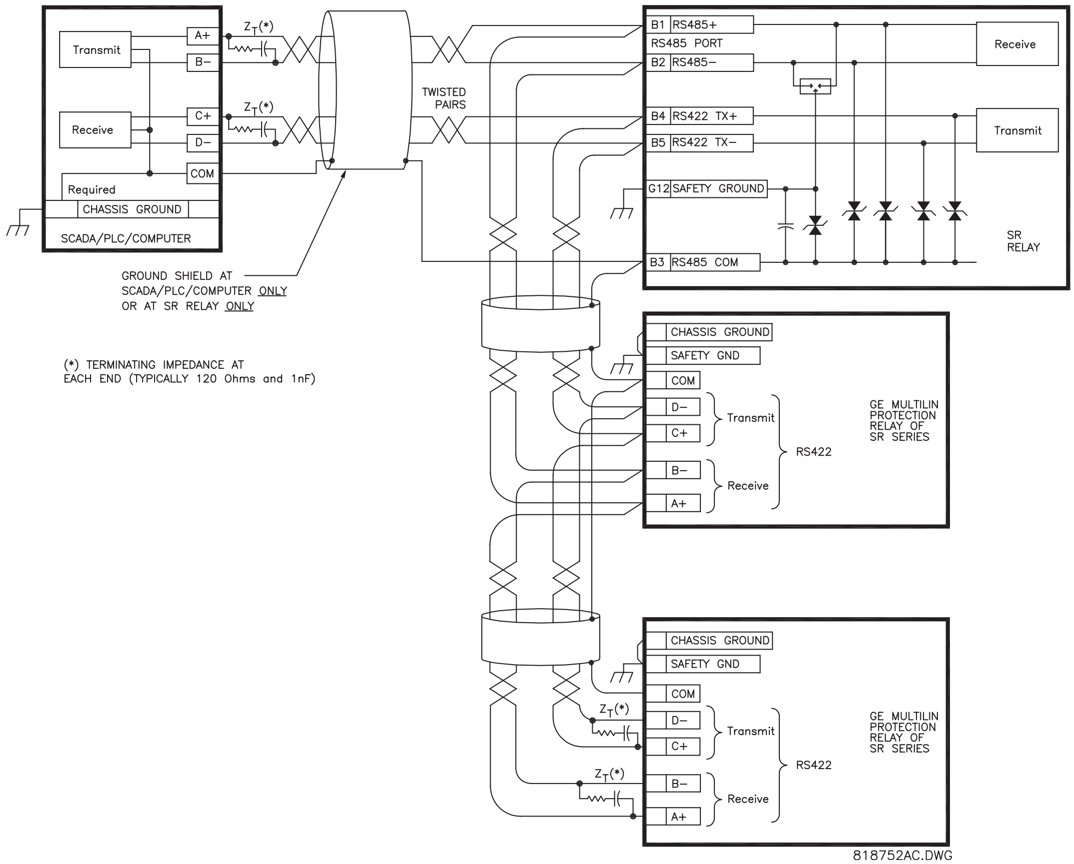


Figure 3–20: RS422 WIRING DIAGRAM

3

3.2.11 RS232 COMMUNICATIONS

The 9-pin RS232 serial port located on the front panel is used in conjunction with the 750/760PC software for programming setpoints and upgrading relay firmware. A standard 9-pin RS232 cable is used to connect the relay to a personal computer as shown below. When downloading new firmware, make sure the relay address is set to 1 and the baud rate is set to 9600.

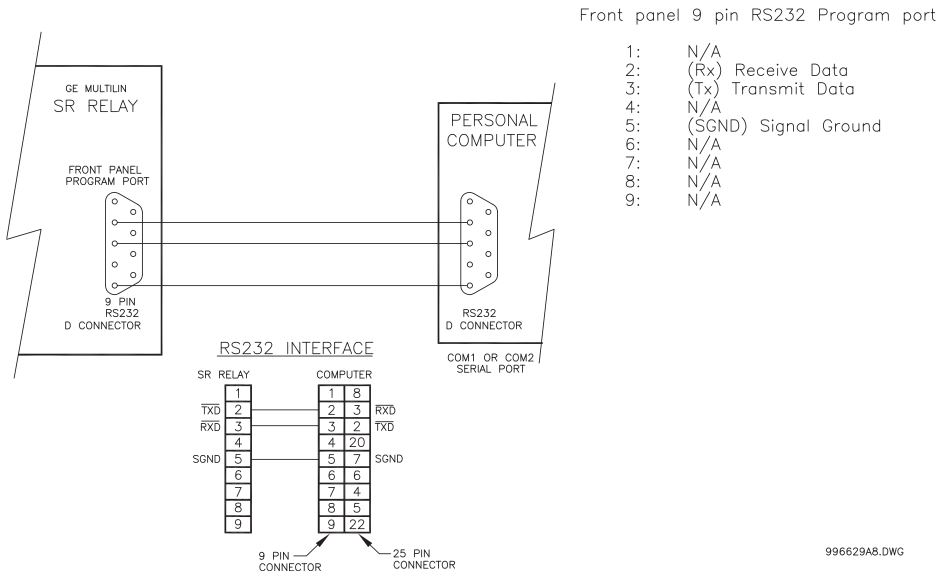


Figure 3–21: RS232 CONNECTION

3.2.12 IRIG-B

IRIG-B is a standard time code format that allows time 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 shift or amplitude modulated (AM) form. 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.

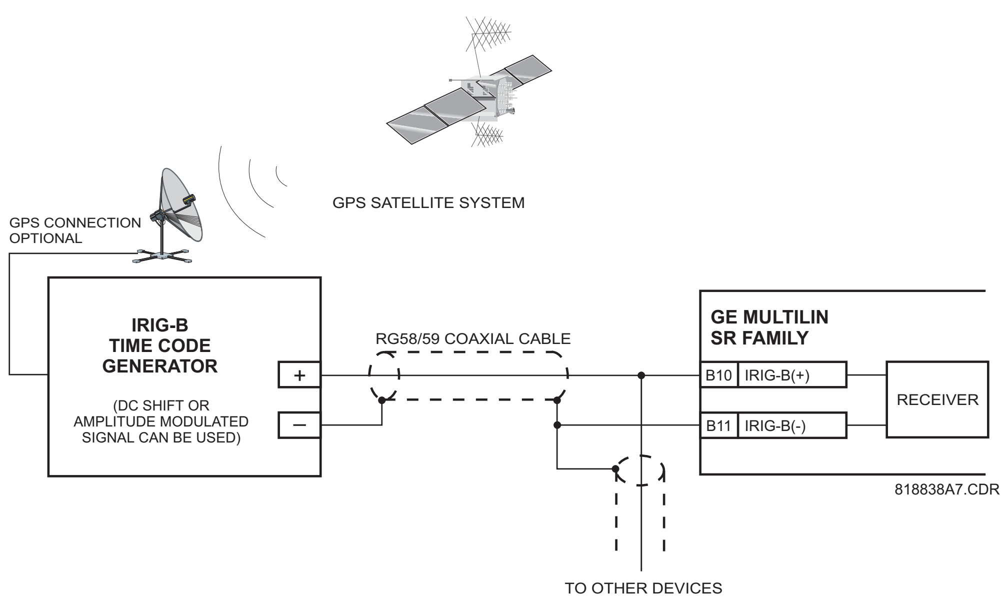


Figure 3–22: IRIG-B CONNECTION

4.1.1 DESCRIPTION

The front panel provides local operator interface with a liquid crystal display, LED status indicators, control keys, and program port. The display and status indicators update alarm and status information automatically. The control keys are used to select the appropriate message for entering setpoints or displaying measured values. The RS232 program port is also provided for connection with a computer running the 750/760PC software.

The 40-character liquid crystal display is backlit to allow visibility under varied lighting conditions. While the keypad and display are not being used, the screen will display system information by scrolling through a maximum of 30 user-selected default messages. These default messages will only appear after a user programmed period of inactivity. Pressing any key during default message scrolling will return the display to the last message shown before the default messages appeared. Trip and alarm condition messages will automatically override default messages.

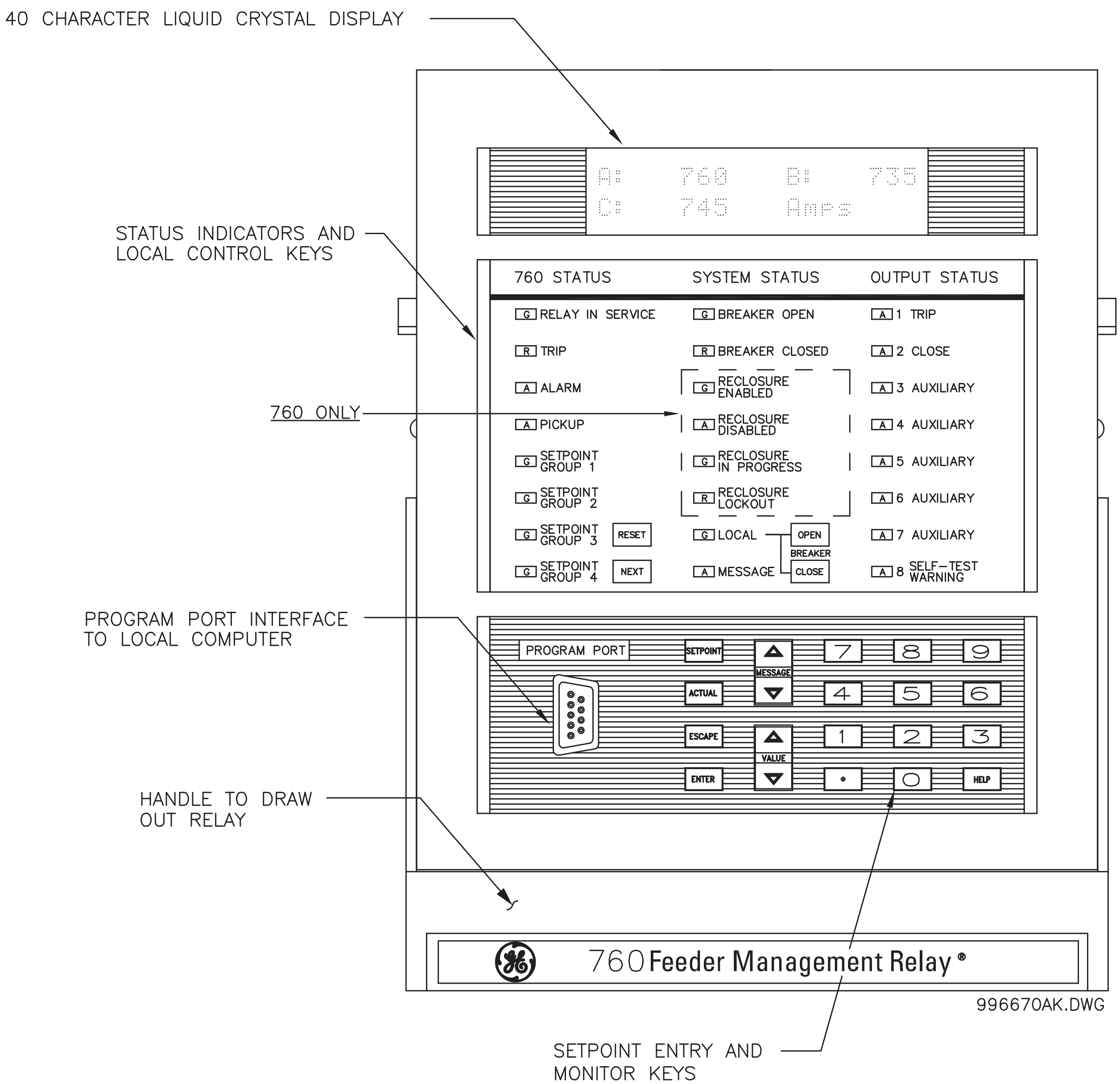


Figure 4–1: 750/760 FRONT PANEL

4.1.2 LED STATUS INDICATORS

a) DESCRIPTION

The front panel indicators are grouped into three columns. The 750/760 Status column indicates the state of the relay; the System Status column indicates the state of the breaker and the system; and the Output Status column indicates the state of the output relays. These LED indicators can be tested by pressing NEXT when no trips or alarms are active. As shown below, the color of each indicator conveys its importance.

G = Green: General Condition
A = Amber: Alert Condition
R = Red: Serious Alarm or Important Status

b) 750/760 STATUS LED INDICATORS

- **RELAY IN SERVICE:** This indicator will be on continuously if the relay is functioning normally and no major self-test errors have been detected. During operation the relay continuously performs various self tests and if a major self-test fails, the indicator will be turned off, all output relays will be de-energized, and the Self-Test Warning LED will be turned on. This indicates a complete loss of protection. See the self-test warning section later in this chapter.
- **TRIP:** This indicator flashes when the relay detects a trip condition and operates the Trip Relay to open the breaker. After the initiating fault has been cleared, this LED can be turned off with a reset.
- **ALARM:** While the relay is detecting an alarm condition, this indicator will flash. Even if latched output relays are programmed to operate with the alarm, the indicator will automatically turn off if the alarm condition clears. Such output relays will remain in the operated state until a reset is performed.

NOTE

Latched Alarm: This relay flashes while the relay is detecting an alarm condition. After the condition clears, the indicator remains illuminated and can be turned off with a reset.

- **PICKUP:** For the purpose of testing and calibration verification, this indicator will light steady when any protection feature has its pickup threshold exceeded. Eventually, if the fault condition persists, a trip will be issued by the relay. If the measured parameter drops below its pickup level, the indicator will turn off.
- **SETPOINT GROUP 1 to 4:** These indicators are flashing if the corresponding group is selected for editing and/or display; they are continuously on if the corresponding group is providing settings for the protection elements.

c) SYSTEM STATUS LED INDICATORS

NOTE

The Open and Closed Status Indicator colors are interchangeable at the time of placing a 750/760 order.

- **BREAKER OPEN:** When the breaker is open, this indicator will be on continuously.
- **BREAKER CLOSED:** When the breaker is closed, this indicator will be on continuously.

  Breaker status indication is based on the breaker 52a and 52b contacts. With both contacts wired to the relay, the closed status is determined by a closed 52a contact and the open status is determined by a closed 52b contact. If both 52a and 52b contacts are open, due to a breaker being racked out of the switchgear, both the Breaker Open and Breaker Closed LED Indicators will be off.

  With a single 52a contact, it is impossible to distinguish between a breaker open state and a racked out breaker. In both situations, the 52a contact will be open. With a single 52b contact, you cannot distinguish between a breaker closed state and a racked out breaker. Likewise, the 52b contact will be open for both situations. To clarify this ambiguity, the breaker connected function should be programmed to an additional logic input. When this additional input is closed, a single 52a or 52b contact will show both breaker states. When the breaker is racked out, this additional breaker connected input should be open. In this case, both breaker status indicators will be off.
- **RECLOSURE ENABLED (760 only):** This indicator will be on continuously when autoreclosure is allowed to operate as programmed. This is when the autoreclose function setpoint is enabled, and if used, the block reclosure logic input is not asserted. Otherwise, this indicator will be off. Note that this indicator will always be in the opposite state of the Reclosure Disabled LED Indicator.
- **RECLOSURE DISABLED (760 only):** This indicator will be on continuously when autoreclosure is not allowed to operate as programmed. This is when the autoreclose function setpoint is disabled, or if used, the block reclosure logic

input is asserted. Otherwise, this indicator will be off. Note that this indicator will always be in the opposite state of the Reclosure Enabled LED.

- **RECLOSURE IN PROGRESS (760 only):** If a trip initiates a reclosing sequence, this indicator will go on continuously during each of the programmed dead times.
- **RECLOSURE LOCKOUT (760 only):** If the programmed reclose sequence has progressed to a final lockout condition, this indicator will be on continuously. Lockout can be cleared by performing a reset.
- **LOCAL:** This indicator turns on if the local mode function has been assigned a logic input which is asserted. In local mode, the front panel OPEN and CLOSE keys operate while the Remote Open and Remote Close logic input functions will not operate. As well, the communication open and close commands have no effect.
- **MESSAGE:** Under normal conditions, the default messages selected during setpoint programming are displayed. If any alarm or trip condition is generated, a diagnostic message overrides the displayed message and this indicator flashes. If there is more than one condition present, NEXT can be used to scroll through the messages. Pressing any other key return to the normally displayed messages. While viewing normally displayed messages, the Message LED continues to flash if any diagnostic message is active. To return to the diagnostic messages from the normally displayed messages, press NEXT. Note that diagnostic messages for alarms disappear with the condition while diagnostic messages for trips remain until cleared by a reset.

d) OUTPUT STATUS LED INDICATORS

The 750/760 has eight (8) output relays: the 1 Trip, 2 Close, and 8 Self-Test Warning relays have fixed operation while the 3 to 7 Auxiliary relays are configurable. Regardless of the mode of operation, the corresponding front panel indicator turns on while the output relay is signaling. If the non-operated state of an output relay is programmed as de-energized, the corresponding indicator will be on when the normally open contacts are closed. If the non-operated state of an output relay is programmed as energized, the corresponding indicator will be on when the normally open contacts are open.

- **1 TRIP:** A trip sequence can be initiated by a protection element, a logic input element, a remote open command, a serial open command, or a front panel open command. When started, the Trip LED turns on briefly while the Trip Relay is energized. After the auxiliary breaker contacts indicate that the breaker has opened, the Trip Relay and indicator stop operating. If both 52a and 52b auxiliary contacts are not installed, the Trip Relay and indicator will de-energize 100 ms after the trip condition clears, or after two seconds.
- **2 CLOSE:** A close sequence can be initiated by a 760 reclosure or a remote, serial, or front panel close command. When started, the Close LED turns on briefly while the Close Relay energizes. After the auxiliary breaker contacts indicate that the breaker has closed, the Close Relay and indicator stop operating. If both 52a and 52b auxiliary contacts are not installed, the Close Relay and indicator operate for 200 ms.
- **3 to 7 AUXILIARY:** These relays are intended for customer specific requirements that can be initiated by any protection element or function whose RELAYS (3-7) setpoint has “3”, “4”, “5”, “6”, or “7” selected. The Auxiliary LEDs (3 to 7) will turn on while the corresponding relays are operating.
- **8 SELF-TEST WARNING:** During normal operation, this indicator is off with the fail-safe Self-Test Warning Relay energized. If any abnormal condition is detected during self monitoring (such as a hardware failure) the indicator turns on and the relay de-energizes. If control power is lost or the relay is drawn out of its case, the Self-Test Warning Relay signals loss of protection by de-energizing, but the LED indicator remains off. Since there are no shorting contacts across the Self-Test Warning Relay, both the normally open and normally closed contacts are open when the unit is drawn out.

4.1.3 KEYPAD OPERATION

The 750/760 display messages are organized into pages under the headings Setpoints and Actual Values. The SETPOINT key navigates through the page headers of programmable parameters (setpoints). The ACTUAL key navigates through the page headers of measured parameters (actual values). Each page is broken down further into logical sub-pages of messages. The MESSAGE ▼ and MESSAGE ▲ keys are used to navigate through the sub-pages. A summary of the setpoints and actual values pages can be found in the Chapters 5: Setpoints and 6: Actual Values, respectively.

The ENTER key is dual purpose. It is used to enter the sub-pages and to store altered setpoint values into memory to complete the change. The ESCAPE key is also dual purpose. It is used to exit from sub-pages and also to abort a setpoint change.

The VALUE ▼ and VALUE ▲ keys are used to scroll through the possible choices of an enumerated setpoint. They also decrement and increment numerical setpoints. Numerical setpoints may also be entered through the numeric keypad.

The HELP key may be pressed at any time to display a list of context sensitive help messages. Continue to press the HELP key to display all the help messages and return to the original display.

The RESET key resets any latched conditions that are not presently active. This includes resetting latched output relays, latched Trip LEDs, breaker operation failure, and trip / close coil failures. The 760 Autoreclose Scheme is also reset with the shot counter being returned to zero and the lockout condition being cleared.

The NEXT key scrolls through any active conditions in the relay. Diagnostic messages are displayed indicating the state of protection and monitoring elements that are picked up, operating, or latched. When the Message LED is on there are messages to be viewed with the NEXT key.

Pressing the OPEN key will attempt to open the breaker connected to the Trip Relay by closing the contact. Likewise, the CLOSE key will attempt to close the breaker connected to the Close Relay by closing the contact. The OPEN and CLOSE keys only operate when the relay is in local mode; local mode can be enabled with a user programmed logic input.

4.1.4 MESSAGES

a) DIAGNOSTIC MESSAGES

Diagnostic messages are automatically displayed for any active conditions in the relay such as trips, alarms, or asserted logic inputs. These messages provide a summary of the present state of the relay. The Message LED flashes when there are diagnostic messages available; press the NEXT key to scroll through the messages. The following shows the format of the various diagnostic messages.

■ PICKUP: <F> ■ < Cause >	These messages show any elements that are presently picked up.
■ TRIP: <F> ■ < Cause >	These messages indicate that an element has tripped. The message remains in the diagnostic queue until the relay is reset.
■ ALARM: <F> ■ < Cause >	These messages show any elements that are presently operating and have been programmed to have an alarm function. When an element is programmed to Latched Alarm, this message remains in the diagnostic queue after the alarm condition clears until the relay is reset.
■ SELF-TEST WARNING: ■ < Cause >	These messages show any self-test warnings.

b) SELF-TEST WARNINGS

The relay performs self diagnostics at initialization (after power up), and continuously as a background task to ensure that every testable unit of the hardware and software is alive and functioning correctly. There are two types of self-test warnings indicating either a minor or major problem. Minor problems indicate a problem with the relay that does not compromise protection of the power system. Major problems indicate a very serious problem with the relay which comprises all aspects of relay operation.

WARNING **Self-Test Warnings may indicate a serious problem with the relay hardware!**

Upon detection of either a minor or major problem, the relay will:

- De-energize the Self-Test Warning Relay.
- Indicate the failure in the diagnostic message queue.
- Record the failure in the Event Recorder.

Upon detection of a major problem, the relay will (if possible) also:

- Turn off the Relay In Service LED.
- Inhibit operation of all output relays.

Table 4–1: SELF-TEST WARNINGS

ERROR	SEVERITY	DESCRIPTION
A/D Virtual Ground	Major	This warning is caused by a failure of the analog to digital converter. The integrity of system input measurements is affected by this failure.
Analog Output +32V	Minor	Caused by the loss of the +32 V DC power supply used to power analog outputs. Analog output currents are affected by this failure.
Clock Not Set	Minor	Occurs if the clock has not been set.
Dry Contact +32V	Minor	Caused by the loss of the +32 V DC power supply used to power dry contacts of logic inputs. Logic inputs using internal power are affected by this failure.
EEPROM Corrupt	Major	Caused by detection of corrupted location(s) in the relay data memory which cannot be self-corrected. Any function of the relay is susceptible to malfunction from this failure.
Factory Service	Major	This warning occurs when the relay is in factory service mode.
FLASH Corrupt	Major	This warning is caused by detection of a corrupted location in the program memory as determined by a CRC error checking code. Any function of the relay is susceptible to malfunction from this failure.
Force Analog Out	Minor	Occurs when the **FORCE A/O FUNCTION** setpoint is “Enabled”.
Force Relays	Minor	Occurs when the **FORCE OUTPUT RELAYS FUNCTION** setpoint is "Enabled".
Internal RS485	Minor	Caused by a failure of the internal RS485 communication link. Attempts to read actual values or write setpoints will produce unpredictable results.
Internal Temp	Minor	Caused by the detection of unacceptably low (less than –40°C) or high (greater than +85°C) temperatures detected inside the unit.
IRIG-B Failure	Minor	Caused when IRIG-B time synchronization has been enabled but the signal cannot be decoded.
Not Calibrated	Minor	This warning occurs when the relay has not been factory calibrated.
Pickup Test	Minor	Occurs when the **PICKUP TEST FUNCTION** setpoint is "Enabled".
Prototype Software	Minor	Occurs when prototype software has been loaded into the relay.
Relay Not Ready	Minor	This warning occurs when the **750/760 OPERATION** setpoint not been set to “Ready”.
RTC Crystal	Minor	This warning is caused by a failure of the Real Time Clock circuit. The ability of the relay to maintain the current date and time is lost.
Simulation Mode	Minor	This warning occurs when the simulation feature of the relay is active.

c) FLASH MESSAGES

Flash messages are warning, error, or general information messages displayed in response to certain key presses. The length of time these messages remain displayed can be programmed in **S1 RELAY SETUP ⇨⇩ FRONT PANEL ⇨ FLASH MESSAGE TIME**. The factory default flash message time is 4 seconds.

■ ADJUSTED VALUE ■ HAS BEEN STORED	This flash message is displayed in response to the ENTER key, while on a setpoint message with a numerical value. The edited value had to be adjusted to the nearest multiple of the step value before it was stored.
■ COMMAND IS BEING ■ EXECUTED	This flash message is displayed in response to executing a command message. Entering "Yes" at a command will display the message **ARE YOU SURE?**. Entering "Yes" again will perform the requested command and display this flash message.
■ DEFAULT MESSAGE ■ HAS BEEN ADDED	This flash message is displayed in response to pressing the [.] key, followed by the ENTER key twice, on any message in **S1 RELAY SETUP ⇨⇩ DEFAULT MESSAGES**.
■ DEFAULT MESSAGE ■ HAS BEEN REMOVED	This message is displayed in response to pressing the [.] key, followed by the ENTER key twice, on any selected default message in **S1 RELAY SETUP ⇨⇩ DEFAULT MESSAGES**.
■ ENTER PASSCODE ■ IS INVALID	This flash message is displayed in response to an incorrectly entered passcode when attempting to enable or disable setpoint access.
■ ENTRY MISMATCH - ■ CODE NOT STORED	This message is displayed while changing the password with the **S1 RELAY SETUP ⇨ PASSCODE ⇨⇩ CHANGE PASSCODE** setpoint. If the passcode entered at the **PLEASE RE-ENTER A NEW PASSCODE** prompt is different from the one entered **PLEASE ENTER A NEW PASSCODE** prompt, the relay dumps the new passcode and display this message

■ INVALID KEY: MUST ■ BE IN LOCAL MODE	This flash message is displayed in response to pressing the OPEN or CLOSE keys while the relay is in Remote Mode. The relay must be put into Local Mode in order for these keys to be operational.
■ NEW PASSCODE ■ STORED	This message is displayed in response to changing the programmed passcode from the **S1 RELAY SETUP ⇨ PASSCODE ⇨⇩ CHANGE PASSCODE** setpoint. The directions to change the passcode were followed correctly and the new passcode was stored as entered.
■ NEW SETPOINT ■ STORED	This flash message is displayed in response to the ENTER key while on any setpoint message. The edited value was stored as entered.
■ NO CONDITIONS ARE ■ CURRENTLY ACTIVE	This flash message is displayed in response to the NEXT key while the Message LED is off. There are no active conditions to display in the diagnostic message queue.
■ OUT OF RANGE - ■ VALUE NOT STORED	This flash message is displayed in response to the ENTER key while on a setpoint message or numerical value. The edited value was either less than the minimum or greater than the maximum acceptable values for the edited setpoint and as a result was not stored.
■ PLEASE ENTER A ■ NON-ZERO PASSCODE	This flash message is displayed while changing the passcode with the **S1 RELAY SETUP ⇨ PASSCODE ⇨⇩ CHANGE PASSCODE** setpoint. An attempt was made to change the passcode to "0" when it was already "0".
■ PRESS [ENTER] TO ■ ADD AS DEFAULT	This flash message is displayed for 5 seconds in response to pressing the ▪ key, followed by the ENTER key while displaying any setpoint or actual value message except those in **S1 RELAY SETUP ⇨⇩ DEFAULT MESSAGES**. Pressing the ENTER key again while this message is displayed adds the setpoint or actual value message to the default list.
■ PRESS [ENTER] TO ■ BEGIN TEXT EDIT	This message is displayed in response to the VALUE ▽ and VALUE △ keys while on a setpoint message with a text entry value. The ENTER key must be pressed to begin editing.
■ PRESS [ENTER] TO ■ REMOVE MESSAGE	This flash message is displayed for 5 seconds in response to pressing the ▪ key, followed by the ENTER key while displaying one of the selected default messages in the subgroup **S1 RELAY SETUP ⇨⇩ DEFAULT MESSAGES**. Pressing the ENTER key again while this message is displayed removes the default message from the list.
■ PRESSED KEY ■ IS INVALID HERE	This flash message is displayed in response to any pressed key that has no meaning in the current context.
■ RESETTING LATCHED ■ CONDITIONS	This flash message is displayed in response to the NEXT key. All active latched conditions (trips, alarms, or latched relays) for which the activating condition is no longer present will be cleared.
■ SETPOINT ACCESS ■ DENIED (PASSCODE)	This flash message is displayed in response to the ENTER key while on any setpoint message. Setpoint access is restricted because the programmed passcode has not been entered to allow access.
■ SETPOINT ACCESS ■ DENIED (SWITCH)	This flash message is displayed in response to the ENTER key while on any setpoint message. Setpoint access is restricted because the setpoint access terminals have not been connected.
■ SETPOINT ACCESS ■ IS NOT ALLOWED	This flash message is displayed in response to correctly entering the programmed passcode at the **S1 RELAY SETUP ⇨ PASSCODE ⇨⇩ ALLOW ACCESS TO SETPOINTS** setpoint. The command to allow access to setpoints has been successfully executed and setpoints can be changed and entered.
■ SETPOINT ACCESS ■ IS NOW RESTRICTED	This flash message is displayed in response to entering the correct programmed passcode at the **S1 RELAY SETUP ⇨ PASSCODE ⇨⇩ RESTRICT ACCESS TO SETPOINTS** setpoint. The command to restrict access to setpoints has been successfully executed and setpoints cannot be changed.

4.2.1 DESCRIPTION

The 750/760PC software may be used for training or testing purposes from any computer running Microsoft Windows software. Setpoints may be edited and printed, actual values may be read, and relay operation may be simulated. The 750/760PC software is included on the GE Multilin Products CD provided with every 750/760 relay

The software can be used to:

- Program and modify setpoints.
- Save setpoint files to a local PC and upload setpoint files into the unit.
- Read and print actual values.
- Monitor relay status.
- Plot, print, and view trending graphs of selected actual values.
- Perform waveform capture (oscillography).
- Download and playback waveforms (Simulation Mode).
- View the Event Recorder
- Get online help on any topic.

The 750/760PC software can be used “stand-alone”, without an attached 750/760 relay, to create or edit 750/760 setpoint files for future use or testing.

4.2.2 REQUIREMENTS

The following minimum requirements must be met for the 750/760PC software to operate properly.

- Processor: minimum 486, Pentium or higher is recommended.
- Memory: minimum 4 MB, 16 MB recommended; a minimum 540 K of conventional memory for Windows 3.1
- Hard Drive: 20 MB free space required before installation of software.
- Operating System: Windows 3.1 and variants, Windows 95/98, Windows NT/2000.

The 750/760PC software is ideal for use on under-used legacy equipment. If running 750/760PC under Windows 3.1/3.11, the following additional considerations must be addressed:

- The `SHARE.EXE` application must be installed.
- Close other applications (spreadsheets, word processors, etc.) before running the software to eliminate any problems that arise from low conventional memory.

4.2.3 HARDWARE CONFIGURATION

The 750/760PC software communicates with the 750/760 via the front panel RS232 port or the rear terminal RS485 ports. To communicate with the relay via the front 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 computer for COM1 or COM2, respectively.

To communicate with the relay via the rear RS485 ports, the GE Multilin F485 RS232/RS485 Converter box is needed. The F485 converter box is connected to the relay using a “straight-through” serial cable. A shielded twisted pair (20, 22 or 24 AWG) cable is used to connect the converter box to the 750/760 rear terminals. The converter box (+, –, GND) terminals are connected to the (B1, B2, B3) relay terminals for relay COM1 respectively. The line should also be terminated in an RC network (i.e. 120 Ω, 1 nF) as described in Section 3.2.1: Typical Wiring on page 3–7.

4.2.4 INSTALLATION/UPGRADE

a) PREPARATION

If 750/760PC is already installed, run the program and check if it needs upgrading as follows:

1. While 750/760PC is running, insert the GE Multilin Products CD and allow it to autostart (alternately, load the `D:\index.htm` file into your default web browser, **OR**

   Go to the GE Multilin website at http://www.GEindustrial.com/multilin (preferred method).
2. Click the “Software” menu item and select “750/760 Motor Management Relay” from the product list.
3. Verify that the version shown on this page is identical to the installed version as shown below. Select the **Help > About 750/760PC** menu item to determine which version is running on the local PC.

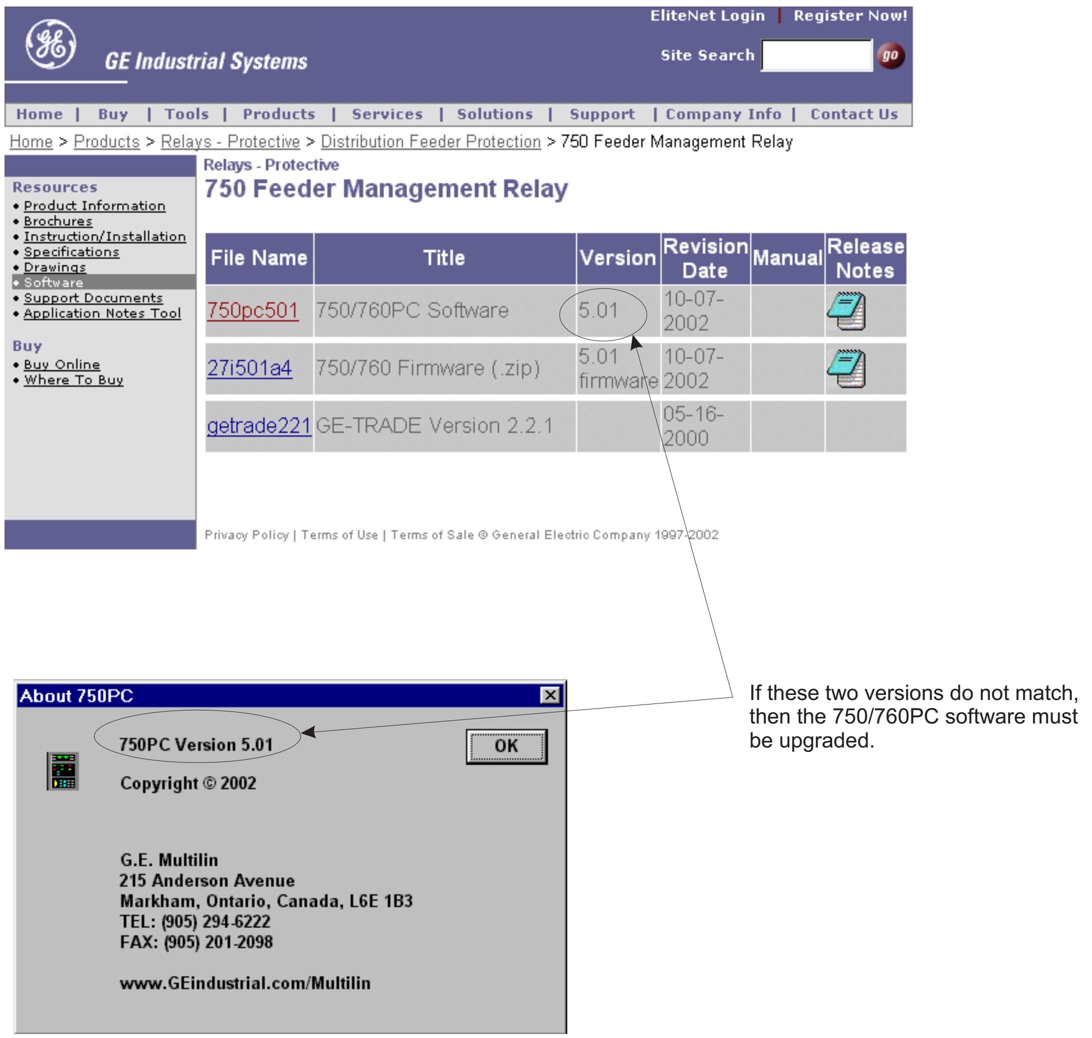


Figure 4–2: CHECKING IF 750/760PC REQUIRES UPGRADING

b) INSTALLING/UPGRADING 750/760PC

Installation/upgrade of the 750/760PC software is accomplished as follows:

1. Ensure that Windows is running on the local PC.
2. Insert the GE Multilin Products CD into your CD-ROM drive or point your web browser to the GE Multilin website at http://www.GEindustrial.com/multilin. With Windows 95/98 or higher, the Products CD will launch the welcome screen automatically; with Windows 3.1, open the Products CD by launching the `index.htm` file in the CD root directory.

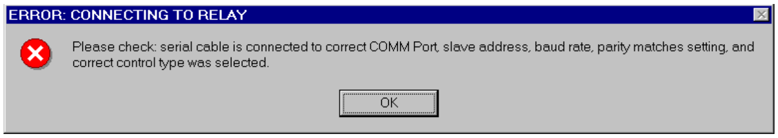
   The Products CD is essentially a “snapshot” of the GE Multilin website at the date printed on the CD. As such, the procedures for installation from the CD and the web are identical; however, to ensure that the newest version of 750/760PC is installed, installation from the web is preferred.

Figure 4–3: GE MULTILIN WELCOME SCREEN

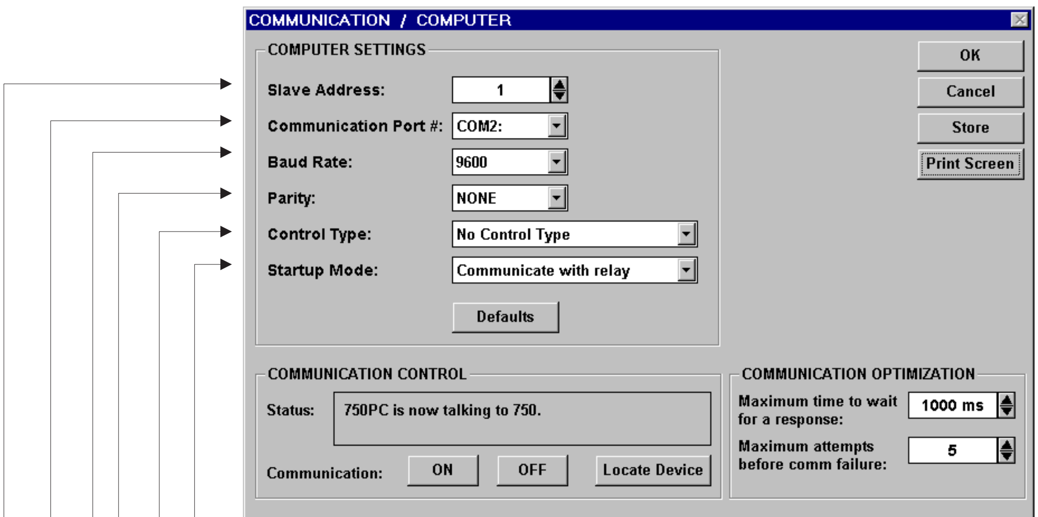
3. Click the Index by Product Name item from the main page and select 750/760 Feeder Management Relay from the product list to open the 750/760 product page.
4. Click the Software item from the Product Resources list to go to the 750/760 software page.
5. The latest version of the 750/760PC software will be shown. Click on the **750/760PC Program** item to download the installation program to your local PC. Run the installation program and follow the prompts to install to the desired directory. When complete, a new GE Multilin group window will appear containing the 750/760PC icon.

4.2.5 STARTUP AND COMMUNICATIONS CONFIGURATION

1. Connect the computer running the 750/760PC software to the relay via one of the RS485 ports (see Section 3.2.10: RS485 and RS422 Communications on page 3–16 for details and wiring) or directly via the RS232 front port.
2. Start 750/760PC. When starting, the software attempts to communicate with the relay. If communications are successfully established, the relay shown on the screen will display the same information seen on the actual relay The LED Status shown will also match the actual relay when communications is established.
3. If 750/760PC cannot establish communications with the relay, this message will appear.



4. Click **OK** to edit the communications settings (or alternately, select the **Communications > Computer** menu item at any time). The Communications/Computer dialog box will appear containing the various communications settings for the local PC. The settings should be modified as shown below.



Set the **Startup Mode** based on user preference. In "Communicate with Relay" mode, 750/760 PC will attempt to establish communications immediately upon startup. While in the "File mode /w default settings", 750/760PC waits for the user to click the ON button before attempting communications – this mode is preferred when the software is being used without an attached 750/760 relay.

Set **Control Type** to match the type of RS232/RS485 converter. If connected through the 750/760 front pane RS232 port, select "No Control Type". If connected through a GE Multilin F485 converter unit, select "MULTILIN RS232/RS485 CONVERTOR". If connected through a modem, select "Modem". If a third-party RS232/RS485 converter is being used, select the appropriate control type from the available list based on the manufacturer's specifications.

Set **Parity** to match the appropriate PARITY setpoint (see S1 RELAY SETUP / PORT SETUP). If connected through the 750/760 front panel RS232 port, set to "None".

Set **Baud Rate** to match the appropriate BAUD RATE setpoint (see S1 RELAY SETUP / PORT SETUP).

Set **Communcation Port #** to ***the COM port on your local PC*** where the 750/760 relay is connected (e.g. COM1 or COM2). On most computers, COM1 is used by the mouse device and as such COM2 is usually available for communications.

Set **Slave Address** to match the SLAVE ADDRESS setpoint (see S1 RELAY SETUP / PORT SETUP).

Figure 4–4: COMMUNICATION/COMPUTER DIALOG BOX

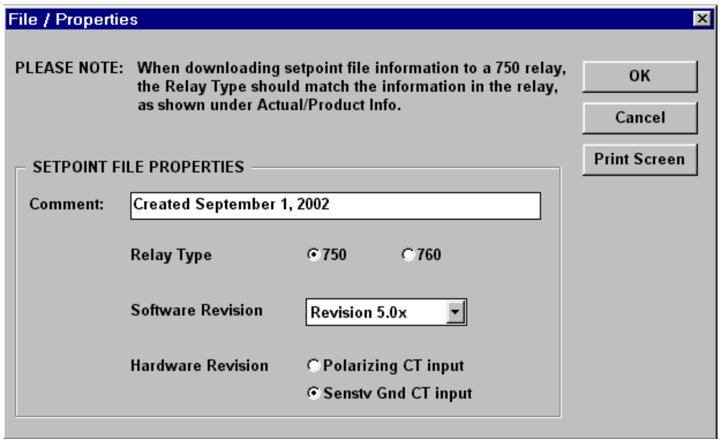
5. To begin communications, click the **ON** button in the **Communication** section of the dialog box. The status section indicates the communications status. If communications are established, the message "750/760PC is now talking to a 750/760" is displayed. As well, the status at the bottom right hand corner of the screen indicates "Communicating".

4.2.6 USING 750/760PC

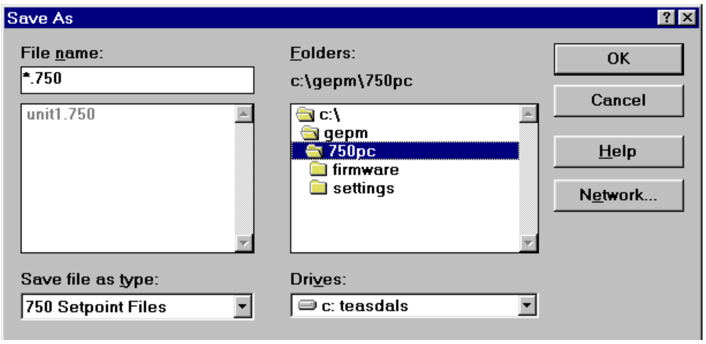
a) SAVING SETPOINTS TO A FILE

Setpoints must be saved to a file on the local PC before performing any firmware upgrades. Saving setpoints is also highly recommended before making any setpoint changes or creating new setpoint files. To save setpoints to a file on the local PC, follow the procedure below.

1. Select the **File > Properties** menu item. The dialog box below appears, allowing for the configuration of the 750/760PC software for the correct firmware version. 750/760PC needs to know the correct version when creating a setpoint file so that setpoints not available in a particular version are not downloaded into the relay.



2. When the correct firmware version is chosen, select the **File > Save As** menu item. This launches the following dialog box. Enter the filename under which the setpoints are saved in the **File Name** box or select any displayed file names to update them. All 750/760 setpoint files should have the extension `750` or `760` (for example, `motor1.750`). Click **OK** to proceed.



3. The software reads all the relay setpoint values and stores them to the selected file.

b) UPGRADING THE 750/760 FIRMWARE

NOTE

Units with bootware versions earlier than 3.00 must be set to a Baud Rate of 9600 and a Slave Address of 1 before downloading new firmware. The bootware version can be checked with the **A5 PRODUCT INFO ⇨⇩ REV CODES ⇨⇩ BOOTWARE REV** actual value.

Prior to downloading new firmware into the 750/760, it is necessary to save the setpoints to a file on the local PC (see the section above for details). Loading new firmware into the 750/760 flash memory is accomplished as follows:

1. Ensure the local PC is connected to the 750/760 via one of the RS485 ports or the front RS232 port and that communications are established. Save the current setpoints to a file using the procedure outlined in the previous section.
2. Select the **Communications > Upgrade Firmware** menu item.
3. A warning message will appear (remember that all previously programmed setpoints will be erased). If you have not yet saved the current setpoints to a file, click **No** to exit. Otherwise, click **Yes** to proceed.

4

4. Next, 750/760PC will request the new firmware file. Locate the appropriate file by changing drives and/or directories until a list of file names appears in the list box. File names for released 750/760 firmware have the following format:

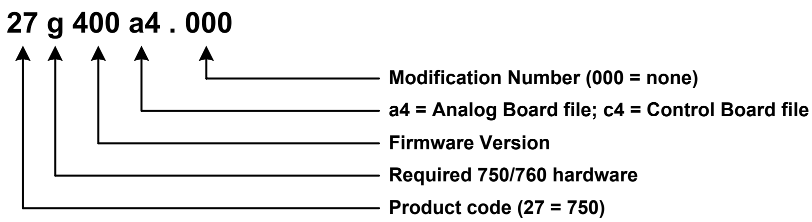


Figure 4–5: 750/760 FIRMWARE FILE FORMAT

5. The 750/760PC software automatically lists all filenames beginning with **27**. Select the appropriate file and click OK to continue.
6. The software will prompt with another Upload Firmware Warning window. This will be the last chance to cancel the firmware upgrade before the flash memory is erased. Click **Yes** to continue or **No** to cancel the upgrade.
7. The software automatically puts the relay into Upload Mode and begins loading the selected file. Upon completion (which may take several minutes), the relay is placed back into Normal Mode.

After successfully updating of the 750/760 firmware, the relay will not be in service and will require setpoint programming. To communicate with the relay, the **Slave Address**, **Baud Rate**, and **Parity** will have to me manually programmed. When communications is established, the saved setpoints must be reloaded back into the relay. See the following section for details on loading saved setpoint files.

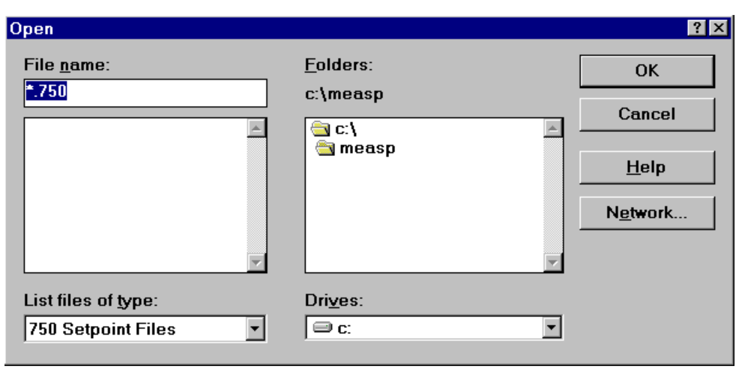
c) LOADING SETPOINTS FROM A FILE

WARNING

An error message will occur when attempting to download a setpoint file with a revision number that does not match the relay firmware. If the firmware has been upgraded since saving the setpoint file, see Upgrading Setpoint Files to a New Revision on page 4–14 for instructions on changing the revision number of a setpoint file.

The following procedure demonstrates how to load setpoints from a file:

1. Select the **File > Open** menu item.
2. 750/760PC will launch the Open window and list all filenames in the 750/760 default directory with the 750/760 extension. Select the setpoint file to download and click OK to continue.

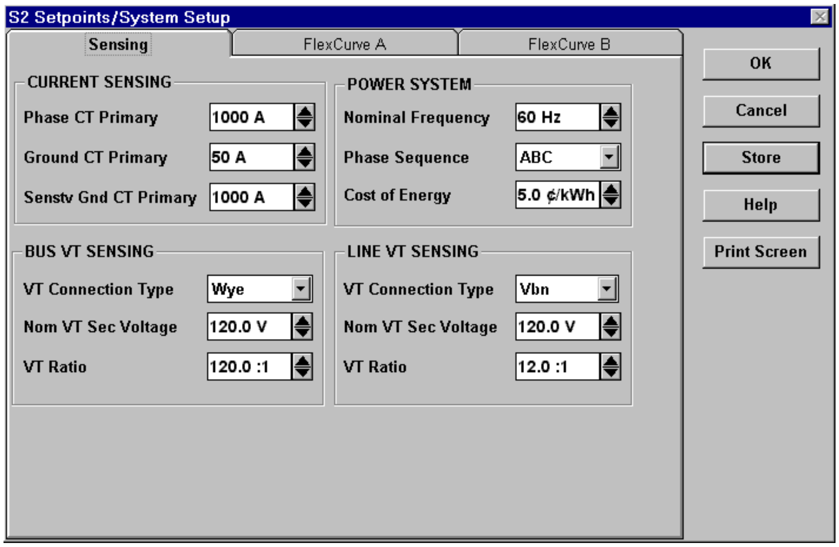


3. Select the **File > Send Info to Relay** menu item. 750/760PC will prompt to confirm or cancel the setpoint file load. Click Yes to update the 750/760 setpoints.

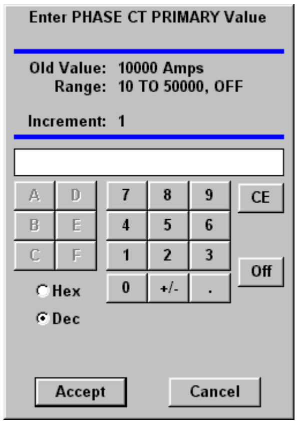
d) ENTERING SETPOINTS

The following example illustrates how setpoints are entered and edited with the 750/760PC software.

1. Select the **Setpoint > System Setup** menu item.
2. Click the **Sensing** tab to edit the S2 SYSTEM SETUP ⇨ CURRENT SENSING setpoints. 750/760PC displays the following window:



3. For setpoints requiring numerical values, e.g. PHASE CT PRIMARY, clicking anywhere within the setpoint box launches a numerical keypad showing the old value, range, and setpoint value increment.



4. Alternately, numerical setpoint values may also be chosen by scrolling with the up/down arrow buttons at the end of the setpoint box. The values increment and decrement accordingly.
5. For setpoints requiring non-numerical pre-set values (e.g. VT CONNECTION TYPE above), clicking anywhere within the setpoint value box displays a drop down selection menu.
6. For setpoints requiring an alphanumeric text string (e.g. message scratchpad messages), the value may be entered directly within the setpoint value box.

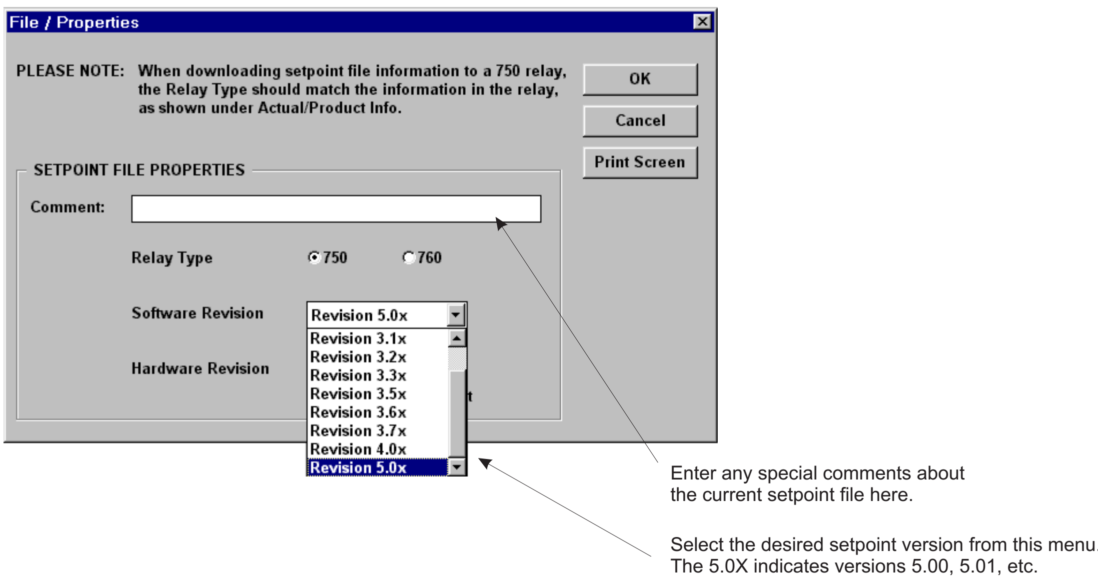
e) UPGRADING SETPOINT FILES TO A NEW REVISION

It may be necessary to upgrade the revision code for a previously saved setpoint file after the 750/760 firmware has been upgraded. This is demonstrated in the following procedure.

1. Establish communications with the 750/760 relay.
2. Select the **Actual > A5 Product Info** menu item and record the **Software Revision** identifier of the relay firmware. For example, 27I**501**A4.000, where **501** is the Software Revision identifier and refers to firmware revision 5.01.
3. Select the **File > Open** menu item and enter the location and file name of the saved setpoint file. When the file is opened, the 750/760PC software will be in File Editing Mode and “Not Communicating”.
4. Select the **File > Properties** menu item and note the version code of the setpoint file. If the **Version** code of the setpoint file (e.g. 5.0X shown below) is different than the **Software Revision** code noted in Step 2, select a **Version** code which matches the **Software Revision** code from the pull-down menu.

   For example,

   If the firmware revision is: 27I501A4.000 (software revision 5.01)
   and the current setpoint file revision is: 4.01
   change the setpoint file revision to: 5.0X



5. Select the **File > Save** menu item to save the setpoint file in the new format.

See Loading Setpoints from a File on page 4–12 for instructions on downloading this setpoint file to the 750/760.

f) PRINTING SETPOINTS AND ACTUAL VALUES

Use the following procedure to print a complete list of setpoint values.

1. Select the **File > Open** menu item and open a previously saved setpoint file OR establish communications with the 750/760.
2. Select the **File > Print Setup** menu item.
3. Select either **Setpoints (All)** or **Setpoints (Enabled Features)** and click **OK**.
4. Select the **File > Print** menu item to print the 750/760 setpoints.

Use the following procedure to print a complete list of actual values.

1. Establish communications with the 750/760.
2. Select the **File > Print Setup** menu item.
3. Select **Actual Values** and click **OK**.
4. Select the **File > Print** menu item to print the 750/760 actual values.

4.2.7 ADVANCED 750/760PC FEATURES

a) WAVEFORM CAPTURE (TRACE MEMORY)

The 750/760PC software can be used to capture waveforms (or view trace memory) from the 750/760 at the instant of a trip. A maximum of 64 cycles can be captured and the trigger point can be adjusted to anywhere within the set cycles. A maximum of 16 waveforms can be buffered (stored) with the buffer/cycle trade-off.

The waveforms captured are: I_a, I_b, I_c, I_g, I_{sg}, V_a, V_b, V_c, and V_s, as well as digital data for the output relays and contact input states.

1. With 750/760PC running and communications established, select the **Actual > Waveform Capture** menu item to open the waveform capture window.
2. The Phase A current waveform for the last 750/760 trip will appear. The date and time of the trip is displayed at the top of the window. The red vertical line indicates the trigger point of the relay.
3. Press the **Setup** button to enter the Graph Attribute page. Program the graphs to be displayed with the pull-down menu beside each graph description. Change the Color, Style, Width, Group#, and Spline selections as desired. Select the same Group# to scale all parameters together.

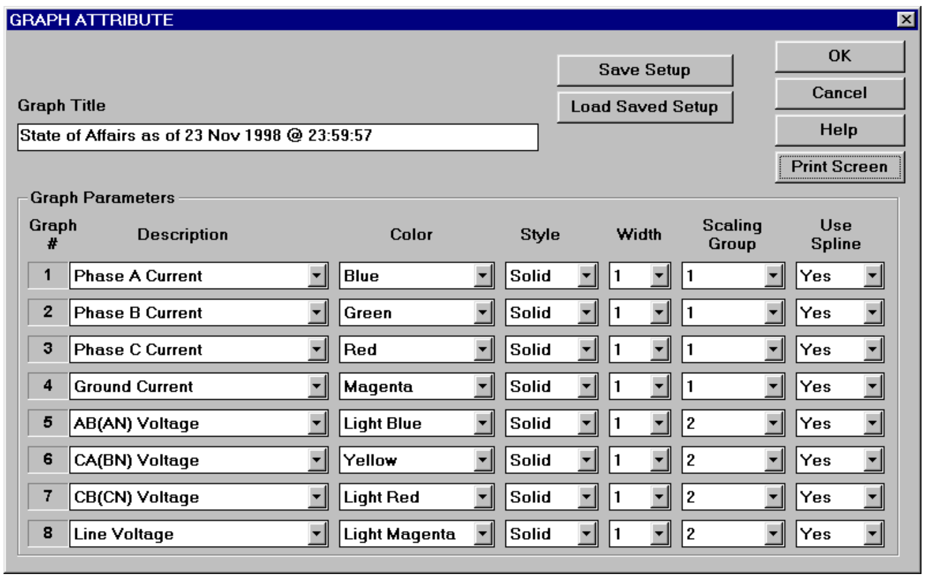


Figure 4–6: GRAPH ATTRIBUTE WINDOW

4. Click **Save** to store these graph attributes, then click **OK** to close the window.
5. The Waveform Capture window will reappear with the selected graph attributes available for use. Select the graphs to display by checking the appropriate checkboxes in the Legend (see diagram below).
6. The Save button stores the current image on the screen to a CSV (comma delimited) file, and Open recalls saved waveforms in CSV format. Waveform captures can also be printed from this window.

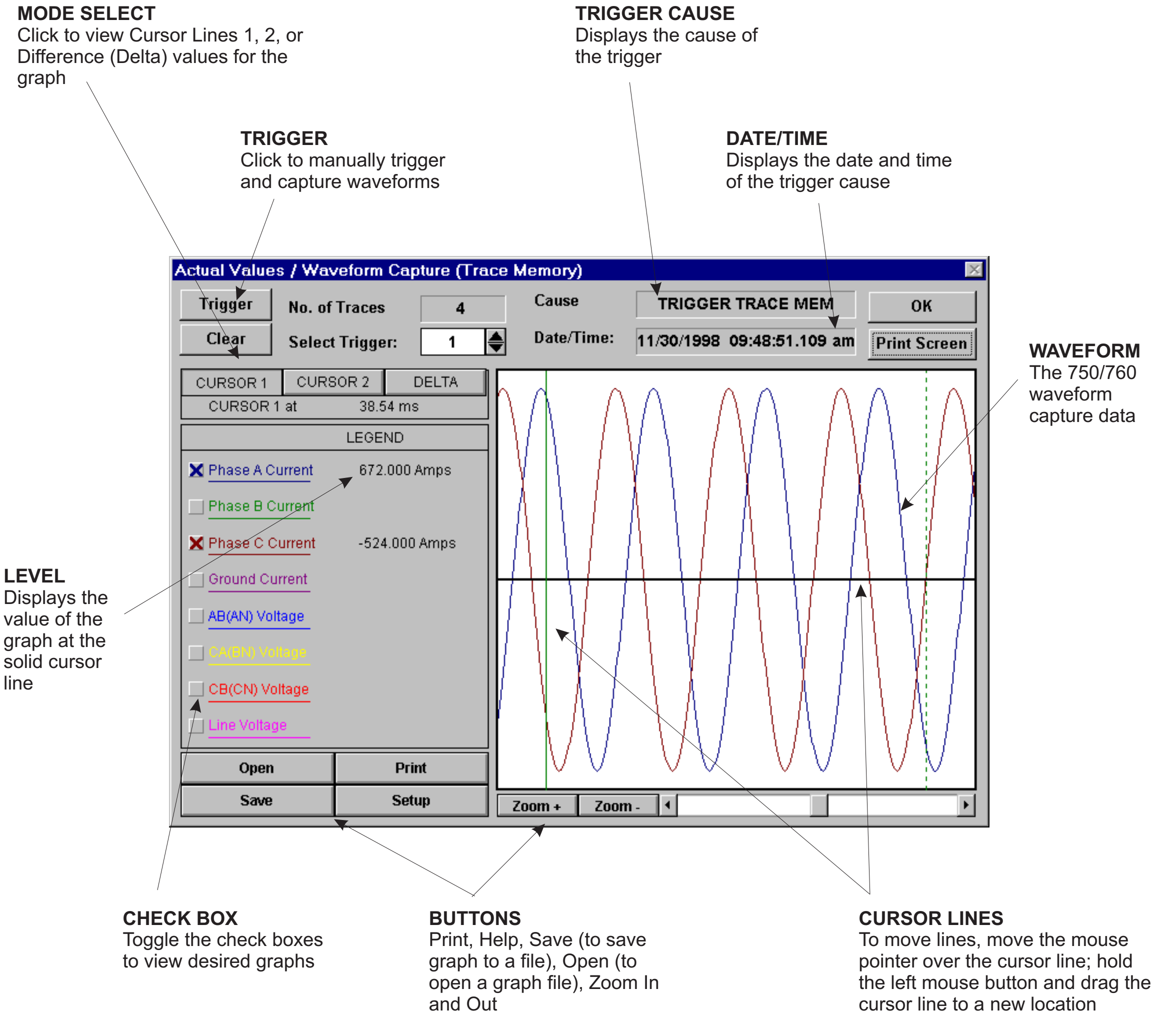


Figure 4–7: WAVEFORM CAPTURE

b) DATA LOGGER

The data logger feature is used to sample and record up to eight actual values at an interval that is defined by the user. Refer to Section 5.2.6: Data Logger on page 5–12 for more details. The Data Logger window behaves in the same manner as the Waveform Capture described above.

c) EVENT RECORDER

The 750/760 event recorder can be viewed through the 750/760PC software. The event recorder stores generator and system information each time an event occurs (e.g. Breaker Failure). A maximum of 128 events can be stored, where E128 is the most recent and E001 is the oldest. E001 is overwritten whenever a new event occurs. Refer to 6.5.1: Event Records on page 6–16 for additional information.

1. With 750/760PC running and communications established, select the **Actual > Event Recording** menu item to open the Event Recording window. This window displays the list of events with the most current event displayed first (see the figure below).
2. Press the View Data button to see details of selected events.
3. The Event Recorder Selector at the top of the View Data window scrolls through different events. Select Save to store the details of the selected events to a file.
4. Select Print to send the events to the system printer, and OK to close the window.

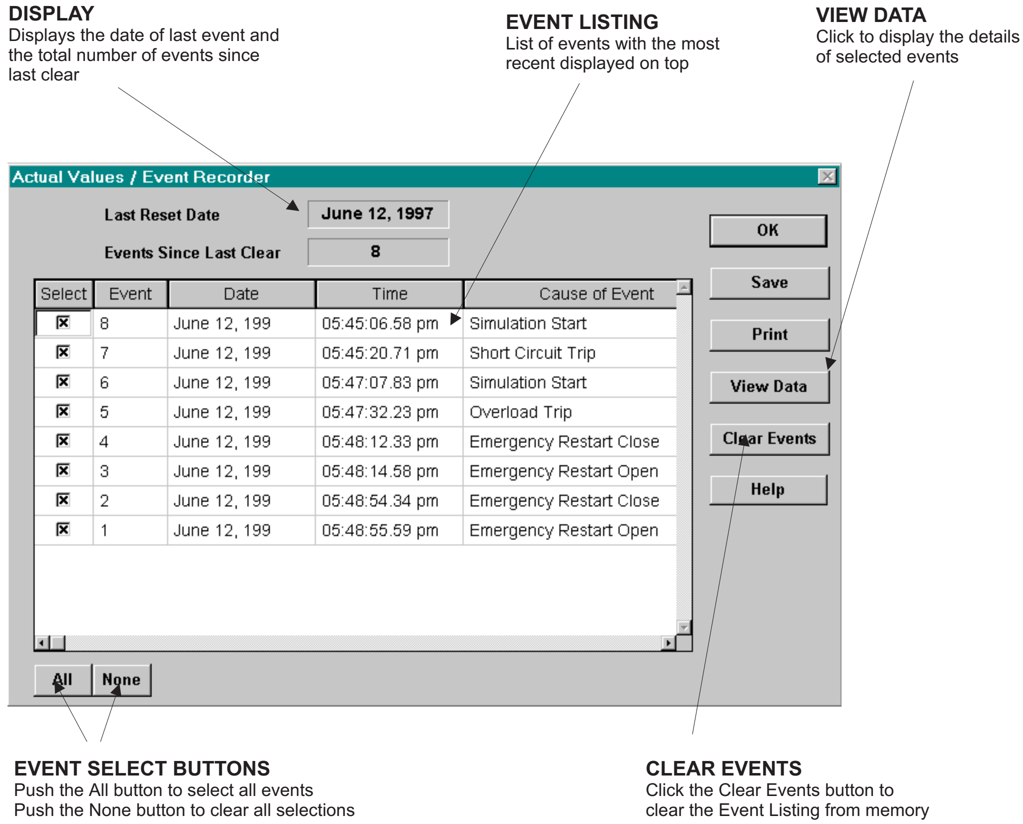


Figure 4–8: 750/760PC EVENT RECORDER

d) USER MAP

The 750/760PC software provides a means to program the 750/760 User Map (Modbus addresses 0180h to 01F7h). Refer to Section 7.3.7: Accessing Data via the User Map on page 7–11 for more information on the User Map.

Selecting **Setpoint > User Map** opens the window below. This window allows the desired addresses to be written to User Map locations. The User Map values that correspond to these addresses are then displayed.

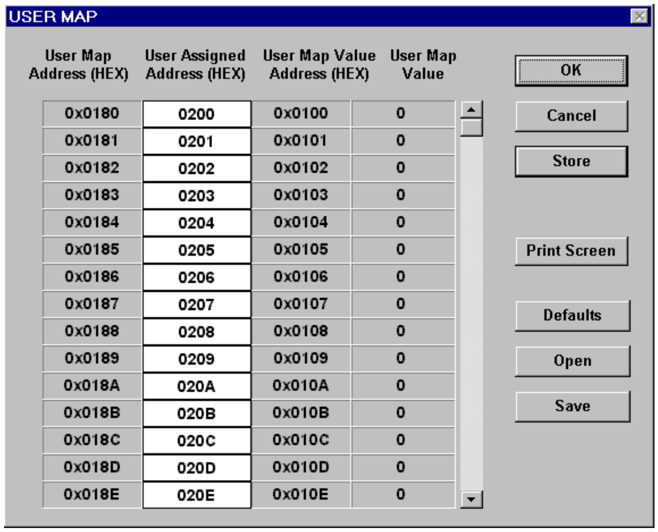


Figure 4–9: USER MAP WINDOW

4

5.1.1 SETPOINTS MESSAGE MAP

The 750/760 has a considerable number of programmable setpoints which makes it extremely flexible. The setpoints have been grouped into a number of pages and sub-pages as shown below. Each page of setpoints (e.g. **S2 SYSTEM SETUP**) has a section which describes in detail all the setpoints found on that page.

■■ SETPOINTS ■■ S1 RELAY SETUP	■ PASSCODE ■ [ENTER] for more	See page 5–7.
	■ COMMUNICATIONS ■ [ENTER] for more	See page 5–7.
	■ CLOCK ■ [ENTER] for more	See page 5–10.
	■ EVENT RECORDER ■ [ENTER] for more	See page 5–10.
	■ TRACE MEMORY ■ [ENTER] for more	See page 5–11.
	■ DATA LOGGER ■ [ENTER] for more	See page 5–12.
	■ FRONT PANEL ■ [ENTER] for more	See page 5–13.
	■ DEFAULT MESSAGES ■ [ENTER] for more	See page 5–14.
	■ USER TEXT MESSAGES ■ [ENTER] for more	See page 5–14.
	■ CLEAR DATA ■ [ENTER] for more	See page 5–15.
	■ INSTALLATION ■ [ENTER] for more	See page 5–15.
■■ SETPOINTS ■■ S2 SYSTEM SETUP	■ CURRENT SENSING ■ [ENTER] for more	See page 5–16.
	■ BUS VT SENSING ■ [ENTER] for more	See page 5–16.
	■ LINE VT SENSING ■ [ENTER] for more	See page 5–17.
	■ PWR SYSTEM ■ [ENTER] for more	See page 5–17.
	■ FLEXCURVE A ■ [ENTER] for more	See page 5–18.
	■ FLEXCURVE B ■ [ENTER] for more	See page 5–18.
■■ SETPOINTS ■■ S3 LOGIC INPUTS	■ LOGIC INPUTS SETUP ■ [ENTER] for more	See page 5–19.
	■ BREAKER FUNCTIONS ■ [ENTER] for more	See page 5–21.

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■ CONTROL FUNCTIONS ■ [ENTER] for more	See page 5–22.
■ USER INPUTS ■ [ENTER] for more	See page 5–22.
■ BLOCK FUNCTIONS ■ [ENTER] for more	See page 5–23.
■ BLOCK OC FUNCTIONS ■ [ENTER] for more	See page 5–24.
■ TRANSFER FUNCTIONS ■ [ENTER] for more	See page 5–25.
■ RECLOSE FUNCTIONS ■ [ENTER] for more	See page 5–26.
■ MISC FUNCTIONS ■ [ENTER] for more	See page 5–26.

ESCAPE / MESSAGE

■■ SETPOINTS
■■ S4 OUTPUT RELAYS

ENTER / ESCAPE

■ 1 TRIP RELAY ■ [ENTER] for more	See page 5–28.
■ 2 CLOSE RELAY ■ [ENTER] for more	See page 5–29.
■ 3 AUX RELAY ■ [ENTER] for more	See page 5–30.
↓	
■ 7 AUX RELAY ■ [ENTER] for more	

ESCAPE / MESSAGE

■■ SETPOINTS
■■ S5 PROTECTION

ENTER / ESCAPE

■ PHASE CURRENT ■ [ENTER] for more	See page 5–36.
■ NEUTRAL CURRENT ■ [ENTER] for more	See page 5–42.
■ GND CURRENT ■ [ENTER] for more	See page 5–46.
■ SENSTV GND CURRENT ■ [ENTER] for more	See page 5–50.
■ NEGATIVE SEQUENCE ■ [ENTER] for more	See page 5–57.
■ VOLTAGE ■ [ENTER] for more	See page 5–62.
■ FREQ ■ [ENTER] for more	See page 5–67.
■ BRKR FAILURE ■ [ENTER] for more	See page 5–70.
■ REV PWR ■ [ENTER] for more	See page 5–71.

ESCAPE / MESSAGE

5

■■ SETPOINTS
■■ S6 MONITORING

ENTER / ESCAPE	■ CURRENT LEVEL ■ [ENTER] for more	See page 5–72.
ESCAPE / MESSAGE	■ PWR FACTOR ■ [ENTER] for more	See page 5–74.
ESCAPE / MESSAGE	■ FAULT LOCATOR ■ [ENTER] for more	See page 5–75.
ESCAPE / MESSAGE	■ DMND ■ [ENTER] for more	See page 5–77.
ESCAPE / MESSAGE	■ A/I ■ [ENTER] for more	See page 5–82.
ESCAPE / MESSAGE	■ A/O ■ [ENTER] for more	See page 5–85.
ESCAPE / MESSAGE	■ FREQ ■ [ENTER] for more	See page 5–87.
ESCAPE / MESSAGE	■ EQUIPMENT ■ [ENTER] for more	See page 5–88.
ESCAPE / MESSAGE	■ PULSED OUTPUT ■ [ENTER] for more	See page 5–94.

ESCAPE / MESSAGE

■■ SETPOINTS
■■ S7 CONTROL

ENTER / ESCAPE	■ SETPOINT GROUPS ■ [ENTER] for more	See page 5–95.
ESCAPE / MESSAGE	■ SYNCHROCHECK ■ [ENTER] for more	See page 5–98.
ESCAPE / MESSAGE	■ MANUAL CLOSE ■ [ENTER] for more	See page 5–100.
ESCAPE / MESSAGE	■ COLD LOAD PICKUP ■ [ENTER] for more	See page 5–102.
ESCAPE / MESSAGE	■ UNDERVOLT RESTORE ■ [ENTER] for more	See page 5–104.
ESCAPE / MESSAGE	■ UNDERFREQ RESTORE ■ [ENTER] for more	See page 5–105.
ESCAPE / MESSAGE	■ TRANSFER ■ [ENTER] for more	See page 5–106.
ESCAPE / MESSAGE	■ AR ■ [ENTER] for more	See page 5–117.

ESCAPE / MESSAGE

■■ SETPOINTS
■■ S8 TESTING

ENTER / ESCAPE	■ OUTPUT RELAYS ■ [ENTER] for more	See page 5–128.
ESCAPE / MESSAGE	■ PICKUP TEST ■ [ENTER] for more	See page 5–129.
ESCAPE / MESSAGE	■ A/O ■ [ENTER] for more	See page 5–129.
ESCAPE / MESSAGE	■ SIMULATION ■ [ENTER] for more	See page 5–130.

5

5.1.2 SETPOINT ENTRY METHODS

Prior to operating the relay on a feeder, setpoints defining system characteristics, inputs, relay outputs, and protection settings must be entered, via one of the following methods:

- Front panel, using the keys and display.
- Front program port, and a portable computer running the 750/760PC software supplied with the relay.
- Rear RS485/RS422 COM1 port or RS485 COM2 port and a SCADA system running user-written software.

Any of these methods can be used to enter the same information. A computer, however, makes entry much easier. Files can be stored and downloaded for fast, error free entry when a computer is used. To facilitate this process, a GE Multilin Products CD with the 750/760PC software is supplied with the relay.

The relay leaves the factory with setpoints programmed to default values, and it is these values that are shown in all the setpoint message illustrations. Many of these factory default values can be left unchanged.

WARNING

At a minimum, the **S2 SYSTEM SETUP** setpoints must be entered for the system to function correctly. To safeguard against the installation of a relay whose setpoints have not been entered, the relay **Relay Not Ready** self-test warning message is displayed. In addition, the Self-Test Warning Relay will be de-energized. Once the relay has been programmed for the intended application, the **S1 RELAY SETUP ⇨⇩ INSTALLATION ⇨ 760 OPERATION** setpoint should be changed from “Not Ready” (the factory default) to “Ready”.

Some messages associated with disabled features are hidden. These context sensitive messages are illustrated with a dotted border on the message box. Before putting the relay in the Ready state, each page of setpoint messages should be worked through, entering values either by keypad or computer.

5.1.3 SETPOINT ACCESS SECURITY

Hardware and passcode security features are designed into the relay to provide protection against unauthorized setpoint changes.

To program new setpoints using the front panel keys, a hardware jumper must be installed across the setpoint access terminals on the back of the relay. These terminals can be permanently wired to a panel mounted key switch if desired. Attempts to enter a new setpoint without the electrical connection across the setpoint access terminals will result in an error message. The jumper does not restrict setpoint access via serial communications.

The relay has a programmable passcode setpoint which may be used to disallow setpoint changes from both the front panel and the serial communications ports. This passcode consists of up to eight (8) alphanumeric characters.

The factory default passcode is “0”. When this specific value is programmed into the relay it has the effect of removing all setpoint modification restrictions. Therefore, only the setpoint access jumper can be used to restrict setpoint access via the front panel and there are no restrictions via the communications ports.

When the passcode is programmed to any other value, setpoint access is restricted for the front panel and all communications ports. Access is not permitted until the passcode is entered via the keypad or is programmed into a specific register (via communications). Note that enabling setpoint access on one interface does not automatically enable access for any of the other interfaces (i.e., the passcode must be explicitly set in the relay via the interface from which access is desired).

A front panel command can disable setpoint access once all modifications are complete. For the communications ports, access is disabled by writing an invalid passcode into the register previously used to enable setpoint access. In addition, setpoint access is automatically disabled on an interface if no activity is detected for thirty minutes.

The 750/760PC software incorporates a facility for programming the relay’s passcode as well as enabling/disabling setpoint access. For example, when an attempt is made to modify a setpoint but access is restricted, the program will prompt the user to enter the passcode and send it to the relay before the setpoint is actually written to the relay. If a SCADA system is used for relay programming, it is up to the programmer to incorporate appropriate security for the application.

5.1.4 COMMON SETPOINTS

To make the application of this device as simple as possible, similar methods of operation and therefore similar types of setpoints are incorporated in various features. Rather than repeat operation descriptions for this class of setpoint throughout the manual, a general description is presented in this overview. Details that are specific to a particular feature will be included in the discussion of the feature. The form and nature of these setpoints is described below.

FUNCTION setpoint:

The **<FeatureName> FUNCTION** setpoint determines the operational characteristics of each feature. The range is as follows:

- If **<FeatureName> FUNCTION:** "Disabled", then the feature is not operational.
- If **<FeatureName> FUNCTION:** "Enabled", then the feature is operational.
- If **<FeatureName> FUNCTION:** "Trip", then the feature is operational. When an output is generated the feature declares a Trip condition, which operates the 1 Trip relay and any other selected output relays, and displays the appropriate trip message.
- If **<FeatureName> FUNCTION:** "Trip & AR" (overcurrent features of 760 Only), then the feature is operational. When an output is generated, the feature declares a Trip condition which operates the 1 Trip relay and any other selected output relays, signals an Initiate to the autoreclose feature, and displays the appropriate trip message.
- If **<FeatureName> FUNCTION:** "Alarm" or "Latched Alarm", then the feature is operational. When an output is generated, the feature declares an "Alarm" condition which operates any selected output relays and displays the appropriate alarm message.
- If **<FeatureName> FUNCTION:** "Control" the feature is operational. When an output is generated, the feature operates any selected output relays.

The "Trip", "Trip & AR", "Alarm", and "Control" function setpoint values are also used to select those operations that will be stored in the Event Recorder.

RELAYS (3–7) setpoint:

The **<FeatureName> RELAYS (3-7)** setpoint selects the relays required to operate when the feature generates an output. The range is any combination of the 3 to 7 Auxiliary relays.

PICKUP setpoint:

The **<FeatureName> PICKUP** setpoint selects the threshold above (for over elements) or below (for under elements) which the measured parameter causes an output from the measuring element.

DELAY setpoint:

The **<FeatureName> DELAY** setpoint selects a fixed time interval to delay an input signal from appearing at the output.

From a contact input change of state to a contact closure of the 1 Trip relay, the total delay is the time selected in this setpoint plus approximately 2 power frequency periods. From an AC parameter input level change measured by an instantaneous feature to a contact closure of the 1 Trip relay, the total delay is the time selected in this setpoint plus approximately 2.5 power frequency periods. In both cases, auxiliary output relays are approximately 5 ms slower.

DIRECTION setpoint:

The **<FeatureName> DIRECTION** setpoint is available for overcurrent features which are subject to control from a directional element. The range is "Disabled", "Forward", and "Reverse".

- If **<FeatureName> DIRECTION:** "Disabled", then the element is allowed to operate for current flow in any direction. There is no supervision from the directional element.
- If **<FeatureName> DIRECTION:** "Forward", then the element is allowed to operate for current flow in the forward direction only, as determined by the directional element.
- If **<FeatureName> DIRECTION:** "Reverse", then the element is allowed to operate for current flow in the reverse direction only, as determined by the directional element.

PHASES REQUIRED FOR ANY OPERATION setpoint:

This setpoint is available for those features which measure each phase parameter individually.

- If **PHASES REQUIRED FOR ANY OPERATION:** "Any One", then an output is generated if any one or more phase parameters are beyond the pickup value.
- If **PHASES REQUIRED FOR ANY OPERATION:** "Any Two", then an output is generated if any combination of two or more phase parameters are beyond the pickup value.
- If **PHASES REQUIRED FOR ANY OPERATION:** "All Three", then n output is generated if all three phase parameters are beyond the pickup value.

5.1.5 LOGIC DIAGRAMS

The logic diagrams provided should be referred to for a complete comprehensive understanding of the operation of each feature. These sequential logic diagrams illustrate how each setpoint, input parameter, and internal logic is used in a feature to obtain an output. In addition to these logic diagrams, written descriptions are provided in the setpoints chapter which includes each feature.

SETPOINTS:

- Shown as a block with a heading labeled ‘SETPOINT’.
- The location of setpoints is indicated by the path heading on the diagram.
- The exact wording of the displayed setpoint message identifies the setpoint.
- Major functional setpoint selections are listed below the name and are incorporated in the logic.

MEASUREMENT UNITS:

- Shown as a block with an inset box labeled ‘RUN’ with the associated pickup/dropout setpoint shown directly above.
- Element operation of the detector is controlled by the signal entering the ‘RUN’ inset. The measurement/comparison can only be performed if a logic ‘1’ is provided at the ‘RUN’ input.
- Relationship between setpoint and input parameter is indicated by the following symbols: "<" (less than), ">" (greater than), etc.
- The ANSI device number (if one exists) is indicated above the block.

TIME DELAYS:

- Shown as a block with the following schematic symbol: |——|.
- If delay is adjustable, associated delay setpoint is shown directly above, and schematic symbol has an additional variability indication, an oblique bar.
- ANSI device number (62) is indicated above the block.

LED INDICATORS:

- Shown as the following schematic symbol, ⊗.
- The exact wording of the front panel label identifies the indicator.

LOGIC:

- Described with basic logic gates (AND, OR, XOR, NAND, NOR). The inverter (logical NOT), is shown as a circle: ❍.

CONDITIONS:

- Shown as a rounded block with a shaded heading labeled ‘CONDITION’.
- Conditions are mutually exclusive, i.e., only one condition can be active at any point in time.
- Conditions latch until another condition becomes active.
- The output of an active condition is 1 or logic high.

5.2.1 PASSCODE

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨ PASSCODE

■ PASSCODE ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	SETPOINT ACCESS: Allowed	*Range: Allowed, Restricted*
	ESCAPE MESSAGE ⇳	RESTRICT ACCESS TO SETPOINTS: No	*Range: Yes, No. Seen only if the passcode is not "0" and* **SETPOINT ACCESS** *is "Allowed".*
	ESCAPE MESSAGE ⇳	ALLOW ACCESS TO SETPOINTS: No	*Range: Yes, No. Seen only if* **SETPOINT ACCESS** *is set to "Restricted".*
	ESCAPE MESSAGE ⇳	CHANGE PASSCODE? No	*Range: Yes, No.*
	ESCAPE MESSAGE ⇧	ENCRYPTED PASSCODE: AIKFBAIK	*Range: Cannot be edited.*

If the passcode security feature is enabled, the setpoint access jumper must be installed on the rear terminals and a passcode must also be entered to program setpoints. When the relay is shipped from the factory the passcode is defaulted to "0". When the passcode is "0", the passcode security feature is always disabled and only the setpoint access jumper is required for changing setpoints from the front panel.

The **ALLOW ACCESS TO SETPOINTS** setpoint is only displayed when **SETPOINT ACCESS** is “Restricted”. In this state, new setpoints cannot be entered. To regain setpoint access, select “Yes” and follow directions to enter the previously programmed passcode. If the passcode is correctly entered, entering new setpoints will be allowed. If no keys are pressed for longer than 30 minutes, setpoint access automatically becomes restricted. Removing the setpoint access jumper immediately restricts setpoint access. If passcode protection is active but the passcode is not known, contact GE Multilin with the **ENCRYPTED PASSCODE** value.

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5.2.2 COMMUNICATIONS

a) MAIN MENU

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ COMMUNICATIONS

■ COMMUNICATIONS ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ PORT SETUP ■ [ENTER] for more	See page 5–8.
	ESCAPE MESSAGE ⇧	■ DNP CONFIGURATION ■ [ENTER] for more	See page 5–9.

The 750/760 relay has setpoints to enable communications through its RS232 and RS485/422 ports. Setpoints are also provided for configuring DNP communications through one of these ports.

b) PORT SETUP

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ COMMUNICATIONS ⇨ PORT SETUP

■ PORT SETUP ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	SLAVE ADDRESS: 1	Range: 1 to 254 in steps of 1
	ESCAPE / MESSAGE ⇳	COM1 RS485/422 BAUD RATE: 9600	Range: 300, 1200, 2400, 4800, 9600, 19200
	ESCAPE / MESSAGE ⇳	COM1 RS485/422 PARITY: None	Range: None, Odd, Even
	ESCAPE / MESSAGE ⇳	COM1 RS485/422 HARDWARE: RS485	Range: RS485, RS422
	ESCAPE / MESSAGE ⇳	COM2 RS485/422 BAUD RATE: 9600	Range: 300, 1200, 2400, 4800, 9600, 19200
	ESCAPE / MESSAGE ⇳	COM2 RS485/422 PARITY: None	Range: None, Odd, Even
	ESCAPE / MESSAGE ⇳	COM2 RS485/422 HARDWARE: RS485	Range: RS485, RS422
	ESCAPE / MESSAGE ⇳	FRONT RS232 BAUD RATE: 9600	Range: 300, 1200, 2400, 4800, 9600, 19200
	ESCAPE / MESSAGE ⇧	FRONT RS232 PARITY: None	Range: None, Odd, Even

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Up to 32 devices can be daisy-chained with one of them a computer or programmable controller. Either COM1 (the two wire RS485 or the four wire RS422 serial communication port) or COM2 (the two wire RS485 port) may be used. One relay can be connected directly to a personal computer via the front panel RS232 port with a standard straight-through RS232 cable.

- **SLAVE ADDRESS:** This setpoint selects the serial communications slave address of the relay. Both COM1 and COM2 use this same address. The front panel RS232 port accepts any address for normal communications, but must be set to “1” when upgrading the relay firmware. Each relay on the same RS485/422 communications link must have a unique address.
- **COM1 and COM2 RS485/422 BAUD RATE:** Selects the baud rate for the COM1 and COM2 RS485/RS422 communication ports. All relays on the communication link, and the computer connecting them, must run at the same baud rate. The fastest response is obtained at 19200 baud. Slower baud rates should be used if noise becomes a problem. The data frame is fixed at 1 start, 8 data, and 1 stop bit.
- **COM1 and COM2 PARITY:** Selects the parity for COM1 and COM2 communications ports.
- **COM1 and COM2 RS485/422 HARDWARE:** Selects the COM1 and COM2 hardware configurations to be either two-wire RS485 or four-wire RS422 communications.
- **FRONT PANEL RS232 BAUD RATE and PARITY:** These setpoints select the baud rate and parity for front panel RS232 serial communications port. When upgrading the relay firmware, the baud rate should be set to 9600.

c) DNP CONFIGURATION

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP CONFIGURATION

```
■ DNP CONFIGURATION
■ [ENTER] for more
```

DNP PORT: None	*Range: None, COM1, COM2, Front*
DNP POINT MAPPING: Disabled	*Range: Disabled, Enabled*
TRANS DELAY: 0 ms	*Range: 0 to 65000 ms in steps of 1*
DATA LINK CONFIRM MODE: Never	*Range: Never, Sometimes, Always*
DATA LINK CONFIRM TIMEOUT: 1000 ms	*Range: 0 to 65000 ms in steps of 1*
DATA LINK CONFIRM RETRIES: 3	*Range: 0 to 100 in steps of 1*
SELECT/OPERATE ARM TIMEOUT: 10000 ms	*Range: 1 to 65000 ms in steps of 1*
WRITE TIME INTERVAL: 0 min	*Range: 0 to 65000 min. in steps of 1*
COLD RESTART INHIBIT: Disabled	*Range: Disabled, Enabled*

5

The relay can be programmed to communicate using the DNP Protocol through one of its ports. Refer to the Device Profile Document on page 7–49 for details. The following setpoints configure the DNP Protocol within the relay.

- **DNP PORT:** Select which communications port will use the DNP protocol for communication. The 750/760 defaults to the Modbus protocol on all ports.
- **DNP POINT MAPPING:** Select whether the User Map will be available through DNP. When enabled, the 120 User Map values are included in the DNP Object 30 point list. See the Device Profile Document on page 7–49 for details.
- **TRANS DELAY:** Select the minimum time from when a DNP request is received and a response issued. A value of zero causes the response to be issued as quickly as possible.
- **DATA LINK CONFIRM MODE:** Select the data link confirmation mode desired for responses sent by the 750/760. When "Sometimes" is selected, data link confirmation is only requested when the response contains more than one frame.
- **DATA LINK CONFIRM TIMEOUT:** Select a desired timeout. If no confirmation response is received within this time, the 750/760 re-sends the frame if retries are still available.
- **DATA LINK CONFIRM RETRIES:** Select the number of retries that will be issued for a given data link frame.
- **SELECT/OPERATE ARM TIMEOUT:** Select the duration of the select / operate arm timer.
- **WRITE TIME INTERVAL:** Select the time that must elapse before the 750/760 will set the “need time” internal indication (IIN). After the time is written by a DNP master, the IIN will be set again after this time elapses. A value of zero disables this feature.
- **COLD RESTART INHIBIT:** When disabled, a cold restart request from a DNP master will cause the 750/760 to be reset. Enabling this setpoint will cause the cold start request to initialize only the DNP sub-module.

WARNING

When COLD START INHIBIT is "Disabled" is selected, a cold restart request causes loss of protection until the 750/760 reset completes.

5.2.3 CLOCK

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ CLOCK

```
■ CLOCK                 [ENTER]⇨  DATE (MM/DD/YYYY):     Range: 0 to 12 / 1 to 31 / 1990 to 2089
■ [ENTER] for more     ⇦[ESCAPE]  03/16/1997

                         [ESCAPE]  TIME (HH:MM:SS):       Range: 0 to 23 : 0 to 59 : 0 to 59
                        [MESSAGE]  16:30:00

                         [ESCAPE]  IRIG-B SIGNAL TYPE:    Range: None, DC Shift, Amplitude Modulated
                        [MESSAGE]  None
```

The relay has an internal real time clock that is used to perform time and date stamping for various relay features such as event, maximum demand, and last trip data recording. Time stamping on multiple relays can be synchronized to ±1 ms with the use of an IRIG-B input. The clock has a battery back up so that the time and date are maintained on the loss of relay control power. The time and date are preset at the factory, but should be changed to correspond to the appropriate time zone.

Enter the current date and time here. The new date and time take effect the instant the ENTER key is pressed.

The **IRIG-B SIGNAL TYPE** setpoint enabled the IRIG-B time synchronization and selects the type of IRIG-B signal to use. The IRIG-B signal contains all necessary time and date stamping data except for the year. The year must be entered with the date. If IRIG-B is enabled and functioning properly, then setting the time and date (except for the year) as described in the previous message will have no effect. If IRIG-B is enabled but the signal cannot be decoded, the **IRIG-B Failure** self-test warning is generated.

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5.2.4 EVENT RECORDER

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ EVENT RECORDER

```
■ EVENT RECORDER        [ENTER]⇨  EVENT RECORDER         Range: Enabled, Disabled
■ [ENTER] for more     ⇦[ESCAPE]  FUNCTION: Enabled

                         [ESCAPE]  RECORD PICKUP          Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled

                         [ESCAPE]  RECORD DROPOUT         Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled

                         [ESCAPE]  RECORD TRIP            Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled

                         [ESCAPE]  RECORD ALARM           Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled

                         [ESCAPE]  RECORD CONTROL         Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled

                         [ESCAPE]  RECORD LOGIC INPUT     Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled

                         [ESCAPE]  RECORD DATE/TIME       Range: Enabled, Disabled
                        [MESSAGE]  EVENTS: Enabled
```

The relay captures a wide variety of events and stores the last 128 in non-volatile memory. See Section 6.5.1: Event Records on page 6–16 for details. A single power system disturbance could conceivably fill half of the event recorder due to the various events that can be captured. Also, some events may happen on a regular basis as part of a control scheme (e.g. Power Factor events in a capacitor bank switching scheme). For this reason, certain event types can be 'filtered' from the event recorder to save room for other events. The following setpoints describe the events that can be filtered.

5.2.5 TRACE MEMORY

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ TRACE MEMORY

■ TRACE MEMORY ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	BUFFER ORGANIZATION: 16 x 256	*Range: 2 x 2048, 4 x 1024, 8 x 512, 16 x 256*
	ESCAPE / MESSAGE ⇳	TRIGGER POSITION: 25%	*Range: 0 to 100% in steps of 1*
	ESCAPE / MESSAGE ⇳	TRIGGER ON PICKUP: Enabled	*Range: Enabled, Disabled*
	ESCAPE / MESSAGE ⇳	TRIGGER ON DROPOUT: Disabled	*Range: Enabled, Disabled*
	ESCAPE / MESSAGE ⇳	TRIGGER ON TRIP: Enabled	*Range: Enabled, Disabled*
	ESCAPE / MESSAGE ⇳	TRIGGER ON ALARM: Enabled	*Range: Enabled, Disabled*
	ESCAPE / MESSAGE ⇧	TRIGGER ON CONTROL: Enabled	*Range: Enabled, Disabled*

The waveform capture feature is similar to a transient / fault recorder. It captures oscillography / waveform data in response to a variety of system events. Data is captured for the analog current and voltage inputs (Ia, Ib, Ic, Ig, Isg, Va, Vb, Vc, Vs) as well as digital data for the output relays and input contact states. The trace memory data can be downloaded to the 750/760PC software for display and diagnostics purposes. All data is stored in volatile RAM memory which means that the information is lost when power to the relay is lost. The amount of data to capture and the trigger point are configurable as described below.

- **BUFFER ORGANIZATION:** Selects the partitioning of waveform capture data storage. The first number indicates the number of events that can be stored in memory. The second number indicates the number of data samples captured per channel for each event. Note that the relay captures 16 samples per cycle. When more waveform captures are triggered than the allowable number of events selected by this setpoint, the oldest data is discarded to make room for the new capture.

  For example, 4 × 1024 indicates that the last three events with 1024 data samples per channel (64 cycles) can be stored in memory. Note that one buffer must be reserved for capturing the next event.

  NOTE: **Changing this setpoint clears any data that is currently in memory.**

- **TRIGGER POSITION:** Selects the amount of data captured before the trigger point. For example, if the **TRIGGER POSITION** is set to "25%" and the **BUFFER ORGANIZATION** is set to "2 × 2048", then there will be 512 samples (32 cycles) captured before the trigger point.

The **TRIGGER ON <EventType>** setpoints select specific event types to trigger new waveform captures

5.2.6 DATA LOGGER

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ DATA LOGGER

■ DATA LOGGER
■ [ENTER] for more

SAMPLE RATE: 1 cycle	Range: *1 cycle, 1 second, 1 min., 5 min., 10 min., 15 min., 20 min., 30 min., 60 min.*
CONTINUOUS MODE: Disabled	Range: *Enabled, Disabled*
BUFFER ORGANIZATION: 16 x 256	Range: *2 x 2048, 4 x 1024, 8 x 512, 16 x 256* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
TRIGGER POSITION: 25%	Range: *0 to 100% in steps of 1* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
TRIGGER ON PICKUP: Enabled	Range: *Enabled, Disabled* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
TRIGGER ON DROPOUT: Enabled	Range: *Enabled, Disabled* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
TRIGGER ON TRIP: Enabled	Range: *Enabled, Disabled* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
TRIGGER ON ALARM: Enabled	Range: *Enabled, Disabled* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
TRIGGER ON CONTROL: Enabled	Range: *Enabled, Disabled* *Seen only if* **CONTINUOUS MODE** *is* "Disabled"
CHNL 1 SOURCE: Phase A Current	Range: *Any values from Table 5–16: Analog Output Parameters on page 5–86.*
CHNL 2 SOURCE: Phase B Current	Range: *Any values from Table 5–16: Analog Output Parameters on page 5–86.*
↓	
CHNL 8 SOURCE: Frequency	Range: *Any values from Table 5–16: Analog Output Parameters on page 5–86.*

The data logger feature samples and record up to eight (8) actual values at user-defined intervals. This recorded data may be downloaded to the 750/760PC software for display and diagnostics. All data is stored in volatile RAM memory which means that the information is lost when power to the relay is lost. Changing any setpoint affecting data logger operation clears any data that is currently in the log.

The **SAMPLE RATE** setpoint select the time interval to record the actual value data. This setpoint multiplied by the number of samples to accumulate determines the duration of the data log record. For example, if the sample rate is 15 minutes and continuous mode is enabled then the duration of the data log record is equal to 15 min × 4096 = 61440 min = 42 days.

There are two basic modes of operation defined by the **CONTINUOUS MODE** setpoint:

- Continuous Mode: Enabled by setting **CONTINUOUS MODE** to "Enabled". At each sampling time the logger will record the actual value(s) programmed and store them in the log. Up to 4096 data samples per channel will be recorded after which the oldest data is replaced by newly sampled data.
- Trigger Mode: Enabled by setting **CONTINUOUS MODE** to "Disabled". The programmed actual value(s) for up to the last 15 events are recorded, each in a separate buffer. The amount of pre-trigger data that to record is also selectable. Before the trigger occurs, pre-trigger data is gathered as required. When the programmed trigger condition takes place, data is collected until the buffer is filled, pre-trigger data collection begins in the next buffer and the relay then waits for the next trigger. Once all buffers have been filled, the oldest data is overwritten when a new trigger occurs.

The **BUFFER ORGANIZATION** and **TRIGGER POSITION** setpoints are only applicable in trigger mode. The **BUFFER ORGANZIATION** selects the number triggers stored and the samples per channel stored for each trigger. For example, "4 x 1024" indicates that the last three triggers with 1024 data samples per channel can be stored in memory. Note that one buffer must be reserved for capturing the next event. The **TRIGGER POSITION** setpoint selects the amount of each buffer to be allocated for pre-trigger data. If set to "0%", data collection effectively starts once the trigger occurs. If set to 100%, only pre-trigger data will be recorded in the buffer.

NOTE: If a trigger occurs before the programmed amount of pre-trigger data is collected, the remainder of the buffer will be filled with post-trigger data until it is full. Actual values in the memory map provide information as to where the true trigger position is in each log buffer.

The **TRIGGER ON <EventType>** setpoints select specific event types to trigger new waveform captures and are applicable only when the data logger is operating in trigger mode. The **CHNL 1 SOURCE** to **CHNL 8 SOURCE** setpoints can be assigned any value assignable as an Analog Output parameter. See Table 5–16: Analog Output Parameters on page 5–86 for a list of values.

NOTE: If all Channel Sources (1 through 8) are set to "Disabled", then the data logger will not collect data in continuous mode or respond to triggers in trigger mode.

5.2.7 FRONT PANEL

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ FRONT PANEL

■ FRONT PANEL ■ [ENTER] for more	FLASH MSG TIME: 4.0 s	Range: 0.5 to 10.0 s in steps of 0.1
	DEFAULT MSG TIME: 300 s	Range: 10 to 900 s in steps of 1
	DEFAULT MSG INTENSITY: 25%	Range: 25%, 50%, 75%, 100%
	DISPLAY FILTER CONSTANT: 0	Range: 0 to 255 in steps of 1
	3 KEY MAX/LAST DMND CLEARING: Disabled	Range: Enabled, Disabled

These setpoints modify some of the front panel relay characteristics to suit different situations.

NOTE: Firmware versions 3.70 and higher do not support a keypad beeper as did previous firmware versions. The 750/760PC software does not support keypad beeper operation.

- **FLASH MSG TIME:** Flash messages are status, warning, error, or information messages displayed for several seconds in response to certain key presses during setpoint programming. The time these messages remain on the display, overriding the normal messages, can be changed to accommodate different user reading rates.
- **DEFAULT MSG TIME:** If no keys are pressed for a period of time, the relay will automatically begin to display a programmed set of default messages. This time can be modified to ensure menu messages remain on the screen long enough during programming or reading of actual values. Once default scanning starts, pressing any key will restore the last message displayed on the screen.
- **DEFAULT MSG INTENSITY:** To extend the life of the phosphor in the vacuum fluorescent display, the brightness of the display can be attenuated when default messages are being displayed. When interacting with the display using the front panel keys, the display will always operate at full brightness.
- **DISPLAY FILTER CONSTANT:** This value is used for filtering the displayed values of current, voltage, and power. It determines how quickly the filter responds and how much the filter will 'smooth' the display values. Smaller values result in quicker response times, but with less smoothing. Larger values result in a slower response time, but with more smoothing. A value of "0" completely disables the filter. A value of "224" results in a reasonably smooth display value with a response time of about one second. A value of "255" results in a very smooth display value, but with a response time of about five seconds.
- **3 KEY MAX/LAST DMND CLEARING:** For increased ease of maximum demand clearing, this setpoint enables the SETPOINT, •, MESSAGE ▲ key sequence to force the maximum demand values to clear. This key sequence operates on any setpoint or actual values page. The keystrokes must be entered in the above order. Any other variation of the key sequence will not permit the clearing of the maximum demand values.

5.2.8 DEFAULT MESSAGES

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ DEFAULT MESSAGES

■ DEFAULT MESSAGES ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	3 MESSAGES SELECTED 27 MESSAGES REMAIN	Range: 0 to 30 messages
	ESCAPE / MESSAGE ⇳	GE MULTILIN 750 REV 5.00	Range: Displays the first selected default message
	ESCAPE / MESSAGE ⇳	A: 0 B: 0 C: 0 Amps	Range: Displays the second selected default message
	ESCAPE / MESSAGE ⇧	GND CURRENT: 0 A 0° Lag	Range: Displays the third selected default message

Under normal conditions, if no front panel keys have been within the time specified by the **S1 RELAY SETUP ⇨⇩ FRONT PANEL ⇨⇩ DEFAULT MESSAGE TIMEOUT** setpoint, the screen begins to sequentially display up to 30 default messages. Any actual value or setpoint message can be selected for default display. In addition, up to 5 user programmable text messages can be created for display as default messages. The relay, for example, could be set to sequentially display a text message identifying the feeder, the system status, the measured current in each phase, and phase time overcurrent pickup value. The first message under this subheading states the number of messages currently selected. The messages that follow are copies of the default messages selected, in the sequence they will be displayed.

Default messages can be added to the end of the default message list, as follows:

1. Allow access to setpoints by installing the setpoint access jumper and entering the correct passcode.
2. Select the setpoint or actual value message to display as a default messaged.
3. Press the [•] key followed by the [ENTER] key while the message is displayed. The screen will display **PRESS [ENTER] TO ADD AS DEFAULT**. Press the [ENTER] key again while this message is being displayed. The message is now added to the default message list.

Default messages can be removed from the default message list, as follows:

1. Allow access to setpoints by installing the setpoint access jumper and entering the correct passcode.
2. Select the message to remove from the **S1 RELAY SETUP ⇨⇩ DEFAULT MESSAGES** default message list.
3. Press the [•] key followed by the [ENTER] key. The screen will display **PRESS [ENTER] TO REMOVE MESSAGE**. Press the [ENTER] key while this message is being displayed. The message is now removed from the default message list, and the messages that follow are moved up to fill the gap.

5.2.9 USER TEXT MESSAGES

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ USER TEXT MESSAGES

■ USER TEXT MESSAGES ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	TEXT 1	Range: 2 lines of 20 ASCII characters

Up to 5 display messages can be programmed with user specific information. When these user text messages are selected as default messages, they can provide system identification information or operator instruction.

To add user text messages, first allow access to setpoints by installing the setpoint access jumper and entering the correct passcode, then use the following procedure:

1. Select the user text message from the **S1 RELAY SETUP ⇨⇩ USER TEXT MESSAGES** setpoints subgroup.
2. Press the [ENTER] key. A solid cursor will appear over the first character position.
3. Use the VALUE ▲ and VALUE ▼ keys to change the character. A space is selected like a character.
4. Press the [ENTER] key to store the character and advance the cursor. Press [ENTER] to skip a character.

5

5. Continue entering characters and spaces until the desired message is displayed. If a character is entered incorrectly, repeatedly press the ENTER key until the cursor returns to the position of the error and enter the correct character. You may also press the ESCAPE and ENTER keys to restart the editing process.
6. Press the MESSAGE ▲ or MESSAGE ▼ key when editing is complete. To select this message as a default message, follow the instructions in the section on adding default messages.

5.2.10 CLEAR DATA

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ CLEAR DATA

■ CLEAR DATA ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	CLEAR ENERGY USE DATA? No	Range: Yes, No
	ESCAPE / MESSAGE ⇳	CLEAR MAX DMND DATA? No	Range: Yes, No
	ESCAPE / MESSAGE ⇧	CLEAR EVENT RECORDER DATA: No	Range: Yes, No

These setpoints are used to clear specific memory functions after the data has been read by an operator. The **CLEAR ENERGY USE** setpoint clears all accumulated power consumption data and updates the **ENERGY USE DATA LAST RESET** date. The **CLEAR MAX DMND** setpoint clears all maximum demand data values and updates the **DMND DATA LAST RESET** date.

The event recorder saves the most recent 128 events, automatically overwriting the oldest event. The **CLEAR EVENT RECORDER** setpoint clears all recorded event data and updates the **EVENT RECORDER LAST RESET** date.

5.2.11 INSTALLATION

PATH: SETPOINTS ⇨ S1 RELAY SETUP ⇨⇩ INSTALLATION

■ INSTALLATION ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	760 OPERATION: Not Ready	Range: Ready, Not Ready *Setpoint reads* **750 OPERATION** *for 750 relays*
	ESCAPE / MESSAGE ⇳	RESET TRIP COUNTER DATA? No	Range: Yes, No
	ESCAPE / MESSAGE ⇳	RESET ARCING CURRENT DATA? No	Range: Yes, No
	ESCAPE / MESSAGE ⇳	RESET AR COUNT DATA? No	Range: Yes, No *Message is only seen in 760 relays.*
	ESCAPE / MESSAGE ⇧	RESET AR RATE DATA? No	Range: Yes, No *Message is only seen in 760 relays.*

WARNING

The **Relay Not Ready** self-test warning message will be displayed until **S1 RELAY SETUP ⇨⇩ INSTALLATION ⇨ 760 OPERATION** is set to "Ready". This warns against the installation of a relay whose setpoints have not been entered for the required application. This setpoint is defaulted to "Not Ready" when the relay leaves the factory.

These setpoints should be used on a new installation or after new equipment has been installed.

The **RESET TRIP COUNTER DATA** setpoint clears all accumulated trip counter values and updates the **TRIP COUNTERS LAST RESET** date. The **RESET ARCING CURRENT** setpoint clears all arcing current data values and updates the **ARCING CURRENT LAST RESET** date.

The **RESET AR COUNT DATA** setpoint clears the autoreclose shot count value and updates the **AR SHOT COUNT LAST RESET** date. The **RESET AR RATE DATA** setpoint clears the autoreclose shot rate value and updates the **ARCING CURRENT LAST RESET** date. These two setpoints are applicable to the 760 only.

5.3.1 CURRENT SENSING

PATH: SETPOINTS ⇨⇩ S2 SYSTEM SETUP ⇨ CURRENT SENSING

```
■ CURRENT SENSING        ENTER ⇨   PHASE CT PRIMARY:        Range: 1 to 50000 A in steps of 1
■ [ENTER] for more     ⇦ ESCAPE    1000 A

                         ESCAPE    GND CT PRIMARY:          Range: 1 to 50000 A in steps of 1
                         MESSAGE ⇳   50 A

                         ESCAPE    SENSTV GND CT            Range: 1 to 50000 A in steps of 1
                         MESSAGE ⇧ PRIMARY:  1000 A
```

This group of setpoints is critical for all overcurrent protection features that have settings specified in multiples of CT rating. When the relay is ordered, the phase, ground, and sensitive ground CT inputs must be specified as either 1 A or 5 A.

As the phase CTs are connected in wye (star), the calculated phasor sum of the three phase currents ($I_a + I_b + I_c$ = Neutral Current = $3I_0$) is used as the input for the neutral overcurrent. 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. For additional details on CT connections, refer to Section 3.2.1: Typical Wiring on page 3–7 for details.

The setpoint entries are the same for Ground and Phase CTs with 1 A and 5 A secondaries. For correct operation, the CT secondary must match the relay as indicated on the relay identification label (e.g. 5 A for a *xxx*:5 CT).

5.3.2 BUS VT SENSING

PATH: SETPOINTS ⇨⇩ S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING

```
■ BUS VT SENSING         ENTER ⇨   VT CONNECTION TYPE:      Range: None, Wye, Delta
■ [ENTER] for more     ⇦ ESCAPE    Wye

                         ESCAPE    NOMINAL VT SECONDARY     Range: 50.0 to 240.0 V in steps of 0.1
                         MESSAGE ⇳ VOLTAGE: 120.0 V

                         ESCAPE    VT RATIO:                Range: 1.0 to 5000.0 in steps of 0.1
                         MESSAGE ⇧  120.0:1
```

With bus VTs installed, the relay can be used to perform voltage measurements, power calculations, and directional control of overcurrent elements.

- **VT CONNECTION TYPE:** Enter “None” if Bus VTs are not used. If Bus VTs are used, enter the VT connection made to the system as “Wye” or “Delta”. An open-delta connection is entered as “Delta”. See Figure 3–9: Typical Wiring Diagram on page 3–7 for details on Delta and Wye wiring.
- **NOMINAL VT SECONDARY VOLTAGE:** This setpoint represents the voltage across the VT secondary winding when nominal voltage is applied to the primary. On a source of 13.8 kV line-line at nominal voltage, with a 14400:120 V VT in the Delta connection, the voltage to be entered is “115 V”. For the Wye connection, the voltage to be entered is 115 / $\sqrt{3}$ = 66.4 V.
- **VT RATIO:** Enter the VT primary to secondary turns ratio with this setpoint. For a 14400:120 VT, the entry would be "120:1" (since 14400 / 120 = 120.0).

5.3.3 LINE VT SENSING

PATH: SETPOINTS ⇨⇩ S2 SYSTEM SETUP ⇨⇩ LINE VT SENSING

```
■ LINE VT SENSING
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
VT CONNECTION:
Vbn
```

Range: Van, Vbn, Vcn, Vab, Vcb

ESCAPE / MESSAGE ⇳

```
NOMINAL VT SECONDARY
VOLTAGE: 120.0 V
```

Range: 50.0 to 240.0 V in steps of 0.1

ESCAPE / MESSAGE ⇧

```
VT RATIO:
 120.0:1
```

Range: 1.0 to 5000.0 in steps of 0.1

With a Line VT installed, the relay can be used to check for a condition of synchronism between two voltages, either line-line or line-neutral.

- **VT CONNECTION:** Enter the Line VT connection made to the system. This selection is critical to the operation of synchrocheck, as it instructs the relay which Bus VT input voltage is to be compared to the Line VT input voltage. See Figure 3–14: Line VT Connections on page 3–11 for the system connection to match this setpoint.
- **NOMINAL VT SECONDARY VOLTAGE:** This setpoint represents the voltage across the VT secondary winding when nominal voltage is applied to the primary. On a source of 13.8 kV line-line at nominal voltage, with a 14400:120 V VT in the Delta connection, the voltage to be entered is 115 V. For the Wye connection, the voltage to be entered is 115 / $\sqrt{3}$ = 66.4 V.
- **VT RATIO:** Enter the VT primary to secondary turns ratio with this setpoint. For a 14400:120 VT, the entry would be "120:1" (since 14400 / 120 = 120.0).

5

5.3.4 POWER SYSTEM

PATH: SETPOINTS ⇨ S2 SYSTEM SETUP ⇨⇩ PWR SYSTEM

```
■ PWR SYSTEM
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
NOMINAL FREQ:
60 Hz
```

Range: Van, Vbn, Vcn, Vab, Vcb

ESCAPE / MESSAGE ⇳

```
PHASE SEQUENCE:
ABC
```

Range: 50.0 to 240.0 V in steps of 0.1

ESCAPE / MESSAGE ⇧

```
COST OF ENERGY:
 5.0 ¢/kWh
```

Range: 1.0 to 25.0 ¢/kWh in steps of 0.1

The power system data is entered in this setpoint subgroup.

- **NOMINAL FREQ:** Enter the nominal power system frequency. This value is used as a default to set the optimal digital sampling rate if the system frequency cannot be measured as there is no voltage available at the bus voltage phase A input terminals.
- **PHASE SEQUENCE:** Enter the phase sequence of the power system.
- **COST OF ENERGY:** Kilowatt hour power usage is converted to a cost of energy using this setpoint. The cost of energy charged by a utility is usually a variable rate depending on total energy consumed or other factors. Enter an estimated average cost in cents per kWh. Approximate energy cost will be determined by the relay, providing a value useful for budgeting purposes.

5.3.5 FLEXCURVES™

PATH: SETPOINTS ⇨⇩ S2 SYSTEM SETUP ⇨⇩ FLEXCURVE A(B)

```
■ FLEXCURVE A
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
CURVE TRIP TIME AT
1.03 x PU:    0 ms
```

Range: 0 to 65535 ms in steps of 1

ESCAPE / MESSAGE ⇳

```
CURVE TRIP TIME AT
1.05 x PU:    0 ms
```

Range: 0 to 65535 ms in steps of 1

↓

ESCAPE / MESSAGE ⇧

```
CURVE TRIP TIME AT
20.0 x PU:    0 ms
```

Range: 0 to 65535 ms in steps of 1

Two user programmable FlexCurves™ can be stored in the relay. These can be used for time overcurrent protection in the same manner as ANSI, IAC, and IEC curves. The custom FlexCurve™ has setpoints for entering times to trip at the following current levels: 1.03, 1.05, 1.1 to 6.0 in steps of 0.1, and 6.5 to 20.0 in steps of 0.5. The relay then converts these points to a continuous curve by linear interpolation between data points.

The following table shows all the pickup levels for which a trip time must be entered.

Table 5–1: FLEXCURVE™ TRIP TIMES

PICKUP (I/I_{pu})	TRIP TIME (ms)	PICKUP	TRIP TIME	PICKUP	TRIP TIME	PICKUP	TRIP TIME
1.03		2.90		4.90		10.5	
1.05		3.00		5.00		11.0	
1.10		3.10		5.10		11.5	
1.20		3.20		5.20		12.0	
1.30		3.30		5.30		12.5	
1.40		3.40		5.40		13.0	
1.50		3.50		5.50		13.5	
1.60		3.60		5.60		14.0	
1.70		3.70		5.70		14.5	
1.80		3.80		5.80		15.0	
1.90		3.90		5.90		15.5	
2.00		4.00		6.00		16.0	
2.10		4.10		6.50		16.5	
2.20		4.20		7.00		17.0	
2.30		4.30		7.50		17.5	
2.40		4.40		8.00		18.0	
2.50		4.50		8.50		18.5	
2.60		4.60		9.00		19.0	
2.70		4.70		9.50		19.5	
2.80		4.80		10.0		20.0	

5.4.1 OVERVIEW

The 750/760 relay has twenty (20) logic inputs which can be used to operate a variety of logic functions for circuit breaker control, external trips, blocking of protection elements, etc. The relay has ‘contact inputs’ and ‘virtual inputs’ that are combined in a form of programmable logic to facilitate the implementation of various schemes.

The relay has 14 rear terminal contact inputs. These contacts can be either wet or dry (see Section 3.2.7: Logic Inputs on page 3–14 for typical wiring of the logic input contacts). External contacts are either open or closed and are debounced for one power frequency cycle to prevent false operation from induced voltage. Because of debouncing, momentary contacts must have a minimum dwell time greater than one power frequency cycle.

The relay also has twenty (20) virtual inputs which are analogous to software switches. They allow all the functionality of logic inputs to be invoked via serial communications or from the front panel. This has the following advantages over contact inputs only:

- The number of logic inputs can be increased without introducing additional hardware.
- Logic functions can be invoked from a remote location over a single RS485 communications channel.
- The same logic function can be invoked both locally via contact input or front panel keypad, and/or remotely via communications.
- Panel switches can be replaced entirely by virtual switches to save cost and wiring.

Virtual inputs are simply memory locations in the relay which can be assigned a value via communications or from the **A1 STATUS ⇨⇩ VIRTUAL INPUTS** actual values menu. If the value stored in memory is "0", then the virtual input is Off; otherwise, the virtual input is On. The state of virtual inputs is written as if it were a setpoint; these values are non-volatile and are found in memory map locations 0090 to 00A4 hex. Momentary virtual inputs are simulated by first writing a "1" to the corresponding register followed by writing a "0". Due to communications delay there will be a dwell time of 50 to 200 ms. Maintained virtual inputs are simulated by writing a "1" to the corresponding register.

5

5.4.2 LOGIC INPUTS SETUP

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨ LOGIC INPUTS SETUP

■ LOGIC INPUTS SETUP ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	INPUT 1 NAME: Logic Input 1	*Range: 18 alphanumeric characters*
	ESCAPE MESSAGE ⇳	INPUT 1 ASSERTED LOGIC: Contact Close	*Range: see description below*
	ESCAPE MESSAGE ⇳	INPUT 2 NAME: Logic Input 2	*Range: 18 alphanumeric characters*
	ESCAPE MESSAGE ⇳	INPUT 2 ASSERTED LOGIC: Contact Close	*Range: see description below*
		↓	
	ESCAPE MESSAGE ⇳	INPUT 20 NAME: Logic Input 20	*Range: 18 alphanumeric characters*
	ESCAPE MESSAGE ⇧	INPUT 20 ASSERTED LOGIC: Contact Close	*Range: see description below*

Each logic input has two setpoints representing the name and asserted logic. The following terms apply to all logic inputs:

- The state of a contact input is either "Open" or "Closed" and is determined directly from the rear terminal inputs.
- The state of a virtual input is either "On" or "Off" and can be set by the user from serial communications or the **A1 STATUS ⇨⇩ VIRTUAL INPUTS** actual values menu.
- The state of a logic input is either "Asserted" or "Not-Asserted".
- The state of Logic Input *n* (where *n* = 1 to 14) is determined by combining the state of Contact Input *n* with the state of Virtual Input *n* according to the **INPUT n ASSERTED LOGIC** setpoint; this is a limited form of programmable logic.

- The state of Logic Input *x* (where *x* = 15 to 20) is determined by the state of Virtual Input *x* according to the **INPUT y ASSERTED LOGIC** setpoint; this is a limited form of programmable logic.
- A logic function is invoked when its corresponding logic input is Asserted.
- One logic input can invoke many logic functions if required.

The **LOGIC INPUT n NAME** setpoint allows the operator to assign a user-friendly description to logic inputs when replacing panel switches with a virtual switch. This name will be displayed in the **A1 STATUS** ⇨⇩ **VIRTUAL INPUTS** actual values menu.

The **LOGIC INPUT n ASSERTED** setpoint determines how to combine the Contact and Virtual Input states to determine the Logic Input state. For Logic inputs 1 through 14, this setpoint may be assigned the following values:

VALUE	LOGIC INPUT ASSERTED WHEN:
Disabled	Never
Contact Close	Contact is closed
Contact Open	Contact is open
Virtual On	Virtual input is on
Virtual Off	Virtual input is off
Closed & Von	Contact is closed AND virtual input is on
Closed & Voff	Contact is closed AND virtual input is off
Open & Von	Contact is open AND virtual input is on
Open & Voff	Contact is open AND virtual input is off
Closed | Von	Contact is closed OR virtual input is on
Closed | Voff	Contact is closed OR virtual input is off
Open | Von	Contact is open OR virtual input is on
Open | Voff	Contact is open OR virtual input is off
Closed X Von	Contact is closed XOR virtual input is on
Closed X Voff	Contact is closed XOR virtual input is off
Open X Von	Contact is open XOR virtual input is on
Open X Voff	Contact is open XOR virtual input is off

For Logic Inputs 15 through 20, this setpoint may be assigned the following values:

VALUE	LOGIC INPUT ASSERTED WHEN:
Disabled	Never
Virtual On	Virtual input is on
Virtual Off	Virtual input is off

5.4.3 BREAKER FUNCTIONS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ BRKR FUNCTIONS

```
■ BRKR FUNCTIONS
■ [ENTER] for more
```

[ENTER] ⇨ / ⇦ [ESCAPE]

```
52a CONTACT:
Disabled
```

Range: Input 1 to Input 20, Disabled

[ESCAPE] / [MESSAGE] ⇳

```
52b CONTACT:
Disabled
```

Range: Input 1 to Input 20, Disabled

[ESCAPE] / [MESSAGE] ⇧

```
BRKR CONTACT:
Disabled
```

Range: Input 1 to Input 20, Disabled

The following logic functions are used to determine whether the circuit breaker is open, closed, or disconnected from the main power circuit, as monitored by auxiliary contacts on a drawout breaker racking mechanism, or on the associated isolating disconnect switches on a fixed circuit breaker.

If neither the 52a or 52b contacts are installed then the following functions cannot be performed:

- Monitoring of breaker position
- Breaker Operation Failure
- Feedback control of Trip (Output Relay 1) and Close (Output Relay 2) relays
- Trip/Close Coil Supervision Without Permissive
- Manual close feature blocking
- Autoreclose
- Transfer

CAUTION

It is strongly recommended that the Breaker Operation Failure alarm be enabled when either 52a or 52b breaker auxiliary contacts are installed.

CAUTION

Breaker logic functions must be assigned to Logic Inputs 1 to 14 as they must only be contacts.

The **52a CONTACT** and **52b CONTACT** setpoints are used to monitor the 52/a and 52/b contacts. The following table determines how these contacts affect the breaker state:

52/A CONTACT INSTALLED?	52/B CONTACT INSTALLED?	INTERPRETATION
Yes	Yes	52a closed indicates breaker is closed 52b closed indicates breaker is open
Yes	No	52a closed indicates breaker is closed 52a open indicates breaker is open
No	Yes	52b open indicates breaker is closed 52b closed indicates breaker is open
No	No	Breaker status unknown

When asserted, the logic input assigned by the **BRKR CONNECTED** setpoint indicates that the breaker is connected to the primary system. When the breaker is determined to be disconnected, the breaker state is shown to be neither open nor closed. For further information regarding operation with only one auxiliary breaker contact, see Section 4.1.2: LED Status Indicators on page 4–2.

5.4.4 CONTROL FUNCTIONS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ CONTROL FUNCTIONS

■ CONTROL FUNCTIONS ■ [ENTER] for more	LOCAL MODE: Disabled	*Range: Input 1 to Input 20, Disabled*
	RESET: Disabled	*Range: Input 1 to Input 20, Disabled*
	REMOTE OPEN: Disabled	*Range: Input 1 to Input 20, Disabled* *Operates only when* **LOCAL MODE** *is* "Disabled"
	REMOTE CLOSE: Disabled	*Range: Input 1 to Input 20, Disabled* *Operates only when* **LOCAL MODE** *is* "Disabled"
	COLD LOAD PICKUP: Disabled	*Range: Input 1 to Input 20, Disabled*
	SETPOINT GROUP 2: Disabled	*Range: Input 1 to Input 20, Disabled*
	SETPOINT GROUP 3: Disabled	*Range: Input 1 to Input 20, Disabled*
	SETPOINT GROUP 4: Disabled	*Range: Input 1 to Input 20, Disabled*

5

The **LOCAL MODE** setpoint places the relay in local mode. The relay is in remote mode if not forced into local mode by this setpoint. The **RESET** setpoint resets the last trip indicator and latched relays. With the 760, it also resets the autoreclose lockout. The **COLD LOAD PICKUP** setpoint initiates the Cold Load Pickup blocking feature. The **SETPOINT GROUP 2** through **SETPOINT GROUP 4** setpoints signal the relay to make Group 2, 3, or 4 the active setpoint group.

The **REMOTE OPEN** and **REMOTE CLOSE** setpoints initiate a breaker opening via the Trip Relay and a breaker closure via the Close Relay, respectively. These setpoints are operational only when the relay is in remote mode (see above).

5.4.5 USER INPUTS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ USER INPUTS ⇨ USER INPUT A(T)

■ USER INPUT A ■ [ENTER] for more	USER INPUT A NAME: User Input A	*Range: 18 alphanumeric characters*
	USER INPUT A SOURCE: Disabled	*Range: Input 1 to Input 20, Disabled*
	USER INPUT A FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
	USER INPUT A RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	USER INPUT A DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*

There are twenty (20) general purpose user input functions (User Inputs A through T) that generate outputs in response to an asserted logic input. These functions can be used to: initiate a trip; initiate a trip and a reclosure (760 only); log a contact operation in the event recorder; convert an external contact into a self-resetting, latched or pulsed contact.; convert an external contact into a Form-C contact; and provide a contact multiplier for an external contact by operating multiple relays.

The setpoints for User Input A are shown above; setpoints for User Inputs B through T are identical.

5.4.6 BLOCK FUNCTIONS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ BLOCK FUNCTIONS

```
■ BLOCK FUNCTIONS
■ [ENTER] for more
```

BLOCK 1 TRIP RELAY: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK 2 CLOSE RELAY: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK RESET: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK UNDERVOLT 1: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK UNDERVOLT 2: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK UNDERVOLT 3: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK UNDERVOLT 4: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK UNDERFREQ 1: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK UNDERFREQ 2: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK FREQ DECAY: Disabled	*Range: Input 1 to Input 20, Disabled*
BYPASS SYNCHROCHECK: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK BRKR STATISTICS: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK NEG SEQ VOLTAGE: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK NTR DISPLACEMNT: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK RESTORATION: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK REV PWR: Disabled	*Range: Input 1 to Input 20, Disabled Seen only if Mod 008 is enabled.*

The logic input functions shown above block various operations within the relay. Protection elements will *not* detect faults, send messages, or illuminate indicators when blocked, except for the **BLOCK TRIP 1 RELAY** setpoint.

A system condition monitor such as Synchrocheck or Closing Spring Charged can be connected to the relay for close supervision. If **BLOCK CLOSE 2 RELAY** is selected, this input must be de-asserted to permit operation of the Close Relay.

The **BYPASS SYNCHROCHECK** setpoint provides a manual override of the synchrocheck monitor, so an operator can close the feeder breaker without the programmed synchrocheck condition.

The **BLOCK BRKR STATISTICS** setpoint blocks the accumulation of breaker statistical data found on the **A3 MAINTENANCE ⇨⇩ TRIP COUNTERS** and **A3 MAINTENANCE ⇨⇩ ARCING CURRENT** actual values pages. This data includes breaker operation and trip counters along with breaker arcing current. This input could be used during testing to prevent maintenance operations from being accumulated.

5.4.7 BLOCK OVERCURRENT FUNCTIONS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ BLK OC FUNCTIONS

■ BLK OC FUNCTIONS ■ [ENTER] for more	
BLK ALL OC: Disabled	Range: Input 1 to Input 20, Disabled
BLK PHASE OC: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEUTRAL OC: Disabled	Range: Input 1 to Input 20, Disabled
BLK GND OC: Disabled	Range: Input 1 to Input 20, Disabled
BLK SENSTV GND OC: Disabled	Range: Input 1 to Input 20, Disabled
BLK PHASE TIME 1: Disabled	Range: Input 1 to Input 20, Disabled
BLK PHASE TIME 2: Disabled	Range: Input 1 to Input 20, Disabled
BLK PHASE INST 1: Disabled	Range: Input 1 to Input 20, Disabled
BLK PHASE INST 2: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEUTRL TIME 1: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEUTRL TIME 2: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEUTRL INST 1: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEUTRL INST 2: Disabled	Range: Input 1 to Input 20, Disabled
BLOCK GND TIME: Disabled	Range: Input 1 to Input 20, Disabled
BLOCK GND INST: Disabled	Range: Input 1 to Input 20, Disabled
BLK SENSTV GND TIME: Disabled	Range: Input 1 to Input 20, Disabled
BLK SENSTV GND INST: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEG SEQ TIME: Disabled	Range: Input 1 to Input 20, Disabled
BLK NEG SEQ INST: Disabled	Range: Input 1 to Input 20, Disabled

These setpoints block overcurrent protection elements. Overcurrent elements will not detect faults, send messages, or illuminate indicators when blocked. These functions can be used to: block overcurrent operation from downstream relays for selective tripping schemes from external directional current/power or other supervision; block overcurrent operation during initial feeder loading when the inrush currents are not know; block neutral operation during single-phase switching or fault burn-off attempts; and block timed phase and neutral operation during deliberate emergency overload operating situations.

5.4.8 TRANSFER FUNCTIONS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ TRANSFER FUNCTIONS

■ TRANSFER FUNCTIONS ■ [ENTER] for more	SELECT TO TRIP: Disabled	Range: Input 1 to Input 20, Disabled
	UNDERVOLT ON OTHER SOURCE: Disabled	Range: Input 1 to Input 20, Disabled
	INCOMER 1 BRKR CLOSED: Disabled	Range: Input 1 to Input 20, Disabled
	INCOMER 2 BRKR CLOSED: Disabled	Range: Input 1 to Input 20, Disabled
	TIE BRKR CONNECTED: Disabled	Range: Input 1 to Input 20, Disabled
	TIE BRKR CLOSED: Disabled	Range: Input 1 to Input 20, Disabled
	BLOCK TRANSFER: Disabled	Range: Input 1 to Input 20, Disabled
	TRANSFORMER LOCKOUT: Disabled	Range: Input 1 to Input 20, Disabled
	SOURCE TRIP: Disabled	Range: Input 1 to Input 20, Disabled
	CLOSE FROM INCOMER1: Disabled	Range: Input 1 to Input 20, Disabled
	CLOSE FROM INCOMER2: Disabled	Range: Input 1 to Input 20, Disabled

The following logic input functions are used exclusively for the bus transfer scheme. Refer to Section 5.8.7: Transfer on page 5–106 for details on implementing the bus transfer scheme.

NOTE

If the bus transfer feature is required, all logic input functions necessary for the operation of this scheme must be assigned to contact inputs before any other functions. This is to ensure there are no conflicts.

The **INCOMER 1(2) BRKR CLOSED** setpoints are used to track breaker state, for prevent-parallel or permission-to-transfer logic. **THE CLOSE FROM INCOMER 1(2)** setpoints signal the bus tie breaker to begin a close operation.

The **TIE BRKR CONNECTED** setpoint is used to inhibit transfers if the breaker cannot be used to pass current from the source to the load, such as when it is in the Test or Disconnected positions. The **TIE BRKR CLOSED** setpoint is used to track breaker state, for prevent-parallel or permission-to-transfer logic.

The **TRANSFORMER LOCKOUT** and **SOURCE TRIP** setpoints are used to initiate a transfer as Source 1(2) is about to be lost. The **BLOCK TRANSFER** setpoint disables the transfer scheme.

5.4.9 RECLOSE FUNCTIONS (760 ONLY)

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ RECLOSE FUNCTIONS

```
■ RECLOSE FUNCTIONS
■ [ENTER] for more
```

INITIATE RECLOSURE: Disabled	*Range: Input 1 to Input 20, Disabled*
CANCEL RECLOSURE: Disabled	*Range: Input 1 to Input 20, Disabled*
BLOCK RECLOSURE: Disabled	*Range: Input 1 to Input 20, Disabled*

These logic input setpoints are used in the autoreclose scheme and are applicable to the 760 relay only. Refer to Section 5.8.8: Autoreclose (760 only) on page 5–117 for more detail.

- **INITIATE RECLOSURE:** Initiates an autoreclose sequence leading to an operation of the Close Relay. This input will *not* cause the Trip Output Relay of the 760 to operate. It is intended for use where the initiating device sends an independent trip to the breaker at the same time it sends an initiate reclosure to the 760.
- **CANCEL RECLOSURE:** Cancels a reclosure sequence in progress and blocks autoreclose scheme from operating.
- **BLOCK RECLOSURE:** Cancels a reclosure sequence in progress and blocks the autoreclose scheme from operating.

5.4.10 MISCELLANEOUS FUNCTIONS

PATH: SETPOINTS ⇨⇩ S3 LOGIC INPUTS ⇨⇩ MISC FUNCTIONS

```
■ MISC FUNCTIONS
■ [ENTER] for more
```

TRIGGER TRACE MEMORY: Disabled	*Range: Input 1 to Input 20, Disabled*
TRIGGER DATA LOGGER: Disabled	*Range: Input 1 to Input 20, Disabled*
SIMULATE FAULT: Disabled	*Range: Input 1 to Input 20, Disabled*
START DMND INTERVAL: Disabled	*Range: Input 1 to Input 20, Disabled*

The SIMULATE FAULT input function is operational only when the relay is in simulation testing mode, the breaker is closed (real or simulated breaker) and presently in the prefault state. When the assigned input is asserted, the relay is forced into the fault state where the programmed 'fault' values are used.

5.5.1 RELAY OPERATION

a) DESCRIPTION

The 750/760 relay is equipped with eight electromechanical output relays: three special purpose (Trip Relay 1, Close Relay 2, and Self-test Warning Relay 8) and five general purpose (Auxiliary Relays 3 to 7). The special purpose relays have fixed operating characteristics and the general purpose relays can be configured by the user. Logic diagrams for each output relay are provided for detailed explanation of their operation.

b) TRIP AND CLOSE RELAYS

Operation of these breaker-control relays is designed to be controlled by the state of the circuit breaker as monitored by a 52a or 52b contact. Once a feature has energized one of these relays it will remain operated until the requested change of breaker state is confirmed by a breaker auxiliary contact and the initiating condition has reset. If the initiating feature resets but the breaker does not change state, the output relay will be reset after either the delay programmed in the Breaker Operation feature or a default interval of 2 seconds expires. If neither of the breaker auxiliary contacts 52a nor 52b is programmed to a logic input, the Trip Relay is de-energized after either the delay programmed in the Breaker Failure feature or a default interval of 100 ms after the initiating input resets and the Close Relay is de-energized after 200 ms. If a delay is programmed for the Trip or Close contact seal in time, then this delay is added to the reset time. Note that the default setting for the seal in time is 40 ms.

Table 5–2: BREAKER AUXILIARY CONTACTS AND RELAY OPERATION

52A CONTACT INSTALLED?	52B CONTACT INSTALLED?	RELAY OPERATION
Yes	Yes	Trip Relay remains operating until 52b indicates an open breaker. Close Relay remains operating until 52a indicates a closed breaker.
Yes	No	Trip Relay remains operating until 52a indicates an open breaker. Close Relay remains operating until 52a indicates a closed breaker.
No	Yes	Trip Relay remains operating until 52b indicates an open breaker. Close Relay remains operating until 52b indicates a closed breaker.
No	No	Trip Relay operates until either the Breaker Failure delay expires (if the Breaker Failure element is enabled) or 100 ms after the feature causing the trip resets. Close Relay operates for 200 ms.

c) AUXILIARY RELAYS 3 TO 7

Operation of these relays is programmed by the user. Each relay can be selected to become either energized or de-energized when operated, and to operate as latched, self-resetting or pulsed.

Table 5–3: AUXILIARY RELAY OPERATION

OUTPUT TYPE	DESCRIPTION
Latched	Upon being operated by any programmed feature, the relay output contacts change state and remain in the new state. The relay can be returned to the non-operated state only by the RESET key, the reset logic input, or a computer reset command. This mode is used for alarms which must be acknowledged, or to provide a lockout function.
Self-resetting	Upon being operated by any programmed feature, the relay output contacts change state and remain in the new state until all features which operate the relay are no longer signaling it to operate. For a relay operated by a single feature, the output contacts follow the state of the feature.
Pulsed	Upon being operated by any programmed feature, the relay output contacts change state and remain in the new state for a programmed time interval called the **PULSED OUTPUT DWELL TIME**. The dwell timer is started when the first feature causes operation of the output relay.

5

5.5.2 TRIP RELAY

PATH: SETPOINTS ⇨⇩ S4 OUTPUT RELAYS ⇨ 1 TRIP RELAY

```
■ 1 TRIP RELAY          ENTER ⇨   TRIP RELAY SEAL IN
■ [ENTER] for more    ⇦ ESCAPE    TIME: 0.04 s
```

Range: 0.00 to 9.99 s in steps of 0.01

A **TRIP RELAY SEAL IN TIME** can be programmed for the Trip Relay. This time is added to the reset time of the Trip Relay, thus extending its pulse width. This is for use in applications where the 52 contacts reporting breaker state to the 750/760 are faster than the 52 contacts that are responsible for interrupting coil current.

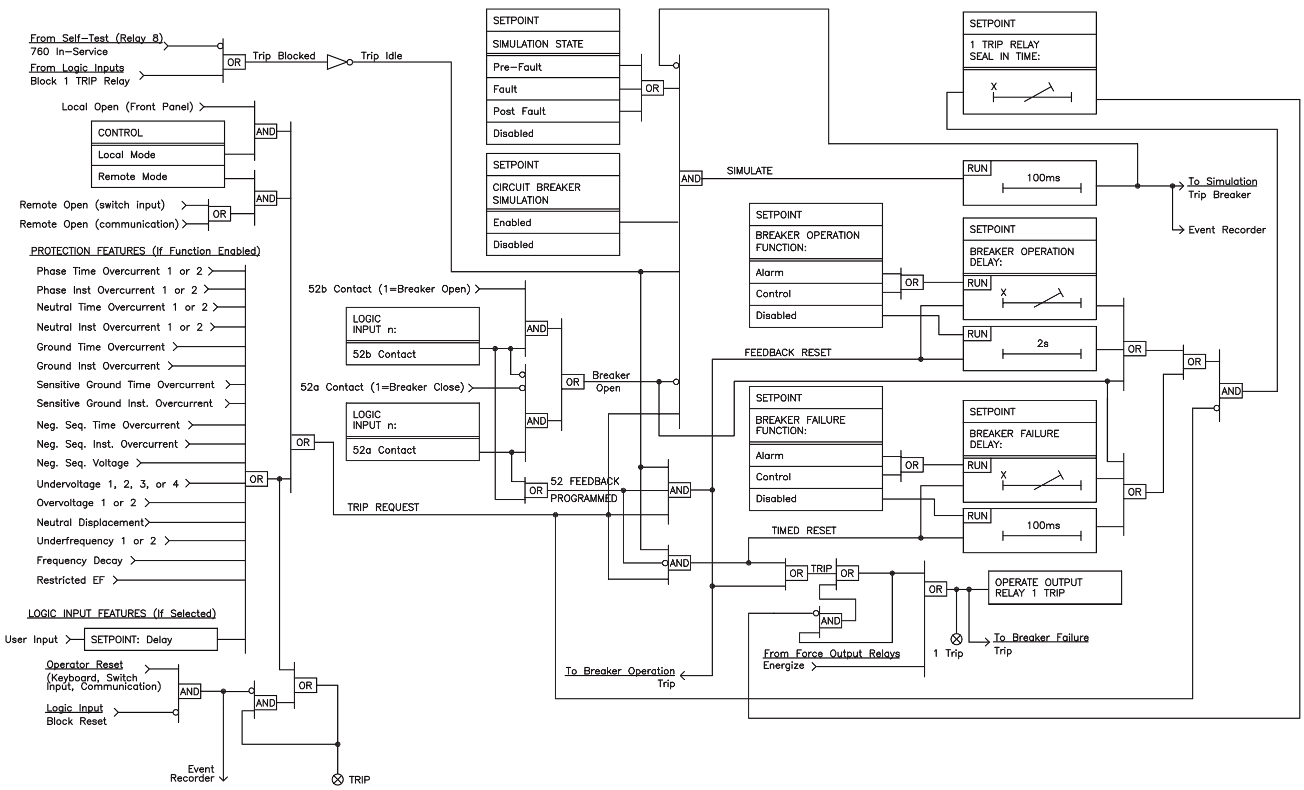

Figure 5–1: OUTPUT RELAY 1 TRIP LOGIC

5.5.3 CLOSE RELAY

PATH: SETPOINTS ⇨⇩ S4 OUTPUT RELAYS ⇨⇩ 2 CLOSE RELAY

```
■ 2 CLOSE RELAY          ENTER ⇨    TRIP RELAY SEAL IN
■ [ENTER] for more     ⇦ ESCAPE     TIME: 0.04 s
```

Range: 0.00 to 9.99 s in steps of 0.01

A **TRIP RELAY SEAL IN TIME** can be programmed for the Close Relay. This time is added to the reset time of the Close Relay, thus extending its pulse width. This is for use in applications where the 52 contacts reporting breaker state to the 750/760 are faster than the 52 contacts that are responsible for interrupting coil current.

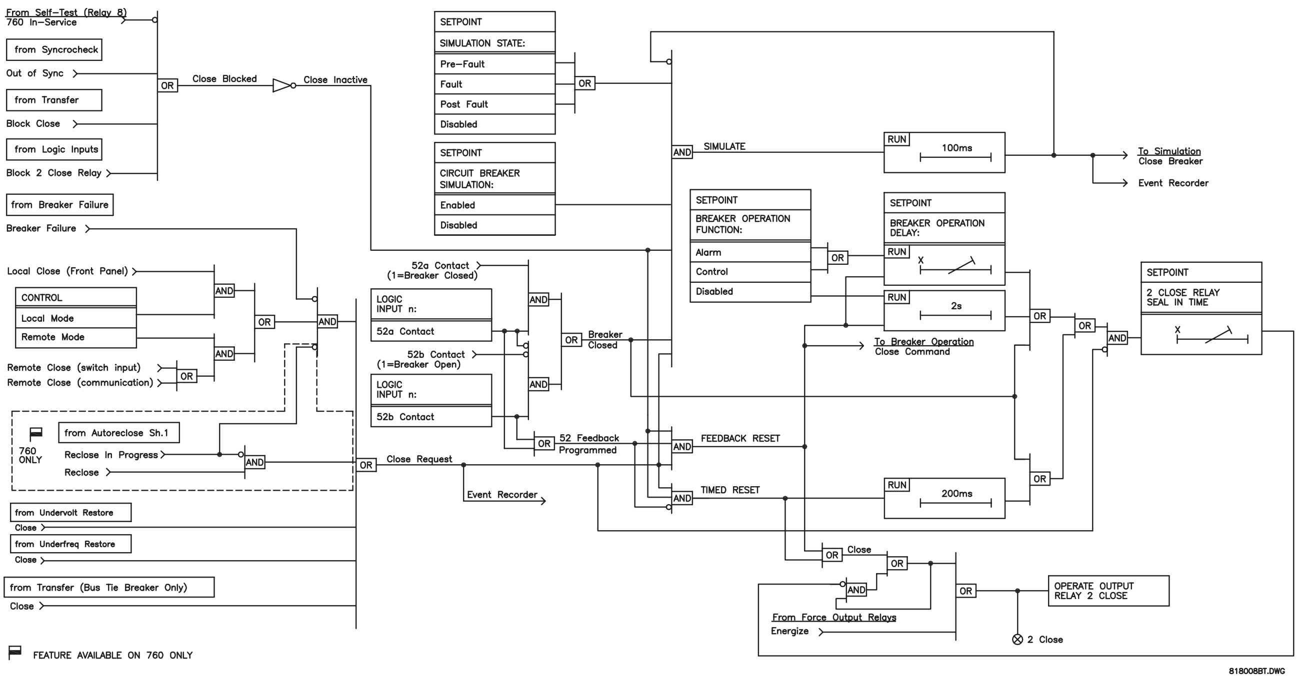

Figure 5–2: OUTPUT RELAY 2 CLOSE LOGIC

5.5.4 AUXILIARY RELAYS

PATH: SETPOINTS ⇨⇩ S4 OUTPUT RELAYS ⇨⇩ 3(7) AUX RELAY

			Range
■ 3 AUX RELAY ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	RELAY 3 NAME: Auxiliary	Range: 16 alphanumeric characters
	ESCAPE / MESSAGE ⇳	RELAY 3 NON-OPERATED STATE: De-energized	Range: Energized, De-energized
	ESCAPE / MESSAGE ⇳	RELAY 3 OUTPUT TYPE: Self-Resetting	Range: Self-Resetting, Latched, Pulsed
	ESCAPE / MESSAGE ⇧	PULSED OUTPUT DWELL TIME: 0.1 s	Range: 0.1 to 6000.0 s in steps of 0.1. Seen only if **RELAY 3(7) OUTPUT TYPE** is "Pulsed"

Figure 3–9: Typical Wiring Diagram on page 3–7 shows relay contacts with no control power applied. If the **RELAY 3(7) NON-OPERATED STATE** setpoint is "De-energized", then the state of the relay contacts is as shown in the wiring diagram. If the non-operated state is "Energized", then the state of the relay contacts is opposite to that shown in the wiring diagram.

This **PULSED OUTPUT DWELL TIME** setpoint is only displayed if the **RELAY 3 OUTPUT TYPE** is selected as "Pulsed". This setpoint determines the time interval that the pulsed contacts remain in the operated state.

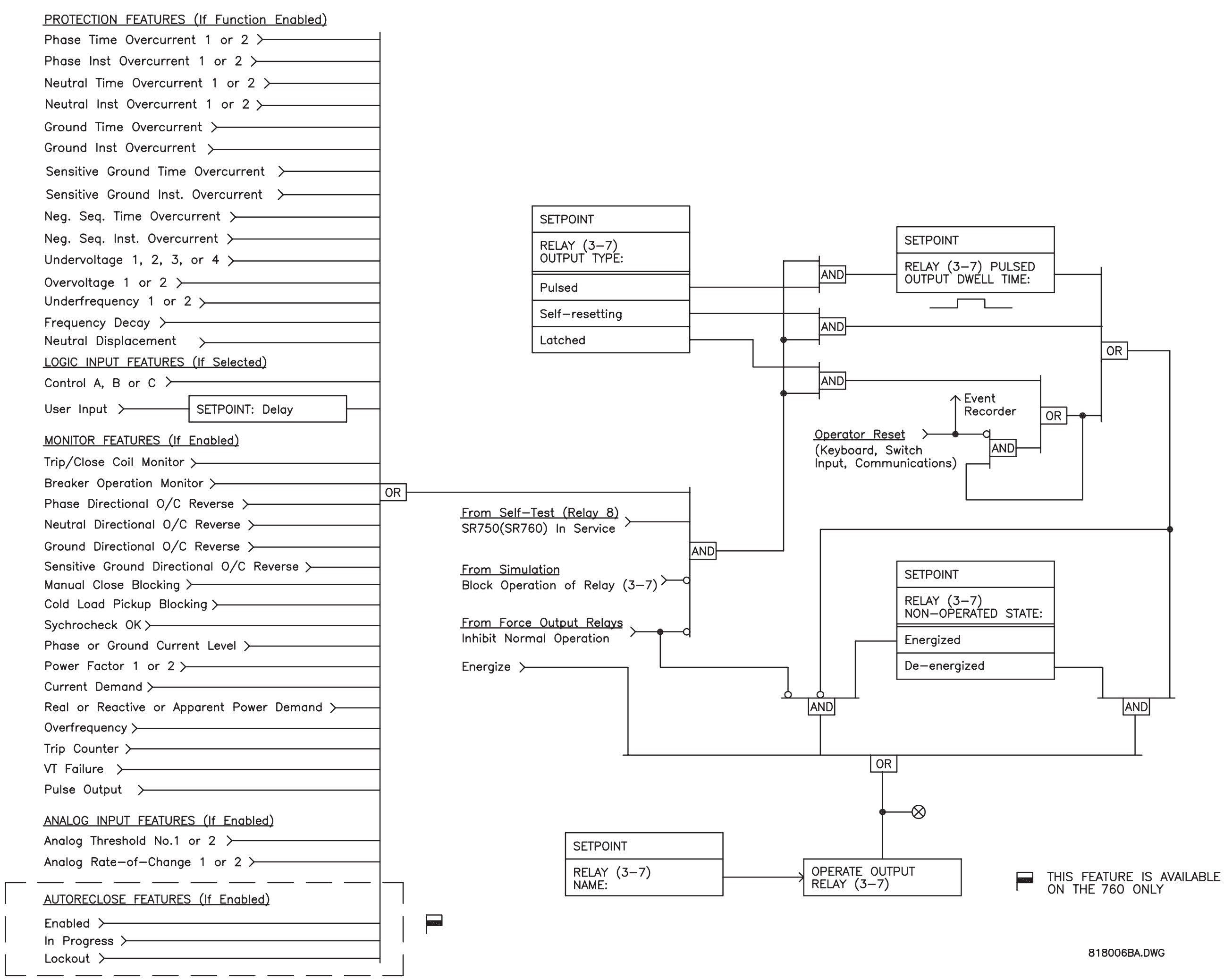

Figure 5–3: OUTPUT RELAYS 3 TO 7 AUXILIARY LOGIC

5.5.5 SELF-TEST WARNING RELAY

There are no user-programmable setpoints associated with the Self-Test Warning Relay (Output Relay 8). The logic for this relay is shown below:

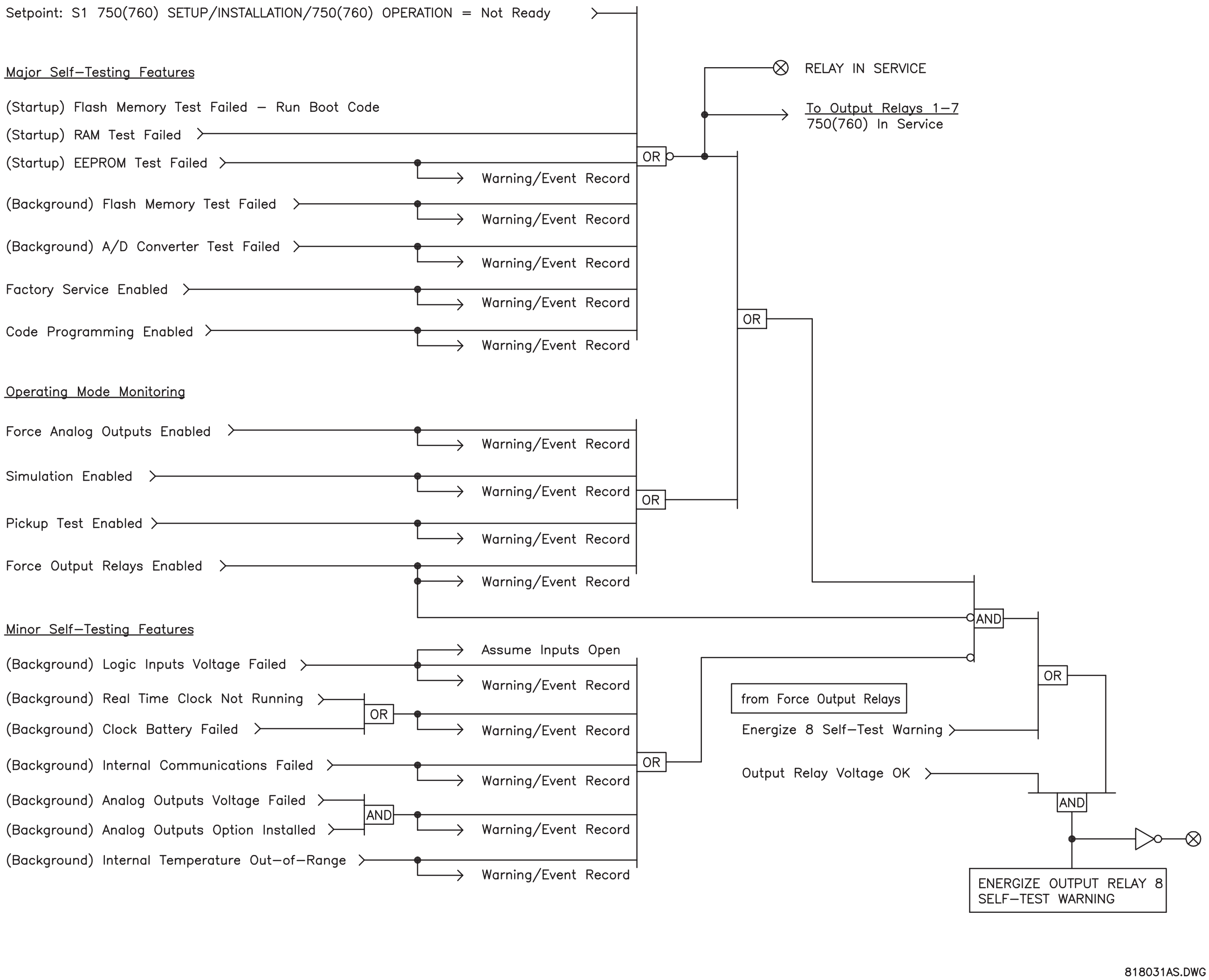

Figure 5–4: OUTPUT RELAY 8 SELF-TEST WARNING LOGIC

5.6.1 OVERVIEW

a) DESCRIPTION

The relay has a total of six phase, two neutral, one ground, one sensitive ground, and one negative sequence time overcurrent elements. The programming of the time-current characteristics of these elements is identical in all cases and will only be covered in this section. The required curve is established by programming a Pickup Current, Curve Shape, Curve Multiplier, and Reset Time. The Curve Shape can be either a standard shape or a user-defined shape programmed with the FlexCurve™ feature.

Accurate coordination may require changing the time overcurrent characteristics of particular elements under different conditions. For manual closing or picking up a cold load, a different time-current characteristic can be produced by increasing the pickup current value. In the 760, the pickup current can also be raised between autoreclose shots. The following setpoints are used to program the time-current characteristics.

- **<ElementName> PICKUP:** The pickup current is the threshold current at which the time overcurrent element starts timing. There is no intentional 'dead band' when the current is above the pickup level. However, accuracy is only guaranteed above a 1.03 per unit pickup level. The dropout threshold is 98% of the pickup threshold. Enter the pickup current corresponding to 1 per unit on the time overcurrent curves as a multiple of the source CT. For example, if 100: 5 CTs are used and a pickup of 90 amps is required for the time overcurrent element, enter "0.9 x CT".
- **<ElementName> CURVE:** Select the desired curve shape. If none of the standard curve shapes is appropriate, a custom FlexCurve™ can be created by entering the trip times at 80 different current values. See **S2 SYSTEM SETUP ⇨⇩ FLEXCURVE A**. Curve formulas are given for use with computer based coordination programs. **Calculated trip time values are only valid for $I / I_{pu} > 1$**. Select the appropriate curve shape and multiplier, thus matching the appropriate curve with the protection requirements. The available curves are shown in the table below.

Table 5–4: TOC CURVE SELECTIONS

ANSI	GE TYPE IAC	IEC	OTHER
Extremely Inverse	Extremely Inverse	Curve A (BS142)	Definite Time
Very Inverse	Very Inverse	Curve B (BS142)	FlexCurve™ A
Normally Inverse	Inverse	Curve C (BS142)	FlexCurve™ B
Moderately Inverse	Short Inverse	IEC Short Inverse	

- **<ElementName> MULTIPLIER:** A multiplier setpoint allows shifting of the selected base curve in the vertical time direction. Unlike the electromechanical time dial equivalent, trip times are directly proportional to the value of the time multiplier setpoint. For example, all trip 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.
- **<ElementName> RESET:** Time overcurrent tripping 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 trip is generated. If less than 100% 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 Linear. The Instantaneous selection is intended for applications with other relays, such as most static units, which set the energy capacity directly to zero when the current falls below the reset threshold. The Linear selection can be used where the relay must coordinate with electromechanical units. With this setpoint, the energy capacity variable is decremented according to the following equation.

$$T_{RESET} = E \times M \times C_R \quad \textbf{(EQ 5.1)}$$

where: T_{RESET} = reset time in seconds; E = energy capacity reached (per unit); M = curve multiplier
C_R = characteristic constant (5 for ANSI, IAC, Definite Time, and FlexCurves™; 8 for IEC)

NOTE: Graphs of standard time-current curves on 11" × 17" log-log graph paper are available upon request. Requests may be placed with our literature department.

b) TOC CURVE CHARACTERISTICS

DEFINITE TIME CURVE:

Definite Time curves trip as soon as the pickup level is exceeded for a specified period of time. The base Definite Time curve has a delay of 0.1 seconds. The curve multiplier adjusts this delay from 0.00 to 10.00 seconds in steps of 0.01.

ANSI CURVES:

The ANSI time overcurrent curve shapes conform to industry standards and the ANSI C37.90 curve classifications for extremely, very, and moderately inverse. The ANSI curves are derived from the following formula:

$$T = M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right) \quad \textbf{(EQ 5.2)}$$

where: T = trip time (seconds); M = multiplier value; I = input current; I_{pickup} = pickup current setpoint
A, B, C, D, E = constants

Table 5–5: ANSI CURVE CONSTANTS

ANSI CURVE SHAPE	A	B	C	D	E
ANSI Extremely Inverse	0.0399	0.2294	0.5000	3.0094	0.7222
ANSI Very Inverse	0.0615	0.7989	0.3400	–0.2840	4.0505
ANSI Normally Inverse	0.0274	2.2614	0.3000	–4.1899	9.1272
ANSI Moderately Inverse	0.1735	0.6791	0.8000	–0.0800	0.1271

Table 5–6: ANSI CURVE TRIP TIMES (IN SECONDS)

MULTIPLIER (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
ANSI EXTREMELY INVERSE										
0.5	2.000	0.872	0.330	0.184	0.124	0.093	0.075	0.063	0.055	0.049
1.0	4.001	1.744	0.659	0.368	0.247	0.185	0.149	0.126	0.110	0.098
2.0	8.002	3.489	1.319	0.736	0.495	0.371	0.298	0.251	0.219	0.196
4.0	16.004	6.977	2.638	1.472	0.990	0.742	0.596	0.503	0.439	0.393
6.0	24.005	10.466	3.956	2.208	1.484	1.113	0.894	0.754	0.658	0.589
8.0	32.007	13.955	5.275	2.944	1.979	1.483	1.192	1.006	0.878	0.786
10.0	40.009	17.443	6.594	3.680	2.474	1.854	1.491	1.257	1.097	0.982
ANSI VERY INVERSE										
0.5	1.567	0.663	0.268	0.171	0.130	0.108	0.094	0.085	0.078	0.073
1.0	3.134	1.325	0.537	0.341	0.260	0.216	0.189	0.170	0.156	0.146
2.0	6.268	2.650	1.074	0.682	0.520	0.432	0.378	0.340	0.312	0.291
4.0	12.537	5.301	2.148	1.365	1.040	0.864	0.755	0.680	0.625	0.583
6.0	18.805	7.951	3.221	2.047	1.559	1.297	1.133	1.020	0.937	0.874
8.0	25.073	10.602	4.295	2.730	2.079	1.729	1.510	1.360	1.250	1.165
10.0	31.341	13.252	5.369	3.412	2.599	2.161	1.888	1.700	1.562	1.457
ANSI NORMALLY INVERSE										
0.5	2.142	0.883	0.377	0.256	0.203	0.172	0.151	0.135	0.123	0.113
1.0	4.284	1.766	0.754	0.513	0.407	0.344	0.302	0.270	0.246	0.226
2.0	8.568	3.531	1.508	1.025	0.814	0.689	0.604	0.541	0.492	0.452
4.0	17.137	7.062	3.016	2.051	1.627	1.378	1.208	1.082	0.983	0.904
6.0	25.705	10.594	4.524	3.076	2.441	2.067	1.812	1.622	1.475	1.356
8.0	34.274	14.125	6.031	4.102	3.254	2.756	2.415	2.163	1.967	1.808
10.0	42.842	17.656	7.539	5.127	4.068	3.445	3.019	2.704	2.458	2.260
ANSI MODERATELY INVERSE										
0.5	0.675	0.379	0.239	0.191	0.166	0.151	0.141	0.133	0.128	0.123
1.0	1.351	0.757	0.478	0.382	0.332	0.302	0.281	0.267	0.255	0.247
2.0	2.702	1.515	0.955	0.764	0.665	0.604	0.563	0.533	0.511	0.493
4.0	5.404	3.030	1.910	1.527	1.329	1.208	1.126	1.066	1.021	0.986
6.0	8.106	4.544	2.866	2.291	1.994	1.812	1.689	1.600	1.532	1.479
8.0	10.807	6.059	3.821	3.054	2.659	2.416	2.252	2.133	2.043	1.972
10.0	13.509	7.574	4.776	3.818	3.324	3.020	2.815	2.666	2.554	2.465

IEC CURVES:

For European applications, the relay offers the four standard curves defined in IEC 255-4 and British standard BS142. These are defined as IEC Curve A, IEC Curve B, IEC Curve C, and Short Inverse. The formulae for these curves are:

$$T = M \times \left(\frac{K}{(I / I_{pu})^E - 1} \right) \quad \text{(EQ 5.3)}$$

where: T = trip time (seconds); M = multiplier setpoint; I = input current; I_{pickup} = pickup current setpoint; K, E = constants

Table 5–7: IEC (BS) INVERSE TIME CURVE CONSTANTS

IEC (BS) CURVE SHAPE	K	E
IEC CURVE A (BS142)	0.140	0.020
IEC CURVE B (BS142)	13.500	1.000
IEC CURVE C (BS142)	80.000	2.000
IEC SHORT INVERSE	0.050	0.040

Table 5–8: IEC CURVE TRIP TIMES (IN SECONDS)

MULTIPLIER (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
IEC CURVE A										
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
IEC CURVE 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
IEC CURVE C										
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
IEC SHORT TIME										
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:

$$T = M \times \left(A + \frac{B}{(I/I_{pu}) - C} + \frac{D}{((I/I_{pu}) - C)^2} + \frac{E}{((I/I_{pu}) - C)^3} \right) \quad \textbf{(EQ 5.4)}$$

where: T = trip time (seconds) M = multiplier setpoint I = input current
I_{pickup} = pickup current setpoint A *to* E = constants

Table 5–9: GE TYPE IAC INVERSE CURVE CONSTANTS

IAC CURVE SHAPE	A	B	C	D	E
IAC EXTREME INVERSE	0.0040	0.6379	0.6200	1.7872	0.2461
IAC VERY INVERSE	0.0900	0.7955	0.1000	–1.2885	7.9586
IAC INVERSE	0.2078	0.8630	0.8000	–0.4180	0.1947
IAC SHORT INVERSE	0.0428	0.0609	0.6200	–0.0010	0.0221

Table 5–10: IAC CURVE TRIP TIMES

MULTIPLIER (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
IAC EXTREMELY INVERSE										
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
IAC VERY INVERSE										
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
IAC INVERSE										
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
IAC SHORT INVERSE										
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

5

5.6.2 PHASE CURRENT

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨ PHASE CURRENT

■ PHASE CURRENT ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ PHASE TIME OC 1 ■ [ENTER] for more	See below
	ESCAPE MESSAGE ⇳	■ PHASE TIME OC 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇳	■ PHASE INST OC 1 ■ [ENTER] for more	See page 5–38.
	ESCAPE MESSAGE ⇳	■ PHASE INST OC 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇧	■ PHASE DIRECTIONAL ■ [ENTER] for more	See page 5–39.

Phase overcurrent protection comprises two time overcurrent, two instantaneous overcurrent, and a phase directional element. The directional element determines whether current flow is in the forward or reverse direction, as determined by the connected polarity of the input CTs and the Maximum Torque Angle selected for the phase directional element. Each phase overcurrent element can be programmed to either disable directionality or provide a trip for current flow in the forward/ reverse direction only. Two elements allow the use of 'Loset' and 'Hiset' detectors in autoreclose applications, zone-selective (blocking) schemes, and distinct settings for faults in different directions. Phase overcurrent protection elements can be blocked individually or by logic inputs.

5

b) PHASE TIME OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨ PHASE CURRENT ⇨ PHASE TIME OC 1(2)

■ PHASE TIME OC 1 ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	PHASE TIME OC 1 FUNCTION: Trip	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
	ESCAPE MESSAGE ⇳	PHASE TIME OC 1 RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	ESCAPE MESSAGE ⇳	PHASE TIME OC 1 PICKUP: 1.00 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01*
	ESCAPE MESSAGE ⇳	PHASE TIME OC 1 CURVE: Ext. Inverse	*Range: see Table 5–4: TOC Curve Selections on page 5–32 for values*
	ESCAPE MESSAGE ⇳	PHASE TIME OC 1 MULTIPLIER: 1.00	*Range: 0.00 to 100.00 in steps of 0.01*
	ESCAPE MESSAGE ⇳	PHASE TIME OC 1 RESET: Instantaneous	*Range: Instantaneous, Linear*
	ESCAPE MESSAGE ⇳	PHASE TIME OC 1 DIRECTION: Disabled	*Range: Disabled, Forward, Reverse*
	ESCAPE MESSAGE ⇧	PHASE TIME OC 1 VOLT RESTRAINT: Disabled	*Range: Enabled, Disabled*

Phase Time Overcurrent 1 and 2 are identical elements. Each consists of the equivalent of three separate time overcurrent relays, ANSI Device 51P, with identical characteristics. These elements can be controlled by the phase directional element, providing operation for current flow in the permitted direction only. Voltage restrained operation which reduces the pickup level with reduced voltage is also available.

Select "Disabled" for the **PHASE TIME OC 1 VOLT RESTRAINT** setpoint if voltage restraint is not required. When set to "Enabled", this feature lowers the pickup value of each individual phase time overcurrent element in a fixed relationship with the corresponding phase input voltage. When voltage restraint is enabled, it is not allowed to change the pickup current setting if the manual close blocking, cold load pickup blocking or autoreclose features are controlling the protection. If the **BUS INPUT VT TYPE** is selected to "None", this feature is automatically disabled.

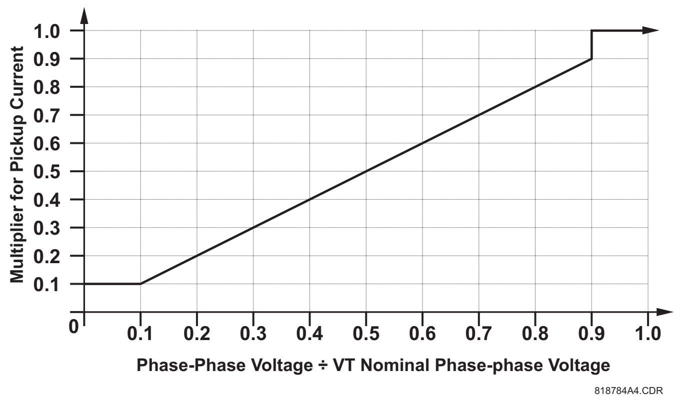

Figure 5–5: VOLTAGE RESTRAINT CHARACTERISTIC FOR PHASE TOC

NOTE

If voltage restraint is enabled, the adjusted pickup, calculated by adjusting the pickup value by the multiplier, will not fall below 0.05 × CT, which is the lowest value for the PHASE TIME OC PICKUP.

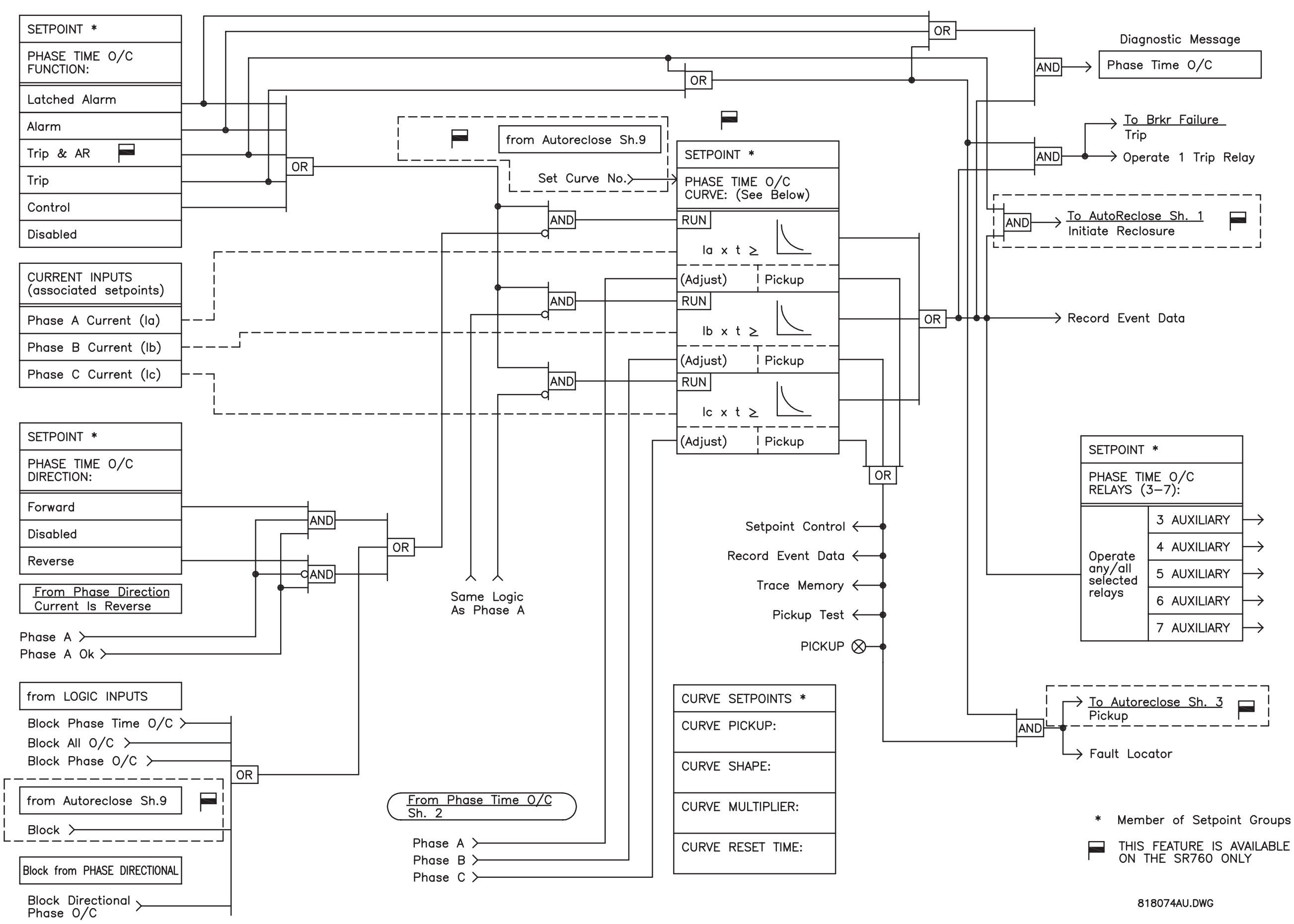

Figure 5–6: PHASE TOC LOGIC (1 OF 2)

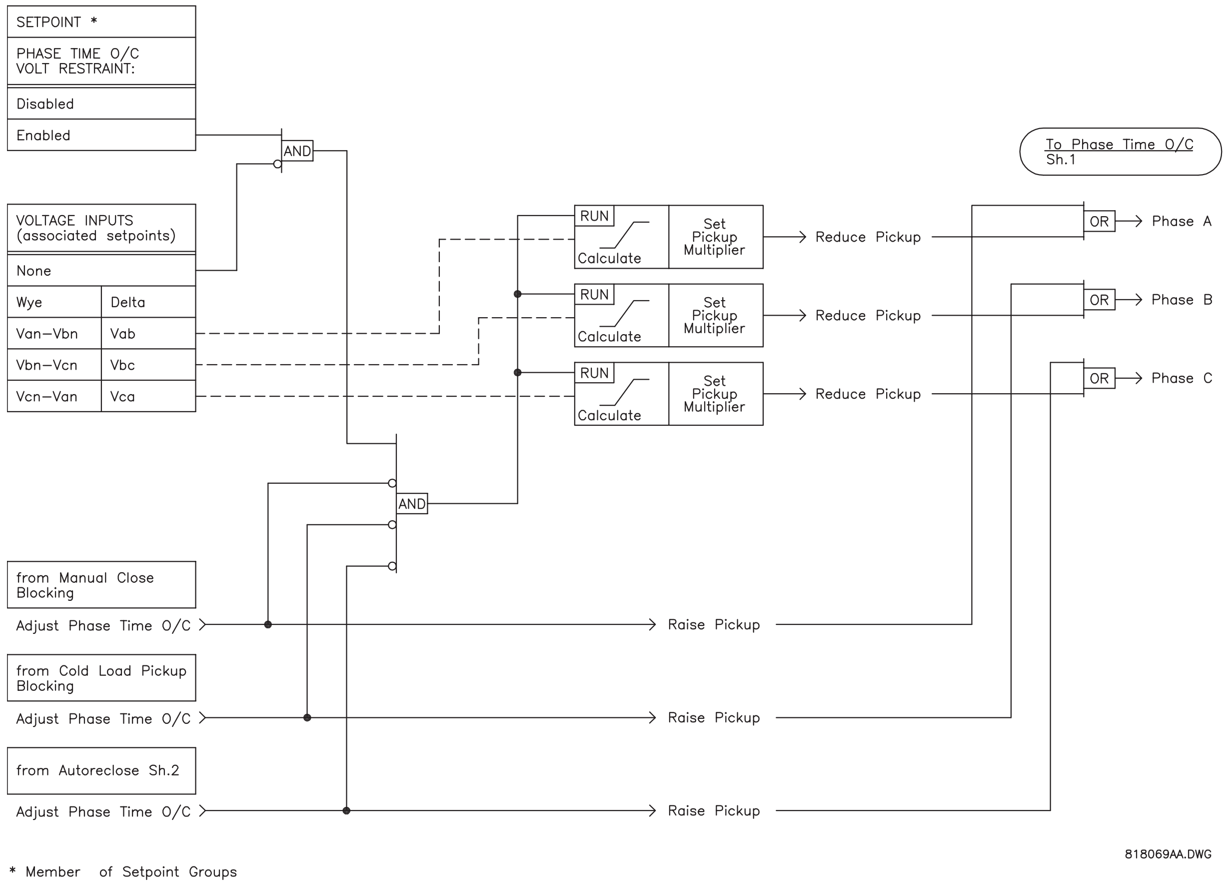

Figure 5–7: PHASE TOC LOGIC (2 OF 2)

c) PHASE INSTANTANEOUS OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨ PHASE CURRENT ⇨⇩ PHASE INST OC 1(2)

```
■ PHASE INST OC 1
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE	PHASE INST OC 1 FUNCTION: Trip	Range: *Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
ESCAPE / MESSAGE ⇳	PHASE INST OC 1 RELAYS (3-7): -----	Range: *Any combination of 3 to 7 Auxiliary relays*
ESCAPE / MESSAGE ⇳	PHASE INST OC 1 PICKUP: 1.00 x CT	Range: *0.05 to 20.00 x CT in steps of 0.01*
ESCAPE / MESSAGE ⇳	PHASE INST OC 1 DELAY: 0.00 s	Range: *0.00 to 600.00 s in steps of 0.01*
ESCAPE / MESSAGE ⇳	PHASES REQUIRED FOR OPERATION: Any One	Range: *Any One, Any Two, All Three*
ESCAPE / MESSAGE ⇧	PHASE INST OC 1 DIRECTION: Disabled	Range: *Disabled, Forward, Reverse*

Phase Instantaneous Overcurrent 1 and 2 are identical elements. Each consists of the equivalent of three separate instantaneous overcurrent relays, ANSI device 50P, all with identical characteristics. These elements can be controlled by the phase directional element, providing operation for current flow in the permitted direction only.

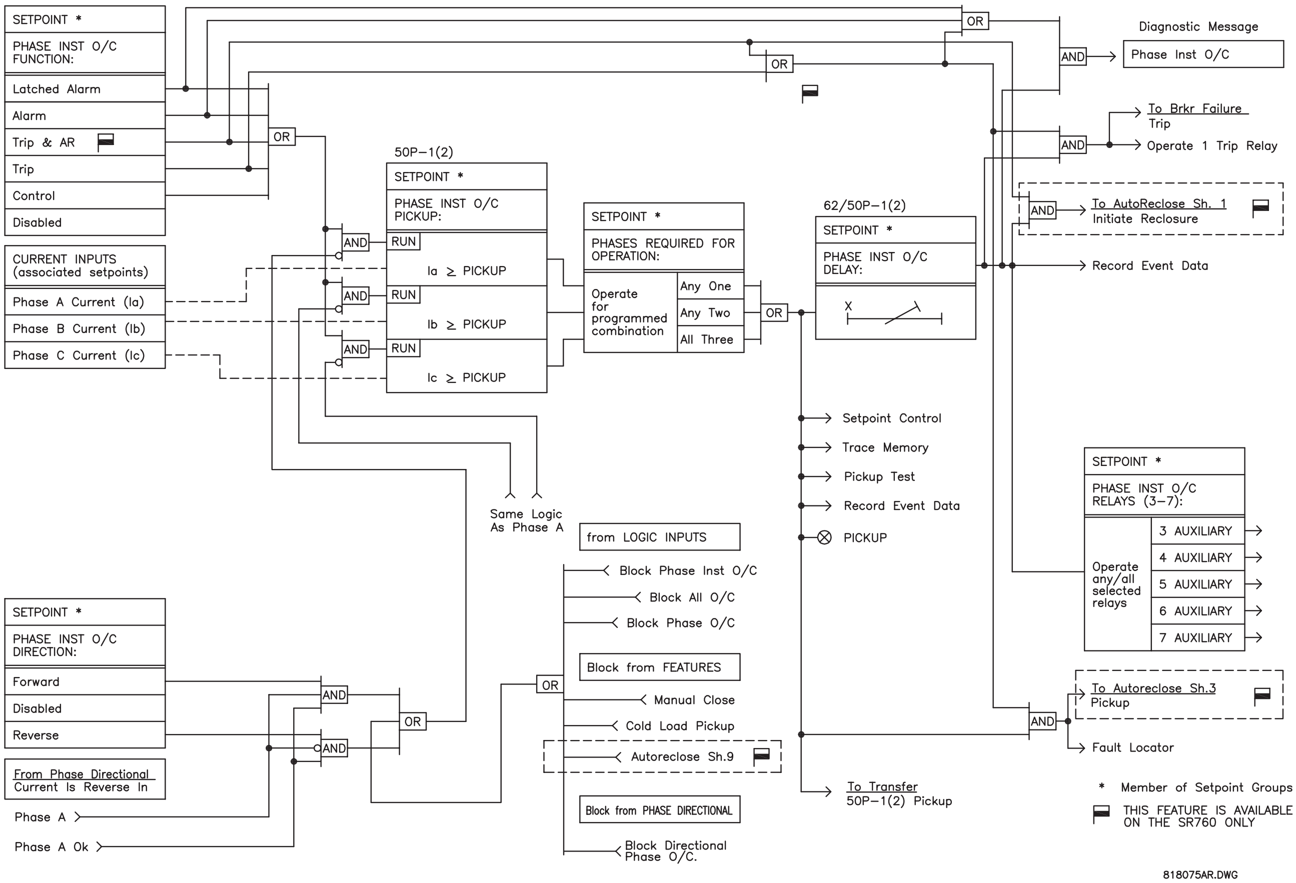

Figure 5–8: PHASE IOC LOGIC

d) PHASE DIRECTIONAL OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨ PHASE CURRENT ⇨⇩ PHASE DIRECTIONAL

```
■ PHASE DIRECTIONAL
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
PHASE DIRECTIONAL
FUNCTION: Disabled
```
Range: *Disabled, Alarm, Latched Alarm, Control*

ESCAPE / MESSAGE ⇳

```
PHASE DIRECTIONAL
RELAYS (3-7): -----
```
Range: *Any combination of 3 to 7 Auxiliary relays*

ESCAPE / MESSAGE ⇳

```
PHASE DIRECTIONAL
MTA: 30° Lead
```
Range: *0 to 359° in steps of 1*

ESCAPE / MESSAGE ⇳

```
MIN POLARIZING
VOLTAGE: 0.05 x VT
```
Range: *0.00 to 1.25 x VT in steps of 0.01*

ESCAPE / MESSAGE ⇳

```
BLK OC WHEN VOLT MEM
EXPIRES: Disabled
```
Range: *Disabled, Enabled*

ESCAPE / MESSAGE ⇧

```
PHASE INST OC 1
DIRECTION: Disabled
```
Range: *Disabled, Forward, Reverse*

Directional overcurrent relaying is necessary for the protection of multiple source feeders, when it is essential to discriminate between faults in different directions. It would be impossible to obtain correct relay selectivity through the use of a non-directional overcurrent relay in such cases. Fault directional control (ANSI device 67) is incorporated into the relay for all phase, neutral, sensitive ground, and negative sequence overcurrent elements. If directional control is selected, it will determine whether current flow in each phase is in the forward or reverse direction, as determined by the connection of the phase source CTs, selected MTA angle, voltage and current phasors. Each overcurrent element can be individually programmed to operate for flow only in specific directions. For increased security, all overcurrent elements under directional control add one power frequency cycle of intentional delay to prevent operational errors on current 'swings'. Some terms commonly used in directional relaying are defined as:

- **Operating Current:** the quantity whose directionality is to be tested.
- **Polarizing Voltage:** a voltage whose phase will remain reasonably constant between a non-faulted and a faulted system, used as a phase reference for the operating current.
- **Relay Connection:** for phase directional relaying, the characteristic angle between the operating current and the polarizing voltage in the non-faulted system.
- **Zero Torque Line:** the boundary line between operating and blocking regions in the complex plane; in an electromechanical directional relay, an operating current near this line generates minimum torque.
- **Maximum Torque Line:** the line perpendicular, through the origin, to the Zero Torque Line in the complex plane; in an electromechanical directional relay, an operating current near this line will generate a maximum amount of torque.
- **Maximum Torque Angle (MTA):** the angle by which the Maximum Torque Line is rotated from the Polarizing Voltage.

The following diagram specifically shows the phasors involved for Phase A directional polarization, but the general principles can be applied to all directional elements.

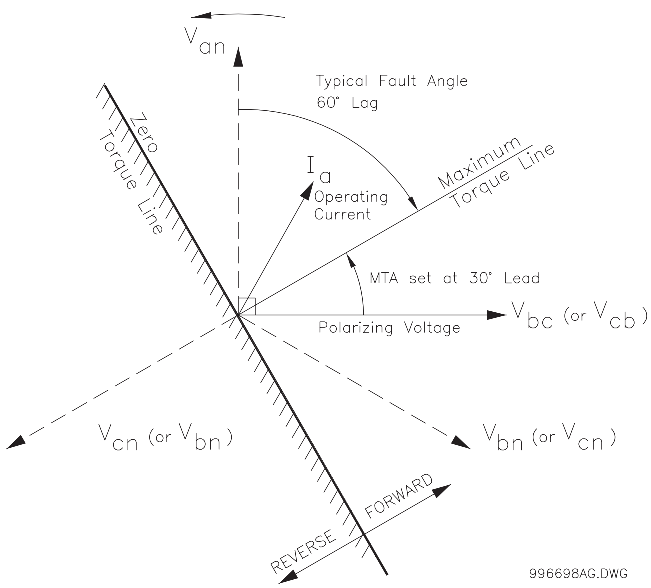

Figure 5–9: PHASE A DIRECTIONAL OVERCURRENT POLARIZATION

The 750/760 uses the secure 90° or quadrature connection exclusively for phase directional polarization. An MTA setting of 90° represents a phase current in-phase with its phase voltage, which is leading the polarizing voltage by 90°. The table below shows the operating currents and polarizing voltages used for phase directional control.

Table 5–11: PHASE DIRECTIONAL OPERATING CHARACTERISTICS

QUANTITY	OPERATING CURRENT	POLARIZING VOLTAGE	
		ABC PHASE SEQUENCE	ACB PHASE SEQUENCE
Phase A	Ia	Vbc	Vcb
Phase B	Ib	Vca	Vac
Phase C	Ic	Vab	Vba

To increase security for three phase faults very close to the location of the VTs used to measure the polarizing voltage, a voltage memory feature is incorporated. This feature remembers the last measurement of the polarizing voltage which is greater than the MIN POLARIZING VOLTAGE value and uses it to determine direction. The voltage memory remains valid for one second after the voltages have collapsed. Once the voltage memory has expired, after one second, the phase overcurrent elements under directional control can be set to block or trip on overcurrent. When set to "Enabled", the **BLOCK OC WHEN VOLT MEM EXPIRES** setpoint will block the operation of any phase overcurrent element under directional control when voltage memory expires. When set to "Disabled", directional blocking of any Phase Overcurrent element will be inhibited. The voltage memory is updated immediately when the polarizing voltage is restored.

To complement the voltage memory feature, a Close Into Fault (CIF) feature allows close-in faults to be cleared when energizing a line. When the **BLOCK OC WHEN VOLT MEM EXPIRES** setpoint is "Disabled", the CIF feature permits operation of any phase overcurrent element if current appears without any voltage. When set to "Enabled" the CIF feature inhibits operation of any phase overcurrent element under directional control under these conditions. In both cases, directional blocking will be permitted to resume when the polarizing voltage becomes greater than the **MIN POLARIZING VOLTAGE** setpoint.

CAUTION

Setting the BLOCK OC WHEN VOLT MEM EXPIRES to "Enabled" will block all phase overcurrent elements under directional control (phase overcurrent element set to trip in either the forward or reverse direction) from operating.

SETTINGS:

- **PHASE DIRECTIONAL MTA:** Enter the maximum torque angle from 0 to 359°, by which the operating current leads the polarizing voltage. This is the angle of maximum sensitivity. The factory default value for maximum torque angle is 30°. This is an appropriate angle for an inductive fault angle of 60°, which is typical of the upper voltage range of distribution feeders. See the Phase A Directional Overcurrent Polarization figure for more information.
- **BLOCK OC WHEN VOLT MEM EXPIRES:** Select the required operation upon expiration of voltage memory. When set to "Enabled", all Phase OC elements under directional control are blocked from operating when voltage memory expires. When set to "Disabled", all phase overcurrent elements are be inhibited by directional control. This setpoint also determines the operation of phase overcurrent elements under directional control upon 'Close Into Fault' (CIF).

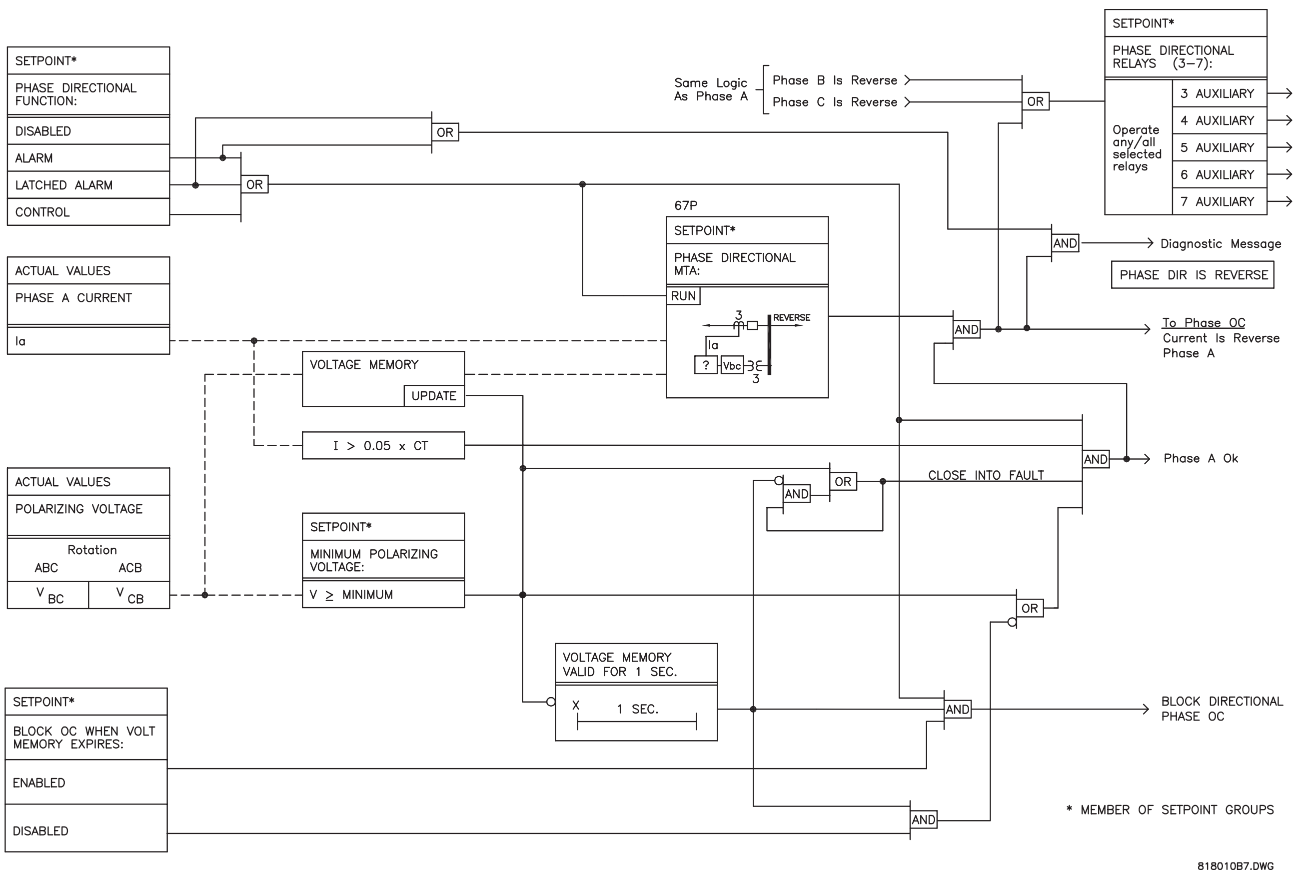

Figure 5–10: PHASE DIRECTIONAL LOGIC

5.6.3 NEUTRAL CURRENT

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEUTRAL CURRENT

■ NEUTRAL CURRENT ■ [ENTER] for more	■ NEUTRAL TIME OC 1 ■ [ENTER] for more	See below
	■ NEUTRAL TIME OC 2 ■ [ENTER] for more	
	■ NEUTRAL INST OC 1 ■ [ENTER] for more	See page 5–43.
	■ NEUTRAL INST OC 2 ■ [ENTER] for more	
	■ NEUTRAL DIRECTION ■ [ENTER] for more	See page 5–44.

Four neutral overcurrent protection elements are provided. Two time overcurrent elements and two instantaneous overcurrent elements. They all monitor the calculated neutral current (3Io = Ia + Ib + Ic) which has DC offset and harmonic components removed. Neutral overcurrent elements can be controlled by the neutral directional element allowing operation for faults in the permitted direction only. Also, the elements can be blocked individually or as a group by logic inputs.

b) NEUTRAL TIME OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEUTRAL CURRENT ⇨ NEUTRAL TIME OC 1(2)

■ NEUTRAL TIME OC 1 ■ [ENTER] for more	NEUTRAL TIME OC 1 FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
	NEUTRAL TIME OC 1 RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	NEUTRAL TIME OC 1 PICKUP: 1.00 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01*
	NEUTRAL TIME OC 1 CURVE: Ext. Inverse	*Range: see Table 5–4: TOC Curve Selections on page 5–32 for values*
	NEUTRAL TIME OC 1 MULTIPLIER: 1.00	*Range: 0.00 to 100.00 in steps of 0.01*
	NEUTRAL TIME OC 1 RESET: Instantaneous	*Range: Instantaneous, Linear*
	NEUTRAL TIME OC 1 DIRECTION: Disabled	*Range: Disabled, Forward, Reverse*

Neutral Time Overcurrent elements 1 and 2 are programmed in this subgroup. They are two identical protection elements each equivalent to a single ANSI device 51N neutral time overcurrent relay.

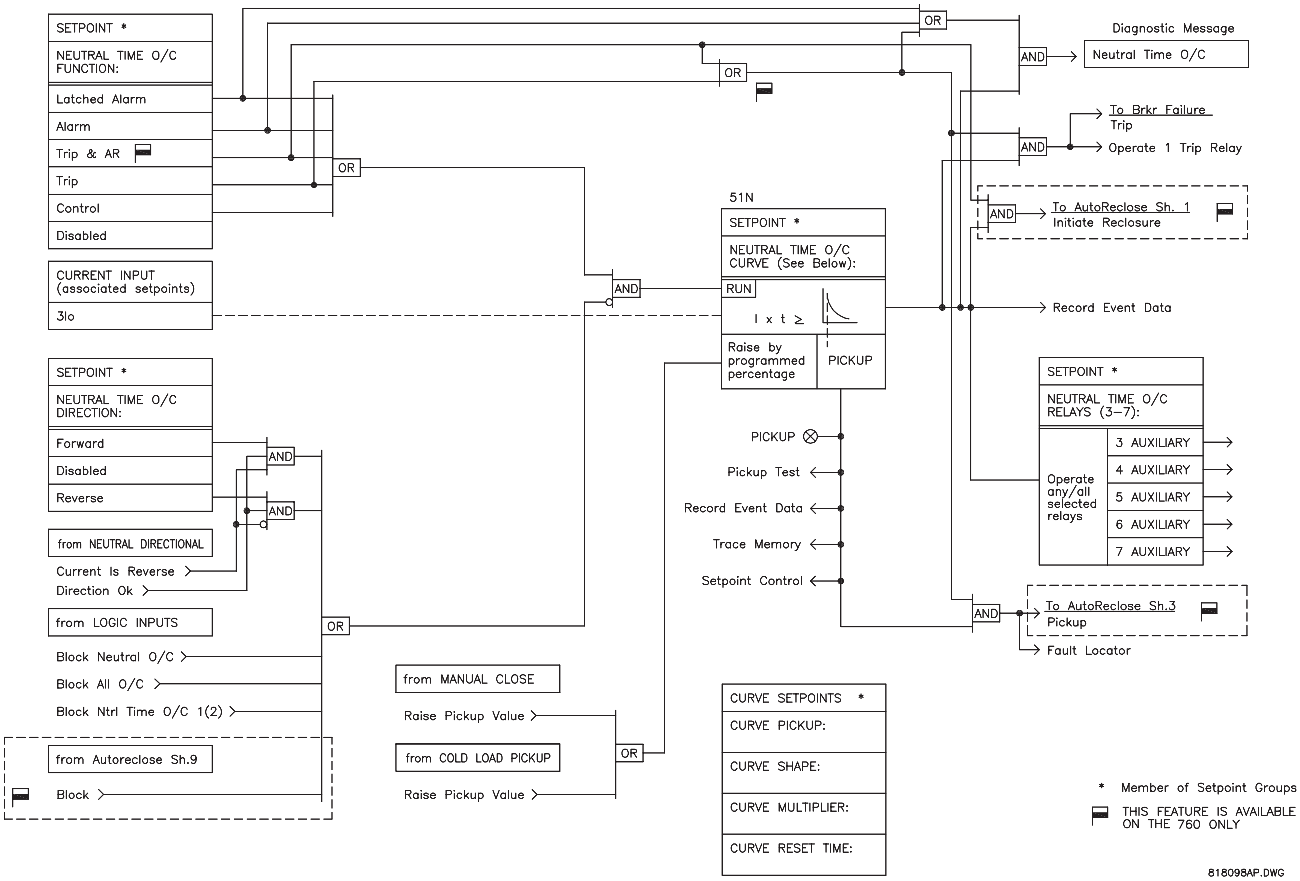

Figure 5–11: NEUTRAL TOC LOGIC

c) NEUTRAL INSTANTANEOUS OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL INST OC 1(2)

■ NEUTRAL INST OC 1 ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	NEUTRAL INST OC 1 FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
	ESCAPE MESSAGE	NEUTRAL INST OC 1 RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	ESCAPE MESSAGE	NEUTRAL INST OC 1 PICKUP: 1.00 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01*
	ESCAPE MESSAGE	NEUTRAL INST OC 1 DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
	ESCAPE MESSAGE	NEUTRAL INST OC 1 DIRECTION: Disabled	*Range: Disabled, Forward, Reverse*

The Neutral Instantaneous Overcurrent elements 1 and 2 are programmed in this subgroup. They are two identical protection elements each equivalent to a single ANSI device 50N neutral instantaneous overcurrent relay.

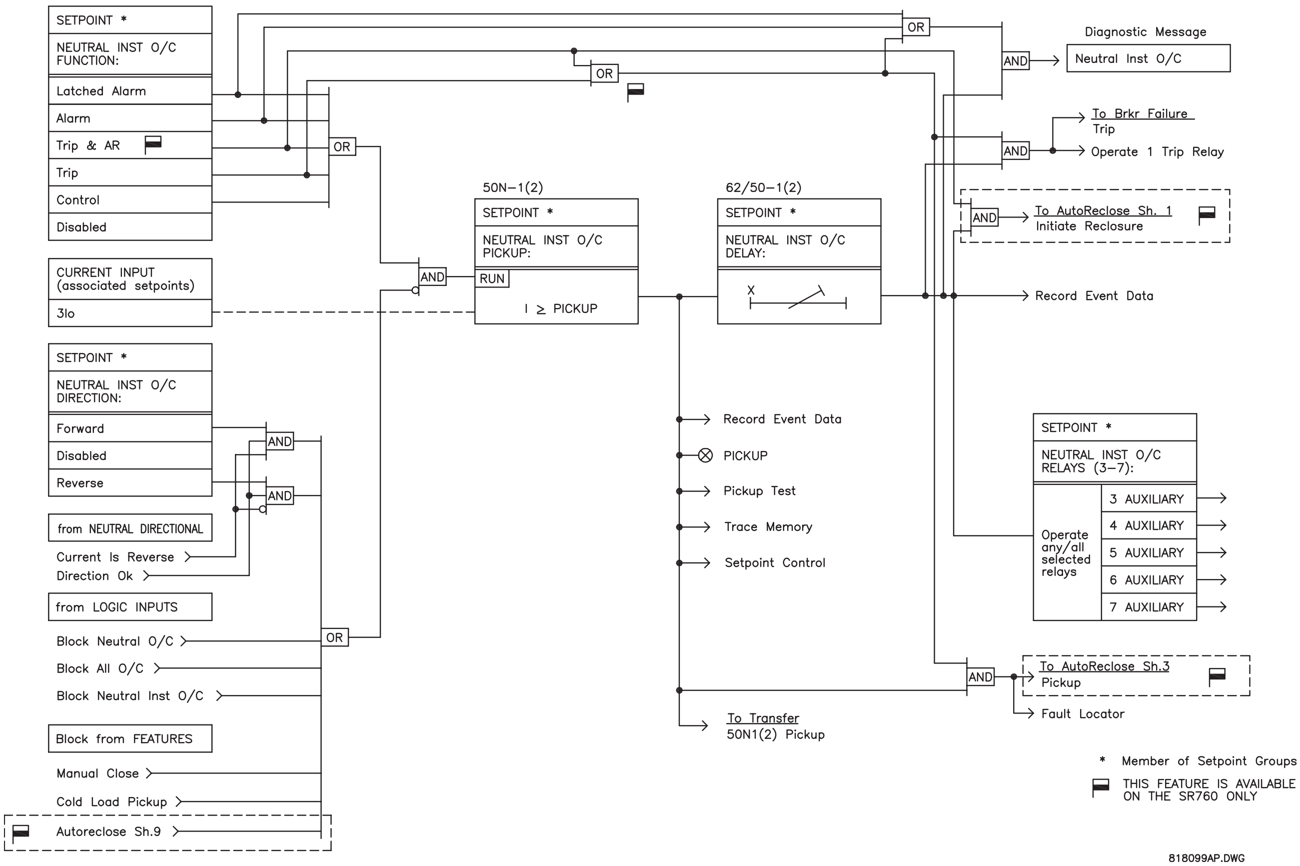

Figure 5–12: NEUTRAL IOC LOGIC

d) NEUTRAL DIRECTIONAL

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEUTRAL CURRENT ⇨⇩ NEUTRAL DIRECTIONAL

■ NEUTRAL DIRECTIONAL ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	NEUTRAL DIRECTIONAL FUNCTION: Disabled	Range: Disabled, Alarm, Latched Alarm, Control
	ESCAPE MESSAGE ⇳	NEUTRAL DIRECTIONAL RELAYS (3-7): -----	Range: Any combination of 3 to 7 Auxiliary relays
	ESCAPE MESSAGE ⇳	NEUTRAL POLARIZING Voltage	Range: Voltage, Current, Dual
	ESCAPE MESSAGE ⇳	NEUTRAL DIRECTIONAL MTA: 315° Lead	Range: 0 to 359° Lead in steps of 1
	ESCAPE MESSAGE ⇧	MIN POLARIZING VOLTAGE: 0.05 x VT	Range: 0.00 to 1.25 x VT in steps of 0.01

The Neutral Directional feature controls the operation of all neutral overcurrent elements and allows them to discriminate between forward or reverse faults. Refer to Phase Directional OC on page 5–39 for more details on directional principles. Neutral directional can be either voltage, current, or dual polarized. The calculated neutral current is always the operating current.

When voltage polarized, the polarizing quantity is the zero sequence voltage which is calculated from the bus input voltages. The VT Connection Type must be wye in this case. If the polarizing voltage drops below the **MIN OPERATING VOLTAGE** value, the direction defaults to forward. The following table shows the operating current and polarizing voltage used for neutral directional control

Table 5–12: NEUTRAL DIRECTIONAL CHARACTERISTICS

QUANTITY	OPERATING CURRENT	POLARIZING VOLTAGE (VT CONNECTION = WYE)	POLARIZING CURRENT
Neutral	$3I_o = I_a + I_b + I_c$	$-V_o = -(V_a + V_b + V_c) / 3$	I_g (see note below)

NOTE

On relays with bootware revision 3.00 or newer, the polarizing current is input via the Ground CT input. Otherwise, the polarizing current is input via a dedicated polarizing CT input. See Section 3.2.3: Current Inputs on page 3–8 for additional details.

When current polarized the Ground CT Input (Terminals G10 and H10) is used to determine neutral current direction. The polarizing current comes from a source CT measuring the current flowing from the ground return into the neutral of a ground fault current source which is usually a transformer. The direction is Forward when the neutral current is within ±90° of the polarizing current. Otherwise, the direction is Reverse. If the polarizing current is less than 5% of CT nominal then the direction defaults to forward.

Dual polarization provides maximum security and reliability. If the polarizing voltage magnitude is insufficient then current polarizing takes control. If the polarizing current magnitude is insufficient then the voltage polarizing takes control. If neither voltage nor current polarizing is possible then the direction defaults to forward.

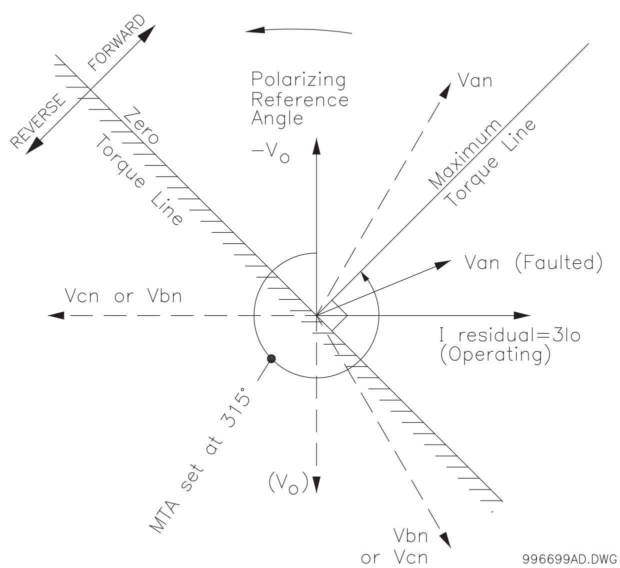

Figure 5–13: NEUTRAL DIRECTIONAL VOLTAGE POLARIZATION

The Neutral Directional specific setpoints are described below.

- **NEUTRAL POLARIZING:** If neutral directional control with both voltage and current polarized elements is desired, enter *Dual*. If neutral directional control with only the voltage polarized element is desired, enter "Voltage". If neutral directional control with only the current polarized element is desired, enter "Current".
- **NEUTRAL DIRECTIONAL MTA:** Enter the maximum torque angle by which the operating current leads the polarizing voltage. This is the angle of maximum sensitivity. This setpoint affects voltage polarizing only. Additional information is provided in the figure above.
- **MIN POLARIZING VOLTAGE:** This setpoint affects the voltage element only. As the system zero sequence voltage is used as the polarizing voltage for this element, a minimum level of voltage must be selected to prevent operation caused by system unbalanced voltages or VT ratio errors. For well-balanced systems and 1% accuracy VTs, this set-point can be as low as 2% of VT nominal voltage. For systems with high-resistance grounding or floating neutrals, this setpoint can be as high as 20%. The default value of "0.05 × VT" is appropriate for most solidly grounded systems.

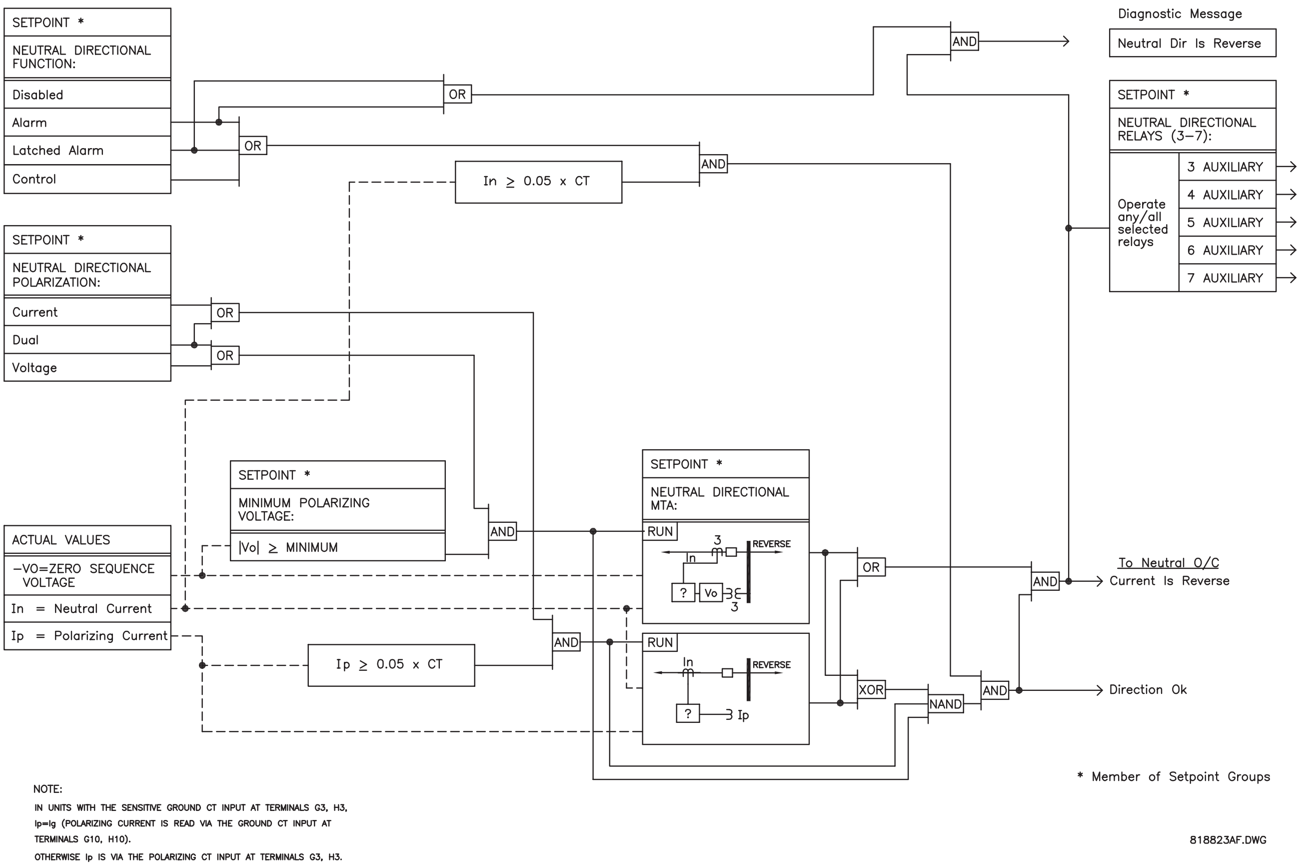

Figure 5–14: NEUTRAL DIRECTIONAL LOGIC

5.6.4 GROUND CURRENT

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ GND CURRENT

■ GND CURRENT ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	■ GND TIME OC 1 ■ [ENTER] for more	See page 5–47.
	ESCAPE / MESSAGE ⇳	■ GND TIME OC 2 ■ [ENTER] for more	
	ESCAPE / MESSAGE ⇳	■ GND INST OC 1 ■ [ENTER] for more	See page 5–48.
	ESCAPE / MESSAGE ⇳	■ GND INST OC 2 ■ [ENTER] for more	
	ESCAPE / MESSAGE ⇧	■ GND DIRECTION ■ [ENTER] for more	See page 5–49.

Separate protection is provided for ground time overcurrent and ground instantaneous overcurrent. These elements monitor the ground current input on Terminals G10 and H10. Ground overcurrent elements can be blocked individually or as a group by logic inputs. Ground overcurrent elements can be controlled by the ground directional element allowing operation for faults in the permitted direction only.

b) GROUND TIME OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ GND CURRENT ⇨ GND TIME OC 1(2)

```
■ GND TIME OC 1
■ [ENTER] for more
```

`GND TIME OC 1` `FUNCTION: Disabled`	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
`GND TIME OC 1` `RELAYS (3-7): -----`	*Range: Any combination of 3 to 7 Auxiliary relays*
`GND TIME OC 1` `PICKUP: 1.00 x CT`	*Range: 0.05 to 20.00 x CT in steps of 0.01*
`GND TIME OC 1` `CURVE: Ext. Inverse`	*Range: See Table 5–4: TOC Curve Selections on page 5–32 for values.*
`GND TIME OC 1` `MULTIPLIER: 1.00`	*Range: 0.00 to 100.00 in steps of 0.01*
`GND TIME OC 1` `RESET: Instantaneous`	*Range: Instantaneous, Linear*
`GND TIME OC 1` `DIRECTION: Disabled`	*Range: Disabled, Forward, Reverse*

The equivalent of a single ground time overcurrent relay, ANSI device 51G, is programmed in this subgroup.

5

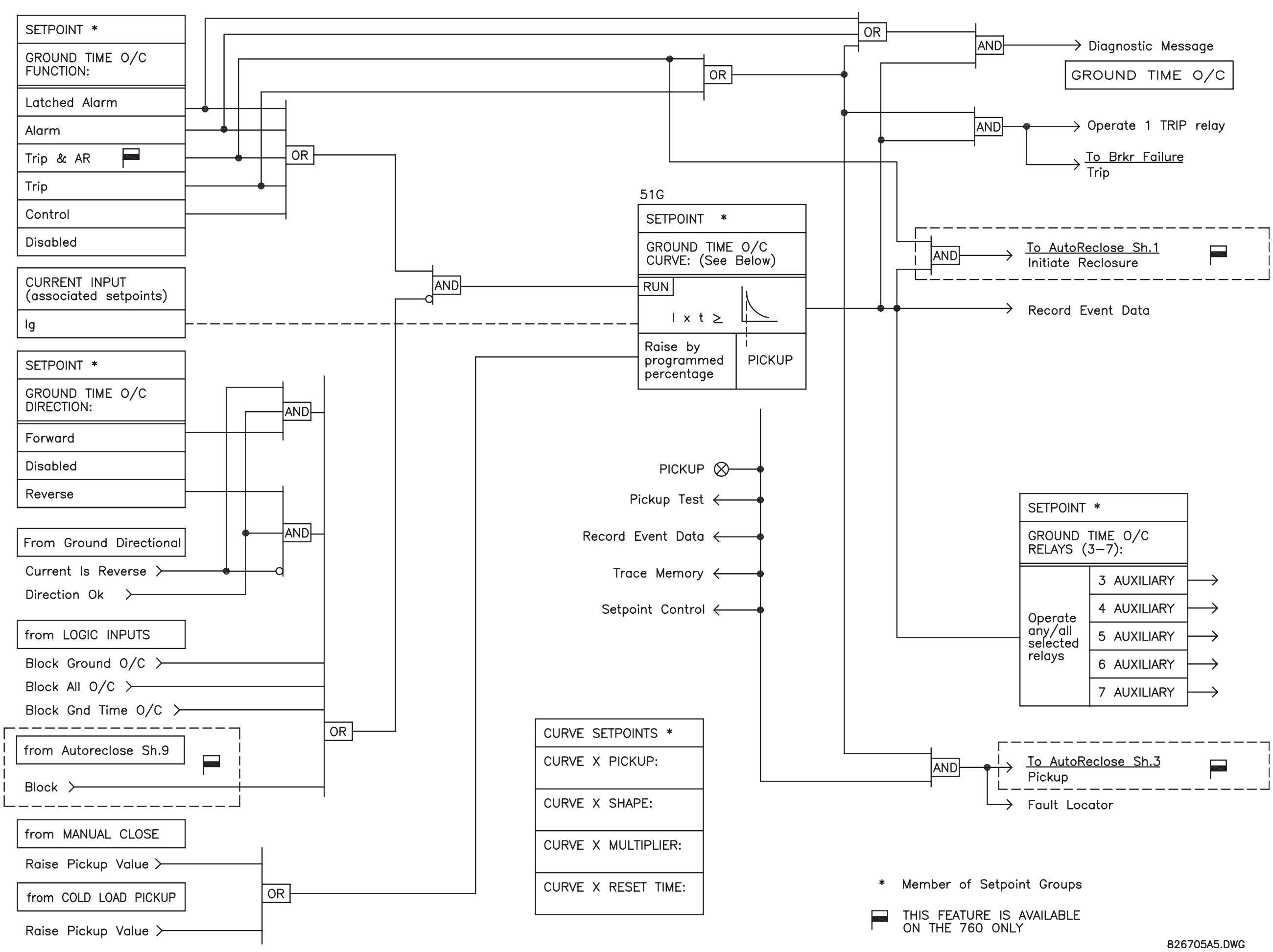

Figure 5–15: GROUND TOC LOGIC

c) GROUND INSTANTANEOUS OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ GND CURRENT ⇨⇩ GND INST OC 1(2)

```
■ GND INST OC 1
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
GND INST OC 1
FUNCTION: Disabled
```

Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control

ESCAPE / MESSAGE ⇳

```
GND INST OC 1
RELAYS (3-7): -----
```

Range: Any combination of 3 to 7 Auxiliary relays

ESCAPE / MESSAGE ⇳

```
GND INST OC 1
PICKUP: 1.00 x CT
```

Range: 0.05 to 20.00 x CT in steps of 0.01

ESCAPE / MESSAGE ⇳

```
GND INST OC 1
DELAY: 0.00 s
```

Range: 0.00 to 600.00 s in steps of 0.01

ESCAPE / MESSAGE ⇧

```
GND INST OC 1
DIRECTION: Disabled
```

Range: Disabled, Forward, Reverse

The equivalent of a single ground instantaneous relay, ANSI device 50G, is programmed in this subgroup.

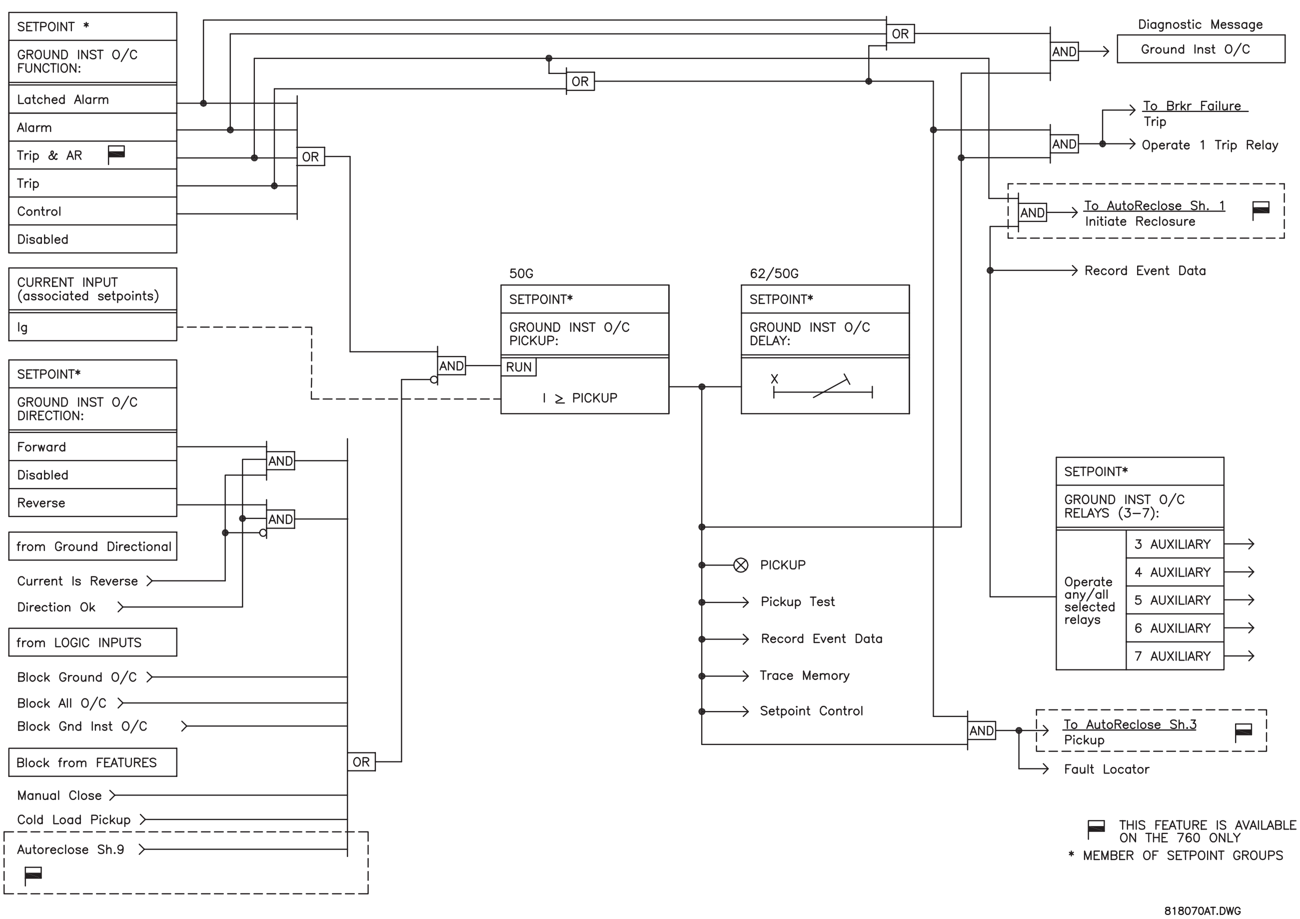

Figure 5–16: GROUND IOC LOGIC

d) GROUND DIRECTIONAL

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ GND CURRENT ⇨⇩ GND DIRECTIONAL

```
■ GND DIRECTIONAL
■ [ENTER] for more
```

```
GND DIRECTIONAL
FUNCTION: Disabled
```
Range: Disabled, Alarm, Latched Alarm, Control

```
GND DIRECTIONAL
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays

```
GND POLARIZING
Voltage
```
Range: Voltage, Current, Dual

```
GND DIRECTIONAL
MTA: 315° Lead
```
Range: 0 to 359° Lead in steps of 1

```
MIN POLARIZING
VOLTAGE: 0.05 x VT
```
Range: 0.00 to 1.25 x VT in steps of 0.01

The Ground Directional feature controls operation of all ground overcurrent elements and allows them to discriminate between forward or reverse faults. Refer to Phase Directional OC on page 5–39 for additional details on directional principles. Ground directional can be either voltage, current, or dual polarized. The ground current input is always the operating current.

When voltage polarized, the polarizing quantity is the zero sequence voltage which is calculated from the bus input voltages. The VT Connection Type must be Wye in this case. If the polarizing voltage drops below the MIN OPERATING VOLTAGE value, the direction defaults to forward. The following table shows the operating current and polarizing quantities used for ground directional control.

Table 5–13: GROUND DIRECTIONAL CHARACTERISTICS

QUANTITY	OPERATING CURRENT	POLARIZING VOLTAGE (VT CONNECTION = WYE)	POLARIZING CURRENT
Ground	I_g	$-V_o = -(V_a + V_b + V_c) / 3$	I_{pol} (see note below)

NOTE: On relays with bootware revision 3.00 or newer, the ground directional element may only be voltage polarized since these relays do not have a polarizing current input. Otherwise, the polarizing current is input via a dedicated polarizing CT input. See Section 3.2.3: Current Inputs on page 3–8 for more details.

When current polarized, the 'Polarizing CT Input' is used to determine ground current direction. The polarizing current comes from a source CT measuring the current flowing from the ground return into the neutral of a ground fault current source which is usually a transformer. The direction is Forward when the sensitive ground current is within ±90° of the polarizing current. Otherwise, the direction is Reverse. If the polarizing current is less than 5% of CT nominal then the direction defaults to forward.

Dual polarization provides maximum security and reliability. If the polarizing voltage magnitude is insufficient then the current polarizing takes control. If the polarizing current magnitude is insufficient then the voltage polarizing takes control. If neither voltage nor current polarizing is possible then the direction defaults to forward.

- **GND POLARIZING:** If ground directional control with both voltage and current polarized elements is desired, enter "Dual". If ground directional control with only the voltage polarized element is desired, enter "Voltage". If ground directional control with only the current polarized element is desired, enter "Current".
- **GND DIRECTIONAL MTA:** Enter the maximum torque angle by which the operating current leads the polarizing voltage. This is the angle of maximum sensitivity. This setpoint affects voltage polarizing only.
- **MIN POLARIZING VOLTAGE:** This setpoint affects the voltage element only. As the system zero sequence voltage is used as the polarizing voltage for this element, a minimum level of voltage must be selected to prevent operation caused by system unbalanced voltages or VT ratio errors. For well-balanced systems and 1% accuracy VTs, this setpoint can be as low as 2% of VT nominal voltage. For systems with high-resistance grounding or floating neutrals, this setpoint can be as high as 20%. The default value of "0.05 x VT" is appropriate for most solidly grounded systems.

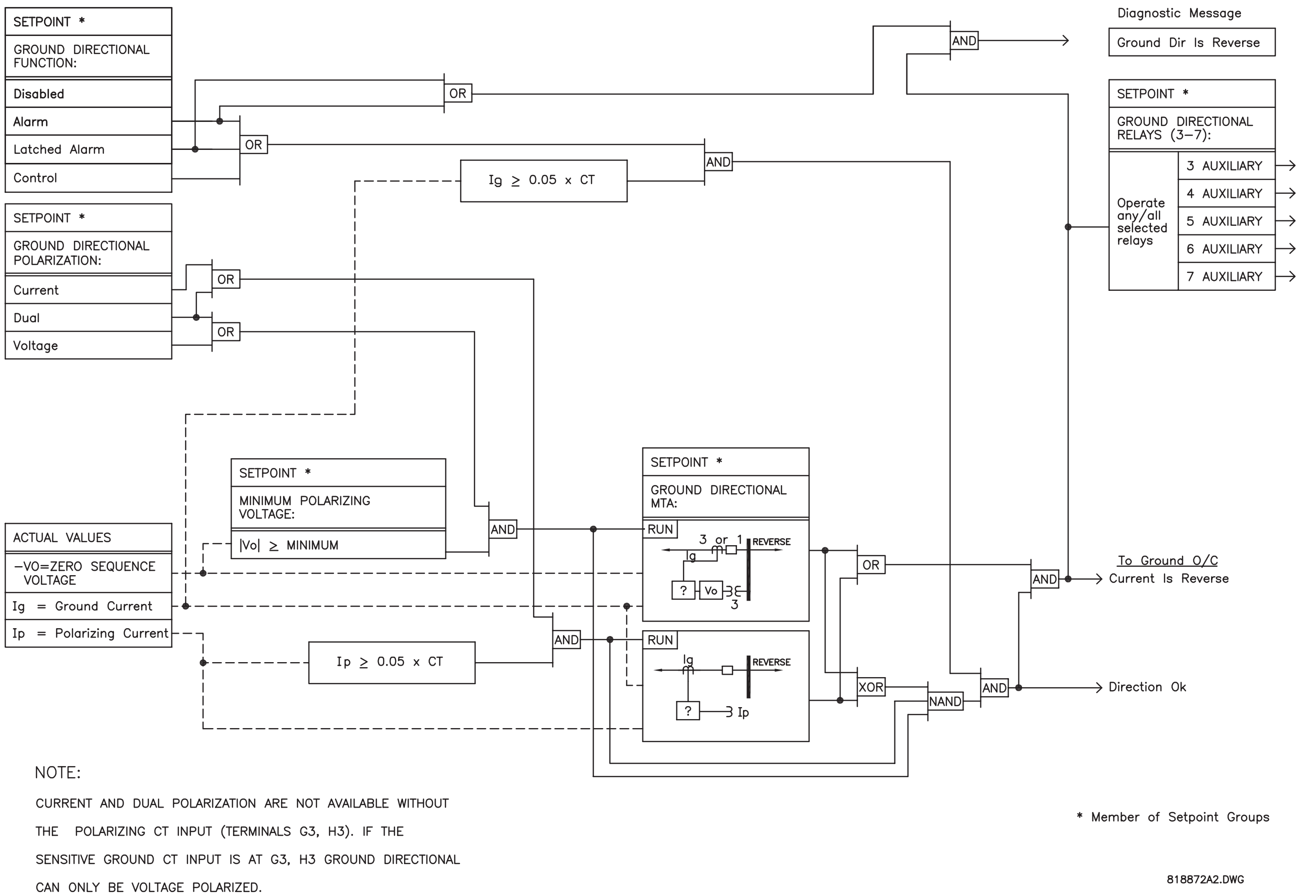

Figure 5–17: GROUND DIRECTIONAL LOGIC

5.6.5 SENSITIVE GROUND CURRENT

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ SENSTV GND CURRENT

```
■ SENSTV GND CURRENT
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
■ SENSTV GND TIME OC
■ [ENTER] for more
```

See page 5–51.

ESCAPE / MESSAGE ⇳

```
■ SENSTV GND INST OC
■ [ENTER] for more
```

See page 5–52.

ESCAPE / MESSAGE ⇳

```
■ SENSTV GND DIRECTN
■ [ENTER] for more
```

See page 5–53.

ESCAPE / MESSAGE ⇧

```
■ RESTRICTED EF
■ [ENTER] for more
```

See page 5–54.

Two sensitive ground overcurrent elements and a restricted earth fault element are provided. One time overcurrent element and one instantaneous element. Sensitive ground overcurrent elements can be controlled by the sensitive ground directional element allowing operation for faults in the permitted direction only. Also, the elements can be blocked individually or as a group by logic inputs.

b) SENSITIVE GROUND TIME OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ SENSTV GND CURRENT ⇨ SENSTV GND TIME OC

	Range
■ SENSTV GND TIME OC ■ [ENTER] for more	
SENSTV GND TIME OC FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
SENSTV GND TIME OC RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
SENSTV GND TIME OC PICKUP: 1.00 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01*
SENSTV GND TIME OC CURVE: Ext. Inverse	*Range: see Table 5–4: TOC Curve Selections on page 5–32 for values*
SENSTV GND TIME OC MULTIPLIER: 1.00	*Range: 0.00 to 100.00 in steps of 0.01*
SENSTV GND TIME OC RESET: Instantaneous	*Range: Instantaneous, Linear*
SENSTV GND TIME OC DIRECTION: Disabled	*Range: Disabled, Forward, Reverse*

The sensitive ground time overcurrent element, ANSI device 51SG is programmed in this subgroup.

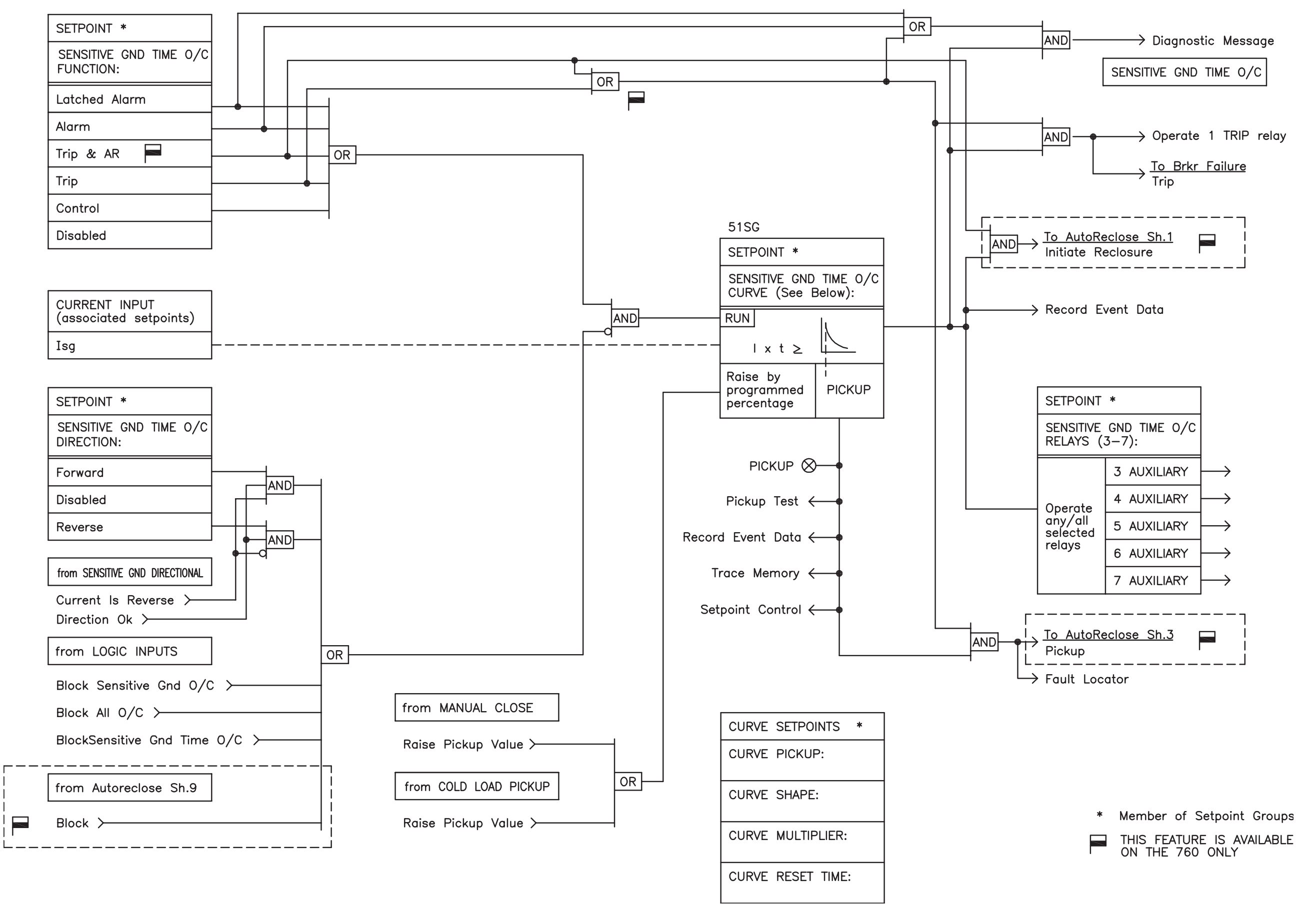

Figure 5–18: SENSITIVE GROUND TOC LOGIC

c) SENSITIVE GROUND INSTANTANEOUS OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ SENSTV GND CURRENT ⇨⇩ SENSTV GND INST OC

```
■ SENSTV GND INST OC
■ [ENTER] for more
```

SENSTV GND INST OC FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
SENSTV GND INST OC RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
SENSTV GND INST OC PICKUP: 1.000 x CT	*Range: 0.005 to 1.000 x CT in steps of 0.001*
SENSTV GND INST OC DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
SENSTV GND INST OC DIRECTION: Disabled	*Range: Disabled, Forward, Reverse*

The sensitive ground instantaneous overcurrent element, ANSI device 50SG is programmed in this subgroup.

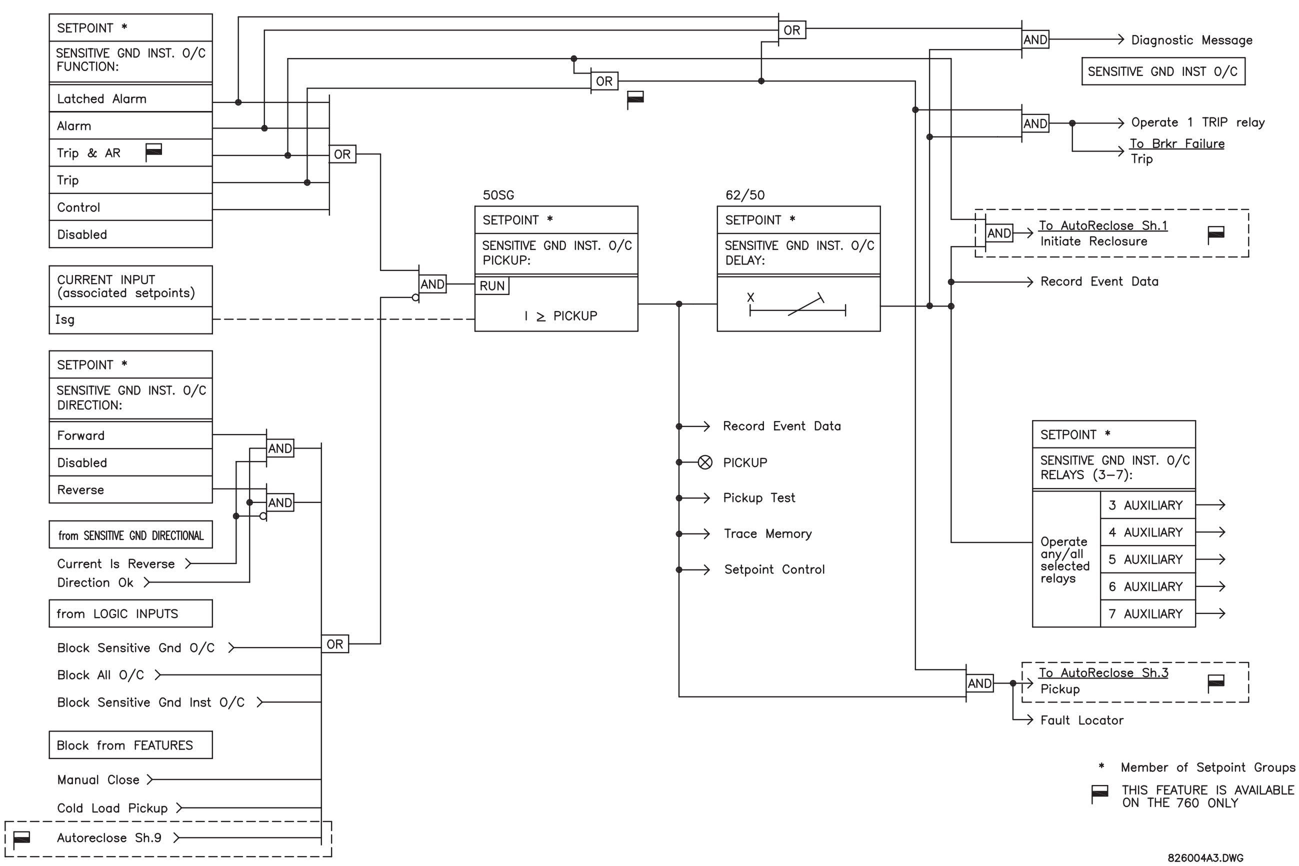

Figure 5–19: SENSITIVE GROUND IOC LOGIC

d) SENSITIVE GROUND DIRECTIONAL

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ SENSTV GND CURRENT ⇨⇩ SENSTV GND DIRECTN

```
■ SENSTV GND DIRECTN
■ [ENTER] for more
```

[ENTER] ⇨ / ⇦ [ESCAPE]

```
SENSTV GND DIRECTN
FUNCTION: Disabled
```
Range: Disabled, Alarm, Latched Alarm, Control

[ESCAPE] [MESSAGE]

```
SENSTV GND DIRECTN
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays

[ESCAPE] [MESSAGE]

```
SENS GND POLARIZING
Voltage
```
Range: Voltage, Current, Dual

[ESCAPE] [MESSAGE]

```
SENSTV GND DIRECTN
MTA: 315° Lead
```
Range: 0 to 359° Lead in steps of 1

[ESCAPE] [MESSAGE]

```
MIN POLARIZING
VOLTAGE: 0.05 x VT
```
Range: 0.00 to 1.25 x VT in steps of 0.01

The sensitive ground directional feature controls the operation of all sensitive ground overcurrent elements and allows them to discriminate between forward or reverse faults. Refer to Phase Directional OC on page 5–39 for more details on directional principles. Sensitive ground directional can be either voltage, current, or dual polarized. The sensitive ground current input is always the operating current.

When voltage polarized, the polarizing quantity is the zero sequence voltage which is calculated from the bus input voltages. The VT Connection Type must be Wye in this case. If the polarizing voltage drops below the MIN OPERATING VOLTAGE value, the direction defaults to forward. The following table shows the operating current and polarizing quantities used for sensitive ground directional control.

Table 5–14: SENSITIVE GROUND DIRECTIONAL CHARACTERISTICS

QUANTITY	OPERATING CURRENT	POLARIZING VOLTAGE (VT CONNECTION = WYE)	POLARIZING CURRENT
Sensitive Ground	I_{sg}	$-V_o = -(V_a + V_b + V_c) / 3$	I_g (see note below)

NOTE

On relays with bootware revision 3.00 or newer, the polarizing current is input via the Ground CT input. Otherwise, the polarizing current is input via a dedicated polarizing CT input. See Section 3.2.3: Current Inputs on page 3–8 for more details.

When current polarized, the Ground CT Input is used to determine sensitive ground current direction. The polarizing current comes from a source CT measuring the current flowing from the ground return into the neutral of a ground fault current source which is usually a transformer. The direction is Forward when the sensitive ground current is within ±90° of the polarizing current. Otherwise, the direction is Reverse. If the polarizing current is less than 5% of CT nominal then the direction defaults to forward.

Dual polarization provides maximum security and reliability. If the polarizing voltage magnitude is insufficient then the current polarizing takes control. If the polarizing current magnitude is insufficient then the voltage polarizing takes control. If neither voltage nor current polarizing is possible then the direction defaults to forward.

- **SENS GND POLARIZING:** If sensitive ground directional control with both voltage and current polarized elements is desired, enter "Dual". With this setpoint, both polarizing quantities must agree that the operating current is in the reverse direction for the sensitive ground directional element to operate the selected output relays. If sensitive ground directional control with only the voltage polarized element is desired, enter "Voltage". If sensitive ground directional control with only the current polarized element is desired, enter "Current".
- **SENSTV GND DIRECTN MTA:** Enter the maximum torque angle by which the operating current leads the polarizing voltage. This is the angle of maximum sensitivity. This setpoint affects voltage polarizing only.
- **MIN POLARIZING VOLTAGE:** This setpoint affects the voltage element only. As the system zero sequence voltage is used as the polarizing voltage for this element, a minimum level of voltage must be selected to prevent operation caused by system unbalanced voltages or VT ratio errors. For well-balanced systems and 1% accuracy VTs, this setpoint can be as low as 2% of VT nominal voltage. For systems with high-resistance grounding or floating neutrals, this setpoint can be as high as 20%. The default value of "0.05 x VT" is appropriate for most solidly grounded systems.

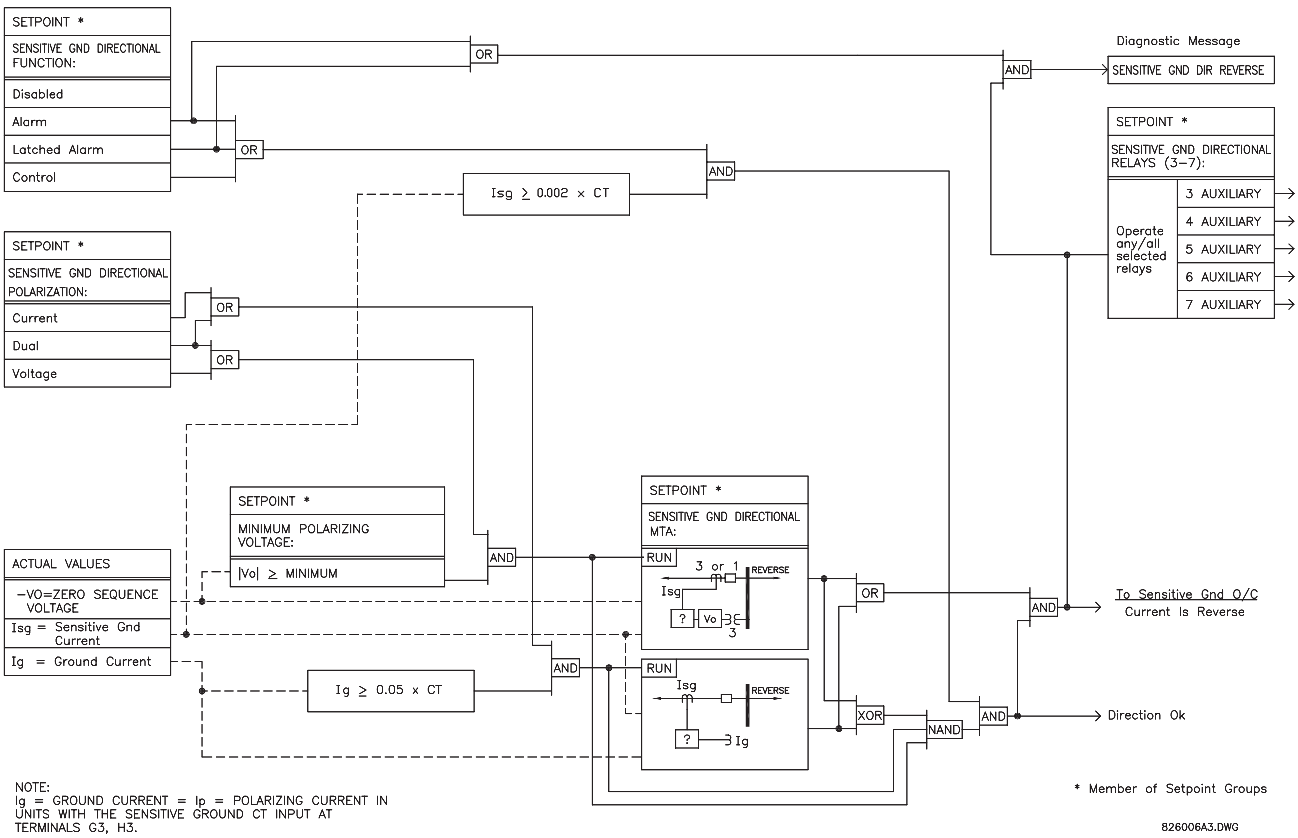

Figure 5–20: SENSITIVE GROUND DIRECTIONAL LOGIC

e) RESTRICTED EARTH FAULT

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ SENSTV GND CURRENT ⇨⇩ RESTRICTED EF

			Range
■ RESTRICTED EF ■ [ENTER] for more	ENTER / ESCAPE	RESTRICTED EARTH FLT FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
	ESCAPE / MESSAGE	RESTRICTED EARTH FLT RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	ESCAPE / MESSAGE	RESTRICTED EARTH FLT PICKUP: 0.100 x CT	*Range: 0.005 to 1.000 x CT in steps of 0.001*
	ESCAPE / MESSAGE	RESTRICTED EARTH FLT DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*

Restricted Earth Fault protection is often applied to transformers having grounded wye windings, to provide sensitive ground fault detection for faults near the transformer neutral. The Sensitive Ground Input (Terminals G3, H3) can be used.

Although the 750/760 is designed for feeder protection, it can provide Restricted Earth Fault protection on transformers that do not have dedicated protection. To use the 750/760 for this type of protection, a stabilizing resistor and possibly a non-linear resistor will be required.

The inclusion of a stabilizing resistor encourages the circulating fault current to flow via the magnetizing impedance of the saturated current transformer thus minimizing spill current in the REF relay. A non-linear resistor will be required where the voltage across the inputs would be greater than 2000 V. Refer to Restricted Earth Fault Inputs on page 3–10 for the connections required to use the 750/760 to perform Restricted Earth Fault protection.

To determine the appropriate value for the Stabilizing Resistor, use the following equation:

$$R_s = \frac{V_s}{I_s} = \frac{I_F \cdot (R_{CT} + 2R_L)}{I_s} \quad \textbf{(EQ 5.5)}$$

where: R_S = resistance value of the stabilizing resistor, V_S = voltage at which the 750/760 will operate
I_S = current flowing through the stabilizing resistor and the 750/760,
I_F = maximum secondary fault current magnitude
R_{CT} = internal resistance of the current transformer, and R_L = resistance of attached wire leads

A non-linear resistor is recommended if the peak fault voltage may be above the relays maximum of 2000 V. The following calculation is done to determine if a non-linear resistor is required. When required, this should be provided by the end-user.

It is assumed that the ratio of the CT kneepoint (V_K) V_S is to 2 for stability. Thus,

$$V_K = 2V_S \quad \textbf{(EQ 5.6)}$$

Next, the voltage that would result from a fault must be determined, neglecting saturation,

$$V_f = I_f \cdot (R_{CT} + 2R_L + R_S) \quad \textbf{(EQ 5.7)}$$

The peak value of this fault voltage would be:

$$V_P = 2\sqrt{2} \cdot \sqrt{V_k \cdot (V_f - V_K)} \quad \textbf{(EQ 5.8)}$$

If V_P is greater than 2000 V, then a non-linear resistor *must* be used.

SAMPLE APPLICATION:

The CTs used in this example are 3000/1, 10P10, 15 VA, and the transformer used in the example is an 11 kV / 400 V, 2000 kVA. At 10P10 the voltage at which the CT will saturate will be 10 x 15 = 150 V. An equivalent IEEE description for this CT would be 3000/1, C150.

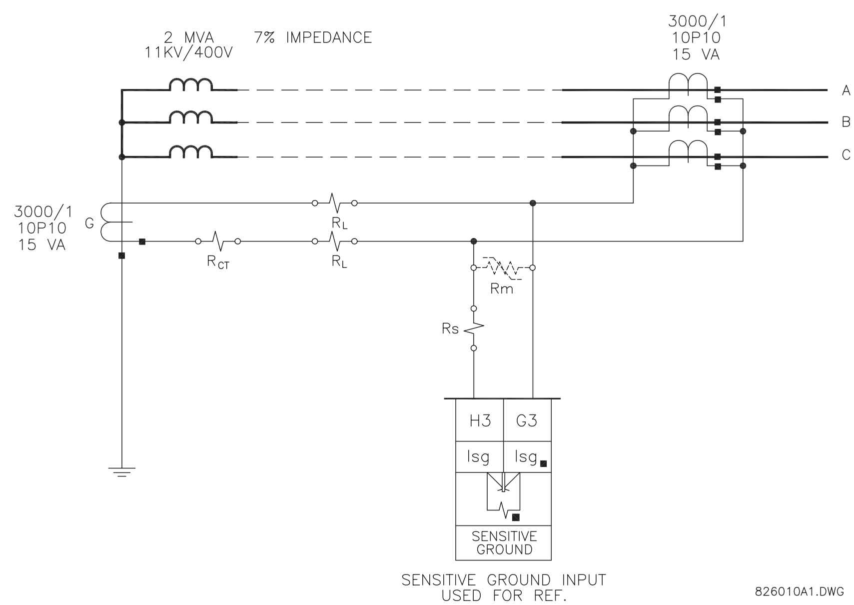

Figure 5–21: RESTRICTED EARTH FAULT SAMPLE APPLICATION

We have: R_{CT} = 3.7 Ω
R_L = 0.954 Ω assuming 600 feet of #12 wire
X(%) = impedance of transformer = 7% = 0.07

The rated transformer current through wye windings is given as: $I_P = \frac{2000 \text{ kVA}}{\sqrt{3} \cdot 400 \text{ V}} = 2887 \text{ A}$ **(EQ 5.9)** and the maximum fault current is: $I_{MAXf} = \frac{I_P}{X(\%)} = \frac{2887\text{ A}}{0.07} = 41243\text{ A}$ **(EQ 5.10)**

Therefore, the secondary full load current is: $I_{SFLC} = \frac{2887\text{ A}}{3000} = 0.962\text{ A}$ **(EQ 5.11)**

and the maximum secondary fault current is: $I_{Smax} = \frac{0.962\text{ A}}{0.07} = 13.74\text{ A} = I_f$ **(EQ 5.12)**

A V_K / V_S ratio of 2 is assumed to ensure operation. As such,

$V_S = I_f(R_{CT} + 2R_L) = 77.05$ V and
$V_K = 2V_S = 154.1$ V

To calculate the size of the stabilizing resistor, assume I_{PICKUP} to be 30% rated transformer current, that is:

$$I_{PICKUP} = 0.3 \times 2887\text{ A} = 866\text{ A (Primary)}$$ **(EQ 5.13)**

This means also (assuming 1% for CT magnetizing current):

$$I_{RELAY\ PICKUP} = \frac{866\text{ A}}{3000} - (4 \times 0.01) = 0.248\text{ A} = I_S$$ **(EQ 5.14)**

and therefore:

$$R_s = \frac{V_s}{I_s} = \frac{77.05\ \Omega}{0.248\text{ A}} = 311\ \Omega$$ **(EQ 5.15)**

5

To determine whether a non-linear resistor is required, we have:

$$V_f = I_f \cdot (R_{CT} + 2R_L + R_s) = 13.748\text{ A} \times (3.7\ \Omega + (2 \times 0.954\ \Omega) + 311\ \Omega) = 4353\text{ V}$$
$$V_P = 2\sqrt{2} \cdot \sqrt{V_K \cdot (V_F - V_K)} \quad \rightarrow \text{use 150 V as value for } V_K$$
$$= 2\sqrt{2} \cdot \sqrt{150\text{ V} \times (4353\text{ V} - 150\text{ V})} = 2246\text{ V}$$ **(EQ 5.16)**

A non-linear resistor is recommended as the peak fault voltage is above relay voltage maximum of 2000 V.

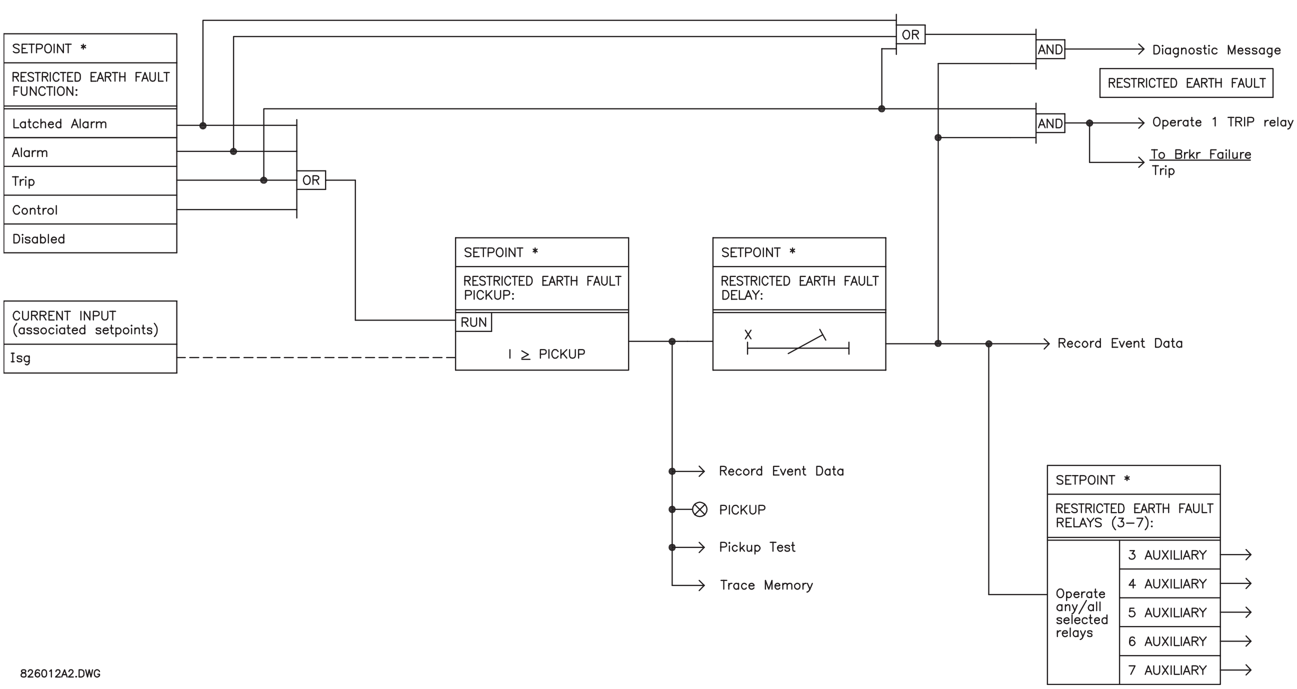

Figure 5–22: RESTRICTED EARTH FAULT LOGIC

5.6.6 NEGATIVE SEQUENCE

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE

```
■ NEGATIVE SEQUENCE
■ [ENTER] for more
```

```
■ NEG SEQ TIME OC
■ [ENTER] for more
```
See below.

```
■ NEG SEQ INST OC
■ [ENTER] for more
```
See page 5–58.

```
■ NEG SEQ DIRECTION
■ [ENTER] for more
```
See page 5–59.

```
■ NEG SEQ VOLTAGE
■ [ENTER] for more
```
See page 5–61.

Separate protection is provided for the calculated negative sequence time overcurrent, instantaneous overcurrent and voltage. Each of these features can be individually blocked by logic inputs.

b) NEGATIVE SEQUENCE TIME OC

A time overcurrent element operating on the negative sequence component of current, ANSI device 46 is programmed in this subgroup.

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE ⇨ NEG SEQ TIME OC

```
■ NEG SEQ TIME OC
■ [ENTER] for more
```

```
NEG SEQ TIME OC
FUNCTION: Disabled
```
Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control

```
NEG SEQ TIME OC
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays

```
NEG SEQ TIME OC
PICKUP: 1.00 x CT
```
Range: 0.05 to 20.00 x CT in steps of 0.01

```
NEG SEQ TIME OC
CURVE: Ext. Inverse
```
Range: see Table 5–4: TOC Curve Selections on page 5–32 for values

```
NEG SEQ TIME OC
MULTIPLIER:    1.00
```
Range: 0.00 to 100.00 in steps of 0.01

```
NEG SEQ TIME OC
RESET: Instantaneous
```
Range: Instantaneous, Linear

```
NEG SEQ TIME OC
DIRECTION: Disabled
```
Range: Disabled, Forward, Reverse

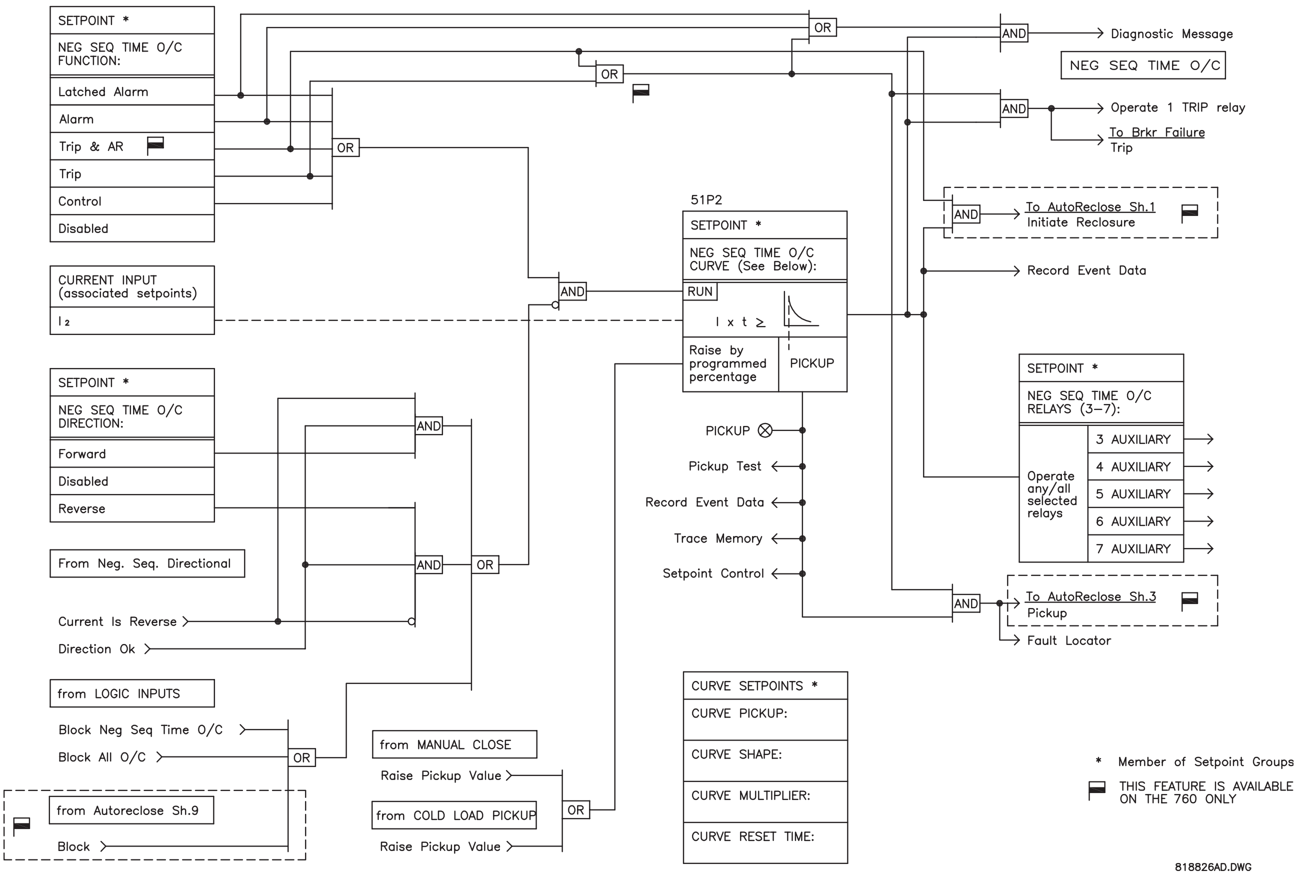

Figure 5–23: NEGATIVE SEQUENCE TOC LOGIC

c) NEGATIVE SEQUENCE INSTANTANEOUS OC

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE ⇨⇩ NEG SEQ INST OC

	Range
■ NEG SEQ INST OC ■ [ENTER] for more	
NEG SEQ INST OC FUNCTION: Disabled	*Range: Disabled, Trip, Trip & AR, Alarm, Latched Alarm, Control*
NEG SEQ INST OC RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
NEG SEQ INST OC PICKUP: 1.000 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.001*
NEG SEQ INST OC DELAY: 0.00 s	*Range: 0.00 to 600.00 s in steps of 0.01*
NEG SEQ INST OC DIRECTION: Disabled	*Range: Disabled, Forward, Reverse*

A instantaneous overcurrent element operating on the negative sequence component of current, ANSI device 46 is programmed in this subgroup.

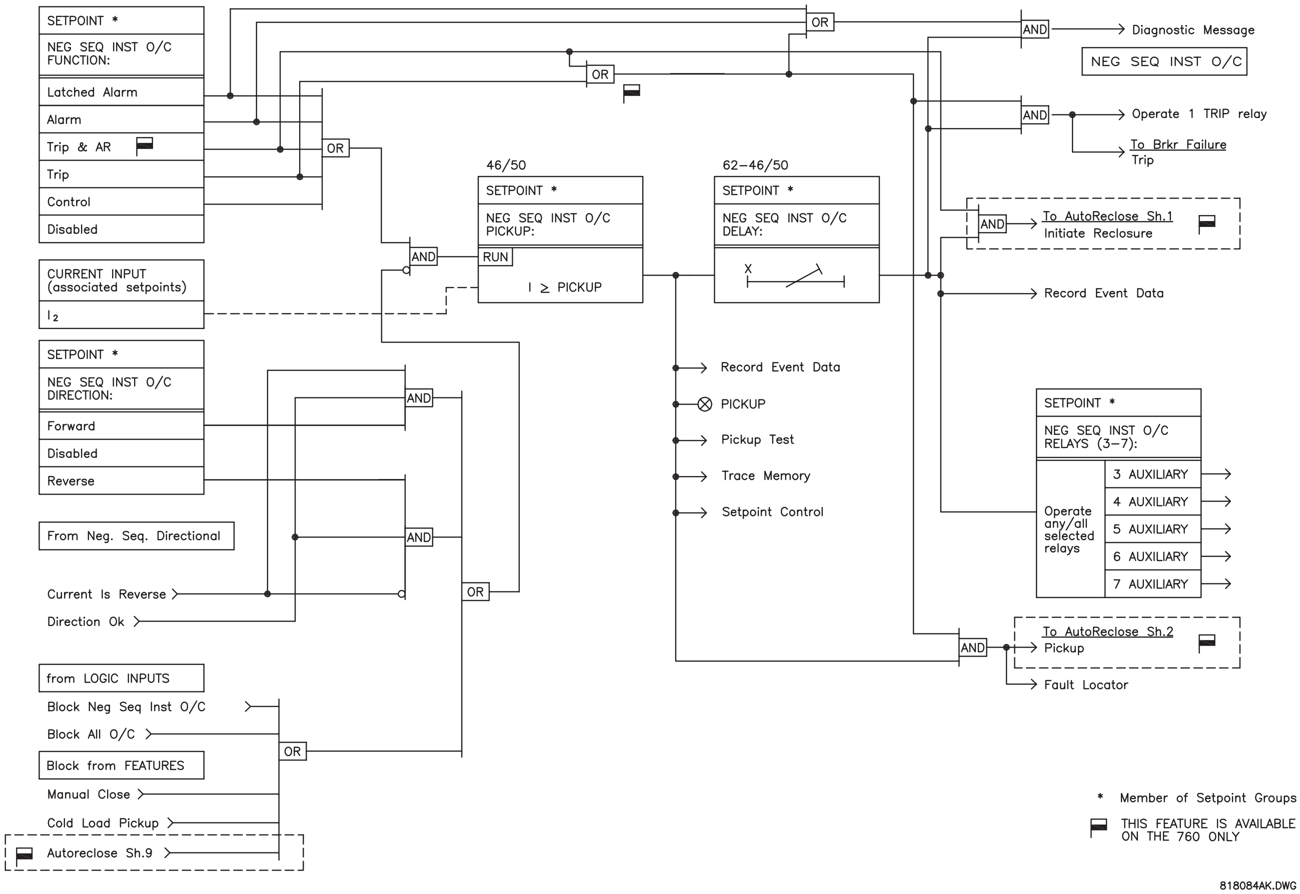

Figure 5–24: NEGATIVE SEQUENCE IOC LOGIC

d) NEGATIVE SEQUENCE DIRECTIONAL

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE ⇨⇩ NEG SEQ DIRECTION

```
■ NEG SEQ DIRECTION
■ [ENTER] for more
```

ENTER / ESCAPE

```
NEG SEQ DIRECTIONAL
FUNCTION: Disabled
```

Range: Disabled, Alarm, Latched Alarm, Control

ESCAPE / MESSAGE

```
NEG SEQ DIRECTIONAL
RELAYS (3-7): -----
```

Range: Any combination of 3 to 7 Auxiliary relays

ESCAPE / MESSAGE

```
NEG SEQ DIRECTIONAL
MTA: 315° Lead
```

Range: 0 to 359° Lead in steps of 1

ESCAPE / MESSAGE

```
MIN POLARIZING
VOLTAGE: 0.05 x VT
```

Range: 0.00 to 1.25 x VT in steps of 0.01

The negative sequence directional feature controls the operation of all negative sequence overcurrent elements and allows them to discriminate between forward or reverse faults. Refer to Phase Directional OC on page 5–39 for more details on directional principles. The operating current and polarizing voltage is shown in the following table. If the polarizing voltage drops below the **MIN OPERATING VOLTAGE** value, the direction defaults to forward.

Table 5–15: NEGATIVE SEQUENCE DIRECTIONAL CHARACTERISTICS

QUANTITY	OPERATING CURRENT	POLARIZING VOLTAGE
Negative Sequence (ABC phase sequence)	$I_{a2} = \dfrac{I_a + a^2 I_b + a I_c}{3}$	$-V_{a2} = -\dfrac{V_a + a^2 V_b + a V_c}{3}$
Negative Sequence (ACB phase sequence)	$I_{a2} = \dfrac{I_a + a I_b + a^2 I_c}{3}$	$-V_{a2} = -\dfrac{V_a + a V_b + a^2 V_c}{3}$

The setpoints for Negative Sequence Directional are described below.

- **NEG SEQ DIRECTIONAL MTA:** Enter the maximum torque angle by which the operating current leads the polarizing voltage. This is the angle of maximum sensitivity.
- **MIN POLARIZING VOLTAGE:** As the system negative sequence voltage is used as the polarizing voltage for this element, a minimum level of voltage must be selected to prevent operation caused by system unbalanced voltages or VT ratio errors. For well-balanced systems and 1% accuracy VTs, this setpoint can be as low as 2% of VT nominal voltage. For systems with high-resistance grounding or floating neutrals, this setpoint can be as high as 20%. The default value of "0.05 x VT" is appropriate for most solidly grounded systems.

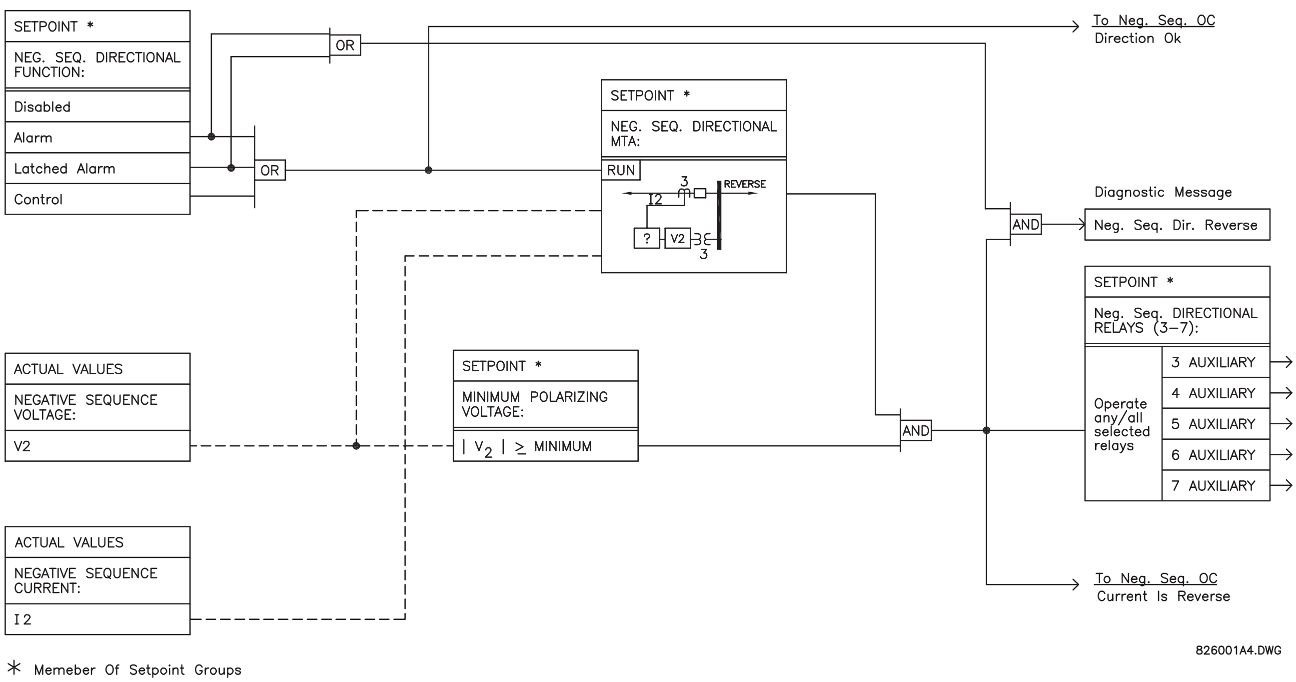

Figure 5–25: NEGATIVE SEQUENCE DIRECTIONAL LOGIC

e) NEGATIVE SEQUENCE VOLTAGE

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ NEGATIVE SEQUENCE ⇨⇩ NEG SEQ VOLTAGE

```
■ NEG SEQ VOLTAGE
■ [ENTER] for more
```

```
NEG SEQ VOLTAGE
FUNCTION: Disabled
```
Range: Disabled, Trip, Alarm, Latched Alarm, Control

```
NEG SEQ VOLTAGE
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays

```
NEG SEQ VOLTAGE
PICKUP: 0.10 x VT
```
Range: 0.00 to 1.25 x VT in steps of 0.01

```
NEG SEQ VOLTAGE
DELAY: 2.0 s
```
Range: 0.0 to 6000.0 s in steps of 0.1

To protect against loss of one or two source phases, or against a reversed phase sequence of voltage, the negative sequence voltage element can be used to either cause a trip or generate an alarm when the negative sequence voltage exceeds the specified threshold for a specified time delay.

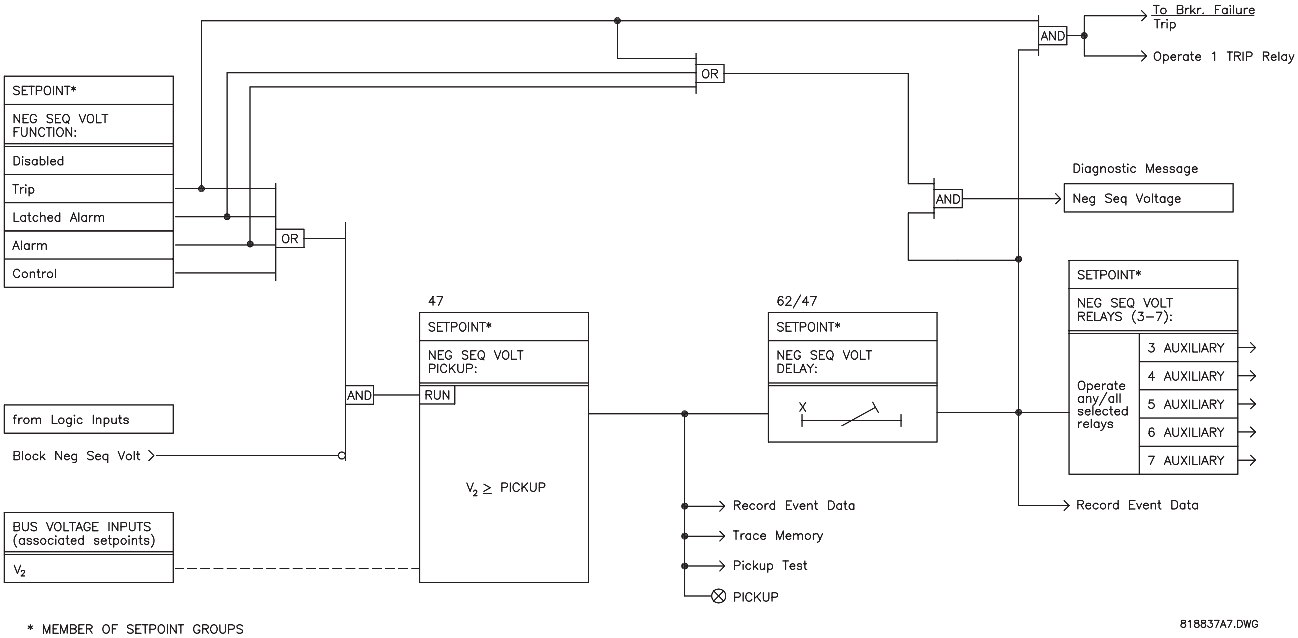

Figure 5–26: NEGATIVE SEQUENCE VOLTAGE LOGIC

5

5.6.7 VOLTAGE

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ VOLTAGE

■ SENSTV GND CURRENT ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ BUS UNDERVOLTAGE 1 ■ [ENTER] for more	See page 5–63.
	ESCAPE MESSAGE ⇳	■ BUS UNDERVOLTAGE 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇳	■ LINE UNDERVOLTAGE 3 ■ [ENTER] for more	See page 5–64.
	ESCAPE MESSAGE ⇳	■ LINE UNDERVOLTAGE 4 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇳	■ OVERVOLTAGE 1 ■ [ENTER] for more	See page 5–65.
	ESCAPE MESSAGE ⇳	■ OVERVOLTAGE 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇧	■ NTR DISPLACEMENT ■ [ENTER] for more	See page 5–66.

There are four undervoltage protection elements which can be used for a variety of applications:

- **Undervoltage Protection:** For voltage sensitive loads, such as induction motors, a drop in voltage will result in an increase in 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. Note that all internal features that are inhibited by an undervoltage condition, such as underfrequency and overfrequency, have their own inhibit functions independent of the undervoltage protection features.
- **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 an inverse time delay characteristic. The undervoltage delay setpoint defines a family of curves as shown below:

The operating time is given by:

$$T = \frac{D}{1 - V/V_{pu}} \quad \textbf{(EQ 5.17)}$$

where: T = Operating Time
D = Undervoltage Delay setpoint
V = Voltage as a fraction of the nominal VT Secondary Voltage
V_{pu} = Pickup Level

NOTE: At 0% of pickup, the operating time equals the Undervoltage Delay setpoint.

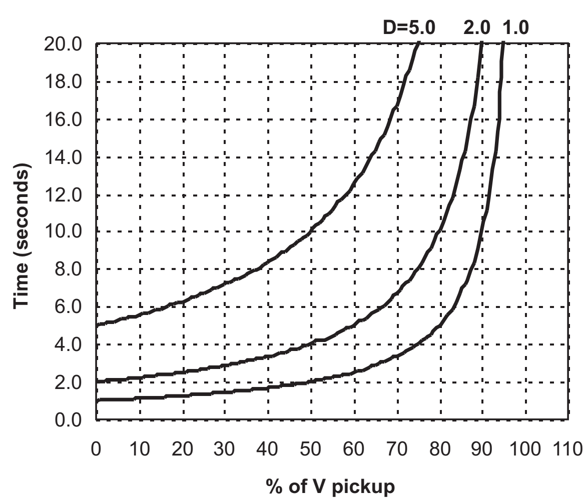

Figure 5–27: INVERSE TIME UNDERVOLTAGE CURVES

b) BUS UNDERVOLTAGE

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ VOLTAGE ⇨ BUS UNDERVOLTAGE 1(2)

■ BUS UNDERVOLTAGE 1 ■ [ENTER] for more	
BUS UNDERVOLTAGE 1 FUNCTION: Disabled	*Range: Disabled, Trip, Alarm, Latched Alarm, Control*
BUS UNDERVOLTAGE 1 RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
BUS UNDERVOLTAGE 1 PICKUP: 0.75 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
BUS UNDERVOLTAGE 1 CURVE: Ext. Inverse	*Range: Definite Time, Inverse Time.*
BUS UNDERVOLTAGE 1 DELAY: 2.0 s	*Range: 0.0 to 6000.0 s in steps of 0.1*
PHASES REQUIRED FOR OPERATION: All Three	*Range: Any One, Any Two, All Three*
MIN OPERATING VOLTAGE: 0.30 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*

Bus Undervoltage 1 and 2 are identical elements that generate outputs in response to undervoltage conditions on the bus voltage inputs. The time delay characteristic can be programmed as definite time or inverse time. A minimum operating voltage level is programmable to prevent undesired operation before voltage becomes available. The setpoints for Undervoltage 1 are shown above; Undervoltage 2 setpoints are identical.

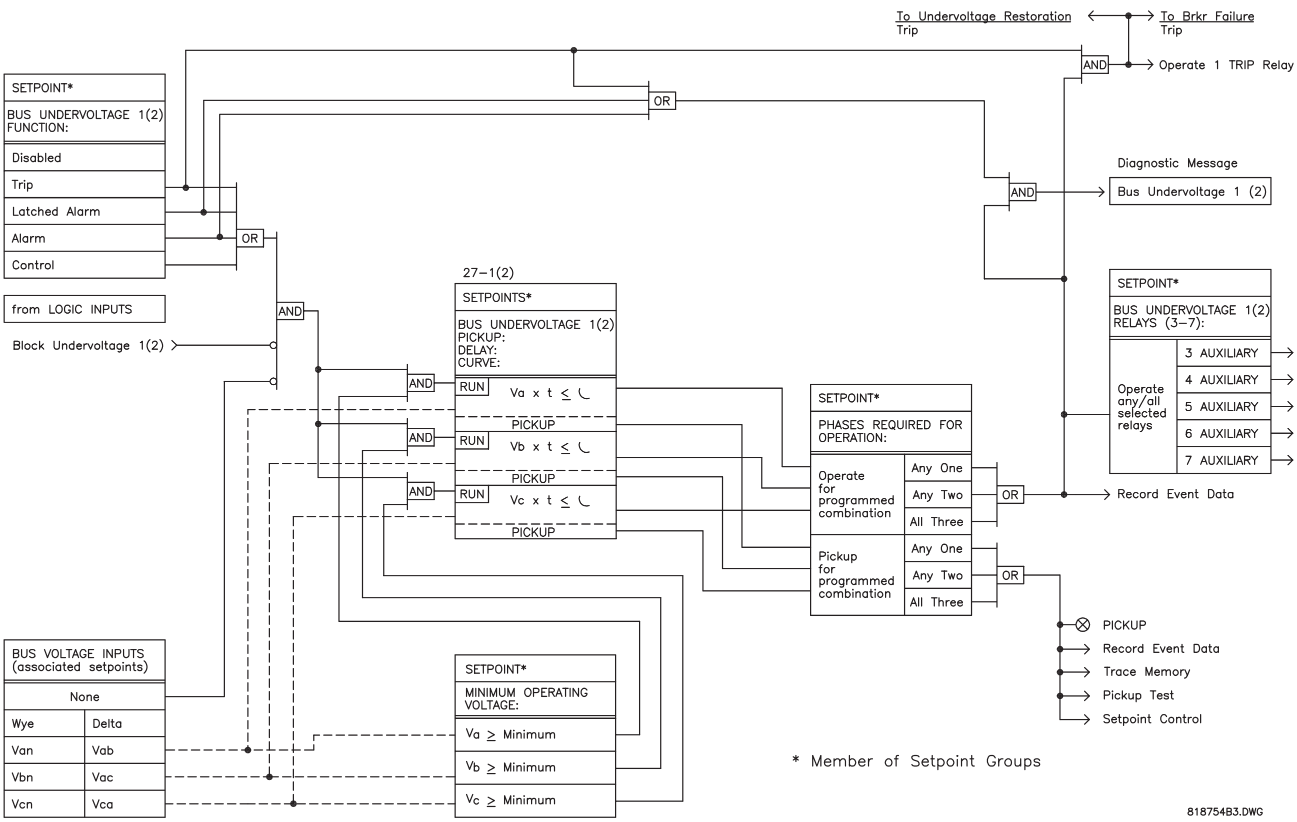

Figure 5–28: BUS UNDERVOLTAGE LOGIC

c) LINE UNDERVOLTAGE

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ VOLTAGE ⇨⇩ LINE UNDERVOLTAGE 3(4)

■ LINE UNDERVOLT 3 ■ [ENTER] for more		
ENTER ⇨ / ⇦ ESCAPE	LINE UNDERVOLT 3 FUNCTION: Disabled	Range: *Disabled, Trip, Alarm, Latched Alarm, Control*
ESCAPE / MESSAGE	LINE UNDERVOLT 3 RELAYS (3-7): -----	Range: *Any combination of 3 to 7 Auxiliary relays*
ESCAPE / MESSAGE	LINE UNDERVOLT 3 PICKUP: 0.75 x VT	Range: *0.00 to 1.25 x VT in steps of 0.01*
ESCAPE / MESSAGE	LINE UNDERVOLT 3 CURVE: Ext. Inverse	Range: *Definite Time, Inverse Time.*
ESCAPE / MESSAGE	LINE UNDERVOLT 3 DELAY: 2.0 s	Range: *0.0 to 6000.0 s in steps of 0.1*
ESCAPE / MESSAGE	MIN OPERATING VOLTAGE: 0.30 x VT	Range: *0.00 to 1.25 x VT in steps of 0.01*

Line undervoltage 3 and 4 are identical protection elements that generate outputs in response to an undervoltage condition on the line voltage input. The time delay characteristic can be programmed as either definite time or inverse time. A minimum operating voltage level is programmable to prevent undesired operation before voltage becomes available. The setpoints for the Undervoltage 3 element are shown above; the Undervoltage 4 setpoints are identical.

5

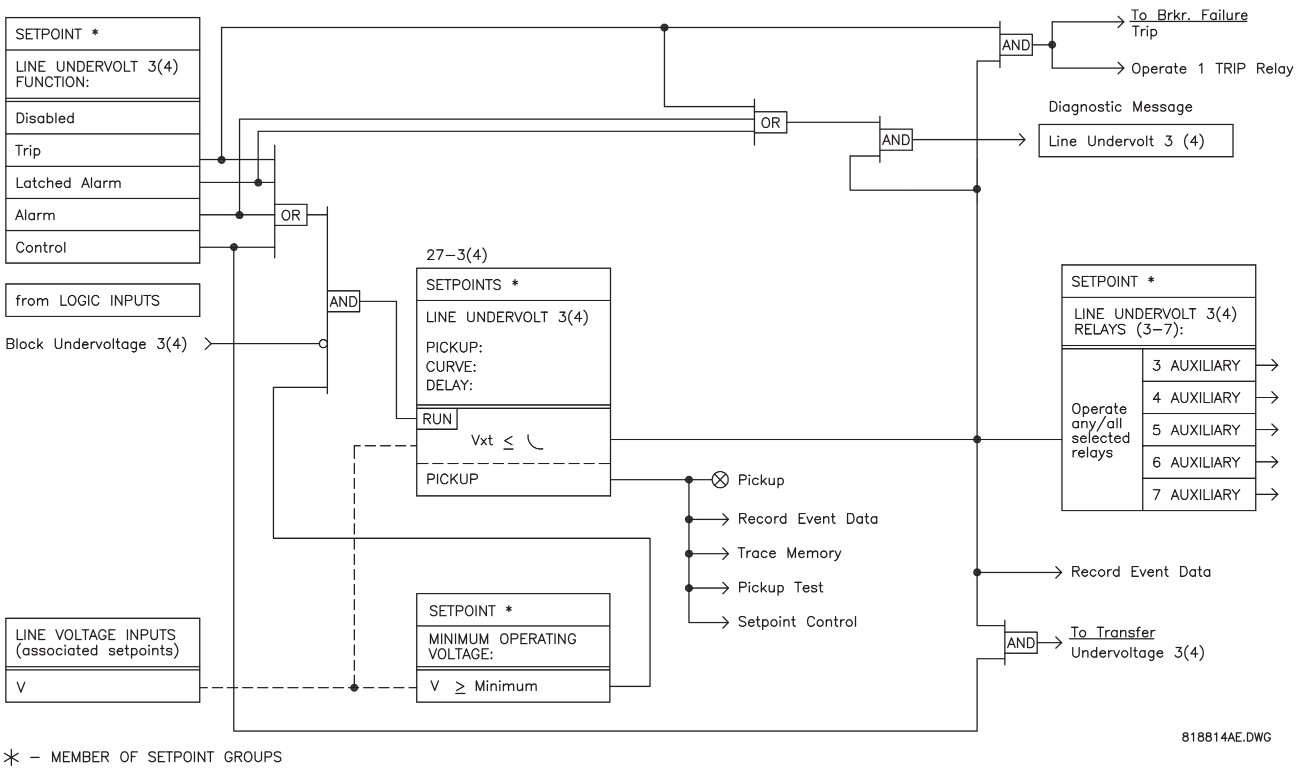

Figure 5–29: LINE UNDERVOLTAGE LOGIC

d) OVERVOLTAGE

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ VOLTAGE ⇨⇩ OVERVOLTAGE 1(2)

```
■ OVERVOLTAGE 1
■ [ENTER] for more
```

```
OVERVOLTAGE 1
FUNCTION: Disabled
```
Range: Disabled, Trip, Alarm, Latched Alarm, Control

```
OVERVOLTAGE 1
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays

```
OVERVOLTAGE 1
PICKUP: 1.25 x VT
```
Range: 0.00 to 1.25 x VT in steps of 0.01

```
OVERVOLTAGE 1
DELAY:     2.0 s
```
Range: 0.0 to 6000.0 s in steps of 0.1

```
PHASES REQUIRED FOR
OPERATION: All Three
```
Range: Any One, Any Two, All Three

To protect voltage sensitive loads and circuits against sustained overvoltage conditions, the Overvoltage 1 and 2 protection features can be used to either cause a trip or generate an alarm when the voltage exceeds a specified voltage value for a specified time delay. The setpoints above are repeated for both Overvoltage 1 and Overvoltage 2.

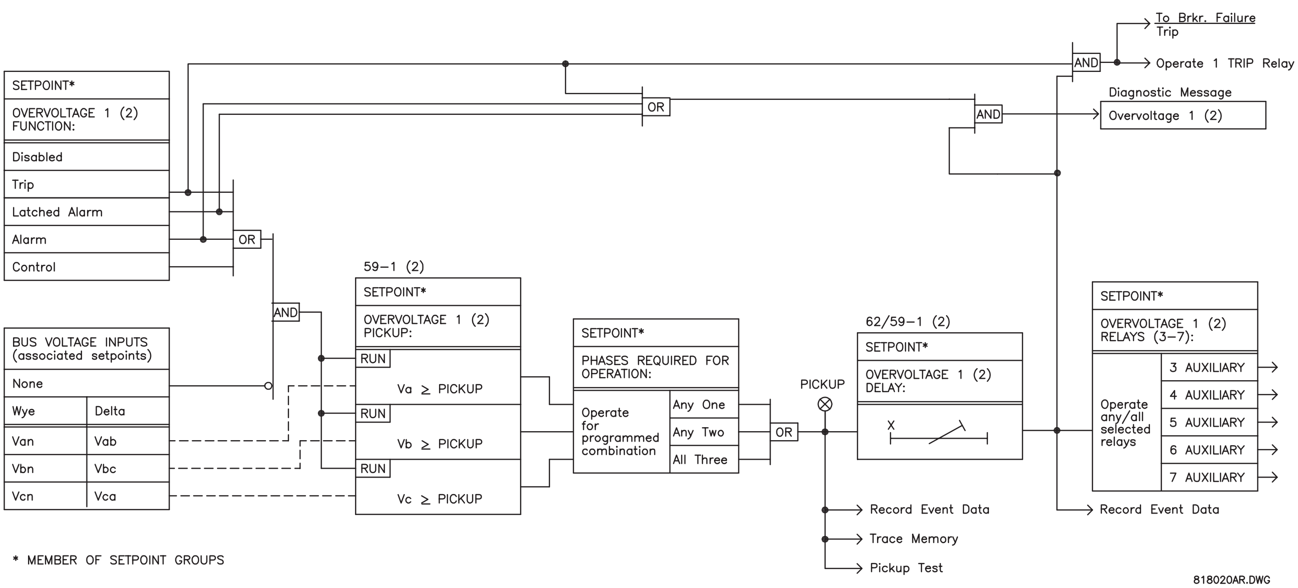

Figure 5–30: OVERVOLTAGE LOGIC

e) NEUTRAL DISPLACEMENT

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ VOLTAGE ⇨⇩ NTR DISPLACEMENT

```
■ NTR DISPLACEMENT
■ [ENTER] for more
```

NTR DISPLACEMENT FUNCTION: Disabled	*Range: Disabled, Trip, Alarm, Latched Alarm, Control*
NTR DISPLACEMENT RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
NTR DISPLACEMENT PICKUP: 1.00 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
NTR DISPLACEMENT CURVE: 2.0 s	*Range: see Table 5–4: TOC Curve Selections on page 5–32 for values*
NTR DISPLACEMENT MULTIPLIER: 2.0 s	*Range: 0.00 to 100.00 in steps of 0.01*
NTR DISPLACEMENT RESET: Instantaneous	*Range: Instantaneous, Linear*

The 750/760 incorporates a Neutral Displacement element, which uses the internally derived $3V_0$ value. This protection element requires the three phase Bus VTs to be wye connected. When setting the pickup level for this element, it is important to consider the error in the VT ratio as well as the normal voltage unbalance on the system. The Neutral Displacement setpoints are as follows.

NOTE: The same curves used for the time overcurrent elements are used for Neutral Displacement. When using the curve to determine the operating time of the Neutral Displacement element, substitute the ratio of neutral voltage to the pickup level for the current ratio shown on the horizontal axis of the curve plot.

Be aware that the neutral displacement feature should be applied with caution. It would normally be applied to give line to ground fault coverage on high impedance grounded or ungrounded systems, which are isolated. This constraint stems from the fact that a measurement of $3V_0$ cannot discriminate between a faulted circuit and an adjacent healthy circuit. Use of a time delayed back-up or an alarm mode allow other protections an opportunity to isolate the faulted element first.

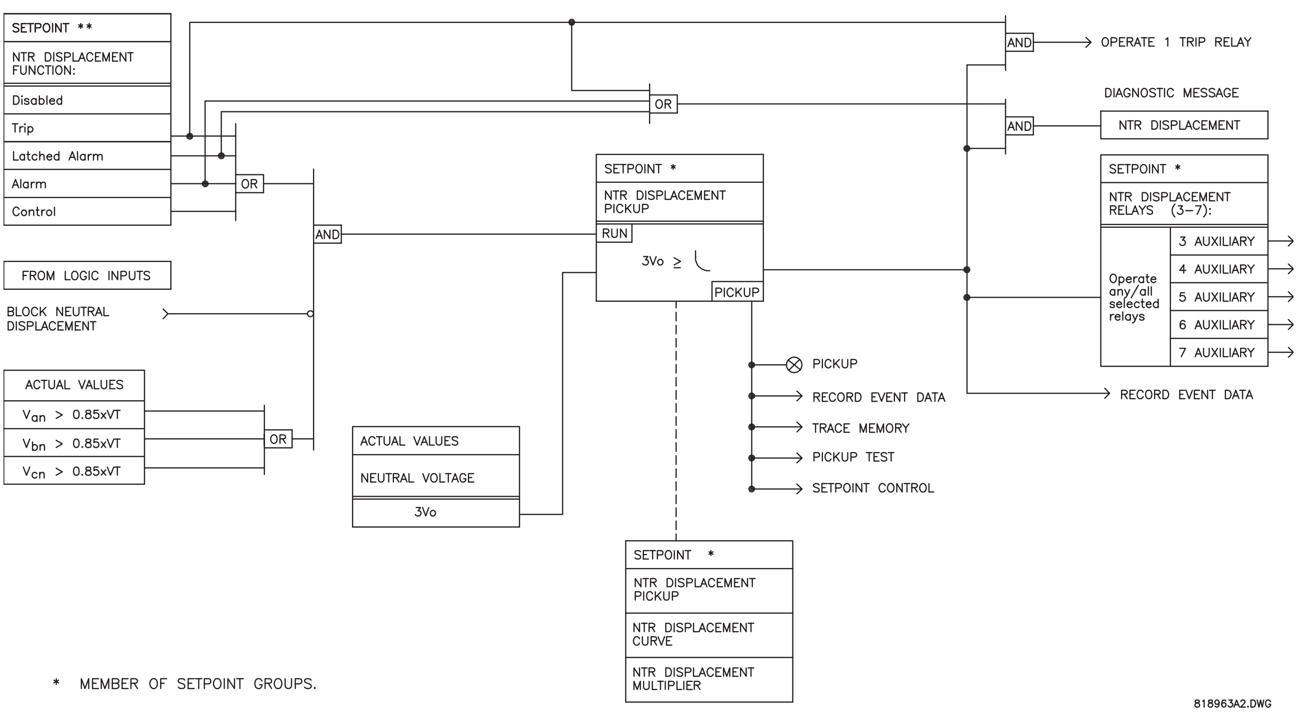

Figure 5–31: NEUTRAL DISPLACEMENT LOGIC

5.6.8 FREQUENCY

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ FREQ

■ FREQ ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ UNDEFREQ 1 ■ [ENTER] for more	See below.
	ESCAPE MESSAGE ⇳	■ UNDEFREQ 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇧	■ FREQ DECAY ■ [ENTER] for more	See page 5-69.

The 750/760 can be used as the primary detecting relay in automatic load shedding schemes based on underfrequency. The need for such a relay arises if during a system disturbance, an area becomes electrically isolated from the main system and suffers a generation deficiency due to the loss of either transmission or generation facilities. If reserve generation is not available in the area, conditions of low system frequency will occur which may lead to a complete collapse. The 750/760 provides two underfrequency and one rate-of-change of frequency protection elements which can automatically disconnect sufficient load to restore an acceptable balance between load and generation.

b) UNDERFREQUENCY

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ FREQ ⇨⇩ UNDERFREQ 1(2)

■ UNDEFREQ 1 ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	UNDEFREQ 1 FUNCTION: Disabled	*Range: Disabled, Trip, Alarm, Latched Alarm, Control*
	ESCAPE MESSAGE ⇳	UNDEFREQ 1 RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays* *See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE MESSAGE ⇳	UNDEFREQ 1 PICKUP: 59.00 Hz	*Range: 20.00 to 65.00 Hz in steps of 0.01* *See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE MESSAGE ⇳	UNDEFREQ 1 DELAY: 2.00 s	*Range: 0.00 to 600.00 s in steps of 0.1* *See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE MESSAGE ⇳	MIN OPERATING VOLTAGE: 0.70 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
	ESCAPE MESSAGE ⇧	MIN OPERATING CURRENT: 0.20 x CT	*Range: 0.00 to 1.25 x CT in steps of 0.01*

There are two identical underfrequency protection elements, ANSI devices 81U-1 and 81U-2. The setpoints for the Underfrequency 1 element are shown above; the Underfrequency 2 setpoints are identical.

- **MIN OPERATING CURRENT:** Enter the minimum voltage required to allow the underfrequency element to operate. This setpoint is used to prevent incorrect operation before energization of the source to the relay location, and during voltage dips.
- **MIN OPERATING CURRENT:** Enter the minimum value of current required on any phase to allow the underfrequency element to operate. This setpoint is used to prevent underfrequency tripping during periods of light load, when this action would have an insignificant effect on the system.

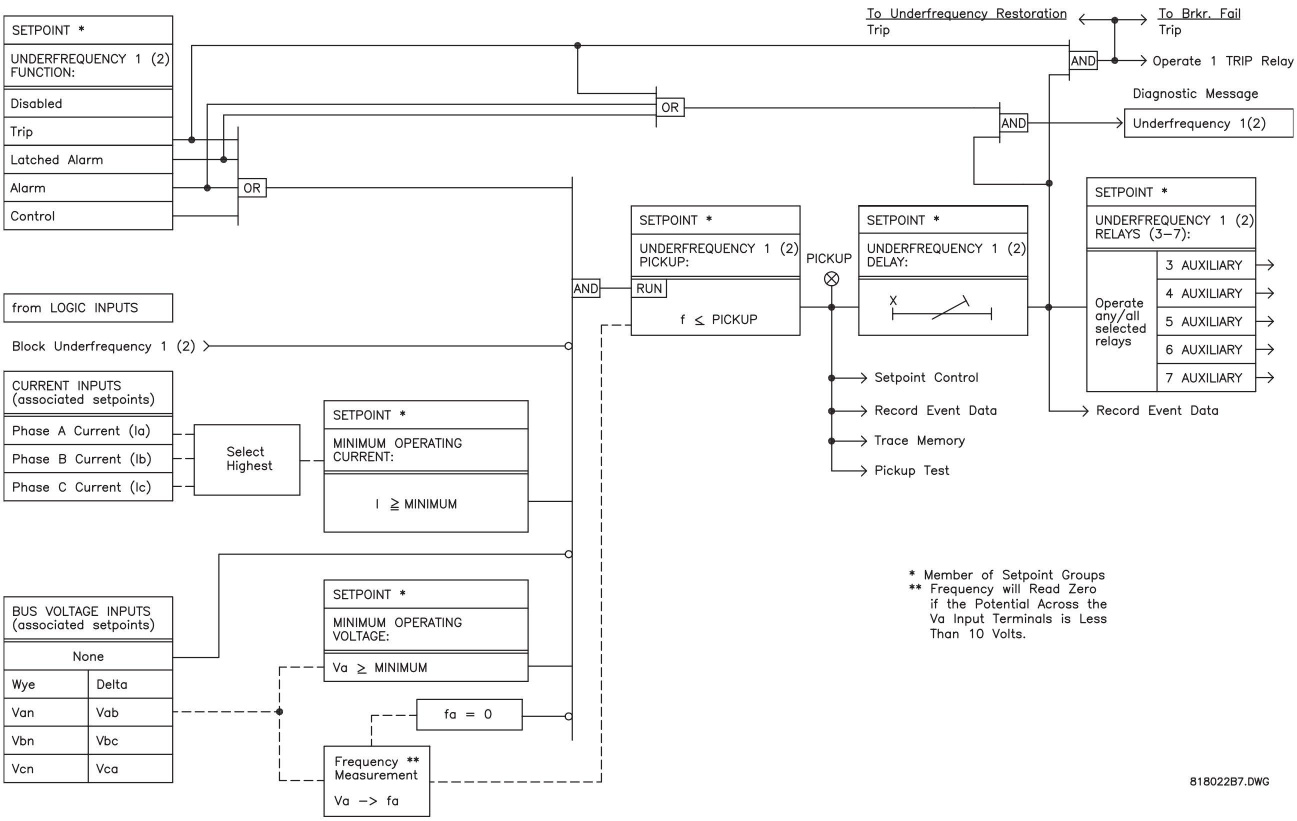

Figure 5–32: UNDERFREQUENCY LOGIC

c) FREQUENCY DECAY

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ FREQ ⇨⇩ FREQ DECAY

```
■ FREQ DECAY
■ [ENTER] for more
```

```
FREQ DECAY
FUNCTION: Disabled
```
Range: Disabled, Trip, Alarm, Latched Alarm, Control

```
FREQ DECAY
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays
See 5.6.1: Overview on page 5–32 for details.

```
FREQ DECAY
RATE: 1.0 Hz/s
```
Range: 0.1 to 5.0 Hz/s in steps of 0.1

```
FREQ DECAY
PICKUP: 59.00 Hz
```
Range: 20.00 to 65.00 Hz in steps of 0.01
See 5.6.1: Overview on page 5–32 for details.

```
FREQ DECAY
DELAY:    2.00 s
```
Range: 0.00 to 600.00 s in steps of 0.01
See 5.6.1: Overview on page 5–32 for details.

```
MIN OPERATING
VOLTAGE: 0.70 x VT
```
Range: 0.00 to 1.25 x VT in steps of 0.01

```
MIN OPERATING
CURRENT: 0.00 x CT
```
Range: 0.00 to 1.25 x CT in steps of 0.01

There is one frequency decay protection element, ANSI device 81D which can provide a faster response to system disturbances than the underfrequency elements. See the previous section for descriptions of the **MIN OPERATING CURRENT** and **MIN OPERATING VOLTAGE** setpoints.

5

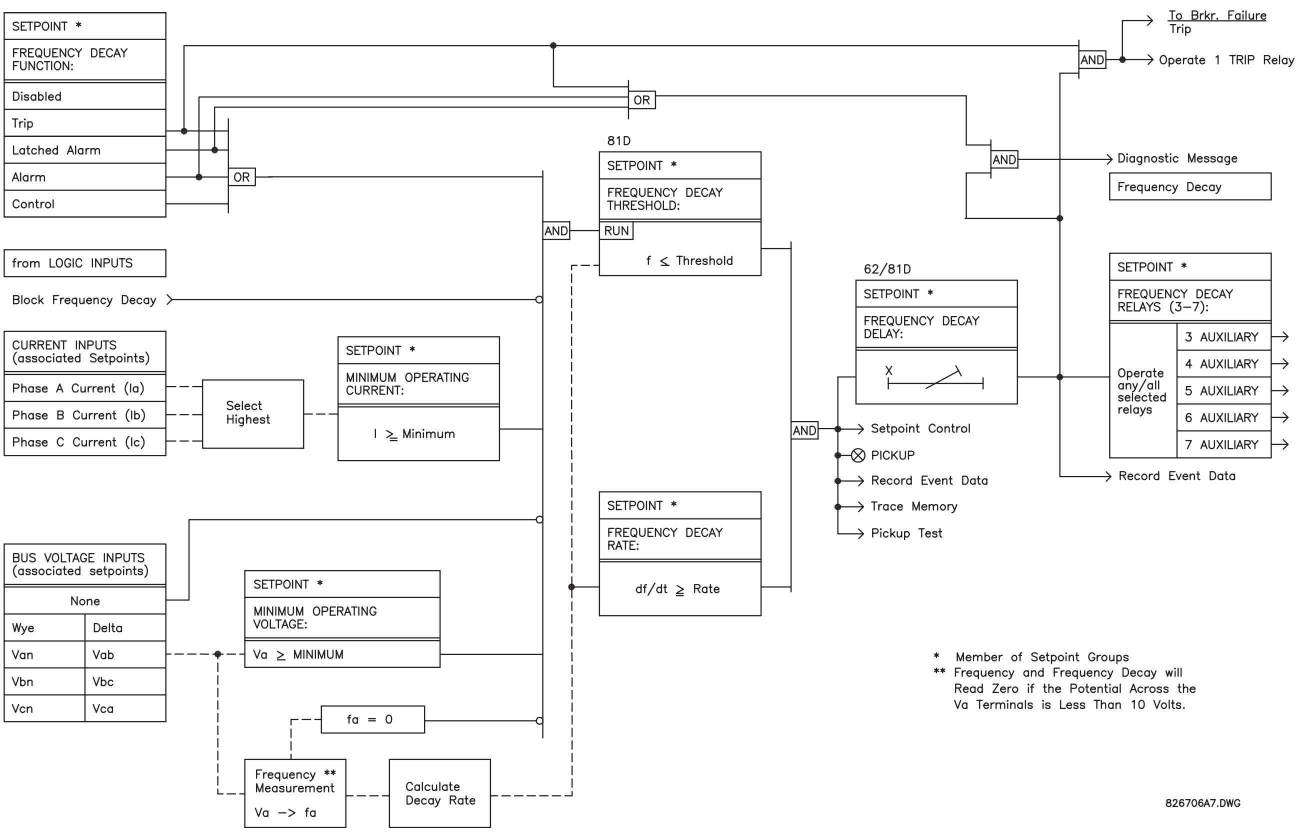

Figure 5–33: FREQUENCY DECAY LOGIC

5.6.9 BREAKER FAILURE

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ BRKR FAILURE

■ BRKR FAILURE ■ [ENTER] for more	
BRKR FAILURE FUNCTION: Disabled	*Range: Disabled, Trip, Alarm, Latched Alarm, Control*
BRKR FAILURE RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays See 5.6.1: Overview on page 5–32 for details.*
BRKR FAILURE DELAY 1: 0.10 s	*Range: 0.03 to 1.00 s in steps of 0.01*
BRKR FAILURE DELAY 2: 0.00 s	*Range: 0.03 to 1.00 s in steps of 0.01*
BRKR FAILURE CURRENT: 1.00 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01*

Breaker failure monitors the phase currents while a trip command exists. If any phase current is above the set level after the **BRKR FAILURE DELAY** time expires, a breaker failure will be declared, which will operate the selected output relays and force the 750/760 autoreclose scheme to lockout.

To provide user flexibility, the 750/760 has included two programmable delays for the breaker failure function. The timers can be used singularly or in combination with each other. The difference between the two is their location in the logic diagram. **BRKR FAILURE DELAY 1** starts counting down from the user programmed delay setpoint once a Trip condition is recognized. On the other hand, **BRKR FAILURE DELAY 2** provides a delay where it does not begin counting down until a trip condition is present, Delay 1 has expired, and one of the phase currents is above the **BRKR FAILURE CURRENT** setpoint. If one of the delays is not required, simply program the unwanted timer to its minimum value.

5

NOTE

The operation of the filter that reduces the overreaching effect of asymmetrical offset currents will cause the measured current to ramp down to zero after the breaker trips. It is strongly recommended that a margin of at least 1.5 power frequency cycles be added to the expected breaker time-to-trip for the **BRKR FAILURE DELAY 1** and **BRKR FAILURE DELAY 2** setpoints.

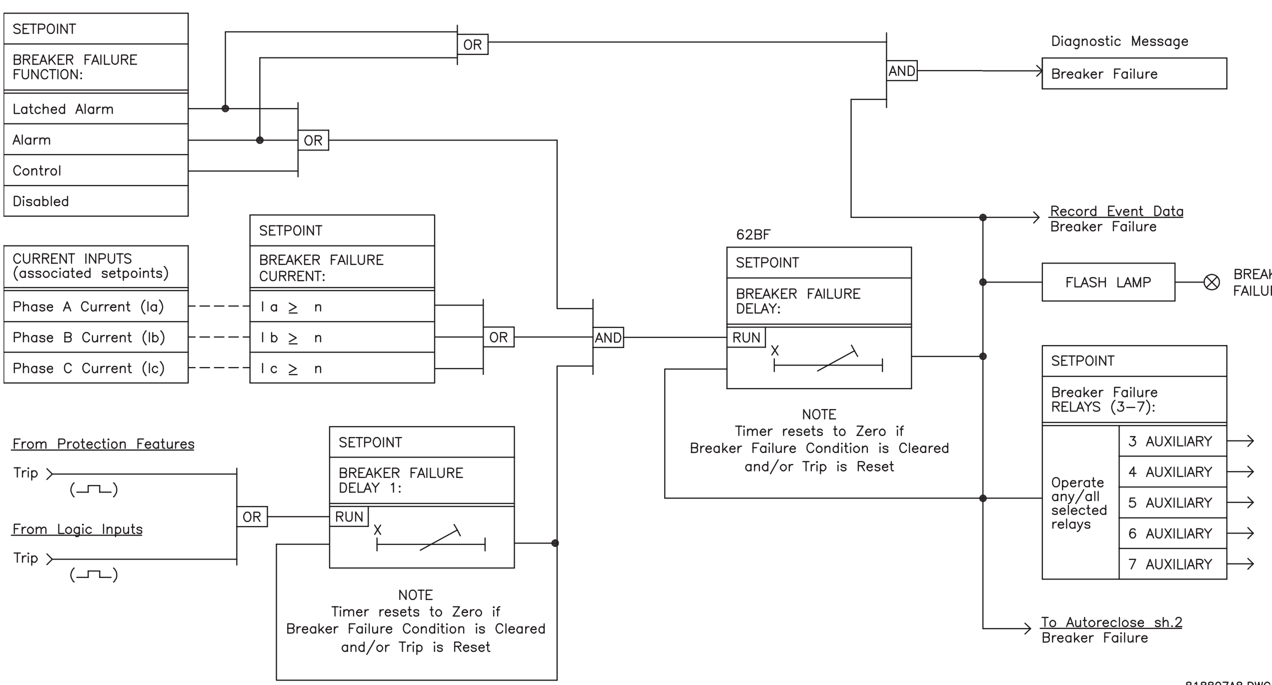

Figure 5–34: BREAKER FAILURE LOGIC

5.6.10 REVERSE POWER (IF ENABLED)

PATH: SETPOINTS ⇨⇩ S5 PROTECTION ⇨⇩ REV PWR

```
■ REV PWR
■ [ENTER] for more
```

```
REV PWR
FUNCTION: Disabled
```
Range: Disabled, Trip, Alarm, Control

```
REV PWR
RELAYS (3-7): -----
```
Range: Any combination of 3 to 7 Auxiliary relays
See 5.6.1: Overview on page 5–32 for details.

```
REV PWR
PICKUP: 0.050 xRATED
```
Range: 0.015 to 0.600 x RATED in steps of 0.001

```
REV PWR
DELAY:    10.0 s
```
Range: 0.0 to 6000.0 s in steps of 0.1

A Reverse Power element is generally associated with generator protection. Such an element is used to detect loss of mechanical power coming into the turbine and to trip the unit to prevent turbine blade heating or other adverse effects in turbo-generator sets. The **REV PWR PICKUP** setting is usually set as low as the relay can measure, but no higher than one-half the electrical power required to motor the generator with total loss of mechanical power. The Reverse Power element is not normally used in conventional feeder protection applications.

The Reverse Power element generates an output when the three-phase reverse real power is greater than the **REV PWR PICKUP** setting. It is recommended to set **REV PWR DELAY** to 1 second or higher to avoid problems with power oscillations that may be experienced on synchronization; a setting in the range of 10 to 15 seconds is typical. Recall that the rated power is calculated as follows:

$$\text{Rated Power} = \sqrt{3} \times V_{\text{sec(line-line)}} \times \text{VT Ratio} \times I_{\text{sec(rated)}} \times \text{CT Ratio} \qquad \textbf{(EQ 5.18)}$$

NOTE: The sensitivity of this element and the requirement to have two times pickup limits its range of application. The motoring power cannot be less that 3% of rated, and the angle away from the 180° angle of maximum sensitivity should not be greater than ±85 to 87° due to reactive loading on the generator.

This element is optional and available from GE Multilin as Mod 008. To order, please contact the factory with the serial number of the 750/760 relay. Refer to Appendix A.1.1: Reverse Power on page A–1 for the complete procedure for installing and verifying the Reverse Power element.

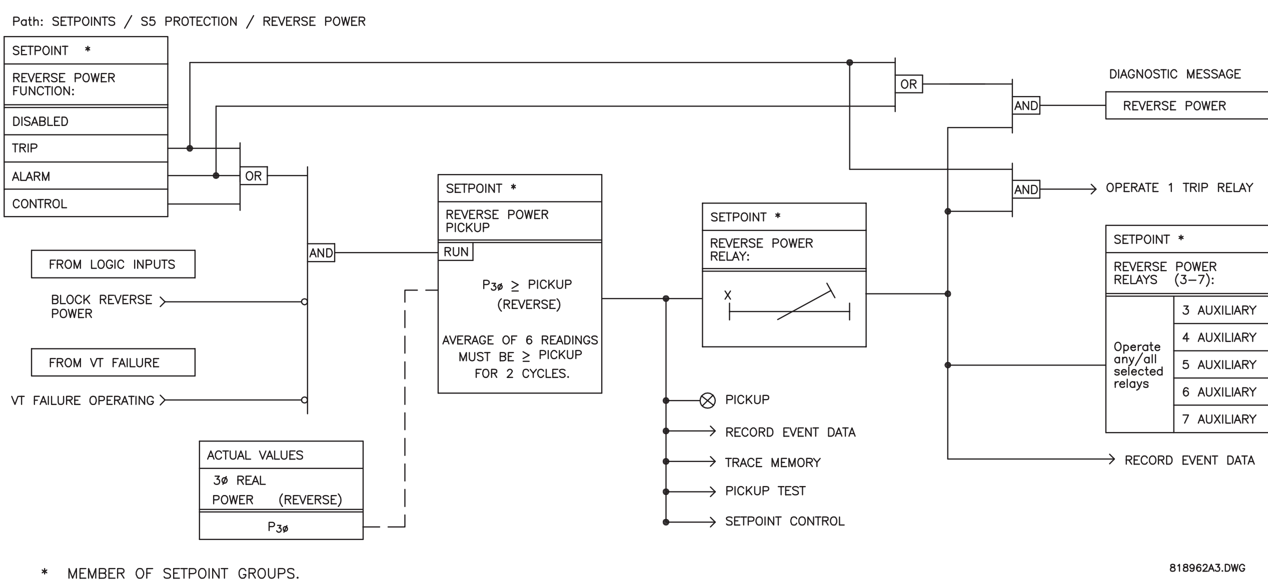

Figure 5–35: REVERSE POWER LOGIC

5.7.1 CURRENT LEVEL

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨ CURRENT LEVEL

■ CURRENT LEVEL ■ [ENTER] for more	■ PHASE CURRENT ■ [ENTER] for more	See below.
	■ NEUTRAL CURRENT ■ [ENTER] for more	See page 5–73.

In addition to the conventional overcurrent protection elements that are used for tripping, separate phase and neutral current level detectors are provided for alarm or control purposes. These elements allow longer time delays to be programmed.

b) PHASE CURRENT LEVEL

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨ CURRENT LEVEL ⇨ PHASE CURRENT

■ PHASE CURRENT ■ [ENTER] for more	PHASE CURRENT FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	PHASE CURRENT RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays* *See 5.6.1: Overview on page 5–32 for details.*
	PHASE CURRENT PICKUP: 1.10 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01* *See 5.6.1: Overview on page 5–32 for details.*
	PHASE CURRENT DELAY: 2 s	*Range: 0 to 60000 s in steps of 1* *See 5.6.1: Overview on page 5–32 for details.*

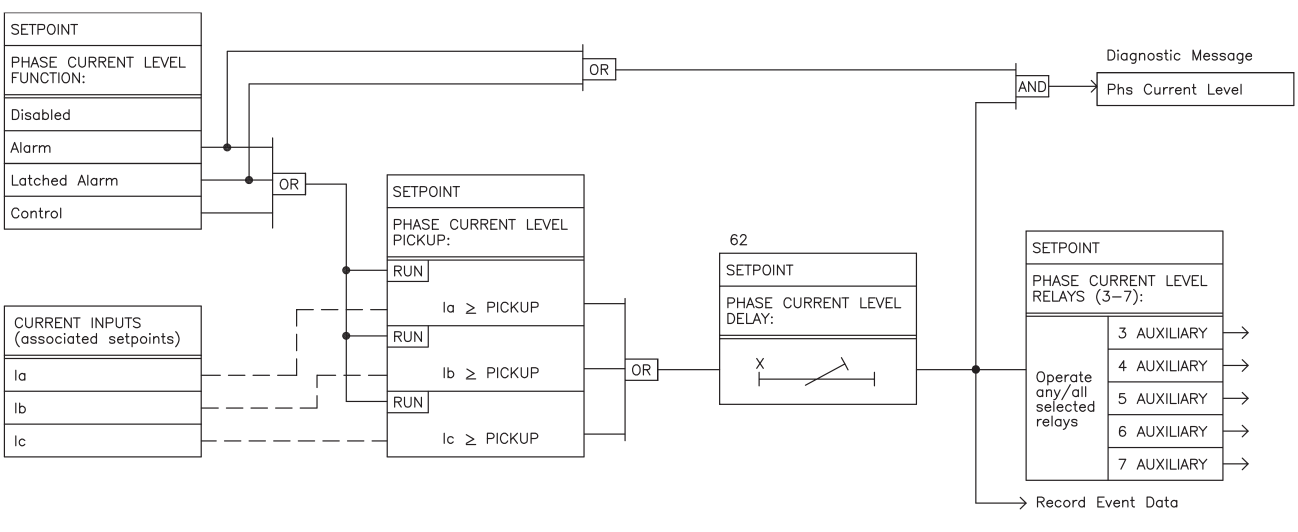

Figure 5–36: PHASE CURRENT LEVEL LOGIC

c) NEUTRAL CURRENT LEVEL

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨ CURRENT LEVEL ⇨⇩ NEUTRAL CURRENT

■ NEUTRAL CURRENT ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	NEUTRAL CURRENT FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	ESCAPE / MESSAGE ⇳	NEUTRAL CURRENT RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE / MESSAGE ⇳	NEUTRAL CURRENT PICKUP: 1.00 x CT	*Range: 0.05 to 20.00 x CT in steps of 0.01 See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE / MESSAGE ⇧	NEUTRAL CURRENT DELAY: 2 s	*Range: 0 to 60000 s in steps of 1 See 5.6.1: Overview on page 5–32 for details.*

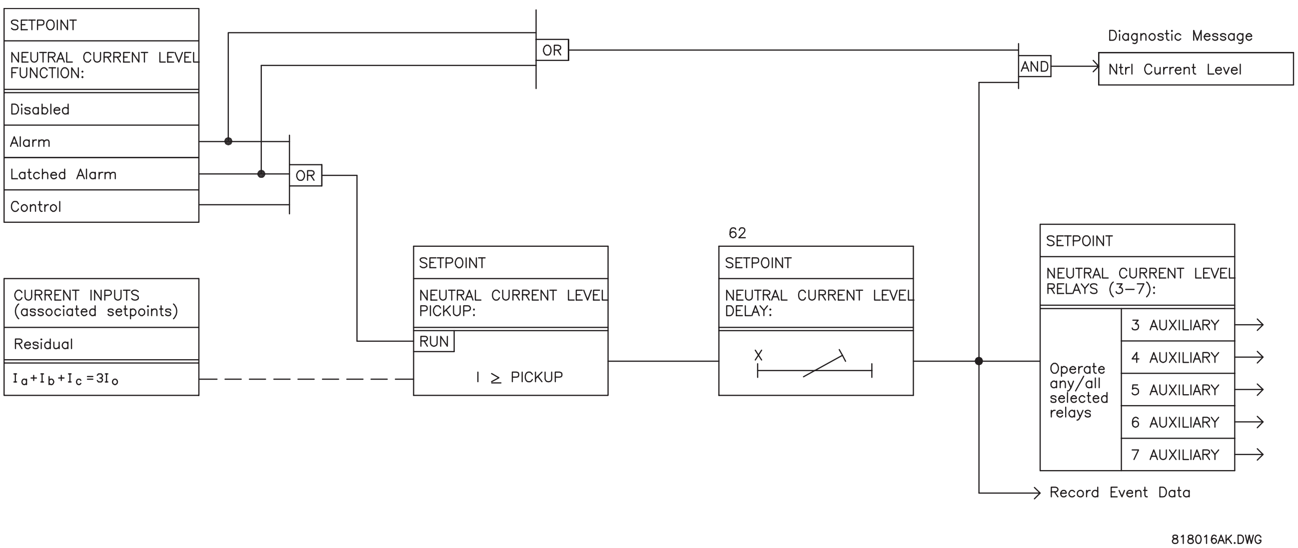

Figure 5–37: NEUTRAL CURRENT LEVEL LOGIC

5.7.2 POWER FACTOR

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ PWR FACTOR ⇨ PWR FACTOR 1(2)

■ PWR FACTOR 1 ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	PWR FACTOR 1 FUNCTION: Disabled	Range: *Disabled, Alarm, Latched Alarm, Control*
	ESCAPE / MESSAGE	PWR FACTOR 1 RELAYS (3-7): -----	Range: *Any combination of 3 to 7 Auxiliary relays* *See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE / MESSAGE	PWR FACTOR 1 PICKUP: 0.80	Range: *–0.99 to 1.00 in steps of 0.01* *Positive values indicate lagging power factor.*
	ESCAPE / MESSAGE	PWR FACTOR 1 DROPOUT: 1.00	Range: *–0.99 to 1.00 in steps of 0.01* *Positive values indicate lagging power factor.*
	ESCAPE / MESSAGE	PWR FACTOR 1 DELAY: 50 s	Range: *0 to 60000 s in steps of 1* *See 5.6.1: Overview on page 5–32 for details.*

It is generally desirable for a system operator to maintain the power factor as close to unity as possible to minimize both costs and voltage excursions. Since the power factor is variable on common non-dedicated circuits, it is advantageous to compensate for low (lagging) power factor values by connecting a capacitor bank to the circuit when required. The relay allows two stages of capacitance switching for power factor compensation.

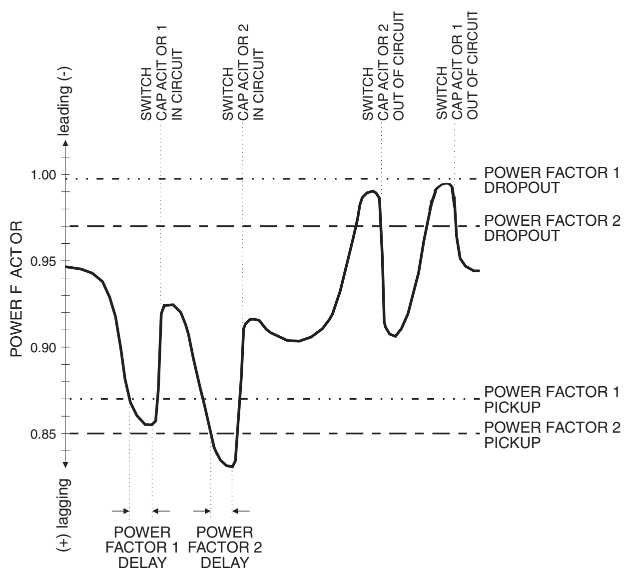

Figure 5–38: CAPACITOR BANK SWITCHING

The relay calculates the average power factor in the three phases, according to the following equation.

$$\text{Average Power Factor} = \frac{\text{Total 3 Phase Real Power}}{\text{Total 3 Phase Apparent Power}} \qquad \textbf{(EQ 5.19)}$$

Two independent elements are available for monitoring power factor, Power Factor 1 and Power Factor 2, each having a pickup and a dropout level. For each element, when the measured power factor becomes more lagging than the pickup level (i.e. numerically less than), the relay will operate a user-selected output contact. This output can be used to control a switching device which connects capacitance to the circuit, or to signal an alarm to the system operator. After entering this state, when the power factor becomes less lagging than the power factor dropout level for a time larger than the set delay, the relay will reset the output contact to the non-operated state.

Both Power Factor 1 and 2 features are inhibited from operating unless all three voltages are above 30% of nominal and one or more currents is above 0. Power Factor 1 and 2 delay timers will only be allowed to time when the 30% threshold is exceeded on all phases and the power factor remains outside of the programmed pickup and dropout levels. In the same way, when a power factor condition starts the Power Factor 1 or 2 delay timer, if all three phase voltages fall below the 30% threshold before the timer has timed-out, the element will reset without operating. A loss of voltage during any state will return both Power Factor 1 and 2 to the reset state.

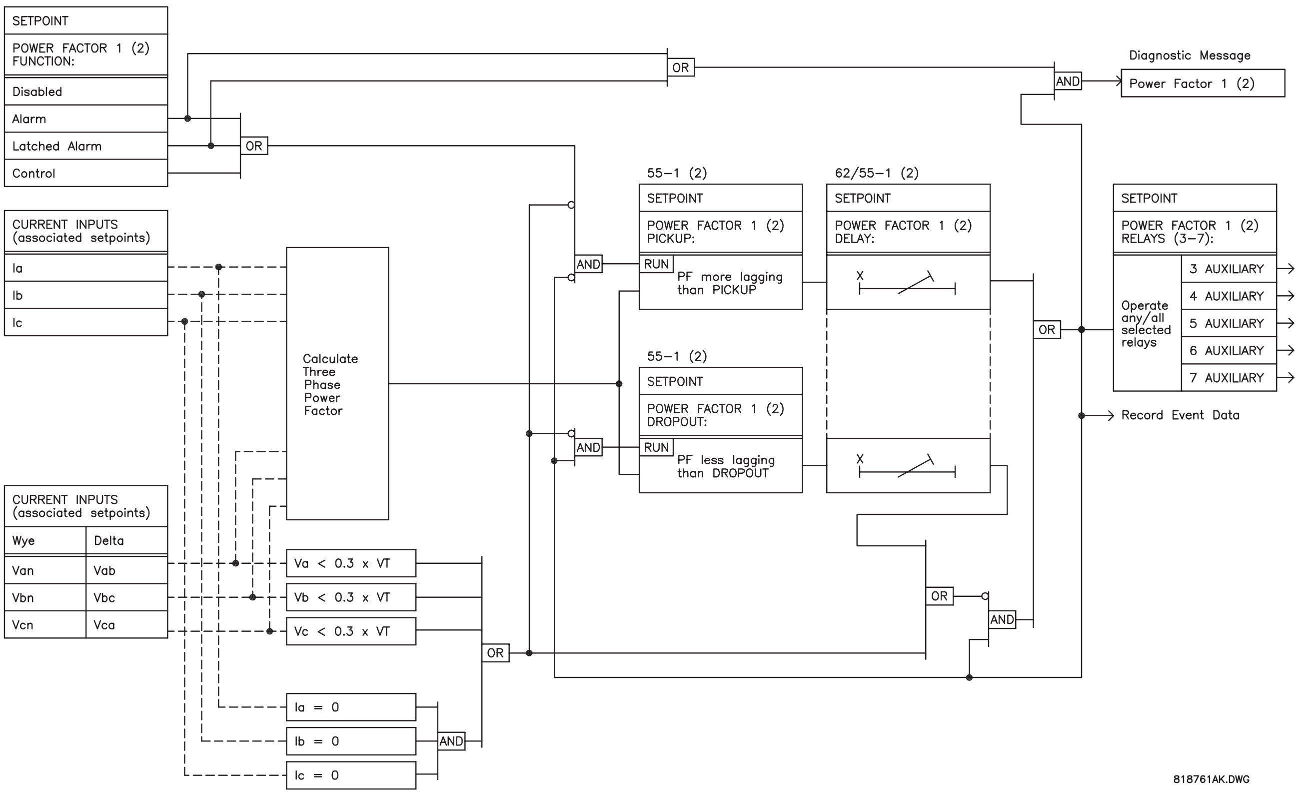

Figure 5–39: POWER FACTOR LOGIC

5.7.3 FAULT LOCATOR

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ FAULT LOCATOR

■ FAULT LOCATOR ■ [ENTER] for more	ENTER / ESCAPE	LENGTH OF FEEDER: 0.1 km	Range: 0.1 to 99.9 km/Miles in steps of 0.1
	ESCAPE / MESSAGE	UNITS OF LENGTH: km	Range: km, Miles
	ESCAPE / MESSAGE	Zpos (RESISTIVE) OF FEEDER: 0.01 Ω	Range: 0.01 to 99.99 Ω in steps of 0.01
	ESCAPE / MESSAGE	Zpos (INDUCTIVE) OF FEEDER: 0.01 Ω	Range: 0.01 to 99.99 Ω in steps of 0.01
	ESCAPE / MESSAGE	Zzero (RESISTIVE) OF FEEDER: 0.01 Ω	Range: 0.01 to 99.99 Ω in steps of 0.01
	ESCAPE / MESSAGE	Zzero (INDUCTIVE) OF FEEDER: 0.01 Ω	Range: 0.01 to 99.99 Ω in steps of 0.01
	ESCAPE / MESSAGE	FAULT TYPE OUTPUT TO RELAYS 4-7: Disabled	Range: Disabled, Enabled
	ESCAPE / MESSAGE	FAULT LOCATION AFTER TRIP: Disabled	Range: Disabled, Enabled

The relay calculates the distance to fault with fault resistance compensation. For the fault location feature, a fault is defined as an event that has caused a current level greater than the pickup threshold of an overcurrent protection feature programmed to "Trip" or "Trip & AR" (760 only), which has remained for sufficient time to cause the relay to produce a Trip command. After this has happened, the apparent distance to the fault is calculated in a background mode, maintaining all other features in operation. The distance calculation is based on the assumptions that:

1. The feeder positive and zero sequence impedances are a constant per unit distance, and
2. Mutual compensation is not required.

If the feeder utilizes conductors of different sizes, or more than one physical arrangement of conductors, or shares poles or towers with a parallel feeder, these assumptions are incorrect and errors are introduced.

The algorithm uses prefault system data to reduce the error caused by variable fault resistance, so inaccuracy is introduced for a fault which occurs when no load current was present. Also, error is introduced if the feeder has sources at locations other than the location of the relay, due to infeed effects.

The algorithm contains three sets of equations that are used to perform the calculations for a specific fault type: phase to ground, phase to phase to ground, phase to phase, and three phase. Each of the sets (other than three-phase) consists of a subset which covers all combinations of phases. The algorithm therefore uses a fault identification procedure to select the appropriate equations to be used for calculation. This procedure uses both prefault and fault current phasors from memory to identify the type of fault. The prefault data is taken from a sample collected three power frequency cycles before the pickup of the overcurrent element to ensure the sample contains only load current. The after fault data is taken from samples collected 1.5 power frequency cycles after overcurrent pickup to ensure the current had existed for at least one complete sampling interval.

5

As well as the apparent distance to the fault, the locator records the feeder apparent reactance (with fault resistance removed if prefault current was available.) This parameter can be very useful in estimating the location of a fault on a feeder tap, where the apparent distance can be calculated as beyond the feeder end. The date, time, type of fault, and phases involved are also stored for the event. Non-volatile memory is provided for the past ten events, in a FIFO queue, available under **A1 STATUS ⇨⇩ FAULT LOCATIONS**.

NOTE

If the feeder has a source with a grounded neutral, and is therefore capable of providing ground fault current, the bus VTs must be both connected and selected as "Wye" in setpoint **S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING ⇨⇩ VT CONNECTION TYPE**, to allow the fault locator to perform the calculations properly. If the fault classification results in a phase to ground fault, the program checks that the setpoint noted above is set to 'Wye' before the calculation is permitted.

Additional explanation of the Fault Locator setpoints is provided below.

- **LENGTH OF FEEDER:** Enter the total length of the feeder, in kilometers or miles as selected by the **UNITS OF LENGTH** setpoint.
- **UNITS OF LENGTH:** Enter the desired units of measurement, either kilometers or miles.
- **Zpos (RESISTIVE/INDUCTIVE) OF FEEDER:** Enter the total real/imaginary component of the feeder positive sequence impedance, in actual ohms.
- **Zzero (RESISTIVE/INDUCTIVE) OF FEEDER:** Enter the total real/imaginary component of the feeder zero sequence impedance, in actual ohms.
- **FAULT TYPE OUTPUT TO RELAYS 4-7:** Selects whether fault type indication on output relays 4 to 7 is enabled. When enabled, relays 4 to 7 will operate to indicate the type of the most recent fault (i.e. Fault Location 0 Fault Type). The auxiliary relays are reset to their non-operated state after the relay is reset. Any combination of relays 4 to 7 may be operated and the outputs are designated as follows.

  Phase A faults operate the 4 Auxiliary relay.
  Phase B faults operate the 5 Auxiliary relay.
  Phase C faults operate the 6 Auxiliary relay.
  Neutral faults operate the 7 Auxiliary relay.

- **FAULT LOCATION AFTER TRIP:** Users utilizing the Fault Distance capability of the product may benefit from having a fault distance message displayed along with other active conditions in the relay. When set to "Enabled", a fault distance message will be displayed when a trip has occurred within the relay. The fault distance message will be removed when the active conditions are reset. This message only appears after the first Trip condition; any subsequent Trips will only update the fault distance value (if required).

5.7.4 DEMAND

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ DMND

■ DMND ■ [ENTER] for more	■ CURRENT ■ [ENTER] for more	See page 5–78.
	■ REAL POWER ■ [ENTER] for more	See page 5–79.
	■ REACTIVE POWER ■ [ENTER] for more	See page 5–80.
	■ APPARENT POWER ■ [ENTER] for more	See page 5–81.

Current demand is measured on each phase, and on three phases for real, reactive, and apparent power. Setpoints allow the user to emulate some common electrical utility demand measuring techniques for statistical or control purposes.

NOTE: The relay is not approved as or intended to be a revenue metering instrument. If used in a peak load control system, the user must consider the accuracy rating and method of measurement employed, and the source VTs and CTs, in comparison with the electrical utility revenue metering system.

The relay can be set to calculate demand by any of three methods.

- **Thermal Exponential:** This selection emulates the action of an analog peak recording thermal demand meter. The relay measures the quantity (RMS current, real power, reactive power, or apparent power) on each phase every second, and assumes the circuit quantity remains at this value until updated by the next measurement. It calculates the *thermal demand equivalent* based on the following equation.

$$d(t) = D(1 - e^{-kt}) \quad \textbf{(EQ 5.20)}$$

where d = demand value after applying input quantity for time t (in minutes),
D = input quantity (constant), k = 2.3 / thermal 90% response time.

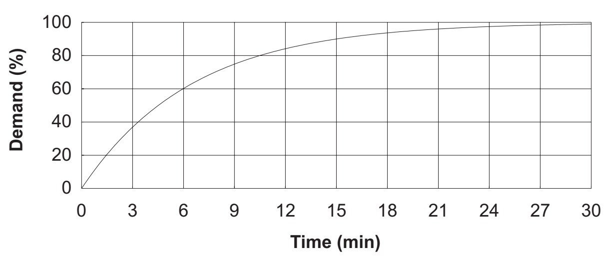

Figure 5–40: THERMAL DEMAND CHARACTERISTIC (15 MINUTE RESPONSE)

The 90% thermal response time characteristic defaults to 15 minutes. A setpoint establishes the time to reach 90% of a steady-state value, just as the response time of an analog instrument. A steady state value applied for twice the response time will indicate 99% of the value.

- **Block Interval:** This selection calculates a linear average of the quantity (RMS current, real power, reactive power, or apparent power) over the programmed demand time interval, starting daily at 00:00:00 (i.e. 12 am). The 1440 minutes per day is divided into the number of blocks as set by the programmed time interval. Each new value of demand becomes available at the end of each time interval.

  The Block Interval with Start Demand Interval Logic Input calculates a linear average of the quantity (RMS current, real power, reactive power, or apparent power) over the interval between successive Start Demand Interval logic input pulses. Each new value of demand becomes available at the end of each pulse. The **S3 LOGIC INPUTS ⇨⇩ MISCELLANEOUS ⇨⇩ START DMND INTERVAL** setpoint programs the input for the new demand interval pulses.

- **Rolling Demand:** This selection calculates a linear average of the quantity (RMS current, real power, reactive power, or apparent power) over the programmed demand time interval, in the same way as Block Interval. The value is updated every minute and indicates the demand over the time interval just preceding the time of update.

b) CURRENT DEMAND

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ DMND ⇨ CURRENT

■ CURRENT ■ [ENTER] for more	
CURRENT DMND FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
MEASUREMENT TYPE: Thermal Exponential	*Range: Thermal Exponential, Block Interval, Rolling Demand. See page 5–77 for details.*
THERMAL 90% RESPONSE TIME: 15 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min. Seen only if* **MEASUREMENT TYPE** *is "Thermal Exponential"*
TIME INTERVAL: 20 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min. Seen only if* **MEASUREMENT TYPE** *is "Block Interval" or "Rolling Demand"*
CURRENT DMND RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary Relays. See 5.6.1: Overview on page 5–32 for details.*
CURRENT DMND PICKUP: 1000 A	*Range: 10 to 1000 A in steps of 1. See 5.6.1: Overview on page 5–32 for details.*

The current demand for each phase is calculated individually, and the demand for each phase is monitored by comparing to a single current demand pickup value. If the current demand pickup is exceeded by any phase, the relay can cause an alarm or signal an output relay.

For the **THERMAL 90% RESPONSE TIME** setpoint, enter the time required for a steady state current to indicate 90% of the actual value. This setpoint allows the user to approximately match the response of the relay to analog instruments. For the **TIME INTERVAL** setpoint, enter the time period over which the current demand calculation is to be performed.

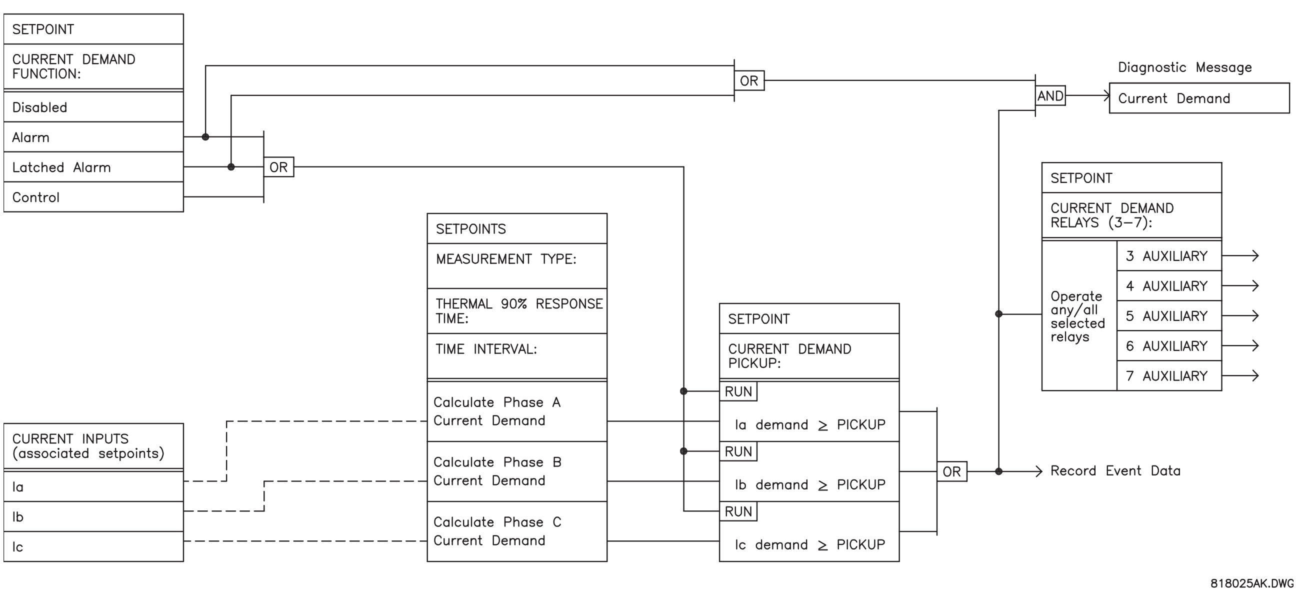

Figure 5–41: CURRENT DEMAND LOGIC

c) REAL POWER DEMAND

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ DMND ⇨⇩ REAL PWR

```
■ REAL PWR
■ [ENTER] for more
```

REAL PWR DMND FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
MEASUREMENT TYPE: Block Interval	*Range: Thermal Exponential, Block Interval, Rolling Demand. See page 5–77 for details.*
THERMAL 90% RESPONSE TIME: 15 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min Seen only if* **MEASUREMENT TYPE** *is "Thermal Exponential"*
TIME INTERVAL: 20 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min Seen only if* **MEASUREMENT TYPE** *is "Block Interval" or "Rolling Demand"*
REAL PWR DMND RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary Relays. See 5.6.1: Overview on page 5–32 for details.*
REAL PWR DMND PICKUP: 10.0 MW	*Range: 0.1 to 3000.0 MW in steps of 0.1 See 5.6.1: Overview on page 5–32 for details.*

The real power demand is monitored by comparing to a pickup value. If the real power demand pickup is ever exceeded, the relay can be configured to cause an alarm or signal an output relay.

For the **THERMAL 90% RESPONSE TIME** setpoint, enter the time required for a steady state power to indicate 90% of the actual value. This setpoint allows the user to approximately match the response of the relay to analog instruments. For the **TIME INTERVAL** setpoint, enter the time period over which the real power demand calculation is to be performed. For the **REAL POWER DMND PICKUP** setpoint, power quantities auto-range to show units appropriate to the power system size.

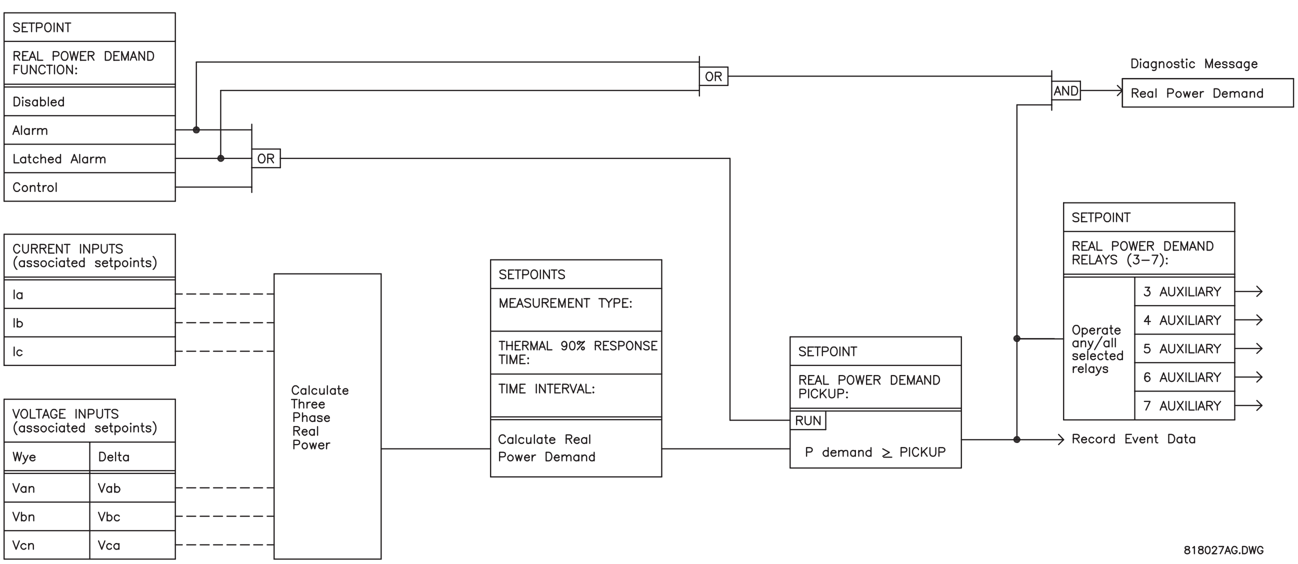

Figure 5–42: REAL POWER DEMAND LOGIC

d) REACTIVE POWER DEMAND

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ DMND ⇨⇩ REAL PWR

■ REACTIVE PWR ■ [ENTER] for more	REACTIVE PWR DMND FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	MEASUREMENT TYPE: Block Interval	*Range: Thermal Exponential, Block Interval, Rolling Demand. See page 5–77 for details.*
	THERMAL 90% RESPONSE TIME: 15 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min Seen only if* **MEASUREMENT TYPE** *is "Thermal Exponential"*
	TIME INTERVAL: 20 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min Seen only if* **MEASUREMENT TYPE** *is "Block Interval" or "Rolling Demand"*
	REACTIVE PWR DMND RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary Relays. See 5.6.1: Overview on page 5–32 for details.*
	REACTIVE PWR DMND PICKUP: 10.0 Mvar	*Range: 0.1 to 3000.0 Mvar in steps of 1 See 5.6.1: Overview on page 5–32 for details.*

The reactive power demand is monitored by comparing to a pickup value. If the reactive power demand pickup is ever exceeded, the relay can be configured to cause an alarm or signal an output relay.

For the **THERMAL 90% RESPONSE TIME** setpoint, enter the time required for a steady state reactive power to indicate 90% of the actual value. This setpoint allows the user to approximately match the response of the relay to analog instruments. For the **TIME INTERVAL** setpoint, enter the time period over which the reactive power demand calculation is to be performed. For the **REACTIVE PWR DMND PICKUP** setpoint, the power quantities auto-range to show units appropriate to the power system size.

5

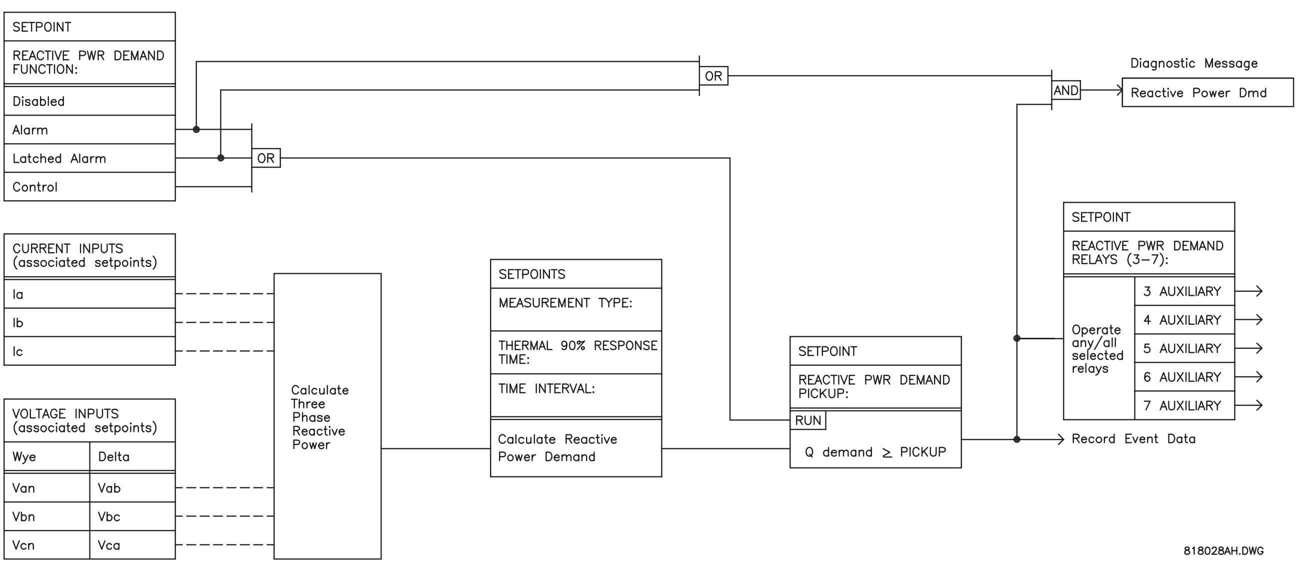

Figure 5–43: REACTIVE POWER DEMAND LOGIC

e) APPARENT POWER DEMAND

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ DMND ⇨⇩ APPARENT PWR

```
■ APPARENT PWR
■ [ENTER] for more
```

ENTER / ESCAPE	APPARENT PWR DMND FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
ESCAPE / MESSAGE	MEASUREMENT TYPE: Block Interval	*Range: Thermal Exponential, Block Interval, Rolling Demand. See page 5–77 for details.*
ESCAPE / MESSAGE	THERMAL 90% RESPONSE TIME: 15 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min. Seen only if* **MEASUREMENT TYPE** *is "Thermal Exponential"*
ESCAPE / MESSAGE	TIME INTERVAL: 20 min	*Range: 5 min, 10 min, 15 min, 20 min, 30 min, 60 min. Seen only if* **MEASUREMENT TYPE** *is "Block Interval" or "Rolling Demand"*
ESCAPE / MESSAGE	APPARENT PWR DMND RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary Relays. See 5.6.1: Overview on page 5–32 for details.*
ESCAPE / MESSAGE	APPARENT PWR DMND PICKUP: 10.0 MVA	*Range: 0.1 to 3000.0 MVA in steps of 1. See 5.6.1: Overview on page 5–32 for details.*

The apparent power demand is monitored by comparing to a pickup value. If the apparent power demand pickup is ever exceeded, the relay can be configured to cause an alarm or signal an output relay.

For the **THERMAL 90% RESPONSE TIME** setpoint, enter the time required for a steady state apparent power to indicate 90% of the actual value. This setpoint allows the user to approximately match the response of the relay to analog instruments. For the **TIME INTERVAL** setpoint, enter the time period over which the apparent power demand calculation is to be performed. For the **APPARENT PWR DMND PICKUP** setpoint, the power quantities auto-range to show units appropriate to the power system size.

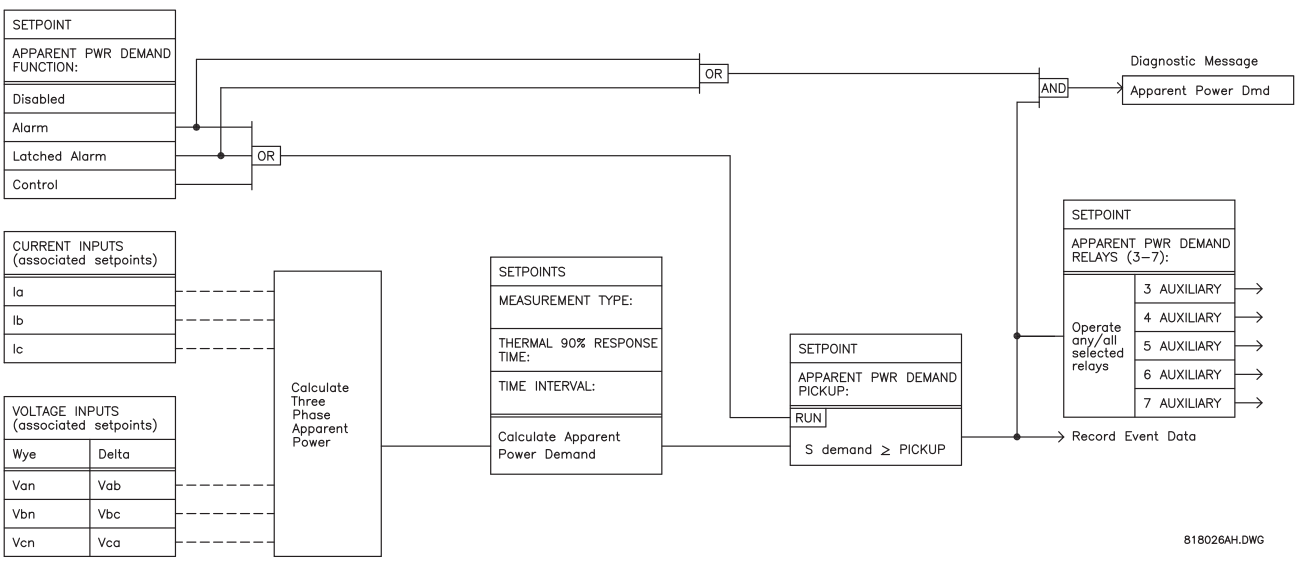

Figure 5–44: APPARENT POWER DEMAND LOGIC

5.7.5 ANALOG INPUT

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ A/I

■ A/I ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ A/I SETUP ■ [ENTER] for more	See page 5–82.
	ESCAPE MESSAGE ⇳	■ ANALOG THRESHOLD 1 ■ [ENTER] for more	See page 5–83.
	ESCAPE MESSAGE ⇳	■ ANALOG THRESHOLD 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇳	■ A/I RATE 1 ■ [ENTER] for more	See page 5–84.
	ESCAPE MESSAGE ⇧	■ A/I RATE 2 ■ [ENTER] for more	

The relay can monitor any external quantity, such as transformer winding temperature, bus voltage, battery voltage, station service voltage, transformer tap position, etc., via an auxiliary current input called the analog input. Any one of the standard transducer output ranges 0 to 1 mA, 0 to 5 mA, 0 to 10 mA, 0 to 20 mA, or 4 to 20 mA can be connected to the analog input terminals.

Two independent elements are available for monitoring the analog input level, Analog Threshold 1 and 2, each having a user programmable name, pickup level, drop out ratio, and a time delay. For each element, when the measured analog input quantity exceeds the pickup level for longer than the associated time delay, the relay can be configured to cause a trip, an alarm, or signal an output contact. The element will drop out only when the user programmed drop out ratio has been met. There are also two elements which measure the analog input rate-of-change, Analog In Rate 1 and 2, which operate in a similar fashion.

5

b) ANALOG INPUT SETUP

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ A/I ⇨ A/I SETUP

■ A/I SETUP ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	A/I NAME: ANALOG INPUT	*Range: Any combination of 20 alphanumeric characters*
	ESCAPE MESSAGE ⇳	A/I UNITS: µA	*Range: Any combination of 6 alphanumeric characters.*
	ESCAPE MESSAGE ⇳	A/I RANGE: 0-20 mA	*Range: 0-1 mA, 0-5 mA, 4-20 mA, 0-20 mA, 0-10 mA*
	ESCAPE MESSAGE ⇳	A/I MIN VALUE: 0 µA	*Range: 0 to 65535 units in steps of 1. Units are programmed in* **A/I UNITS** *above.*
	ESCAPE MESSAGE ⇧	A/I MAX VALUE: 20000 µA	*Range: 0 to 65535 units in steps of 1. Units are programmed in* **A/I UNITS** *above.*

Before the analog input can be used for monitoring, the value of the input must be converted to the quantity that is being measured. The relay simplifies this process by internally scaling the transducer output, and displaying and monitoring the actual measured parameter. Note the resolution that will result from the selection of the minimum and maximum setpoints. For example, if 0 to 20 mA is to be represented via the 0 to 20 mA analog input, an input of 4.5 mA will translate to a 5 mA actual value reading. This is due to the rounding up of the value, since the analog input actual value is an F1 format. If a range of 0 to 200 mA was programmed to be represented via the 0 to 20 mA input, 4.5 mA will result in a 45 mA actual value.

For the **A/I MIN VALUE** and **A/I MAX VALUE** setpoints, enter the value which corresponds to the minimum/maximum output value of the transducer. For example, if a temperature transducer which outputs 4 to 20 mA for temperatures 0 to 250°C is connected to the analog input, then enter "0" for **A/I MIN VALUE**. The relay then interprets 4 mA as representing 0°C. Intermediate values between the minimum and maximum are scaled linearly.

c) ANALOG THRESHOLD

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ A/I ⇨⇩ ANALOG THRESHLD 1(2)

Display		Range
■ ANALOG THRESHLD 1 ■ [ENTER] for more	A/I THRESHLD 1 NAME: ANALOG INPUT	*Range: Any combination of 18 alphanumeric characters*
	ANALOG THRESHLD 1 FUNCTION: Disabled	*Range: Disabled, Trip, Alarm, Latched Alarm, Control, Blk Thrsh 1*
	ANALOG THRESHLD 1 RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary Relays. See 5.6.1: Overview on page 5–32 for details.*
	ANALOG THRESHLD 1 PICKUP: 100 µA	*Range: 0 to 65535 units in steps of 1. Units reflect the **A/I UNITS** setpoint value.*
	ANALOG THRESHLD 1 DROP OUT RATIO: 5	*Range: 2 to 20 in steps of 1*
	ANALOG THRESHLD 1 PICKUP TYPE: Over	*Range: Over, Under*
	ANALOG THRESHLD 1 DELAY: 100 s	*Range: 0 to 60000 s in steps of 1*

Monitoring of the analog input can be performed by two separate functions, each operating at different thresholds of analog input current and each having a selection to trip, alarm, or control. Control allows the element to signal its own output relay(s). For user flexibility, independent user names can also be programmed for each Analog Threshold.

Note that connected analog input will still be read and displayed in **A2 METERING ⇨⇩ A/I** if both **ANALOG THRESHLD 1 FUNCTION** and **ANALOG THRESHLD 2 FUNCTION** are set to “Disabled”. The “Blk Thrsh 1" value applies to the **ANALOG THRESHLD 2 FUNCTION** setpoint only.

The value programmed in the **ANALOG THRESHLD 1 DROP OUT RATIO** setpoint represents the value at which the element will effectively drop out as a percentage of the pickup value. If the pickup level is 5000 µA and this setpoint is programmed for a drop out ratio of “10”, then the drop out current will be 4500 µA. The drop out ratio is defined as follows:

$$\text{Drop Out} = \text{pickup} - \frac{\text{pickup} \times \text{dropout ratio}}{100} \qquad \textbf{(EQ 5.21)}$$

The **ANALOG THRESHLD 1 PICKUP TYPE** setpoint determines if pickup will occur when the analog input is over or under the programmed threshold. When set to “Over”, the Drop Out value is calculated shown in the equation above.

5

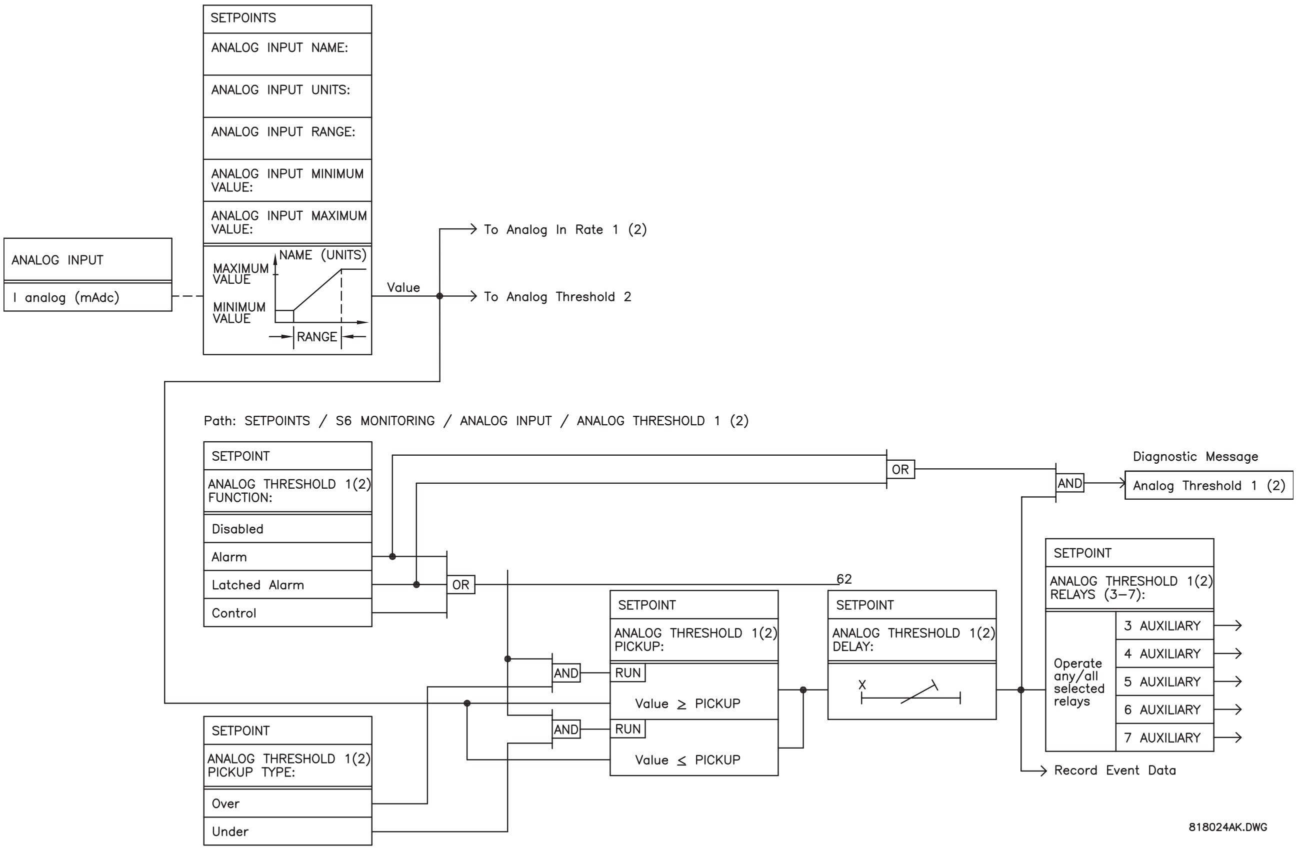

Figure 5–45: ANALOG INPUT THRESHOLD LOGIC

d) ANALOG INPUT RATE OF CHANGE

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ A/I ⇨⇩ A/I RATE 1(2)

■ A/I RATE 1 ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	A/I RATE 1 FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	ESCAPE MESSAGE ⇳	A/I RATE 1 RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary Relays. See 5.6.1: Overview on page 5–32 for details.*
	ESCAPE MESSAGE ⇳	A/I RATE 1 PICKUP: 10.0 µA /hour	*Range: 0 to 65535 units in steps of 1. Units reflect the* **A/I UNITS** *setpoint value.*
	ESCAPE MESSAGE ⇧	A/I RATE 1 DELAY: 0 s	*Range: 0 to 60000 s in steps of 1*

The relay has fast and slow analog input rates of change. The fast rate of change measures over the last one minute interval and detects a rapid increase or decrease in the input quantity. The slow rate of change measures over the last one hour interval and detects the long term trend of the input quantity. A positive rate indicates an increasing analog input and a negative rate indicates a decreasing analog input.

The fast (slow) analog input rate of change is calculated as follows. Every second (minute) the present analog input reading is captured and a new rate of change calculated for the previous minute (hour). The rate is calculated using the previous sixty analog input readings and the 'Least Squares Approximation' method that generates an equation for the best line through the sample points as shown below. The rate of change is equal to the slope of this line which is a stable quantity not unduly affected by noise or fluctuations from the input.

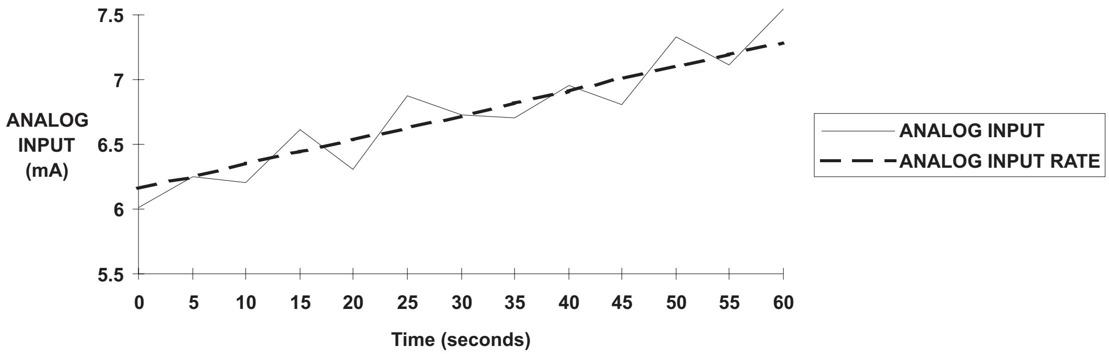

Figure 5–46: ANALOG INPUT RATE OF CHANGE MEASUREMENT

Note that connected analog input will still be read and displayed in **A2 METERING ⇨⇩ A/I** if both **A/I RATE 1 FUNCTION** and **A/I RATE 2 FUNCTION** are set to "Disabled".

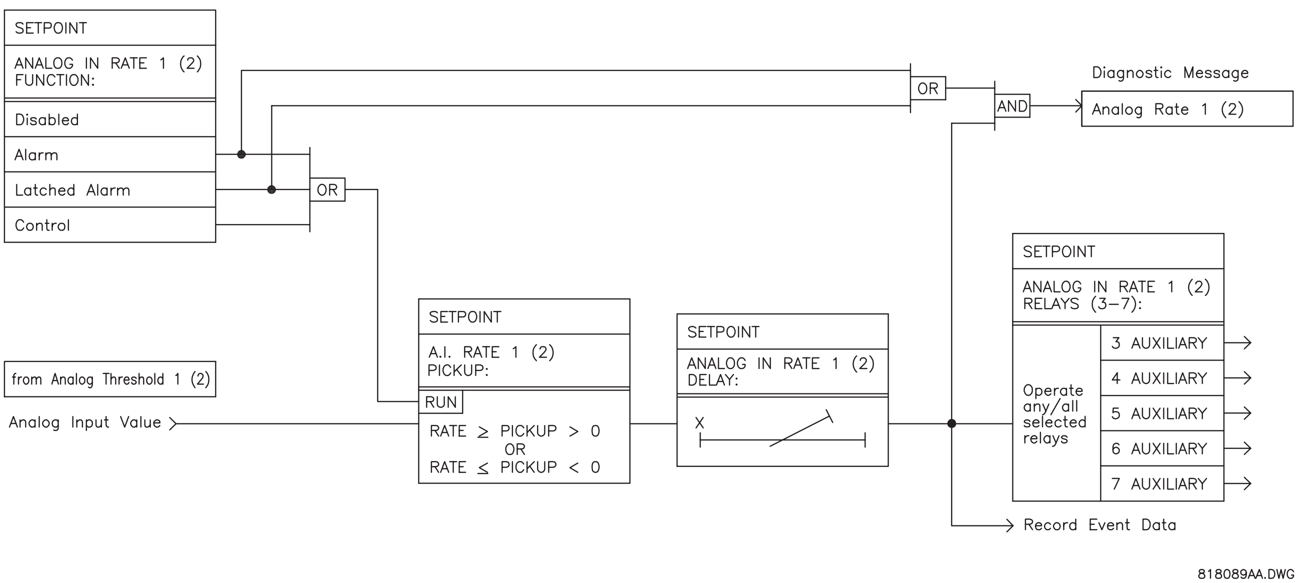

Figure 5–47: ANALOG INPUT RATE OF CHANGE LOGIC

5.7.6 ANALOG OUTPUTS

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ A/O ⇨ A/O 1(8)

■ A/O 1 ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	A/O 1 SOURCE: Disabled	Range: *See Table 5–16: Analog Output Parameters on page 5–86.*
	ESCAPE / MESSAGE ⇳	A/O 1 MIN: -100.0 MW	Range: *As per function selection. See Table 5–16: Analog Output Parameters on page 5–86.*
	ESCAPE / MESSAGE ⇧	A/O 1 MAX: 100.0 MW	Range: *As per function selection. See Table 5–16: Analog Output Parameters on page 5–86.*

There are three analog output channel types: A, B, and C (see Table 5–16: Analog Output Parameters on page 5–86 for parameter-channel correspondence). Type A channel ranges extend from a minimum of 0 units. Type B channels range between definite boundaries. Type C channels include the direction of flow. The following diagram illustrates these characteristics.

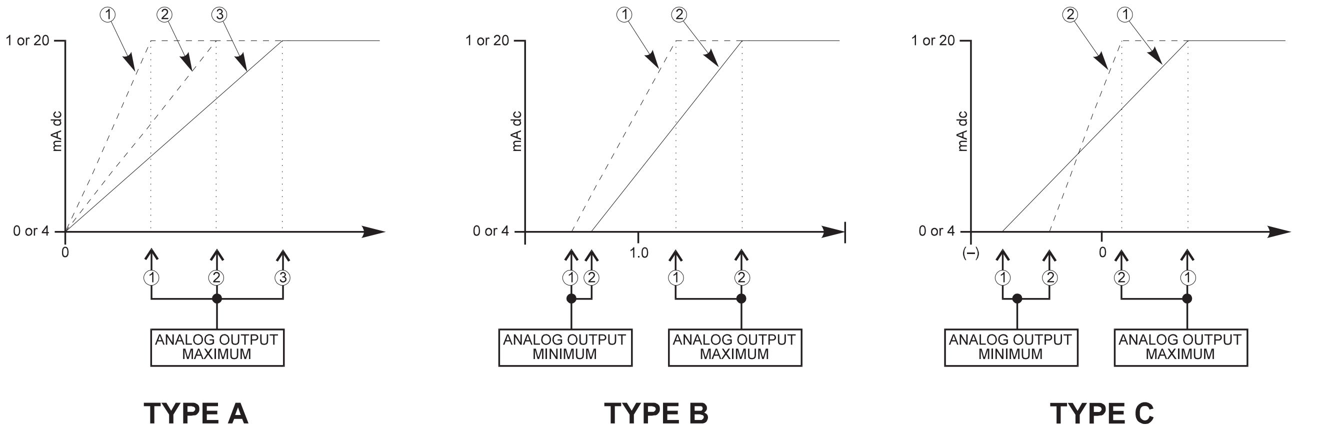

Figure 5–48: ANALOG OUTPUTS CHANNEL CHARACTERISTICS

Each channel can be programmed to represent a parameter from the following table:

Table 5–16: ANALOG OUTPUT PARAMETERS (SHEET 1 OF 2)

PARAMETER NAME	RANGE / UNITS	STEP	DEFAULTS		CHANNEL TYPE
			MIN.	MAX.	
Phase A/B/C Current	0 to 65535 Amps	1	0	2000	A
Phase A/B/C Current Angle	0 to 359° Lag	1	0	359	A
Average Current	0 to 65535 Amps	1	0	2000	A
% Of Load-To-Trip	0 to 2000%	1	0	1000	A
Neutral Current	0 to 65535 Amps	1	0	2000	A
Neutral Current Angle	0 to 359° Lag	1	0	359	A
Phase AN/BN/CN Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Phase AN/BN/CN Voltage Angle	0 to 359° Lag	1	0	359	A
Average Phase Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Line AB/BC/CA Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Line AB/BC/CA Voltage Angle	0 to 359° Lag	1	0	359	A
Average Line Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Frequency	20.00 to 65.00 Hz	0.01	47.00	63.00	B
3ϕ Real Power	–3000.0 to 3000.0 MW[1]	0.1	–100.0	100.0	C
3ϕ Reactive Power	–3000.0 to 3000.0 Mvar[1]	0.1	–100.0	100.0	C
3ϕ Apparent Power	0.0 to 3000.0 MVA[1]	0.1	0.0	100.0	A
3ϕ Power Factor	0.00 Lead to 0.00 Lag	0.01	0.99 Lag	0.50 Lag	B
Last Phase A/B/C Demand	0 to 65535 Amps	1	0	2000	A
Last Watt Demand	–3000.0 to 3000.0 MW[1]	0.1	–100.0	100.0	C
Last Var Demand	–3000.0 to 3000.0 Mvar[1]	0.1	–100.0	100.0	C
Last VA Demand	0.0 to 3000.0 MVA[1]	0.1	0.0	100.0	A
Analog Input	0 to 65535 Units	1	0	1000	A
Last Fault Distance	–327.67 to 327.67 km/miles	0.01	–50.00	50.00	C
Positive Watthours	0.0 to 6553.5 MWh[1]	0.1	0.0	1000.0	A
Negative Watthours	0.0 to 6553.5 MWh[1]	0.1	0.0	1000.0	A
Positive Varhours	0.0 to 6553.5 Mvarh[1]	0.1	0.0	1000.0	A
Negative Varhours	0.0 to 6553.5 Mvarh[1]	0.1	0.0	1000.0	A
Ground Current	0 to 65535 Amps	1	0	2000	A
Ground Current Angle	0 to 359° Lag	1	0	359	A

[1] Power and energy quantities auto-range to display units appropriate to power system size.

Table 5–16: ANALOG OUTPUT PARAMETERS (SHEET 2 OF 2)

PARAMETER NAME	RANGE / UNITS	STEP	DEFAULTS		CHANNEL TYPE
			MIN.	MAX.	
Polarizing Current	0 to 65535 Amps	1	0	2000	A
Polarizing Current Angle	0 to 359° Lag	1	0	359	A
ϕA/ϕB/ϕC Real Power	–3000.0 to 3000.0 MW[1]	0.1	–100.0	100.0	C
ϕA/ϕB/ϕC Reactive Power	–3000.0 to 3000.0 Mvar[1]	0.1	–100.0	100.0	C
ϕA/ϕB/ϕC Apparent Power	0.0 to 3000.0 MVA[1]	0.1	0.0	100.0	A
ϕA/ϕB/ϕC Power Factor	0.00 Lead to 0.00 Lag	0.01	0.99 Lag	0.50 Lag	B
Synchro Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Synchro Voltage Angle	0 to 359° Lag	1	0	359	A
Synchro Frequency	20.00 to 65.00 Hz	0.01	47.00	63.00	B
Frequency Decay Rate	–10.00 to 10.00 Hz/s	0.01	–0.50	0.50	C
Positive/Negative/Zero Sequence Current	0 to 65535 Amps	1	0	2000	A
Positive/Negative/Zero Sequence Current Angle	0 to 359° Lag	1	0	359	A
Positive/Negative/Zero Sequence Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Positive/Negative/Zero Sequence Voltage Angle	0 to 359° Lag	1	0	359	A
Synchro Voltage Difference	0.00 to 655.35 kV	0.01	0.00	100.00	A
Synchro Angle Difference	0 to 359° Lag	1	0	359	A
Synchro Frequency Difference	20.00 to 65.00 Hz	0.01	47.00	63.00	B
Sensitive Ground Current	0.00 to 655.35 A	0.01	0.00	20.00	A
Sensitive Ground Current Angle	0 to 359° Lag	1	0	359	A
Neutral Voltage	0.00 to 655.35 kV	0.01	0.00	100.00	A
Neutral Voltage Angle	0 to 359° Lag	1	0	359	A

[1] Power and energy quantities auto-range to display units appropriate to power system size.

5.7.7 OVERFREQUENCY

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ OVERFREQ

■ OVERFREQ ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	OVERFREQ FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	ESCAPE MESSAGE ⇳	OVERFREQ RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	ESCAPE MESSAGE ⇳	OVERFREQ PICKUP: 60.50 Hz	*Range: 20.00 to 65.00 Hz in steps of 0.01*
	ESCAPE MESSAGE ⇧	OVERFREQ DELAY: 5.0 s	*Range: 0.0 to 6000.0 s in steps of 0.1*

A significant overfrequency condition, likely caused by a breaker opening and disconnecting load from a particular generation location, can be detected and used to quickly ramp the turbine speed back to normal. If this is not done, the over speed can lead to a turbine trip, which would then subsequently require a turbine start up before restoring the system. If the overfrequency turbine ramp down is successful, the system restoration can be much quicker. The overfrequency monitoring feature of the relay can be used for this purpose at a generating location.

The overfrequency feature is inhibited from operating unless the phase A voltage is above 30% of nominal. When the supply source is energized, the overfrequency delay timer will only be allowed to time when the 30% threshold is exceeded and the frequency is above the programmed pickup level. In the same way, when an overfrequency condition starts the overfrequency delay timer and the phase A voltage falls below the 30% threshold before the timer has expired, the element will reset without operating.

Note that the system frequency will still be measured and displayed in **A2 METERING ⇨⇩ FREQ** if both the Overfrequency and Underfrequency functions are set to "Disabled".

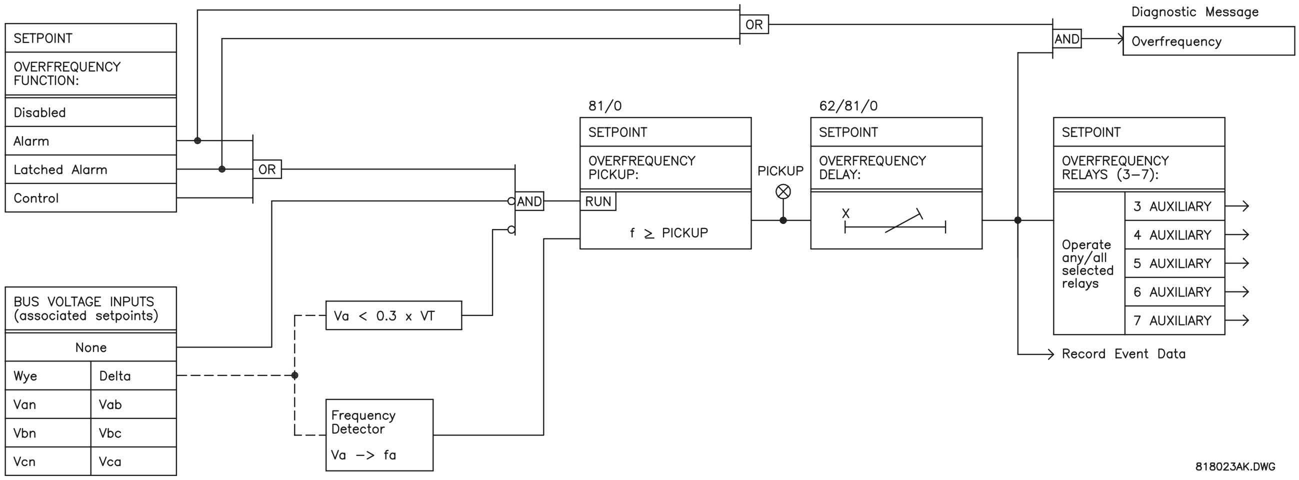

Figure 5–49: OVERFREQUENCY LOGIC

5.7.8 EQUIPMENT

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ EQUIPMENT

■ EQUIPMENT ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	■ TRIP COUNTER ■ [ENTER] for more	See page 5–88.
	ESCAPE / MESSAGE ⇳	■ ARCING CURRENT ■ [ENTER] for more	See page 5–89.
	ESCAPE / MESSAGE ⇳	■ BRKR OPERATION ■ [ENTER] for more	See page 5–91.
	ESCAPE / MESSAGE ⇳	■ COIL MON 1 ■ [ENTER] for more	See page 5–92.
	ESCAPE / MESSAGE ⇳	■ COIL MON 2 ■ [ENTER] for more	
	ESCAPE / MESSAGE ⇧	■ VT FAILURE ■ [ENTER] for more	See page 5–93.

The equipment monitoring features are provided to detect failures or unusual operating conditions of the feeder circuit breaker and the bus VTs.

b) TRIP COUNTER

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ EQUIPMENT ⇨ TRIP COUNTER

■ TRIP COUNTER ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	TRIP COUNTER FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	ESCAPE / MESSAGE ⇳	TRIP COUNTER RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	ESCAPE / MESSAGE ⇧	TRIP COUNTER LIMIT: 10000 Trips	*Range: 1 to 10000 Trips in steps of 1*

When the total number of trips detected reaches the TRIP COUNTER LIMIT setpoint, an output will occur.

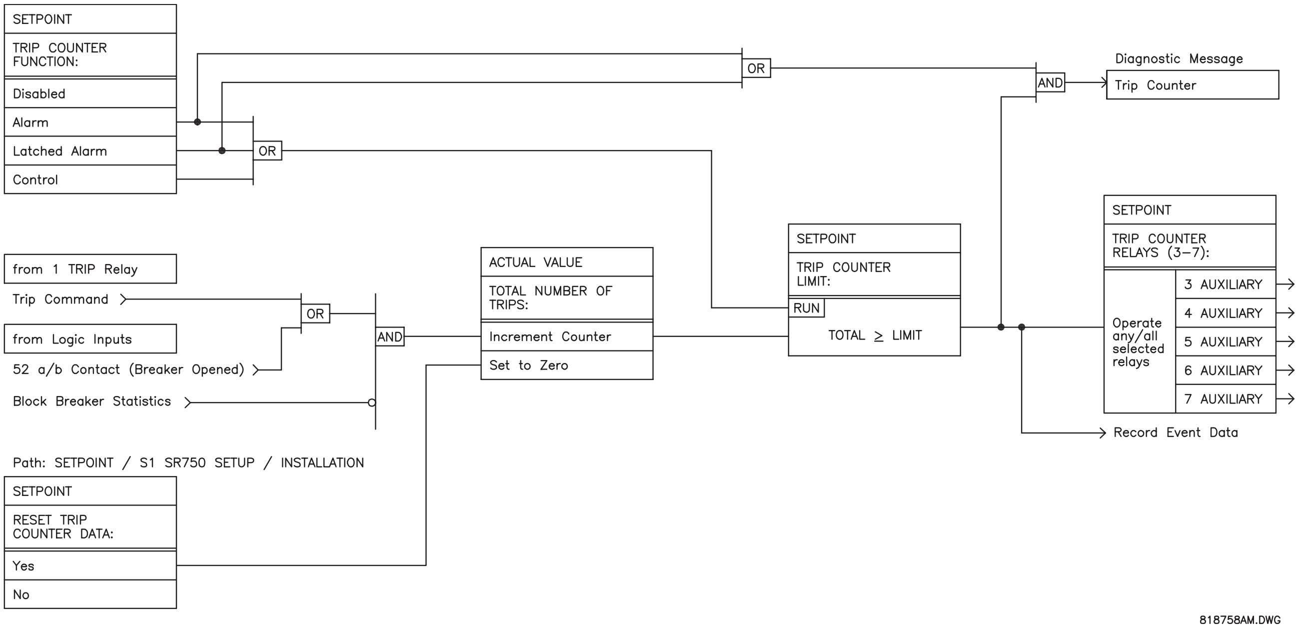

Figure 5–50: TRIP COUNTER LOGIC

c) ARCING CURRENT

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ EQUIPMENT ⇨⇩ ARCING CURRENT

■ ARCING CURRENT ■ [ENTER] for more	ENTER / ESCAPE	ARCING CURRENT FUNCTION: Disabled	Range: Disabled, Alarm, Latched Alarm, Control
	ESCAPE / MESSAGE	ARCING CURRENT RELAYS (3-7): -----	Range: Any combination of 3 to 7 Auxiliary relays
	ESCAPE / MESSAGE	ARCING CURRENT START DELAY: 32 ms	Range: 0 to 100 ms in steps of 1
	ESCAPE / MESSAGE	TOTAL ARCING CURRENT LIMIT: 1000 kA2-cyc	Range: 1 to 50000 kA^2-cyc in steps of 1

The relay calculates an estimate of the per-phase wear on the breaker contacts by measuring and integrating the arcing current squared passing through the contacts while they are opening. 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 be used to generate an alarm. The threshold value can be set to a maintenance specification provided by the breaker manufacturer.

For the **TOTAL ARCING CURRENT START DELAY** setpoint, enter the expected ms time delay, from the moment a trip command is issued, until the breaker contacts will actually begin to open. This setpoint is used by the relay to determine when to start integrating. The integration continues for 100 ms, by which time most modern breakers will have cleared a fault.

For the **TOTAL ARCING CURRENT LIMIT**, enter the total arcing current in kA^2–cycle, at which this feature is to cause an alarm. For example, if an alarm is desired as soon as the total arcing current in any phase exceeds 1000 kA^2–cycle, enter "1000" for this setpoint. An output will occur when the total arcing current in any phase reaches this setpoint.

Note that the total arcing current for each phase will still be available for display under **A3 MAINTENANCE ⇨⇩ ARCING CURRENT** if the **ARCING CURRENT FUNCTION** set to "Disabled".

5

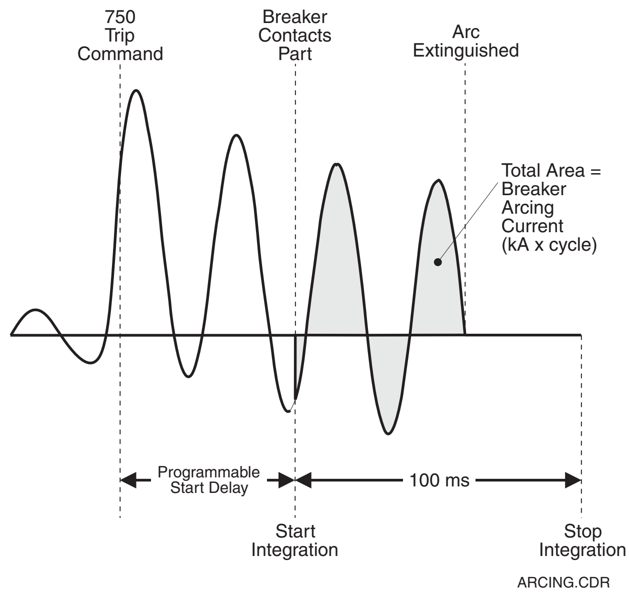

Figure 5–51: ARCING CURRENT MEASUREMENT

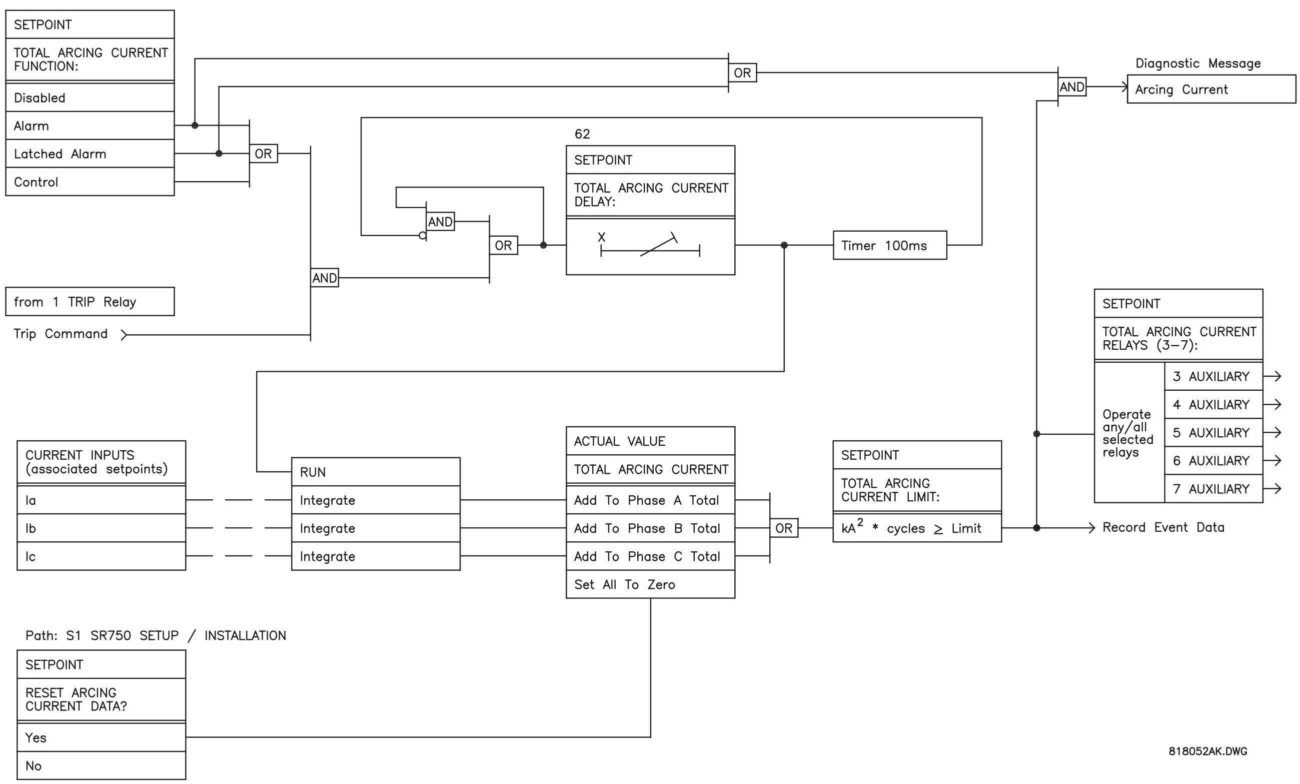

Figure 5–52: ARCING CURRENT LOGIC

d) BREAKER OPERATION

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ EQUIPMENT ⇨⇩ BRKR OPERATION

```
■ BRKR OPERATION
■ [ENTER] for more
```

ENTER ⇨ / ⇦ ESCAPE

```
BRKR OPERATION
FUNCTION: Disabled
```

Range: Disabled, Alarm, Latched Alarm, Control

ESCAPE / MESSAGE ⇳

```
BRKR OPERATION
RELAYS (3-7): -----
```

Range: Any combination of 3 to 7 Auxiliary relays

ESCAPE / MESSAGE ⇧

```
BRKR OPERATION
DELAY: 0.10 s
```

Range: 0.03 to 1.00 s in steps of 0.01

Circuit breakers typically have both a 52a (breaker tripped = open) contact and a 52b (breaker tripped = closed) contact. Either or both of these contacts can be connected to the relay logic inputs, from which breaker status is detected. Interpretation of breaker status depends on which 52 contacts are installed. See System Status LED Indicators on page 4–2 and Breaker Functions on page 5–21 for more information on 52a (52b) contacts. If neither 52a nor 52b contacts are installed, correct breaker operation will not be verified and a breaker operation alarm can never occur.

A breaker operation failure can be caused by either of the following conditions if **BRKR OPERATION FUNCTION** is set to "Alarm" or "Control".

- The breaker does not respond to a trip command within the programmed breaker operation delay time.
- The breaker does not respond to a close command within the programmed time.

When a breaker operation failure is declared, the selected output relays will operate, but the Close Relay and 760 autoreclosure will be inhibited. If the 760 already has a reclosure scheme in progress, it will be sent to lockout.

A Breaker Operation failure condition results if the breaker does not respond within the **BRKR OPERATION DELAY** time. This time is a characteristic of the breaker being used.

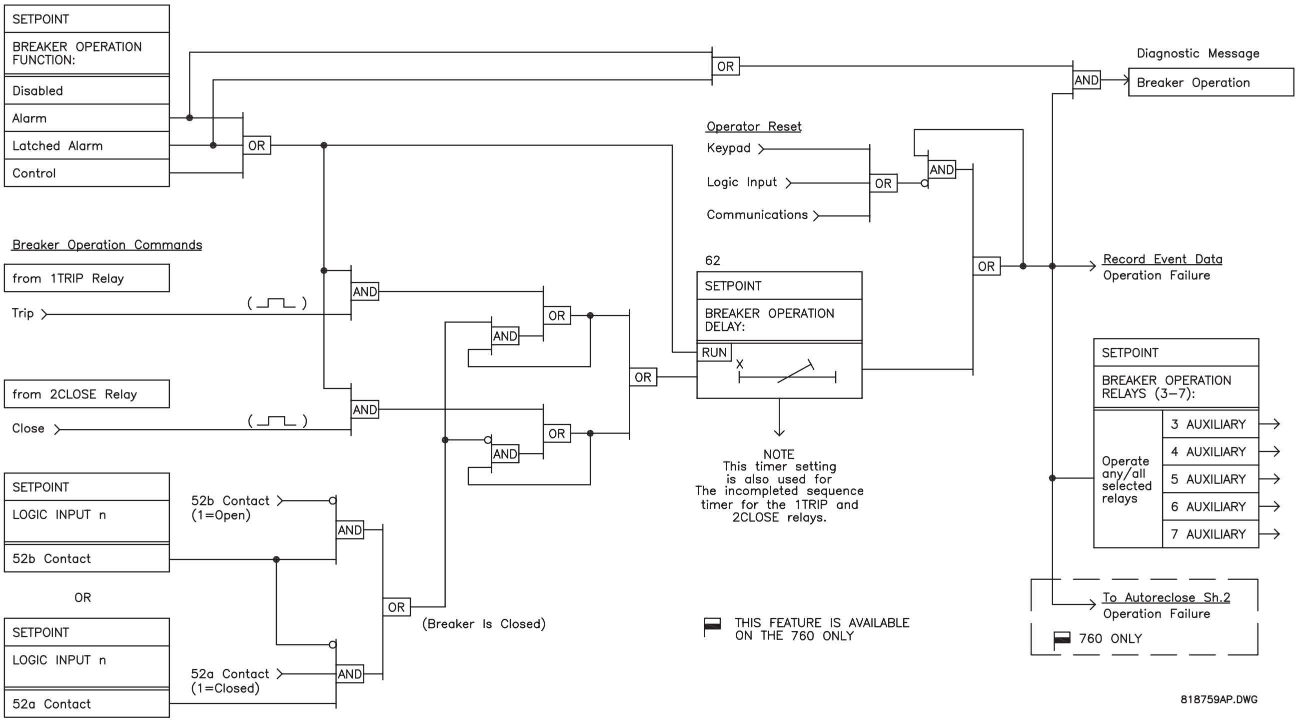

Figure 5–53: BREAKER OPERATION LOGIC

e) COIL MONITOR

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ EQUIPMENT ⇨⇩ COIL MON 1(2)

■ COIL MON 1 ■ [ENTER] for more	COIL MON 1 NAME: Trip Coil Monitor	*Range: Any combination of 18 alphanumeric characters.*
	COIL MON 1 FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	COIL MON 1 RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	BRKR STATE BYPASS: Disabled	*Range: Enabled, Disabled*
	COIL MON 1 DELAY: 5 s	*Range: 5 to 100 s in steps of 1*
	COIL MON 1 TYPE: Trip	*Range: Trip, Close*

Coil Monitor 1 and 2 are programmed in this subgroup. They are two identical elements that may be used to monitor trip or close coils. The operation of this feature is described in Section 3.2.6: Trip/Close Coil Supervision on page 3–12.

Detection of a failed circuit regardless of the breaker state (i.e. detection of a failed trip circuit when the breaker is open) requires **BRKR STATE BYPASS** to be "Enabled". Generally, this selection will require a wiring modification of the breaker, as detailed in Section 3.2.6: Trip/Close Coil Supervision on page 3–12.

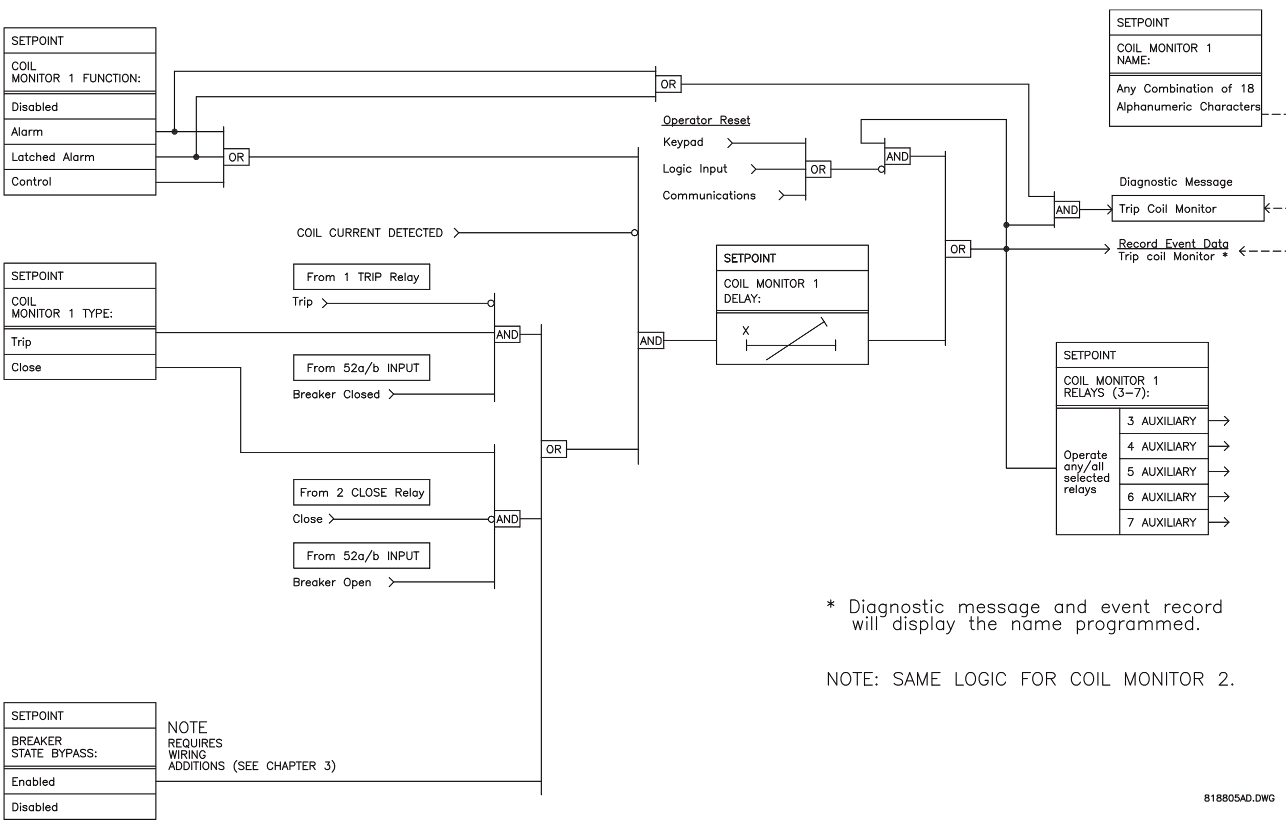

Figure 5–54: COIL MONITOR LOGIC

f) VT FAILURE

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ EQUIPMENT ⇨⇩ VT FAILURE

Display		Message	Range
■ VT FAILURE ■ [ENTER] for more	ENTER / ESCAPE	VT FAILURE FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
	ESCAPE / MESSAGE	VT FAILURE RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
	ESCAPE / MESSAGE	VT FAILURE DELAY: 10 s	*Range: 0 to 60000 s in steps of 1*

The 750/760 detects a VT fuse failure when there are significant levels of negative sequence voltage without correspondingly significant levels of negative sequence current measured at the output CTs. Also, if there is not a significant amount of positive sequence voltage when there is positive sequence current then it could indicate that all the VT fuses have been pulled or the VTs have been racked out.

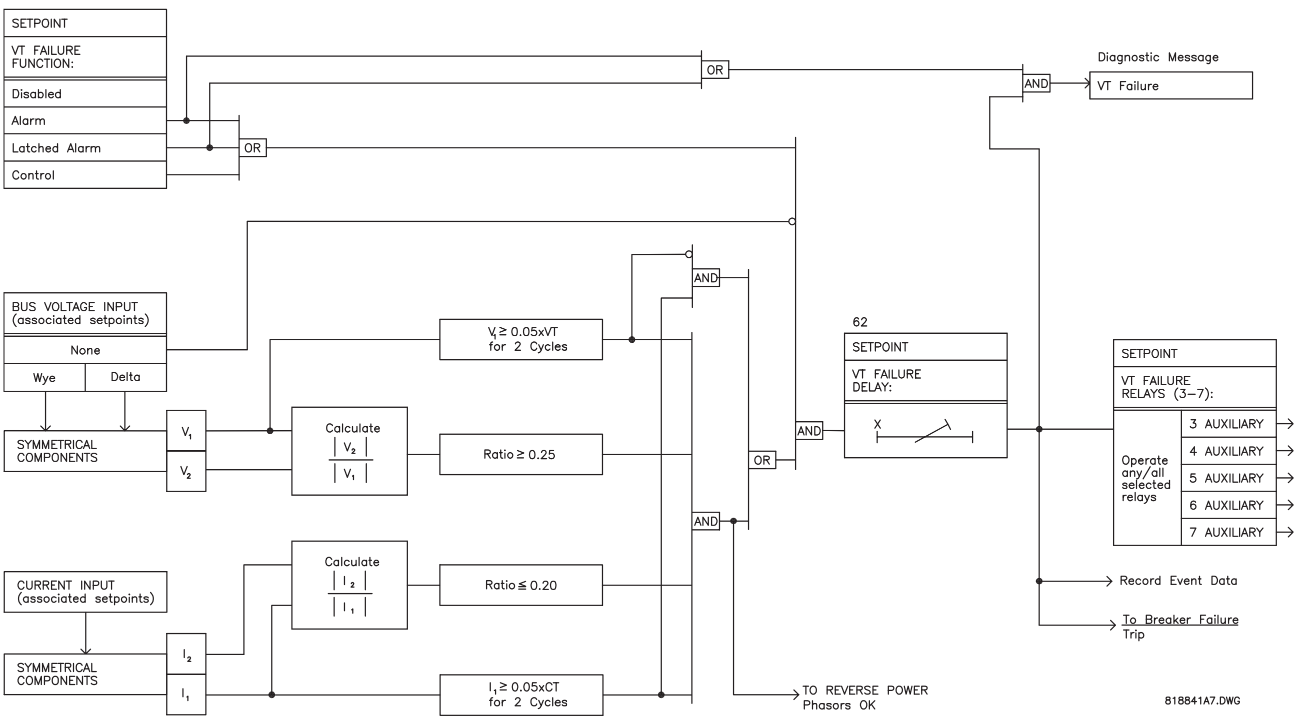

Figure 5–55: VT FAILURE LOGIC

5.7.9 PULSE OUTPUT

PATH: SETPOINTS ⇨⇩ S6 MONITORING ⇨⇩ PULSED OUTPUT

■ PULSED OUTPUT
■ [ENTER] for more

Display	Range
PULSED OUTPUT FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
POS WATTHOURS PULSED RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
POS WATTHOURS PULSED INTERVAL: 10.0 MWh	*Range: 0.0 to 6553.5 MWh in steps of 0.1. Quantities auto-range to appropriate units.*
NEG WATTHOURS PULSED RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
NEG WATTHOURS PULSED INTERVAL: 10.0 MWh	*Range: 0.0 to 6553.5 MWh in steps of 0.1. Quantities auto-range to appropriate units.*
POS VARHOURS PULSED RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
POS VARHOURS PULSED INTERVAL: 10.0 Mvarh	*Range: 0.0 to 6553.5 Mvarh in steps of 0.1. Quantities auto-range to appropriate units.*
NEG VARHOURS PULSED RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
NEG VARHOURS PULSED INTERVAL: 10.0 Mvarh	*Range: 0.0 to 6553.5 Mvarh in steps of 0.1. Quantities auto-range to appropriate units.*

5

The 750/760 can operate selected auxiliary relays after an adjustable interval for the quantities shown above. Pulses occur at the end of each programmed interval. Upon power up of the relay the Pulse Output function, if enabled, will continue from where it was at loss of control power. For example, if control power is removed when the positive watthours actual value is 16.0 MWh, when control power is re-applied a pulse will occur at 26 MWh if the interval is set to 10.0 MWh.

Note that the Output relay(s) used for this element must be set to "Self-Resetting" under **S4 OUTPUT RELAYS**. The pulses will consist of a one second on time and a one second off time. This feature should be programmed such that no more than one pulse per two seconds will be required or the pulsing will lag behind the interval activation.

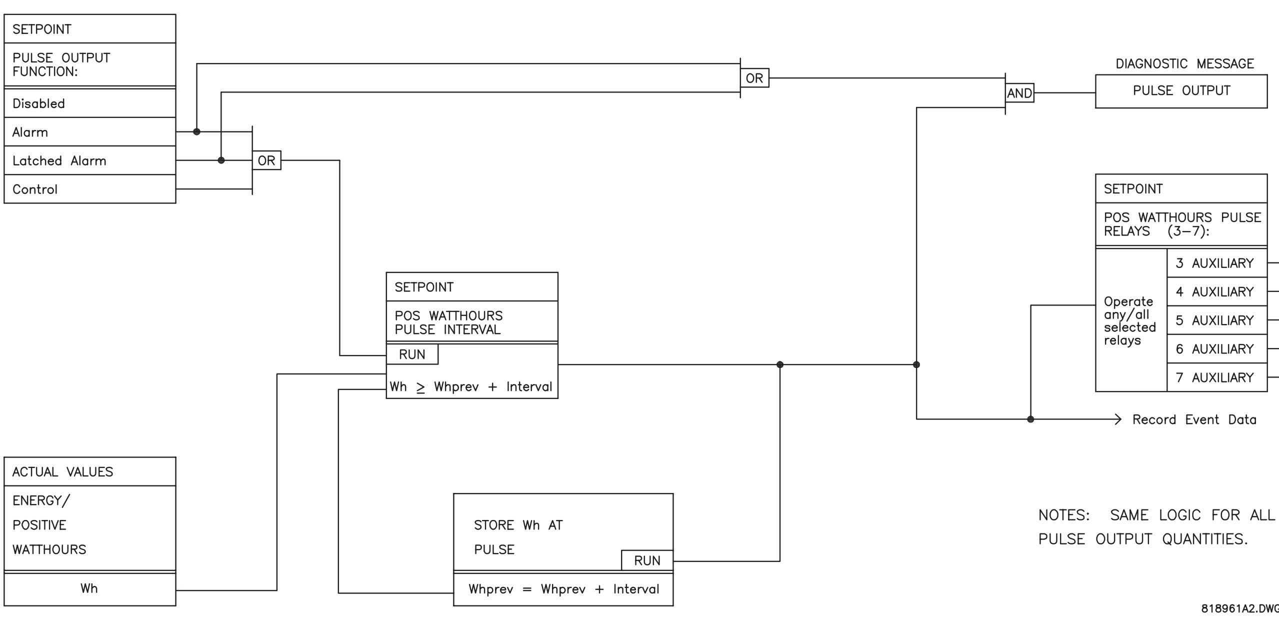

Figure 5–56: PULSED OUTPUT LOGIC

5.8.1 SETPOINT GROUPS

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨ SETPOINT GROUPS

■ SETPOINT GROUPS ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	ACTIVE SETPOINT GROUP: Group 1	*Range: Group 1, Group 2, Group 3, Group 4*
	ESCAPE MESSAGE ⇳	EDIT SETPOINT GROUP: Active Group	*Range: Group 1, Group 2, Group 3, Group 4, Active Group*
	ESCAPE MESSAGE ⇳	OPEN BRKR INHIBIT: Disabled	*Range: Enabled, Disabled*
	ESCAPE MESSAGE ⇳	OVERCURRENT PICKUP INHIBIT: Disabled	*Range: Enabled, Disabled*
	ESCAPE MESSAGE ⇳	OVERVOLTAGE PICKUP INHIBIT: Disabled	*Range: Enabled, Disabled*
	ESCAPE MESSAGE ⇳	UNDERVOLTAGE PICKUP INHIBIT: Disabled	*Range: Enabled, Disabled*
	ESCAPE MESSAGE ⇧	UNDERFREQ PICKUP INHIBIT: Disabled	*Range: Enabled, Disabled*

All setpoints contained under the **S5 PROTECTION** setpoints page are reproduced in four groups, identified as Groups 1, 2, 3, and 4. These multiple setpoints provide the capability of both automatic and manual changes to protection settings for different operating situations. Automatic (adaptive) protection setpoint adjustment is available to change settings when the power system configuration is altered. By monitoring the state of a bus tie breaker on the bus connected to the associated feeder breaker, different settings may be used depending the tie breaker state. Automatic group selection can be initiated by use of a logic input. The manual adjustment capability is available for those users who use different settings for different seasons of the year. Manual group selection can be initiated from the keypad or via communications.

In order to allow the display and editing of one group while another group is used for protection, two operating states have been assigned to setpoint groups. The "Active Group" is used for protection, and is indicated by the appropriate faceplate LED indicator being turned on continuously. The 'Edit' group is displayed and may be used to alter protection settings. It is indicated by the appropriate faceplate LED indicator being flashed. If a single group is selected to be both the Active and Edit group, the appropriate indicator is on continuously.

The setpoint group to be edited is selected through the **EDIT SETPOINT GROUP** setpoint. Group 1 is the default for the "Active Group" and will be used unless another group is requested to become active. The active group can be selected with the **ACTIVE SETPOINT GROUP** setpoint or by logic input. If there is a conflict in the selection of the active group, between a setpoint and logic input, or between two logic inputs, the higher numbered group will be made active. For example, if the logic inputs for Group 2, 3, and 4 are all asserted the relay would use Group 4. If the logic input for Group 4 then becomes deasserted, the relay will use Group 3. Any change from the default Group 1 will be stored in the event recorder.

In some application conditions, the user may require that the relay will not change from the present active group. This prevention of a setpoint group change can be applied when any of the overcurrent (phase, neutral, ground, sensitive ground, or negative sequence), overvoltage, bus or line undervoltage, or underfrequency elements are picked-up.

NOTE

Pickup of a protection element is possible when selected to any function except "Disabled", so elements that are not used to perform tripping can also inhibit setpoint changes. A setpoint change can also be prevented if the breaker is open, so that a fault detected before a reclosure will not cause a group change while the breaker is open.

CAUTION

Each setpoint group includes the selection of Auxiliary Output Relays 3 to 7 that can be operated by the protection features. As these relays are hard-wired to external equipment, the selection should only be changed from that in setpoint Group 1 with considerable care.

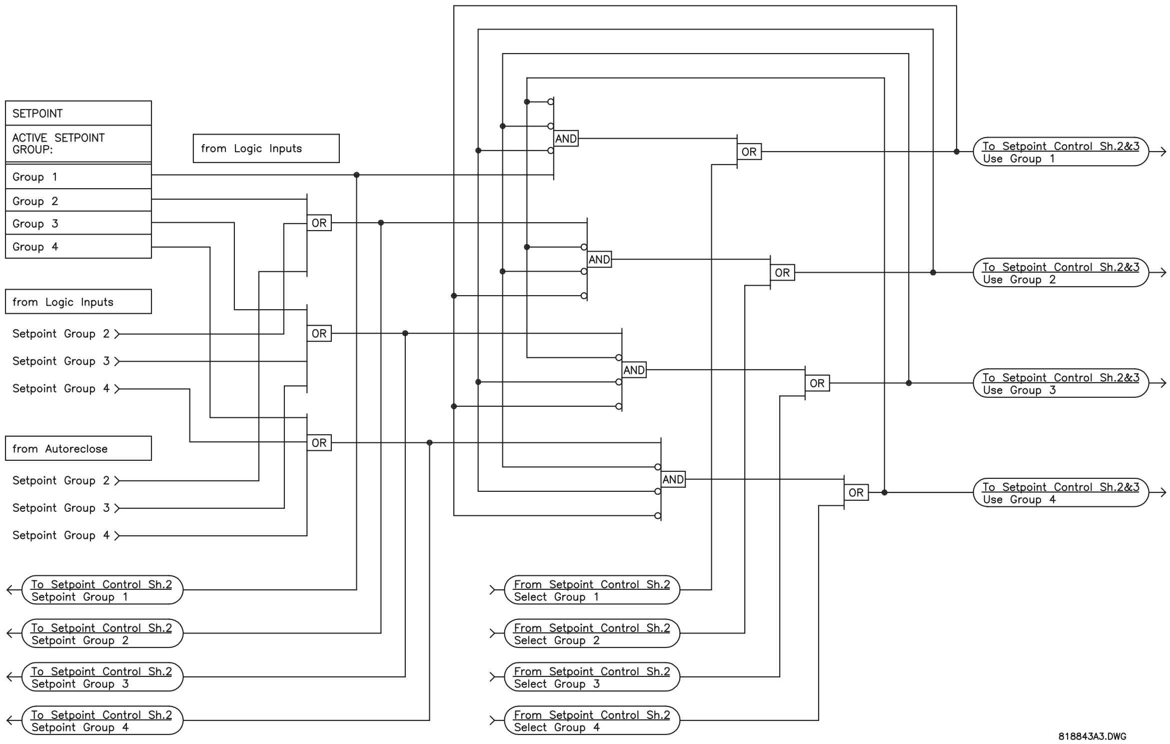

Figure 5–57: SETPOINT CONTROL (1 OF 3)

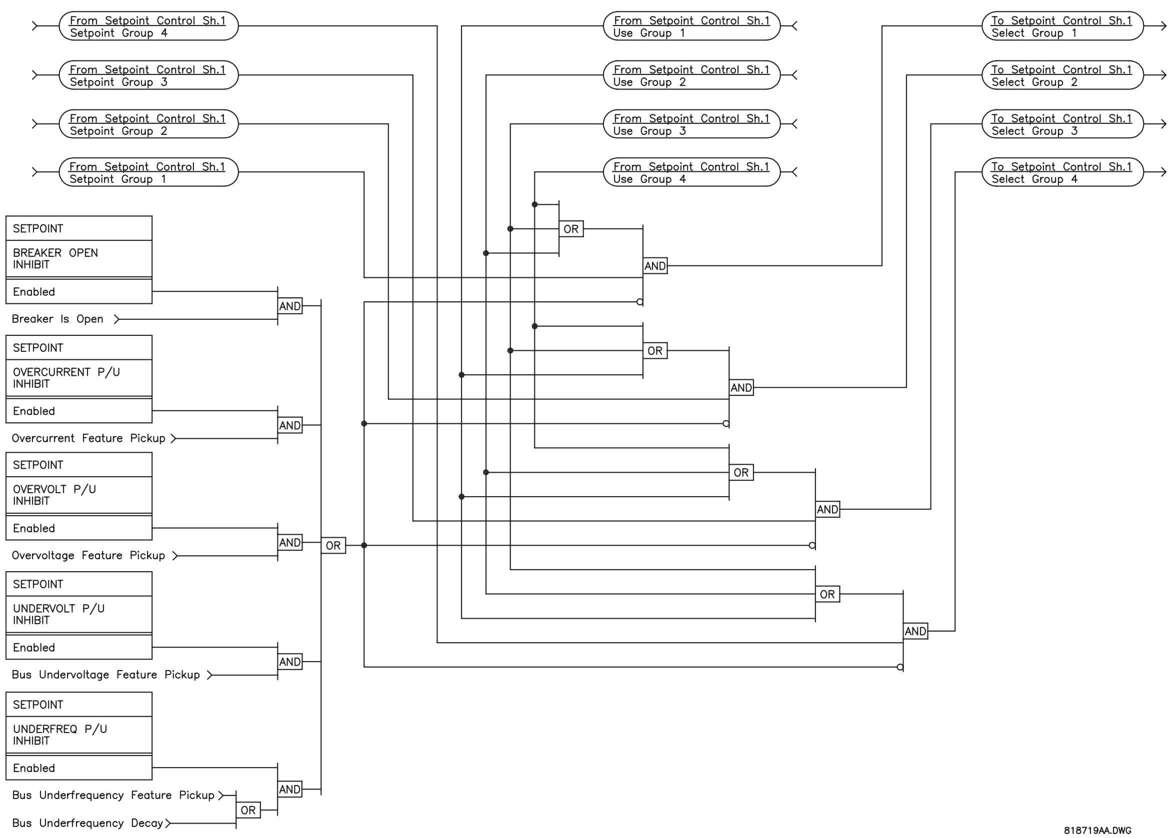

Figure 5–58: SETPOINT CONTROL (2 OF 3)

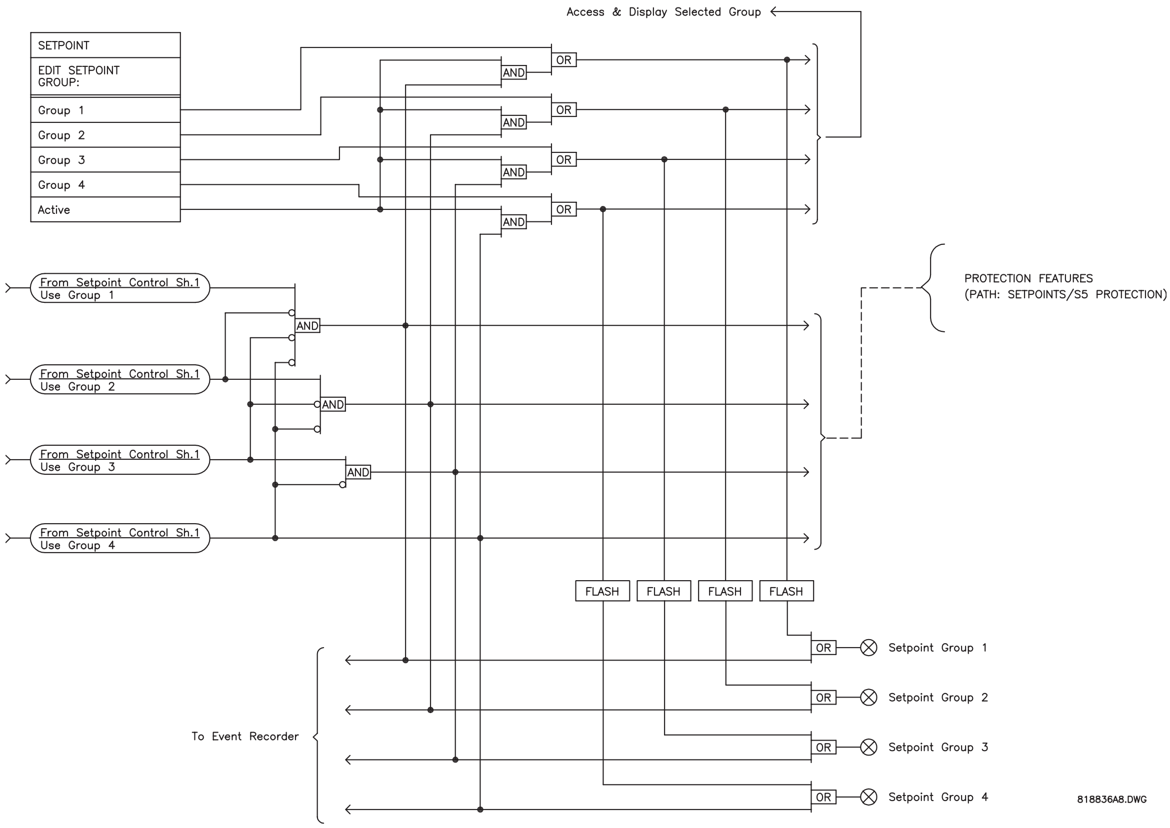

Figure 5–59: SETPOINT CONTROL (3 OF 3)

5.8.2 SYNCHROCHECK

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ SYNCHROCHECK

Message	Range
■ SYNCHROCHECK ■ [ENTER] for more	
SYNCHROCHECK FUNCTION: Disabled	*Range: Disabled, Alarm, Latched Alarm, Control*
SYNCHROCHECK RELAYS (3-7): -----	*Range: Any combination of 3 to 7 Auxiliary relays*
DEAD SOURCE PERMISSIVE: Off	*Range: Off, DB&DL, LL&DB, DL&LB, DL|DB, DLxDB*
DEAD BUS MAX VOLTAGE: 0.20 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
DEAD LINE MAX VOLTAGE: 0.20 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
LIVE BUS MIN VOLTAGE: 0.80 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
LIVE LINE MIN VOLTAGE: 0.80 x VT	*Range: 0.00 to 1.25 x VT in steps of 0.01*
MAX VOLTAGE DIFFERENCE: 2.00 kV	*Range: 0.01 to 100.00 kV in steps of 0.01*
MAX ANGLE DIFFERENCE: 24°	*Range: 0 to 100° in steps of 1*
MAX FREQ DIFFERENCE: 2.00 Hz	*Range: 0.00 to 5.00 Hz in steps of 0.01*

If a breaker can be a paralleling point between two generation sources, it is common practice to automatically perform a check to ensure the sources are within allowable voltage limits before permitting closing of the breaker. Synchrocheck provides this feature by checking that the bus and line input voltages are within the programmed differentials of voltage magnitude, phase angle position, and frequency. If this feature is enabled, the check will be performed before either manual close or automatic reclose signals can operate the Close Output Relay. The synchrocheck programming can allow for permitted closing if either or both of the sources are de-energized. The measured line input voltage magnitude and frequency are also made available as actual values under **A2 METERING ⇨⇩ SYNCHRO VOLTAGE**. The frequency is only displayed if the voltage at the relay terminals is at least 10.0 V. The differential values of angle, magnitude, and frequency are also made available for display.

WARNING **With a Delta connected Bus VT, Phase to Neutral voltages cannot be determined. Thus Synchrocheck cannot be used with a Delta connected Bus VT and a Wye connected Line VT.**

The **DEAD SOURCE PERMISSIVE** setpoint selects the combination of dead and live sources that bypass synchrocheck and permit a breaker closure. The voltage levels that determine whether a source is dead or live are configurable in the four setpoints following this one. The **DEAD SOURCE PERMISSIVE** range is as follows:

"Off": Dead source permissive is disabled.
"DB&DL": Dead Bus AND Dead Line.
"LL&DB": Live Line AND Dead Bus.
"DL&LB": Dead Line AND Live Bus.
"DL|DB": Dead Line OR Dead Bus.
"DLxDB": Dead Line XOR Dead Bus (one source is Dead and one is Live).

For the **DEAD BUS MAX VOLTAGE** and **DEAD LINE MAX VOLTAGE** setpoints, enter the voltage magnitude as a fraction of the bus or line VT input nominal voltage. If the bus or line voltage falls below these values, the single bus/line voltage input used for synchrocheck will be considered "Dead", or de-energized.

For the **LIVE BUS MIN VOLTAGE** and **LIVE LINE MIN VOLTAGE** setpoints, enter the voltage magnitude as a fraction of the bus or line VT input nominal voltage. If the bus or line voltage rises above the respective setting, the single bus or line voltage input used for synchrocheck is established as "Live", or energized.

The voltage, angular, and frequency differences of the primary systems are also entered through the **MAX VOLTAGE DIFFERENCE**, **MAX ANGLE DIFFERENCE**, and **MAX FREQ DIFFERENCE** setpoints, respectively. A voltage magnitude, angular, or frequency differential on the two input voltages below the values entered here is within the permissible limit for synchronism.

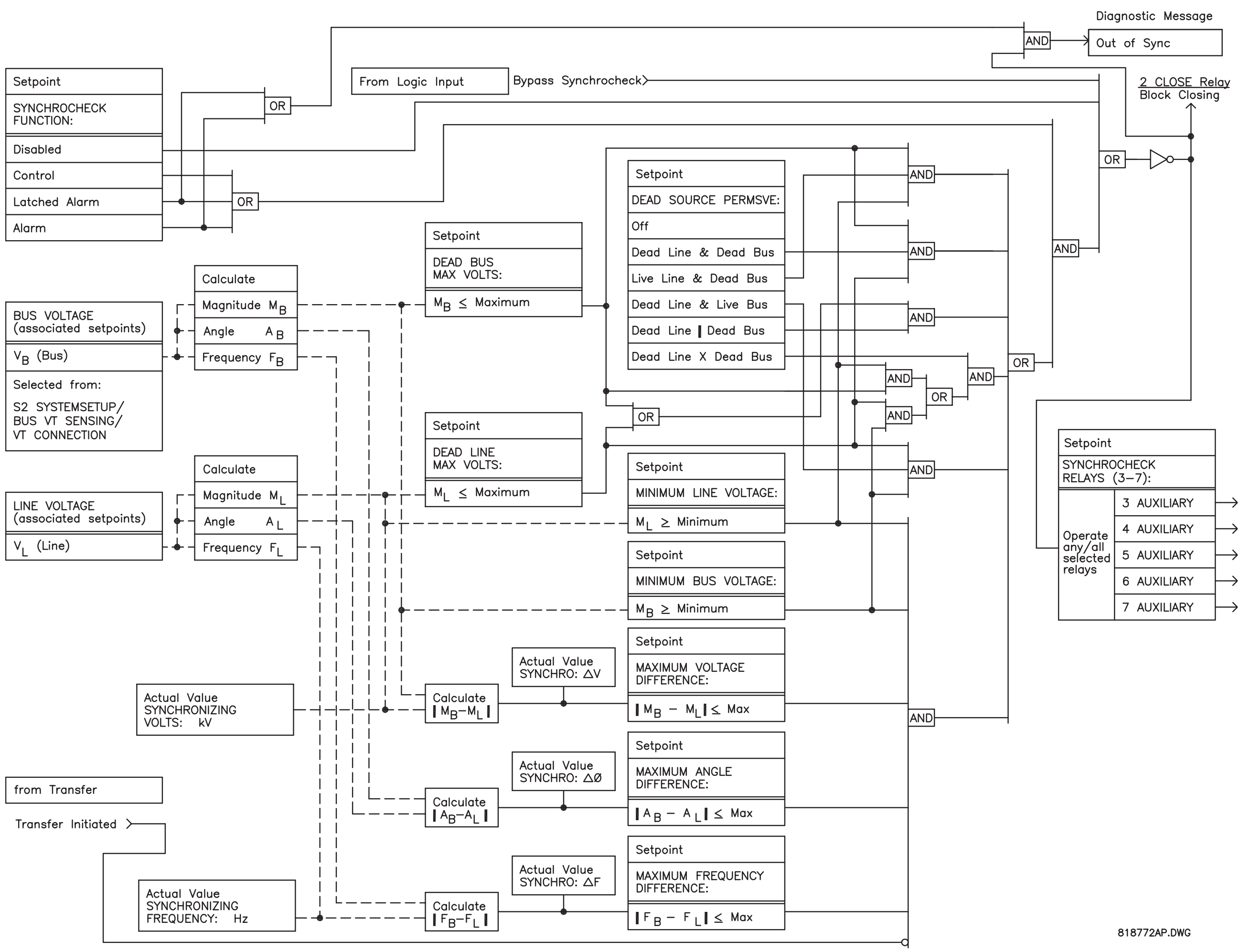

Figure 5–60: SYNCHROCHECK LOGIC

5.8.3 MANUAL CLOSE BLOCKING

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ MANUAL CLOSE

Message	Display	Range
■ MANUAL CLOSE ■ [ENTER] for more	ENTER / ESCAPE	
	MANUAL CLOSE FUNCTION: Disabled	Range: Disabled, Alarm, Latched Alarm, Control
ESCAPE / MESSAGE	MANUAL CLOSE RELAYS (3-7): -----	Range: Any combination of 3 to 7 Auxiliary relays
ESCAPE / MESSAGE	MANUAL CLOSE BLOCK TIME: 5 s	Range: 1 to 1000 s in steps of 1
ESCAPE / MESSAGE	PHASE INST OC 1 BLOCKING: Disabled	Range: Disabled, Enabled
ESCAPE / MESSAGE	NEUTRAL INST OC 1 BLOCKING: Disabled	Range: Disabled, Enabled
ESCAPE / MESSAGE	GND INST OC BLOCKING: Disabled	Range: Disabled, Enabled
ESCAPE / MESSAGE	SENSTV GND INST OC BLOCKING: Disabled	Range: Disabled, Enabled
ESCAPE / MESSAGE	NEG SEQ INST OC BLOCKING: Disabled	Range: Disabled, Enabled
ESCAPE / MESSAGE	PHASE TIME OC 1 RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
ESCAPE / MESSAGE	NEUTRAL TIME OC 1 RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
ESCAPE / MESSAGE	GND TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
ESCAPE / MESSAGE	SENSTV GND TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
ESCAPE / MESSAGE	NEG SEQ TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
ESCAPE / MESSAGE	SELECT SETPOINT GROUP: Active Group	Range: Group 1, Group 2, Group 3, Group 4, Active Group

The 750/760 can be programmed to block instantaneous overcurrent elements and raise the pickup level of time overcurrent elements when a manual breaker close is performed. This prevents optimally set overcurrent elements from erroneously operating on startup due to inrush currents.

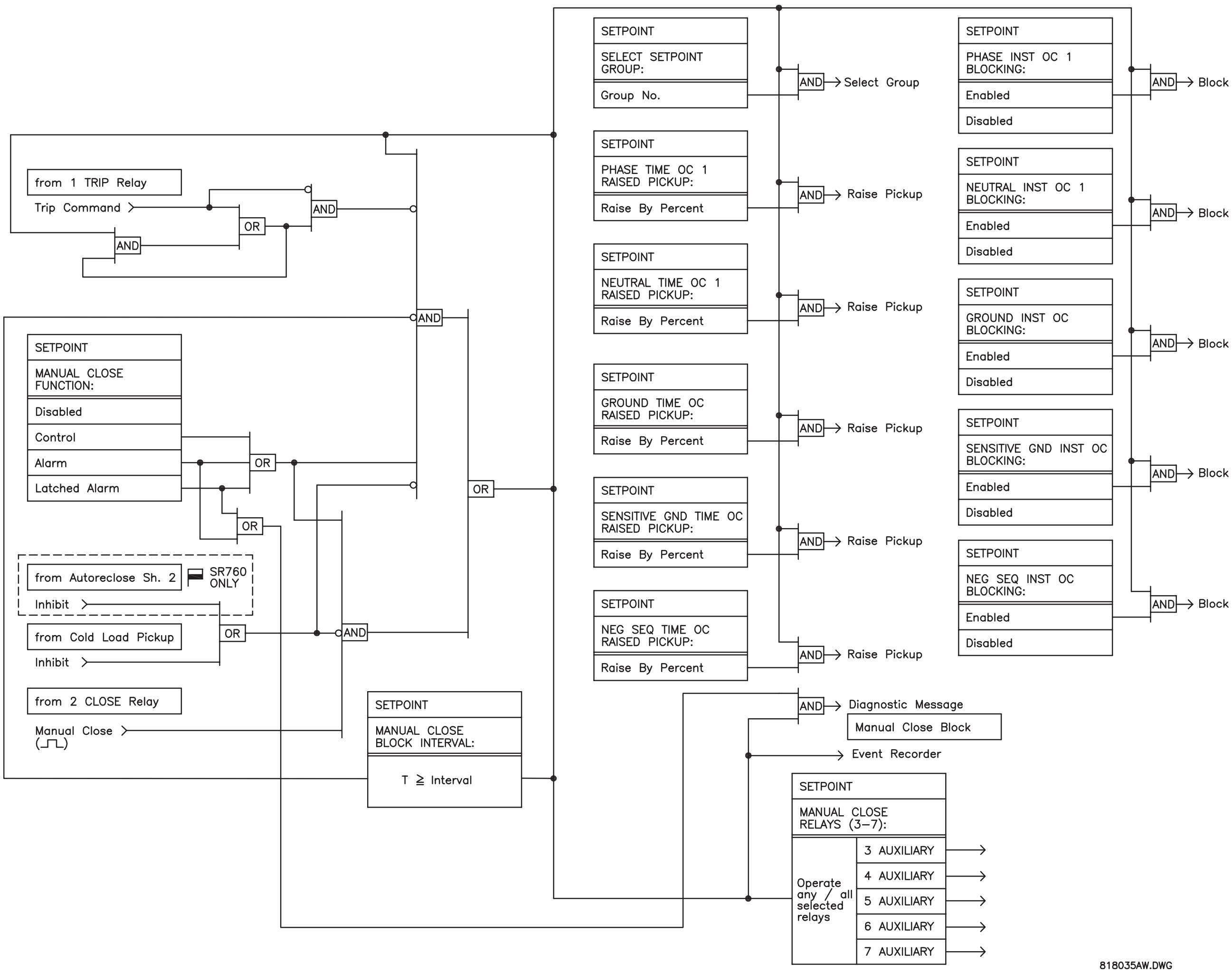

Figure 5–61: MANUAL CLOSE BLOCKING LOGIC

5.8.4 COLD LOAD PICKUP BLOCKING

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ COLD LOAD PICKUP

■ COLD LOAD PICKUP ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	COLD LOAD PICKUP FUNCTION: Disabled	Range: Disabled, Alarm, Latched Alarm, Control
	ESCAPE / MESSAGE ⇳	COLD LOAD PICKUP RELAYS (3-7): -----	Range: Any combination of 3 to 7 Auxiliary relays
	ESCAPE / MESSAGE ⇳	OUTAGE TIME BEFORE COLD LOAD: 100 min	Range: 1 to 1000 min. in steps of 1
	ESCAPE / MESSAGE ⇳	COLD LOAD PICKUP BLOCK TIME: 5 s	Range: 1 to 1000 s in steps of 1
	ESCAPE / MESSAGE ⇳	PHASE INST OC 1 BLOCKING: Disabled	Range: Disabled, Enabled
	ESCAPE / MESSAGE ⇳	NEUTRAL INST OC 1 BLOCKING: Disabled	Range: Disabled, Enabled
	ESCAPE / MESSAGE ⇳	GND INST OC BLOCKING: Disabled	Range: Disabled, Enabled
	ESCAPE / MESSAGE ⇳	NEG SEQ INST OC BLOCKING: Disabled	Range: Disabled, Enabled
	ESCAPE / MESSAGE ⇳	PHASE TIME OC 1 RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
	ESCAPE / MESSAGE ⇳	NEUTRAL TIME OC 1 RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
	ESCAPE / MESSAGE ⇳	GND TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
	ESCAPE / MESSAGE ⇳	NEG SEQ TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
	ESCAPE / MESSAGE ⇧	SELECT SETPOINT GROUP: Active Group	Range: Group 1, Group 2, Group 3, Group 4, Active Group

The 750/760 can be programmed to block instantaneous overcurrent elements and to raise the pickup level of time overcurrent elements when a cold load condition is detected. Under normal operating conditions, the actual load on a feeder is less than the maximum connected load, since not all consumers require maximum load at the same time. When such a feeder is closed after a prolonged outage, the feeder inrush and motor accelerating current may be above some protection settings. Without historical data on a particular feeder, some utilities assume an initial cold load current of about 500% of normal load, decaying to 300% after one second, 200% after 2 seconds, and 150% after 4 seconds. See the figure below.

A cold load condition is initiated and overcurrent settings are altered when all phase currents drop below 5% of the nominal current for an amount of time greater than the **OUTAGE TIME BEFORE COLD LOAD** setpoint. The cold load condition can also be immediately initiated by asserting the logic input function ‘Cold Load Pickup’. Overcurrent settings are returned to normal after any phase current is restored to greater than 10% of nominal and then a timer of duration equal to **COLD LOAD PICKUP BLOCK TIME** expires.

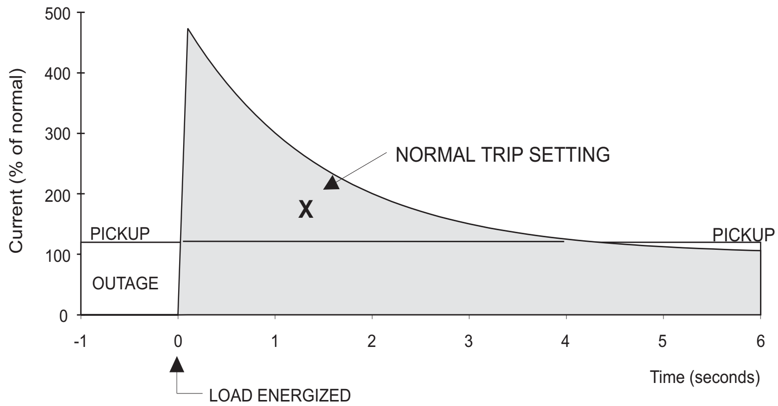

Figure 5–62: COLD LOAD PICKUP

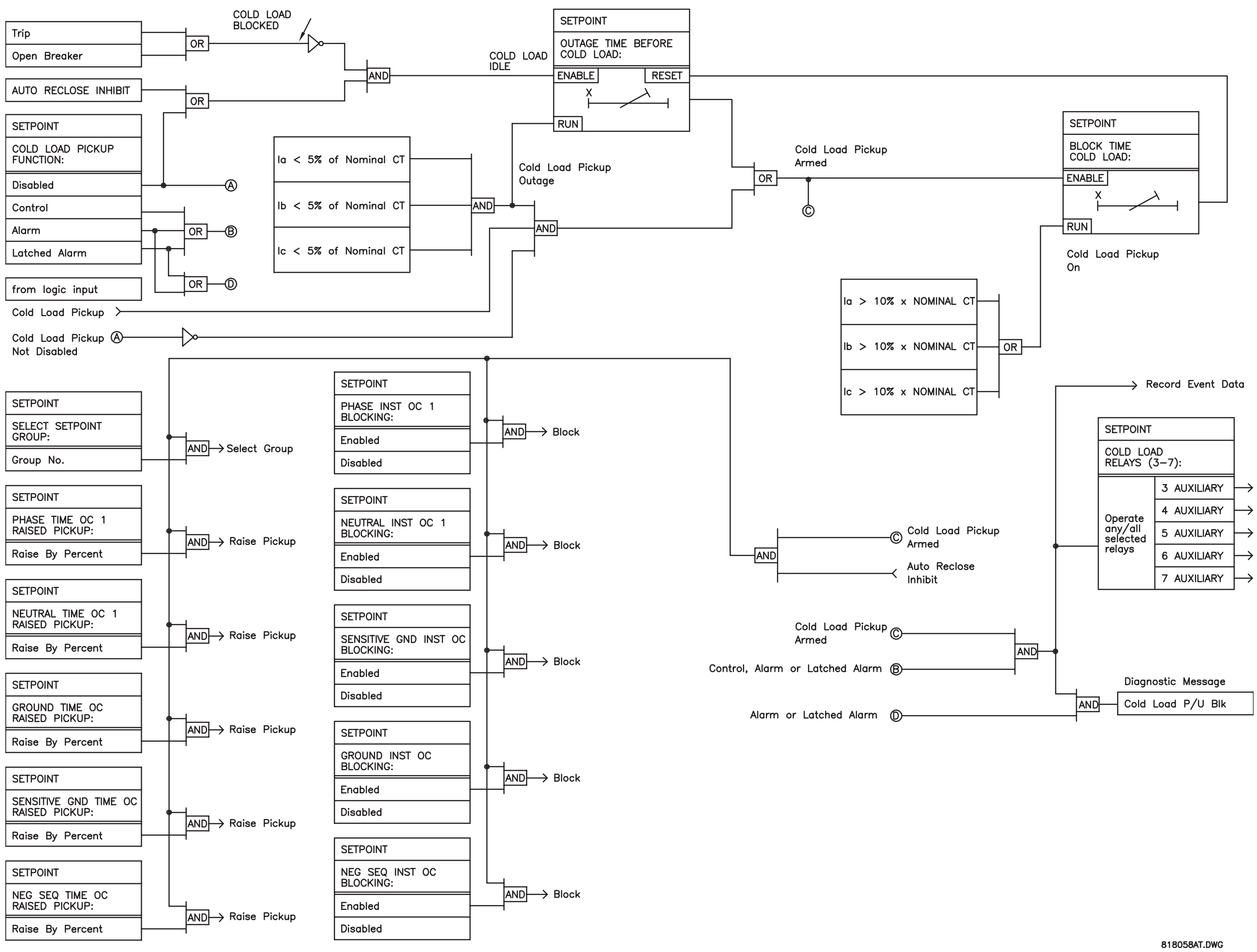

Figure 5–63: COLD LOAD PICKUP LOGIC

5

5.8.5 UNDERVOLTAGE RESTORATION

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ UNDERVOLT RESTORE

Message	Display	Range
■ UNDERVOLT RESTORE ■ [ENTER] for more		
ENTER ⇨ / ⇦ ESCAPE	UNDERVOLT RESTORE FUNCTION: Disabled	Range: *Disabled, Alarm, Latched Alarm, Control*
ESCAPE / MESSAGE ⇳	UNDERVOLT RESTORE RELAYS (3-7): -----	Range: *Any combination of 3 to 7 Auxiliary relays*
ESCAPE / MESSAGE ⇳	UNDERVOLT RESTORE SOURCE: Bus	Range: *Bus, Line*
ESCAPE / MESSAGE ⇳	PHASES REQUIRED FOR OPERATION: All Three	Range: *Any One, Any Two, All Three. Seen only if* **UNDERVOLT RESTORE SOURCE** *is "Bus"*
ESCAPE / MESSAGE ⇳	UNDERVOLT RESTORE MIN VOLTS: 0.90 x VT	Range: *0.00 to 1.25 x VT in steps of 0.01*
ESCAPE / MESSAGE ⇳	UNDERVOLT RESTORE DELAY: 10 s	Range: *0 to 10000 s in steps of 1*
ESCAPE / MESSAGE ⇧	INCOMPLETE SEQUENCE TIME: 100 min	Range: *1 to 10000 min. in steps of 1*

This scheme is initiated by a trip of either the Bus or Line Undervoltage elements. After the feeder breaker has been tripped, it will display the **UVolt Restore Init** message and operate any programmed output relays. Once initiated it will monitor the bus voltage level, and send a close command to the Close Relay when the voltage on the programmed number of phases has risen above the programmed level for a selected time interval. The scheme is equipped with an incomplete sequence timer, so it will not remain initiated for an indeterminate time, but will automatically reset if the voltage does not recover during the programmed interval. Initiation of the scheme can be canceled by a reset command. Cancellation of a previous initiation is only effective if the voltage is above the restoration threshold. A “Block Restoration” logic input is available to prevent both initiation and operation. It is recommended that if automatic undervoltage restoration is to be used, that the cold load pickup feature is also enabled, to prevent the breaker from tripping shortly after it is automatically closed.

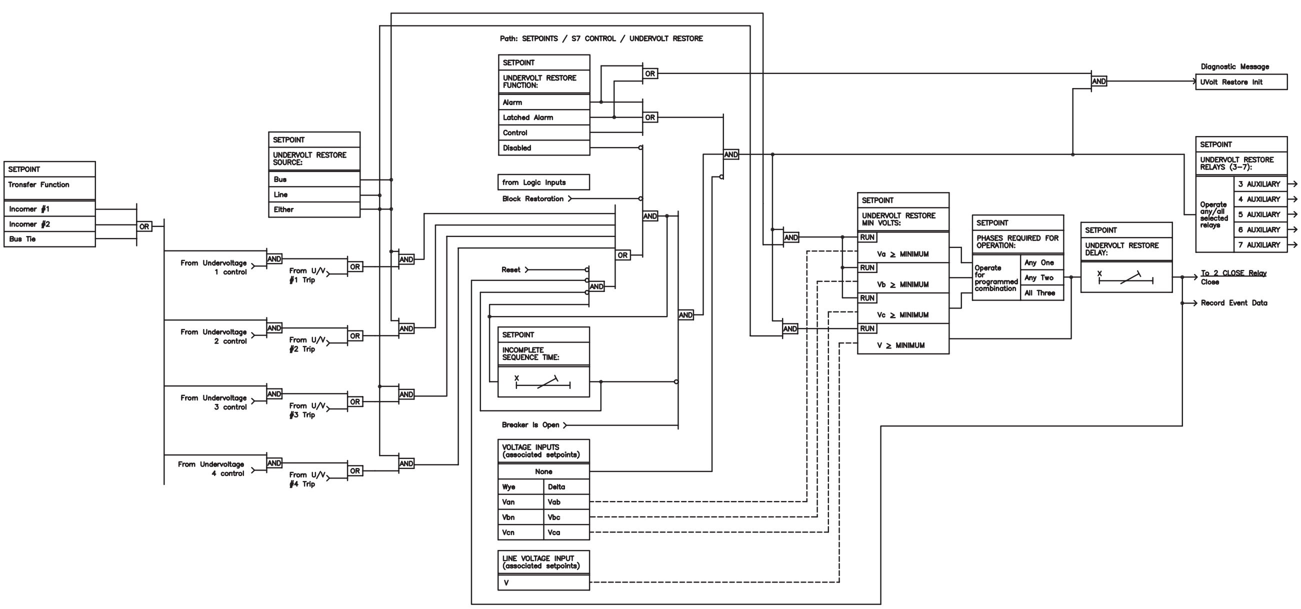

Figure 5–64: UNDERVOLTAGE RESTORATION LOGIC

5.8.6 UNDERFREQUENCY RESTORATION

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ UNDERFREQ RESTORE

■ UNDERFREQ RESTORE ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	UNDERFREQ RESTORE FUNCTION: Disabled	Range: *Disabled, Alarm, Latched Alarm, Control*
	ESCAPE / MESSAGE ⇳	UNDERFREQ RESTORE RELAYS (3-7): -----	Range: *Any combination of 3 to 7 Auxiliary relays*
	ESCAPE / MESSAGE ⇳	UNDERFREQ RESTORE MIN VOLTS: 0.90 x VT	Range: *0.00 to 1.25 x VT in steps of 0.01*
	ESCAPE / MESSAGE ⇳	UNDERFREQ RESTORE MIN FREQ: 59.90 Hz	Range: *20.00 to 65.00 Hz in steps of 0.01*
	ESCAPE / MESSAGE ⇳	UNDERFREQ RESTORE DELAY: 10 s	Range: *0 to 10000 s in steps of 1*
	ESCAPE / MESSAGE ⇧	INCOMPLETE SEQUENCE TIME: 100 min	Range: *1 to 10000 min. in steps of 1*

This scheme is initiated by a trip of either the Bus Underfrequency elements. After the feeder breaker has been tripped, it will display the **UFreq Restore Init** and operate any programmed output relays. Once initiated it will monitor the bus voltage level and frequency, and send a close command to the Close Relay when the voltage on the phase A input has risen above the programmed minimum level and frequency for a selected time interval. The scheme is equipped with an incomplete sequence timer, so it will not remain initiated for an indeterminate time, but will automatically reset if the voltage does not recover during the programmed interval. Initiation of the scheme can be canceled by a reset command. Cancellation of a previous initiation is only effective if the voltage and frequency are above the restoration thresholds. A “Block Restoration” logic input is available to prevent both initiation and operation. It is recommended that if automatic underfrequency restoration is to be used, that the cold load pickup feature is also enabled, to prevent the breaker from tripping shortly after it is automatically closed.

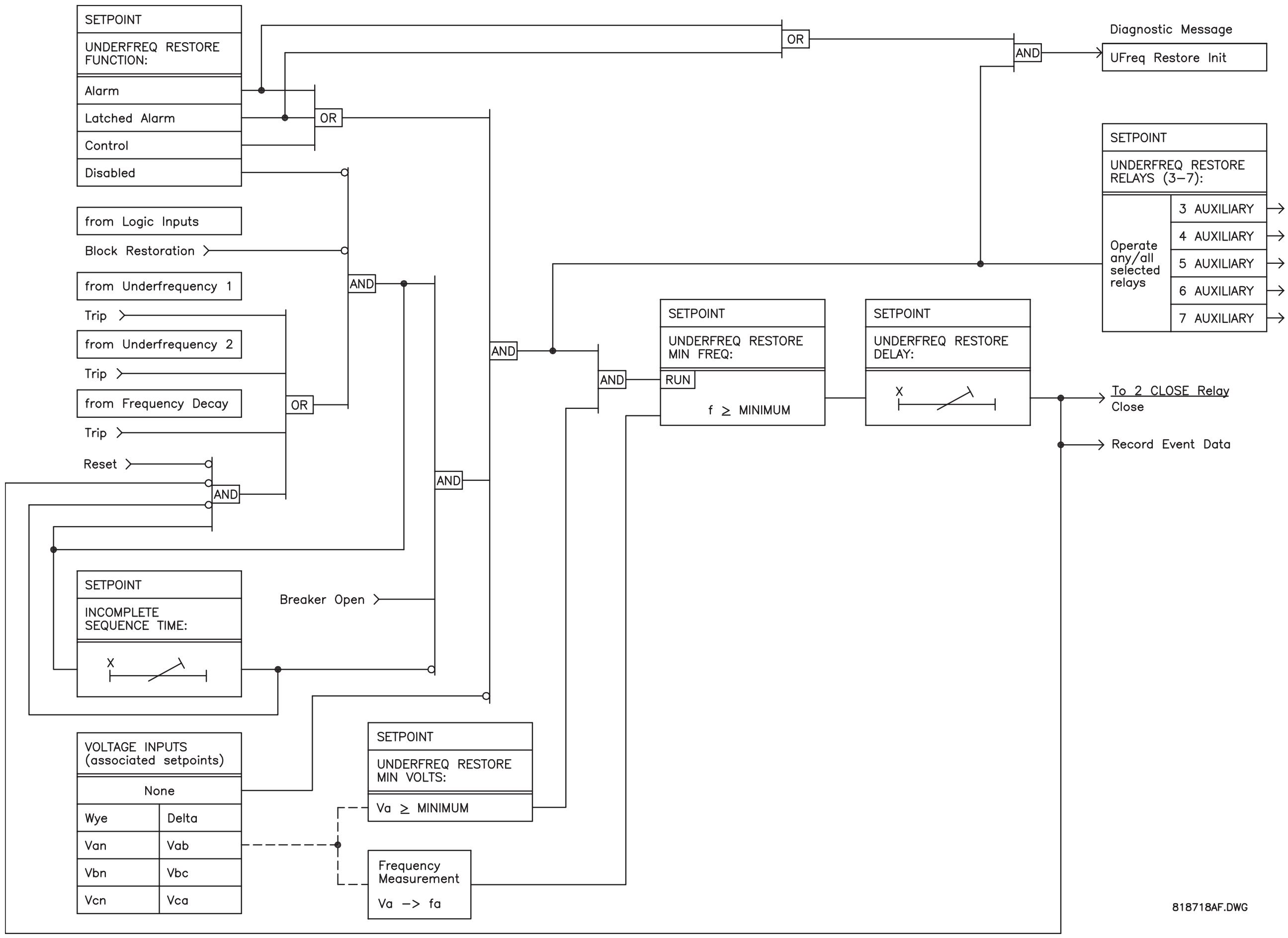

Figure 5–65: UNDERFREQUENCY RESTORATION LOGIC

5.8.7 TRANSFER

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ TRANSFER

Message	Range
■ TRANSFER ■ [ENTER] for more	
TRANSFER FUNCTION: Disabled	*Range: Disabled, Incomer 1, Incomer 2, Bus Tie*
TRANSFER DELAY THIS SOURCE: 1.0 s	*Range: 0.0 to 10.0 s in steps of 0.1*
TRANSFER DELAY OTHER SOURCE: 3.0 s	*Range: 0.0 to 10.0 s in steps of 0.1*
BLOCK TRIP ON DOUBLE LOSS: Disabled	*Range: Disabled, Enabled*

The Transfer scheme is intended for application to a set of three circuit breakers, two of which, (Incomers 1 and 2) connect sources of electrical energy to two busses which can be paralleled through the Bus Tie breaker. Normal configuration of the system is with both incoming breakers closed and the bus tie breaker open. Figure 5–58: Setpoint Control (2 of 3) on page 5–96 shows this arrangement. The equipment designations on this drawing will be used in the discussion.

The transfer scheme minimizes the effect of outages on one of the incoming supplies by opening the incoming breaker connected to that supply, and then re-energizing the dead bus by closing the bus tie breaker to transfer the dead bus to the live source. To protect against damage to motors connected to the dead bus, the bus tie breaker is not allowed to close, after a transfer has been initiated, until the decaying (residual) voltage on the bus has been reduced to a safe level.

After the lost source has been reestablished, the scheme provides three methods to restore the system to normal configuration, two manual and one automatic. If the sources cannot be synchronized, the bus tie breaker must be manually opened before the open incomer can be manually closed. In this procedure the incomer will only be allowed to close if the incoming source (Line VT) voltage is above a live threshold and the load (Bus VT) voltage is below a dead threshold value. If the sources are synchronized with synchrocheck supervision, it is possible to manually close the open incomer to parallel all three breakers. The scheme will then automatically open a breaker that had been previously selected to trip if all three breakers become closed. In this instance, the bus tie breaker is 'Selected To Trip' and will open. The automatic method of returning the system to normal configuration uses the undervoltage tripped portion of the restoration scheme.

In addition to the relay required for each of the three circuit breakers, it is required to connect one contact from a three-position switch to each relay. This switch (Device 43/10) is used to select the breaker that will trip after all breakers become closed. It is also recommended that a two-position switch (Device 43/83) with three contacts be connected to each relay as an "Auto-Off" transfer scheme selector.

Because a relay is required on the bus tie breaker, it allows bus-splitting operation. This is accomplished by setting the time overcurrent elements in the relay on the bus tie breaker to trip faster than the incomers, opening the bus tie before an incomer when operating from only one source.

The scheme can be used in conjunction with both non-drawout and drawout switchgear. Drawout switchgear designs can make use of an auxiliary switch that confirms that the monitored breaker is in the "Connected" position, and is therefore ready for operation. Fixed breaker installations can use contacts on the associated isolating disconnect switches (if available) for this purpose. The scheme design can be applied to:

1. Substations with no signaling from upstream equipment.
2. Substations with an upstream circuit breaker equipped with a trip signal (Device 94).
3. Substations with a source transformer and transformer fault detection signal (Device 86T).
4. Both 1 and 2 above.

The only differences in implementing the transfer scheme among the configurations presented above is by connecting additional logic signals to the relay when available and by placing a jumper on one logic input if the breaker is non-drawout and has no disconnect auxiliary switches.

Besides the setpoints and logic incorporated into the transfer scheme, the relays make use of some or all of the logic inputs, phase instantaneous (Device 50P-1 or 2), neutral overcurrent (Device 50N-1 or 2), both line undervoltage elements (Devices 27-3 and 27-4), and the synchrocheck (Device 25) features of the relays.

The following discussion is based on Configuration 4 above, using drawout breakers. Schematic diagrams of the DC connections required by an example scheme with this configuration are presented in the schematics on pages 5–111 to 5–113. Logic for each relay of the scheme is presented in the logic diagrams on pages 5–114 to 5–116. Connections that are not required for configurations other than Configuration 3 above are indicated as "optional" on the schematic diagrams.

NOTE

All connections for AC voltage and current are outlined in Chapter 3. The scheme design requires that the AC voltage connections for 'Line' and 'Bus' sources on the incomer relays be in accordance with Figure 5–66: Transfer Scheme One Line Diagram on page 5–110 regardless of configuration. The connection of AC voltage to the relay on the bus tie does not affect operation of the scheme, **but** the connection to the line voltage input terminals must be a phase-phase voltage.

For the following discussion assume that Source 1 is the failed side. Identical logic with all 1s and 2s interchanged applies to Relay 2 for a loss of Source 2. A transfer (trip of Incomer 1 followed by Bus Tie closing) from Relay 1 can be initiated by:

- Operation of transformer 1 lockout relay (Device 86T1).
- Operation of the Source 1 breaker auxiliary trip device (Device 94-1).
- Time out of Relay 1 line voltage inverse time undervoltage element (Device 27-4) caused by low voltage on Source 1.

A transfer initiation is blocked if:

- Any of the three breakers is not in the connected state.
- Incoming Breaker 2 (which is to become the new source) is presently open.
- An overcurrent condition on Bus 1 is detected by Devices 50P-1 or 2 or 50N-1 or 2, to prevent a faulted bus from being transferred to a healthy source.
- The line definite time Undervoltage element (Device 27-3) on Source 2 is operated, indicating low voltage on the other source.

Once a condition has caused Relay 1 to initiate a transfer, including the close signal to Relay 3 on the Bus Tie breaker, the command is maintained until Relay 1 determines that Breaker 1 has opened. When Relay 3 receives the close command from Relay 1, it is captured and retained until either the Bus Tie breaker closes or the Block Transfer logic input is received. Relay 3 is inhibited from initiating a close command to Breaker 3 by its synchrocheck element. Synchrocheck provides the bus decayed (residual) voltage permission-to-close, when the Bus 1 voltage decays to the preset level.

The three breakers are under prevent-parallel checking whenever the transfer scheme is operational. If a third breaker is closed when the other two breakers are already closed, the scheme will automatically trip the breaker selected by Switch 43/10, 'Selected To Trip'.

If the transfer scheme is not required, set **TRANSFER FUNCTION** to "Disabled". If not disabled, this setpoint assigns the function of the associated circuit breaker to the relay. This selection programs the relay to use the logic required by each of the three breakers. Select "Incomer 1" or "Incomer 2" for this setpoint if the relay is associated with the breaker to be used as Incomer 1 or 2 respectively. Select "Bus Tie" if the relay is associated with the bus tie breaker.

The **TRANSFER DELAY THIS SOURCE** time establishes an interval from the reset of an operated instantaneous overcurrent element on this source, during which the line instantaneous undervoltage element (Device 27-3) is allowed to block a transfer. The **TRANSFER DELAY OTHER SOURCE** delay time prevents transfers that could otherwise be caused by a non-simultaneous return of source voltages after a loss of both sources. It establishes an interval from the return of the first source to the return of the second source during which a transfer cannot be initiated.

The **BLOCK TRIP ON DOUBLE LOSS** setpoint selects the required scheme operation in the event of a simultaneous loss of both Source 1 and Source 2. If it is desired to have both of the Incomers trip on timed undervoltage when this occurs, select "Disabled". If it is desired to prevent the Incomers from tripping on timed undervoltage when this occurs, select "Enabled". With either selection a transfer-initiated close of the bus tie breaker is not allowed.

The settings and functions of other elements associated with the transfer scheme are shown below:

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- **Output Relays 4-7 Auxiliary (all breakers):** These output relays are used to implement the transfer scheme, and must therefore not be operated by any other feature of the relay. These relays must be programmed to have a non-operated state of 'De-energized' with the output type as 'Self-reset'. These are the default settings.
- **Instantaneous Phase (50P1 or 2) and Neutral (50N-1 or 2) [Incomers 1 and 2 only]:** These fault detectors can be used as an input to transfer scheme logic in this application, and therefore the function setpoint of elements that are used must be set to Control. These elements block a transfer while a fault, which can cause a severe voltage dip, is present on the load side of the breaker. This fault should be cleared by time overcurrent protection on the incomer or an upstream breaker. If Device 50P is set properly, during this event it will allow Device 27-4 to time out before the inverse time phase overcurrent operates, but still prevent transfer initiation. The 50P element should be set above the maximum current caused by either the bus motor contribution to an upstream fault, or the maximum current during low voltage conditions. The 50N element should be set to detect arcing ground faults, but allow permitted unbalances.
- **Line Undervoltage 3 (27-3) [Incomers 1 and 2 only]:** Since element is used as an input to transfer scheme logic in this application, set **LINE UNDERVOLTAGE 3 FUNCTION** to "Control". An Undervoltage 3 operation signals Relay 2 to block transfer initiation from that relay, as Source 1 is experiencing low voltage. Also, Device 27-3 is enabled by instantaneous overcurrent to block transfer initiation. This ensures that if a fault on the load side of Bus 1 causes a dip below the undervoltage pickup setting, transfer will not be initiated until the voltage has risen above the voltage setting for the interval established by the **TRANSFER DELAY THIS SOURCE** setpoint. The Device 27-3 pickup setting should be below the minimum expected normal (low) voltage, usually around 0.9 of pickup voltage. A Definite Time curve with the delay set to zero provides instantaneous operation. The minimum operating voltage must be set to zero.

  Line Undervoltage 4 (27-4) [Incomers 1 and 2 only]: Since this element is used as a transfer scheme logic input in this application, set **LINE UNDERVOLTAGE 4 FUNCTION** to "Control". An Undervoltage 4 operation initiates a transfer on loss-of-source. Typical settings have a pickup about 0.7 to 0.8 of pickup voltage, an "Inverse Time" curve setting, and a delay setting to provide operation in 0.7 to 1.4 seconds at 0 V. The minimum operating voltage must be set to zero.
- **Synchrocheck (25) [Incomers 1 and 2 only]:** The synchrocheck function can be selected as either Control or Alarm. It is imperative that the **DEAD SOURCE PERMISSIVE** setpoint be "LL&DB" (Live Line and Dead Bus) to allow initial closing of the incoming breakers. The user establishes all other setpoints for this element.

  Synchrocheck (25) [Bus Tie only]: This element is used to provide synchronism check supervision when paralleling the busses. The Dead Source Permissive portion of this feature is also used to measure the residual voltage on the bus that has lost source. To ensure that transfers are supervised by the decayed voltage magnitude only, the 'in-synchronism' elements are blocked while a transfer is in progress. The synchrocheck function can be selected as either Control or Alarm. It is imperative that the **DEAD SOURCE PERMISSIVE** setpoint be either "DL|DB" (Dead Line or Dead Bus) or "DLXDB" (Dead Line or Dead Bus, but not both) to allow for transfers to either incomer.

The **DEAD BUS MAX VOLTAGE** and **DEAD LINE MIN VOLTAGE** setpoints establish the level of decayed voltage above which transfers are inhibited. A normal setting for this element is about 0.25 of pickup of nominal voltage. Because the 750/760 measures a single phase-phase voltage, these values should be multiplied by $1/\sqrt{3}$ to cover the case of a phase-ground fault on a measured phase reducing that phase voltage but leaving the other two phases at a higher voltage. If experience shows this setpoint causes a delay of transfer presenting problems, it is occasionally raised to a maximum of 0.40 of pickup. The user establishes all other setpoints for this element.

The Logic Inputs for Incomers 1 and 2 and the Bus Tie relays are programmed as follows. Note that the input number matches the wiring shown on the DC schematics. It is not necessary that the specific inputs are programmed as shown, but field connections must match the logic functions.

NOTE

If logic inputs identified as optional on the schematics and the following table are not required, they can be programmed to perform other functions. The Message Mode may be programmed to Disabled or Self Reset.

Table 5–17: LOGIC INPUTS FOR INCOMER 1, 2, AND BUS TIE RELAYS

INPUT	INCOMER #1	INCOMER #2	BUS TIE
1	Name: ***Local Mode*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**	Name: ***Local Mode*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**	Name: ***Local Mode*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**
2	Name: ***Remote Close*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**	Name: ***Remote Close*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**	Name: ***Remote Close*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**
3	Name: ***Remote Open*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**	Name: ***Remote Open*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**	Name: ***Remote Open*** Asserted Logic: **Contact Open** **Contact Close** **Open | Von** **Open | Voff** **Closed | Von** **Closed | Voff**
4	Name: ***52a*** or ***52b Contact*** Asserted Logic: **Contact Close**	Name: ***52a*** or ***52b Contact*** Asserted Logic: **Contact Close**	Name: ***52a*** or ***52b Contact*** Asserted Logic: **Contact Close**
5	Name: ***Breaker Connected*** Asserted Logic: **Contact Close**	Name: ***Breaker Connected*** Asserted Logic: **Contact Close**	Name: ***Breaker Connected*** Asserted Logic: **Contact Close**
6	Name: ***Selected To Trip*** Asserted Logic: **Contact Open** **Contact Close**	Name: ***Selected To Trip*** Asserted Logic: **Contact Open** **Contact Close**	Name: ***Selected To Trip*** Asserted Logic: **Contact Open** **Contact Close**
7	Name: ***Undervoltage On Other Source*** Asserted Logic: **Contact Close**	Name: ***Undervoltage On Other Source*** Asserted Logic: **Contact Close**	Name: ***Close From Incomer 1*** Asserted Logic: **Contact Close**
8	Name: ***Incomer 2 Breaker Closed*** Asserted Logic: **Contact Close**	Name: ***Incomer 1 Breaker Closed*** Asserted Logic: **Contact Close**	Name: ***Incomer 1 Breaker Closed*** Asserted Logic: **Contact Close**
9	Name: ***Tie Breaker Connected*** Asserted Logic: **Contact Close**	Name: ***Tie Breaker Connected*** Asserted Logic: **Contact Close**	Name: ***Close From Incomer 2*** Asserted Logic: **Contact Close**
10	Name: ***Tie Breaker Closed*** Asserted Logic: **Contact Close**	Name: ***Tie Breaker Closed*** Asserted Logic: **Contact Close**	Name: ***Incomer 2 Breaker Closed*** Asserted Logic: **Contact Close**
11 (optional)	Name: ***Block Transfer*** Asserted Logic: **Contact Open** **Contact Close**	Name: ***Block Transfer*** Asserted Logic: **Contact Open** **Contact Close**	Name: ***Block Transfer*** Asserted Logic: **Contact Open** **Contact Close**
12 (optional)	Name: ***Transformer Lockout*** Asserted Logic: **Contact Open** **Contact Close**	Name: ***Transformer Lockout*** Asserted Logic: **Contact Open** **Contact Close**	
13 (optional)	Name: ***Source Trip*** Asserted Logic: **Contact Open** **Contact Close**	Name: ***Source Trip*** Asserted Logic: **Contact Open** **Contact Close**	

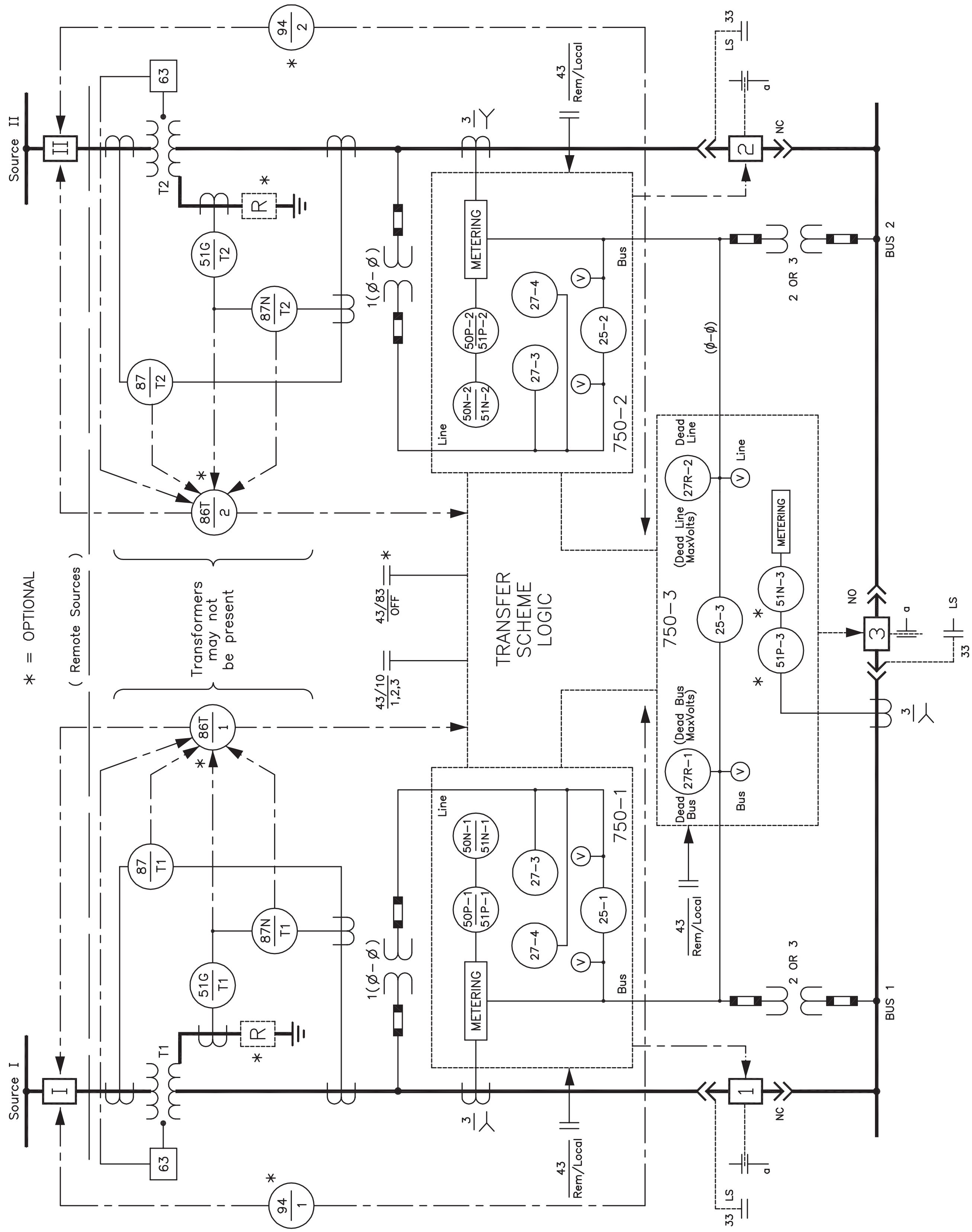

Figure 5–66: TRANSFER SCHEME ONE LINE DIAGRAM

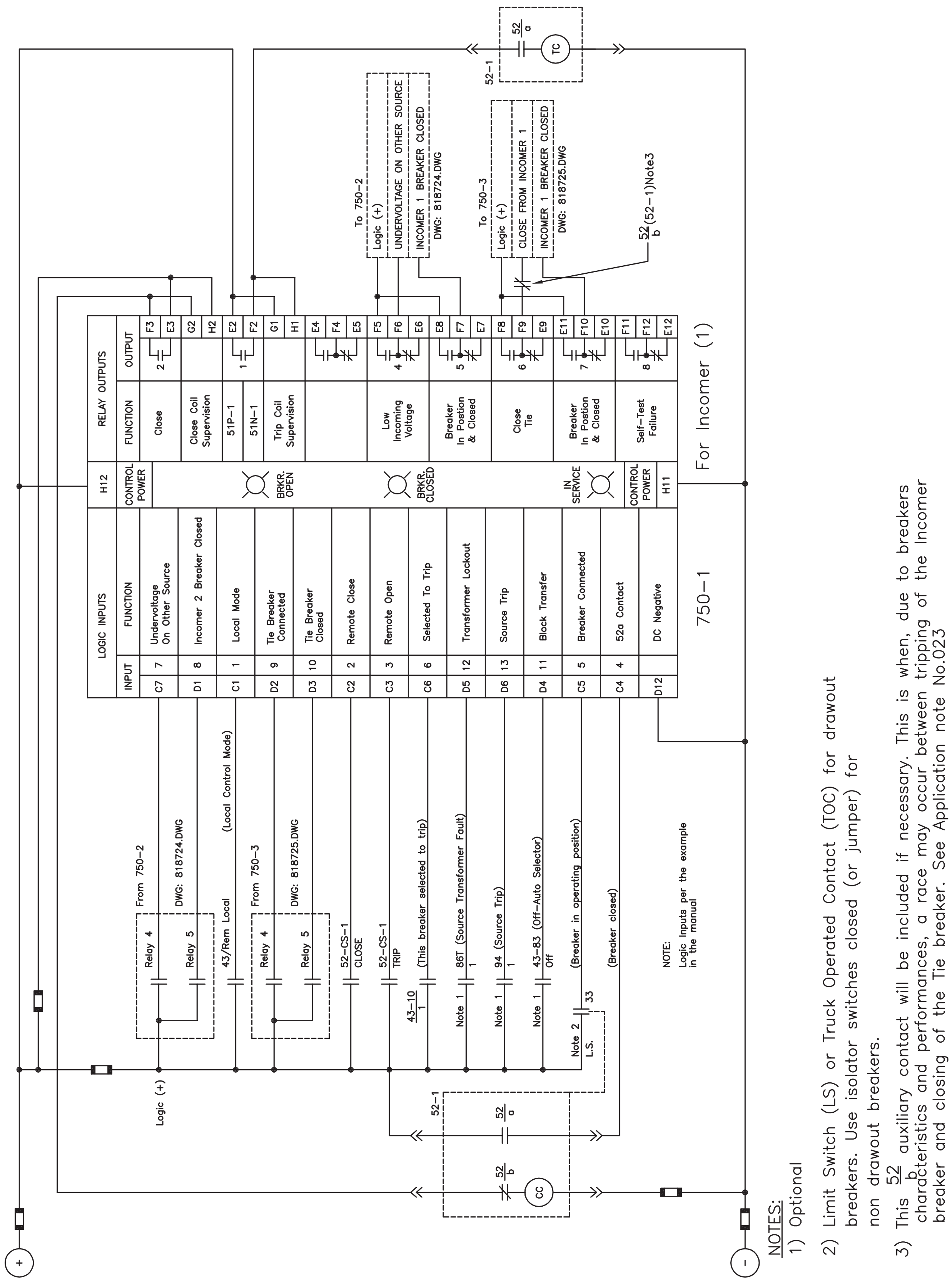

Figure 5–67: TRANSFER SCHEME INCOMER NO. 1 DC SCHEMATIC

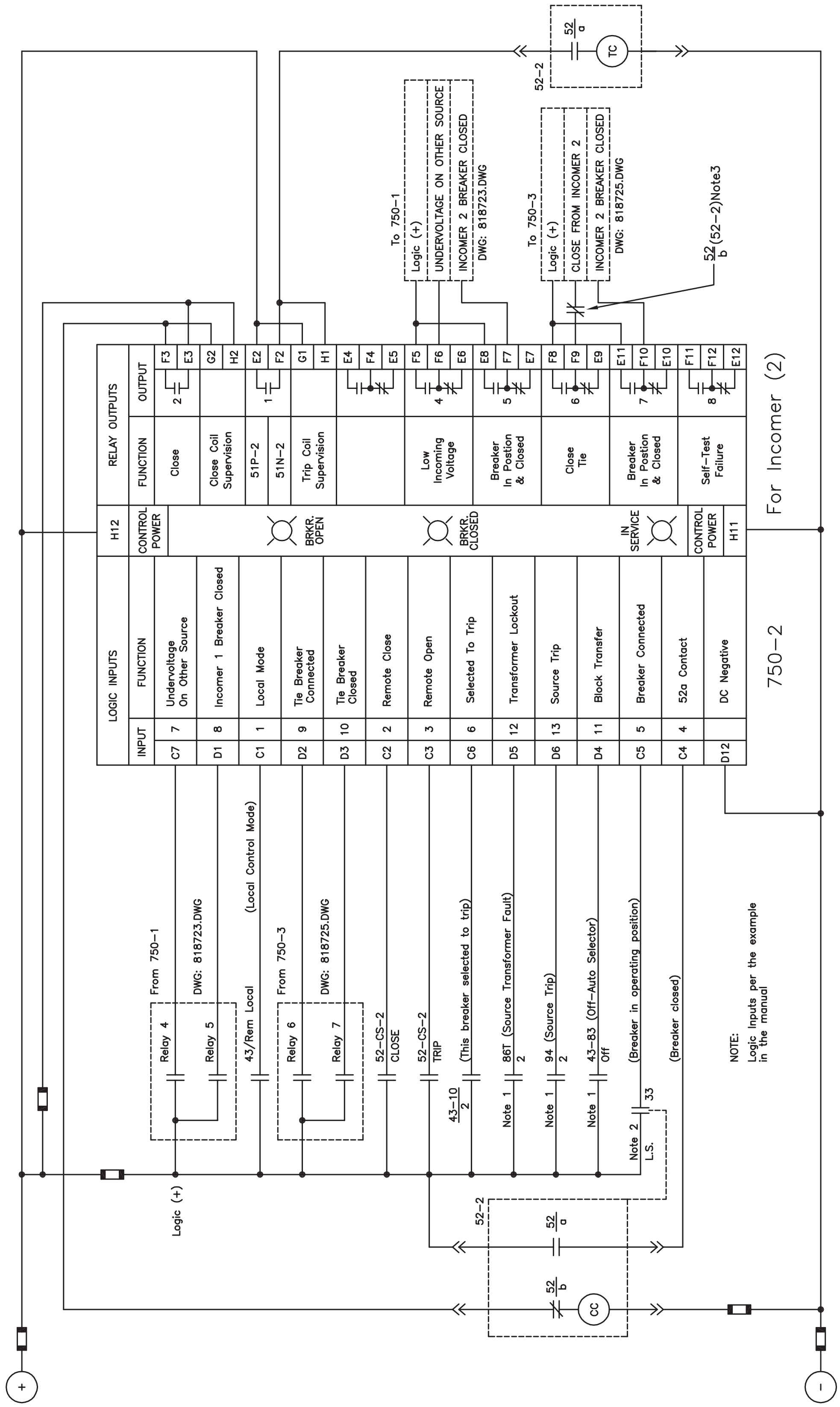

Figure 5–68: TRANSFER SCHEME INCOMER NO. 2 DC SCHEMATIC

NOTES:

1) Optional

2) Limit Switch (LS) or Truck Operated Contact (TOC) for drawout breakers. Use isolator switches closed (or jumper) for non drawout breakers.

3) This 52b auxiliary contact will be included if necessary. This is when, due to breakers characteristics and performances, a race may occur between tripping of the Incomer breaker and closing of the Tie breaker. See Application note No.023

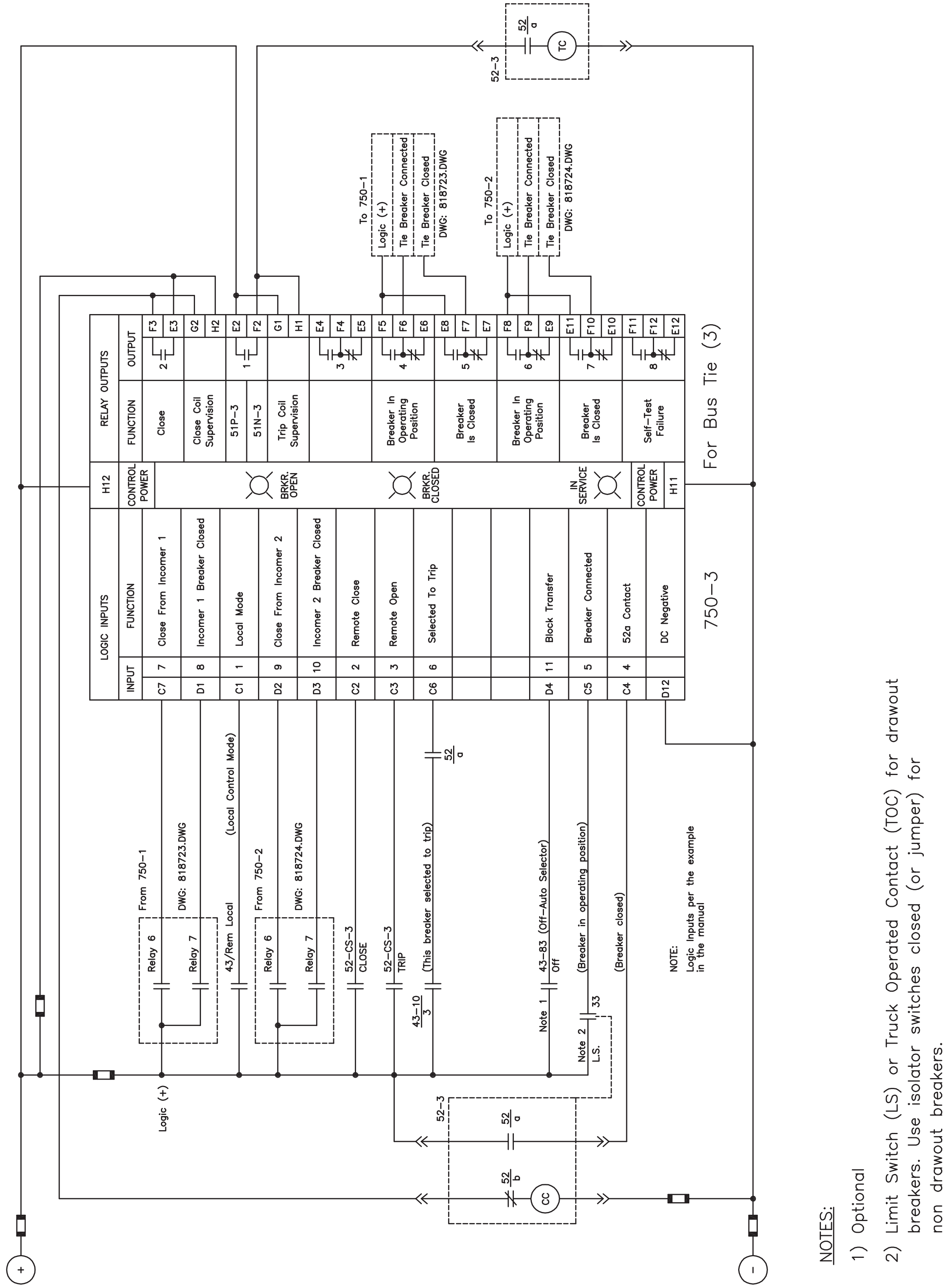

Figure 5–69: TRANSFER SCHEME BUS TIE BREAKER DC SCHEMATIC

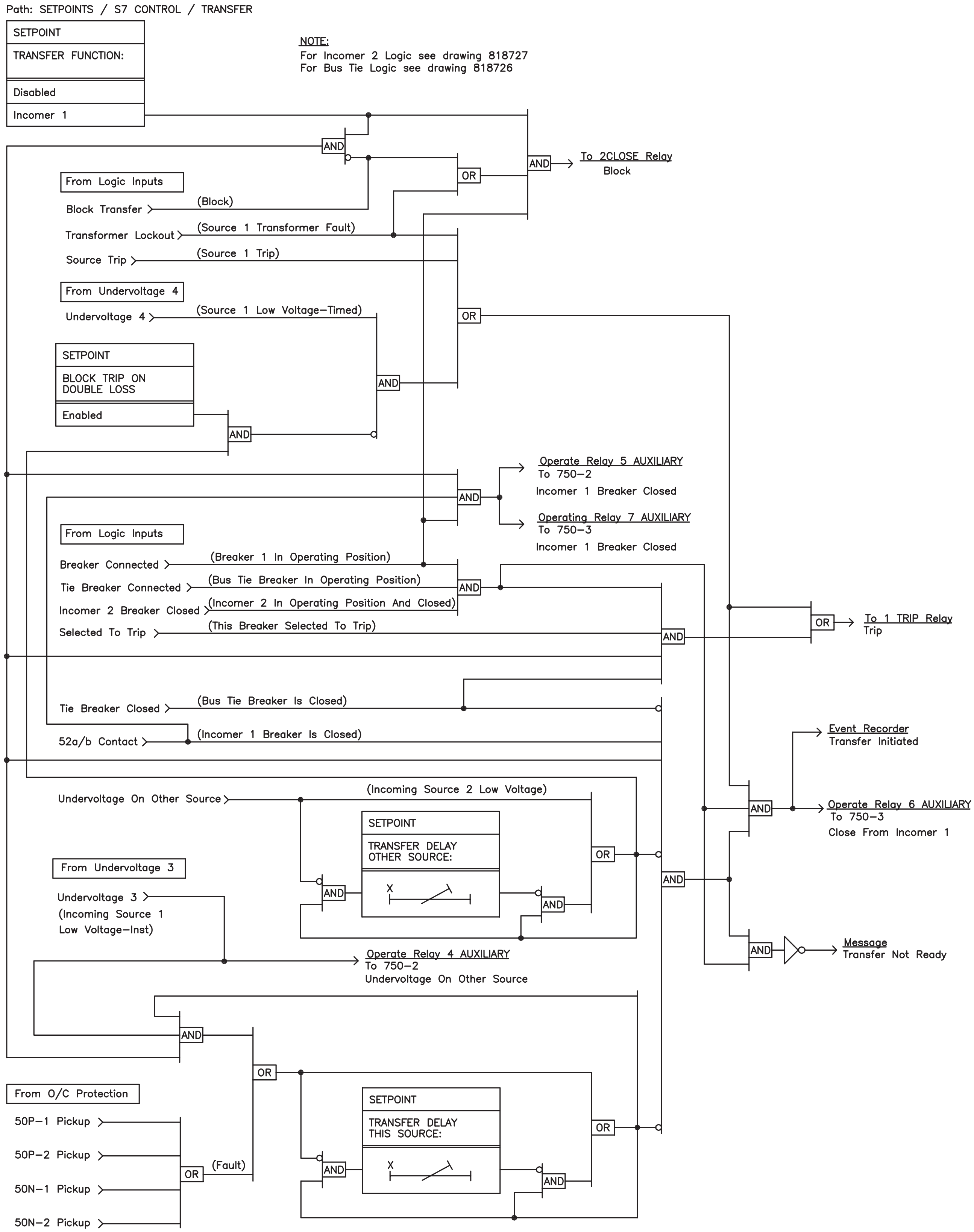

Figure 5–70: TRANSFER SCHEME INCOMER NO. 1 LOGIC

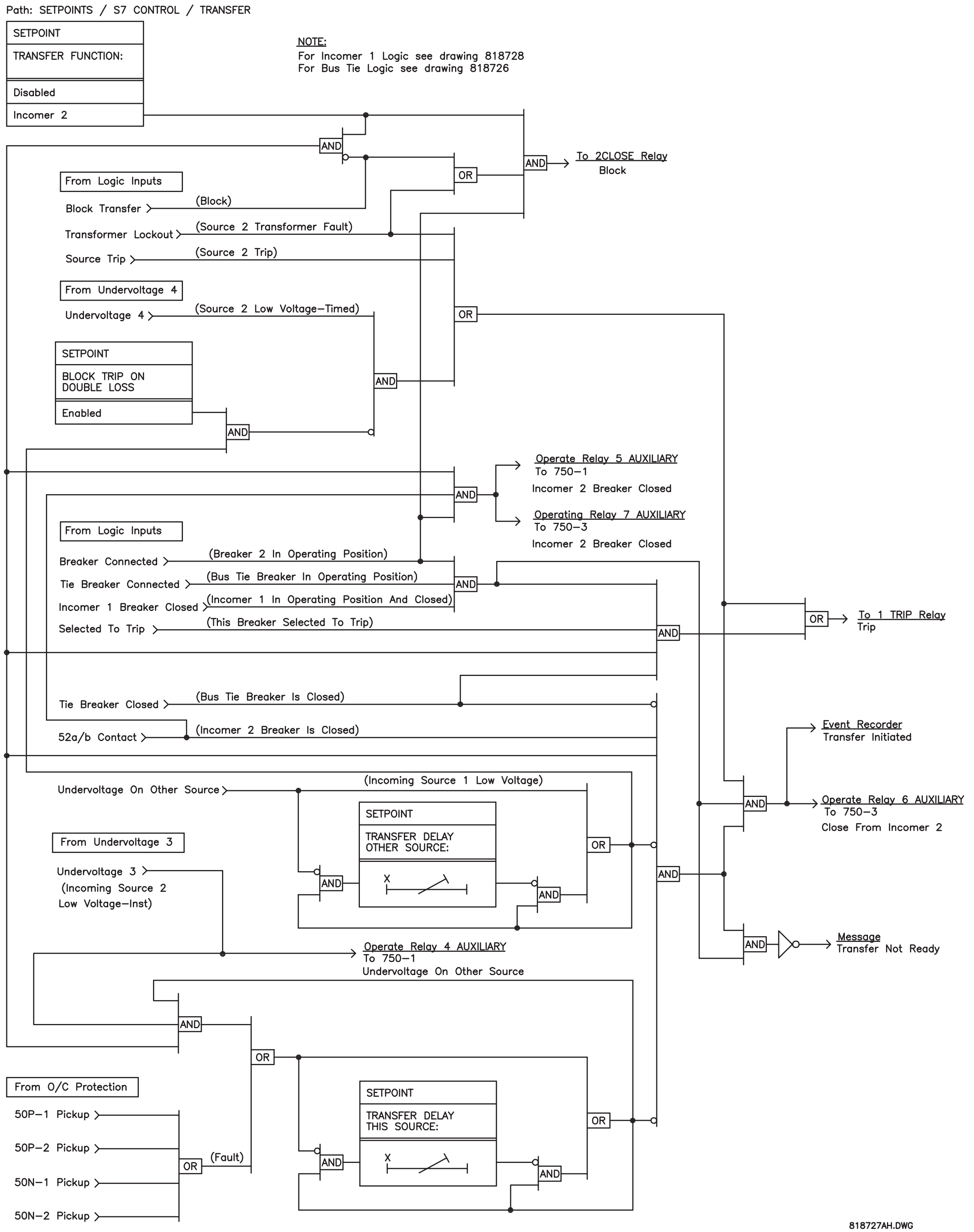

Figure 5–71: TRANSFER SCHEME INCOMER NO. 2 LOGIC

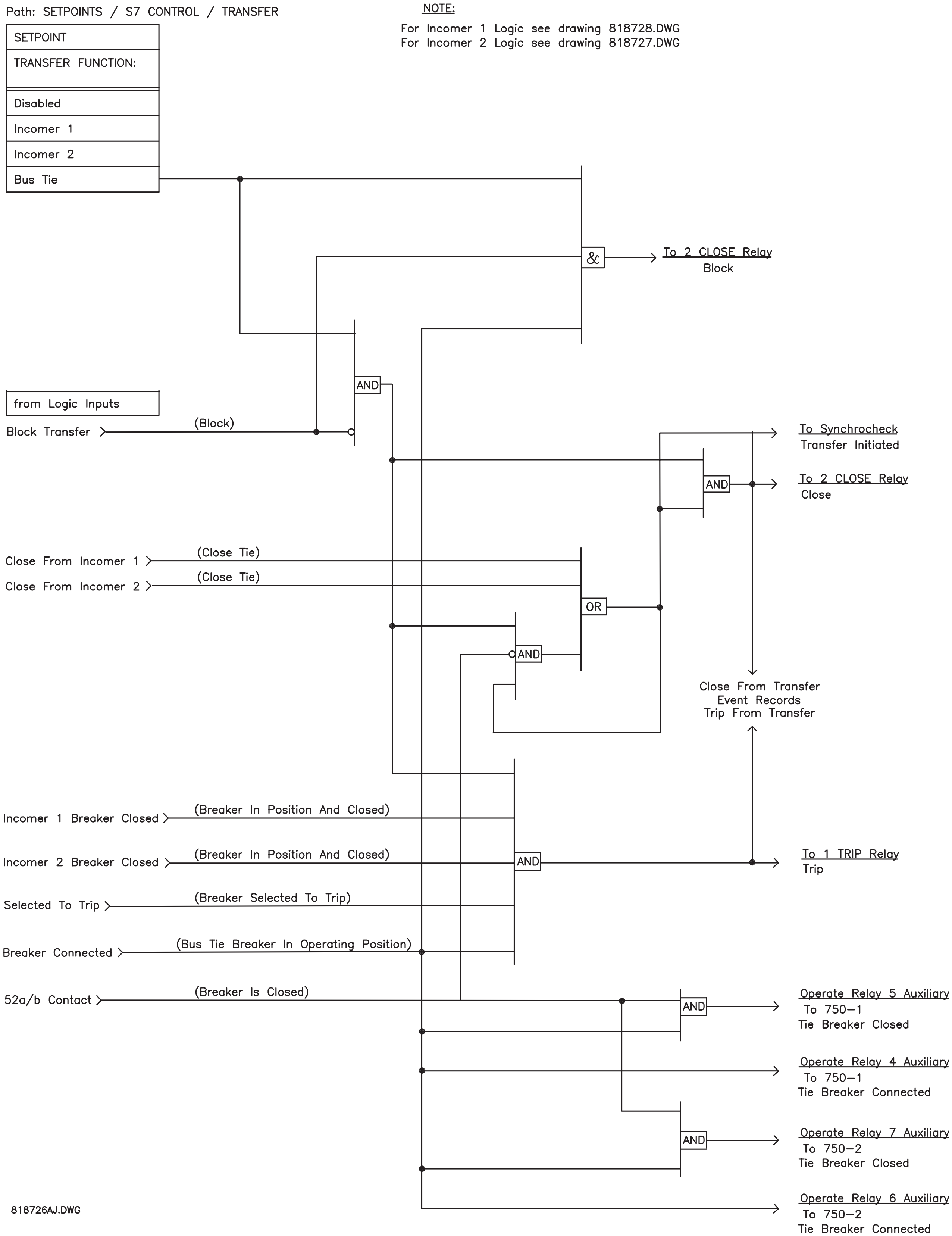

Figure 5–72: TRANSFER SCHEME BUS TIE BREAKER LOGIC

5.8.8 AUTORECLOSE (760 ONLY)

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ AR

■ AR ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ SCHEME SETUP ■ [ENTER] for more	See page 5–118.
	ESCAPE MESSAGE ⇳	■ RATE SUPERVISION ■ [ENTER] for more	See page 5–121.
	ESCAPE MESSAGE ⇳	■ CURRENT SUPERVISION ■ [ENTER] for more	See page 5–121.
	ESCAPE MESSAGE ⇳	■ ZONE COORDINATION ■ [ENTER] for more	See page 5–123.
	ESCAPE MESSAGE ⇳	■ RECLOSURE 1 ■ [ENTER] for more	See page 5–125.
	ESCAPE MESSAGE ⇳	■ RECLOSURE 2 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇳	■ RECLOSURE 3 ■ [ENTER] for more	
	ESCAPE MESSAGE ⇧	■ RECLOSURE 4 ■ [ENTER] for more	

The 760 has a very flexible autoreclose scheme that allows for the many different control strategies typical of utility applications. Up to four reclosure ‘shots’ are possible with separately programmable ‘dead times’ for each shot. Reclosure can be initiated from any 760 overcurrent element or from external sources. Between each shot, overcurrent protection setpoints can be adjusted in order to co-ordinate with downstream devices. To prevent breaker wear, a ‘current supervision’ feature can reduce the number of shots when the fault current is high. A ‘zone co-ordination’ feature can maintain protection coordination with downstream reclosers. Logic inputs are available for blocking and disabling the scheme.

Front panel LEDs indicate the present state of the autoreclose scheme. Note that display message group **A1 STATUS ⇨⇩ AR** can also be accessed to determine the present state of the autoreclose scheme.

- **Reclosure Enabled**: The scheme is enabled and may reclose if a trip occurs.
- **Reclosure Disabled**: The scheme is not enabled and will not reclose until the scheme is enabled.
- **Reclosure In Progress**: An autoreclosure has been initiated but the breaker has not yet been closed.
- **Reclosure Lockout**: The scheme has gone to ‘lockout’ and must be reset before further recloses are permitted.

The reclosure scheme is considered enabled when all of the following four conditions are true:

1. The **AR FUNCTION** setpoint is set to "Enabled".
2. Either a 52a or 52b contact is installed and has been programmed to a logic input function.
3. Neither the ‘Block Reclosure’ nor ‘Cancel Reclosure’ logic input functions are asserted.
4. The scheme is not in the lockout state.
5. The AR Block Time Upon Manual Close timer is not active.

Following is a simplified description of how the autoreclose scheme works. Refer to the logic diagrams in this section and the Application Example on page 5–127 for further details.

A fault occurs resulting in an overcurrent element tripping the circuit breaker and initiating a reclosure. Once the breaker is detected open a ‘dead timer’ is started. Once this timer exceeds the value programmed for the **DEAD TIME BEFORE RECLOSURE** Reclosure 1 setpoint, the shot counter is incremented and a breaker closure is initiated using the ‘2 Close’ output contact. At the same time, overcurrent element characteristics are modified according to the Reclosure 1 setpoints.

5

If the fault is permanent, subsequent overcurrent element(s) will trip and initiate reclosure. The scheme will eventually go to lockout when the **MAX NUMBER OF RECLOSURE SHOTS** has been met and another trip occurs. If a breaker failure condition is detected at any time during operation, the scheme will again go straight to lockout. When in lockout, the 760 disables the reclose scheme and returns all protection setpoints to their initial values. To re-enable the autoreclose scheme the relay must be reset via the front panel reset key, the Reset logic input function, communications, or by a manual close operation. The latter resets the scheme only after the **AR BLOCK TIME UPON MANUAL CLOSE** timer expires, and no overcurrent elements are picked up.

If the fault is transient in nature then no overcurrent element(s) will trip after the breaker has closed. The scheme will automatically reset when the reset timer, started upon the first reclosure initiation, exceeds the **AR RESET TIME** setpoint value. This autoreclosure reset returns the shot counter to zero and all protection setpoints to their initial values.

An anti-pumping feature is built into the reset mechanism. Otherwise, breaker pumping could occur when the fault level is between the initial overcurrent pickup level and the adjusted overcurrent pickup level for a reclosure shot. It prevents a permanent fault from continuously repeating the trip breaker, initiate reclose, close breaker, automatic reset of autoreclose scheme, trip breaker sequence. If this condition is detected the anti-pumping feature returns protection setpoints to their initial values without resetting the shot counter. The relay will then continue to trip and reclose until lockout is reached.

b) SCHEME SETUP

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ AR ⇨ SCHEME SETUP

```
■ SCHEME SETUP
■ [ENTER] for more
```

Message	Range
AR FUNCTION: Disabled	Range: *Enabled, Disabled*
MAX NUMBER OF RECLOSURE SHOTS: 1	Range: *1 to 4 in steps of 1*
AR RESET TIME: 60 s	Range: *1 to 1000 s in steps of 1*
AR BLOCK TIME UPON MANUAL CLOSE: 10 s	Range: *0 to 200 s in steps of 1*
AR EXTERNAL CLOSE LOGIC: Disabled	Range: *Enabled, Disabled*
INCOMPLETE SEQUENCE TIME: 30 s	Range: *1 to 1000 s in steps of 1*
RECLOSURE ENABLED RELAYS (3-7): -----	Range: *Any combination of the 3 to 7 Auxiliary relays*
RECLOSURE IN PROGRESS RELAYS (3-7): -----	Range: *Any combination of the 3 to 7 Auxiliary relays*
RECLOSURE LOCKOUT RELAYS (3-7): -----	Range: *Any combination of the 3 to 7 Auxiliary relays*

The setpoints shown above setup the general characteristics of the scheme. The **AR FUNCTION** and **MAX NUMBER OF RECLOSURE SHOTS** setpoints are critical and must be set appropriately.

NOTE

For an overcurrent element to initiate a reclosure it must be set to the "Trip & AR" function.

- **MAX NUMBER OF RECLOSURE SHOTS**: This setpoint specifies the number of reclosures that should be attempted before reclosure lockout occurs. The dead time and overcurrent characteristics for each reclosure shot are entered in the subsequent message groups **RECLOSURE 1** to **RECLOSURE 4**.
- **AR RESET TIME**: The reset timer is used to set the total time interval for a single fault event, from the first trip until either lockout or successful reclosure. Generally, this setpoint is set to the same delay that would be used for the ‘reclaim time’ in a traditional scheme with fixed protection settings. This time must be set to a value greater than the sum of all programmed dead times plus the maximum time to trip on each reclose shot.

NOTE **Set the AR RESET TIME timer to a delay longer than the INCOMPLETE SEQUENCE timer.**

- **AR BLOCK TIME UPON MANUAL CLOSE**: The autoreclose scheme can be disabled for a programmable time delay after the associated circuit breaker is manually closed. This prevents manual reclosing onto a fault. 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 timer expires, the autoreclose scheme is automatically reset. The lockout state will be cleared and the shot counter will be set to zero.

NOTE Manual circuit breaker closures can be initiated by either the front panel breaker CLOSE key when in local mode, or by the Remote Close logic input and computer communications when in remote mode.

- **AR EXTERNAL CLOSE LOGIC**: For applications where the breaker may be closed directly, without using the 760 to provide the closing signal to the breaker, enabling this setpoint will use breaker state to determine if a manual close has occurred. The 760 uses the detection of a manual close to disable the autoreclose scheme to prevent reclosing onto a fault. Also, if the Autoreclose scheme is in the lockout state, a successful manual close would result in the autoreclose scheme being automatically reset after the AR BLOCK TIME UPON MANUAL CLOSE time has expired.

  When "Enabled", this setpoint uses the detection of the breaker going from the open state to the closed state to determine if a manual close has occurred. The breaker state is determined by the 52a/b contact feedback to the 760. When set to "Disabled", only close commands sent via the 760 will be considered as a manual close for the autoreclose scheme logic.

- **INCOMPLETE SEQUENCE TIME**: This timer sets 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 "Reclosure In Progress" state. If all conditions allowing a breaker closure are not satisfied when this timer expires, the reclosure initiation is abandoned. Any combinations of the following conditions block the breaker from closing:

  – Breaker status logic inputs (52a or 52b contact) fail to report the breaker has opened;
  – The “Block 2 Close Relay” logic input function is asserted;
  – The synchrocheck feature is blocking breaker closes.

NOTE **This timer must be set to a delay less than the AR RESET TIME timer.**

- **RECLOSURE ENABLED RELAYS**: Select the relays required to operate while the front panel Reclosure Enabled indicator is on.
- **RECLOSURE IN PROGRESS RELAYS**: Select the relays required to operate while the front panel Reclosure In Progress indicator is on. This indicator is on when the autoreclose scheme has been initiated, but has not yet sent a close command. This output could be used to block the operation of a transformer tap changer during a reclosure sequence.
- **RECLOSURE LOCKOUT RELAYS**: Select the relays required to operate while the front panel Reclosure Lockout indicator is on. This indicator is on when the autoreclose scheme has progressed to a lockout condition, such that no further breaker closures will be initiated until the 760 has been reset.

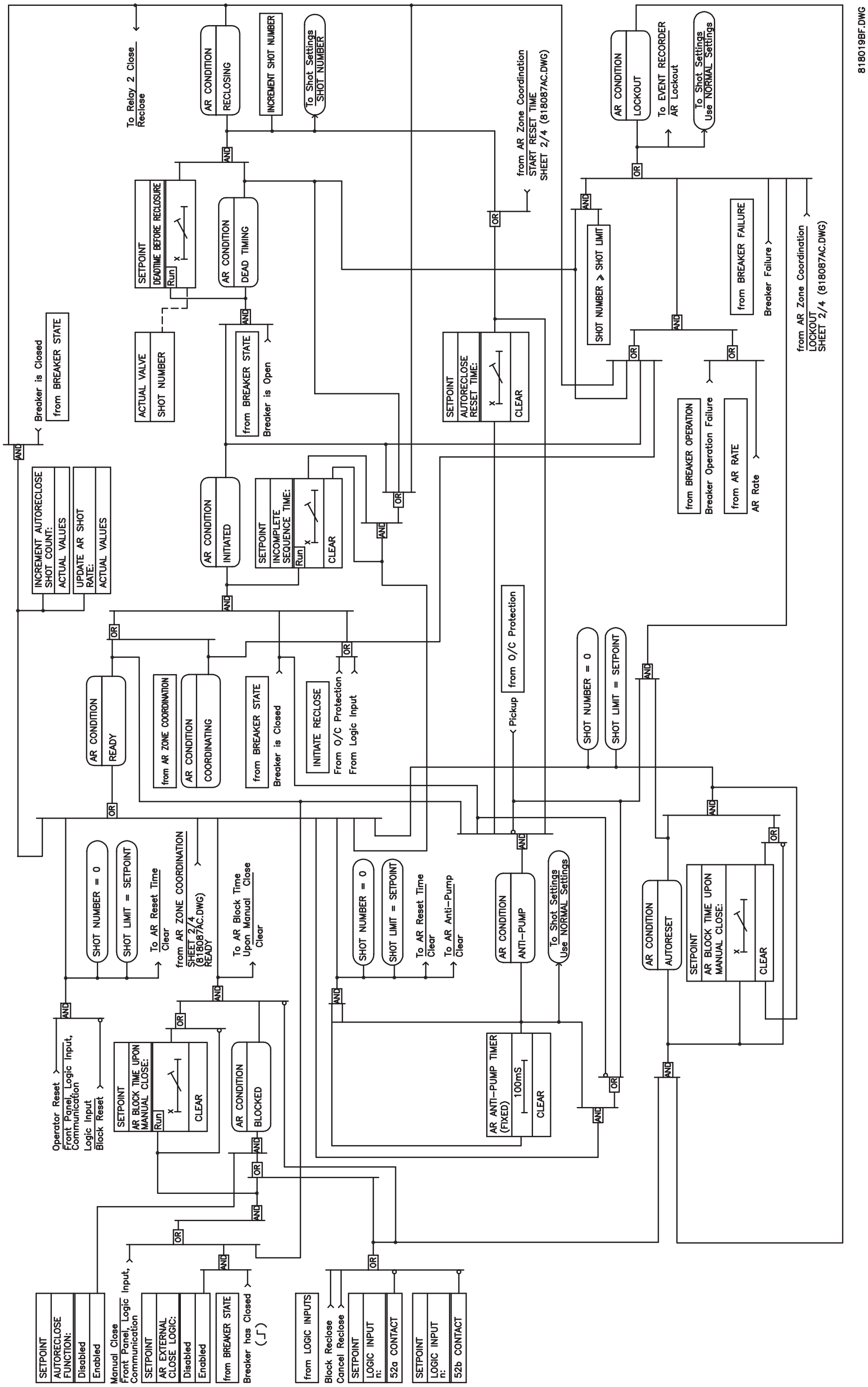

Figure 5–73: AUTORECLOSE SCHEME SETUP LOGIC

c) AUTORECLOSE RATE SUPERVISION

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ AR ⇨⇩ RATE SUPERVISION

```
■ RATE SUPERVISION
■ [ENTER] for more
```

```
RATE SUPERVISION
FUNCTION: Disabled
```
Range: *Disabled, Alarm, Latched Alarm, Control*

```
RATE SUPERVISION
RELAYS (3-7): -----
```
Range: *Any combination of the 3 to 7 Auxiliary relays*

```
MAX AR
RATE: 25 /hr.
```
Range: *1 to 50/hr. in steps of 1*

The autoreclose rate supervision feature monitors the number of recloses per hour. Once the number of recloses within one hour exceeds the **MAX AR RATE** setpoint, the autoreclose scheme is sent to lockout.

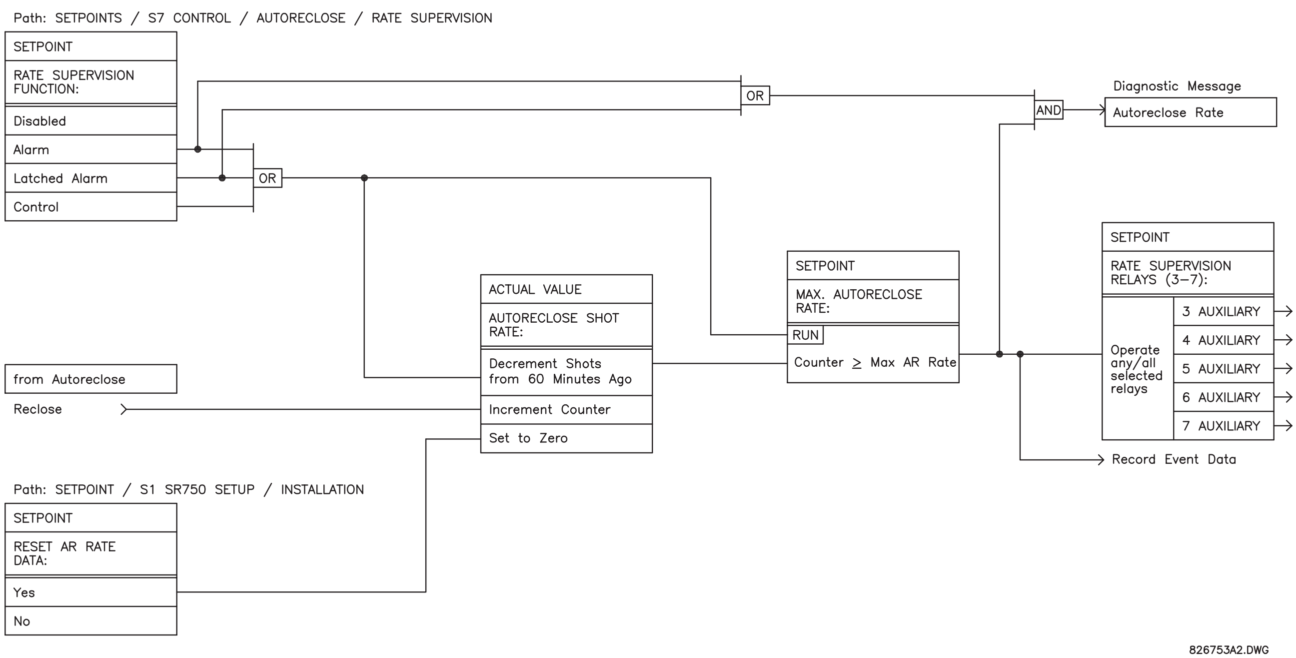

Figure 5–74: AUTORECLOSE RATE SUPERVISION LOGIC

d) AUTORECLOSE CURRENT SUPERVISION

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ AR ⇨⇩ CURRENT SUPERVISION

```
■ CURRENT SUPERVISION
■ [ENTER] for more
```

```
CURRENT SUPERVISION
FUNCTION: Disabled
```
Range: *Enabled, Disabled*

```
3 SHOTS FOR CURRENT
ABOVE: 17.00 x CT
```
Range: *0.00 to 20.00 x CT in steps of 0.01*

```
2 SHOTS FOR CURRENT
ABOVE: 18.00 x CT
```
Range: *0.00 to 20.00 x CT in steps of 0.01*

```
1 SHOTS FOR CURRENT
ABOVE: 19.00 x CT
```
Range: *0.00 to 20.00 x CT in steps of 0.01*

```
CURRENT SUPERVISION
TO LOCKOUT: Disabled
```
Range: *Enabled, Disabled*

```
LOCKOUT FOR CURRENT
ABOVE: 20.00 x CT
```
Range: *0.00 to 20.00 x CT in steps of 0.01*

5

The current supervision feature is used to limit breaker wear. When fault current exceeds user-programmed levels, it reduces the number of reclose shots permitted.

Once a reclose sequence is initiated, the maximum current measured on any phase is compared to the setpoint current levels. The relay then determines the maximum number of shots allowed or whether the scheme goes immediately to lockout. The lowest number of permitted shots, whether set by the **MAX NUMBER OF RECLOSE SHOTS** setpoint or the Current Supervision feature, always takes precedence unless current supervision takes the scheme to lockout. Lockout has the highest priority. Once the current supervision feature has reduced the total number of shots, a subsequent shot can still reduce the limit further.

The fault current level above which the number of autoreclosure shots will be reduced to one, two, or three shots can be selected. If the autoreclose scheme is to be taken directly to lockout without reclosing, set the **CURRENT SUPERVISION TO LOCKOUT** setpoint to "Enabled"

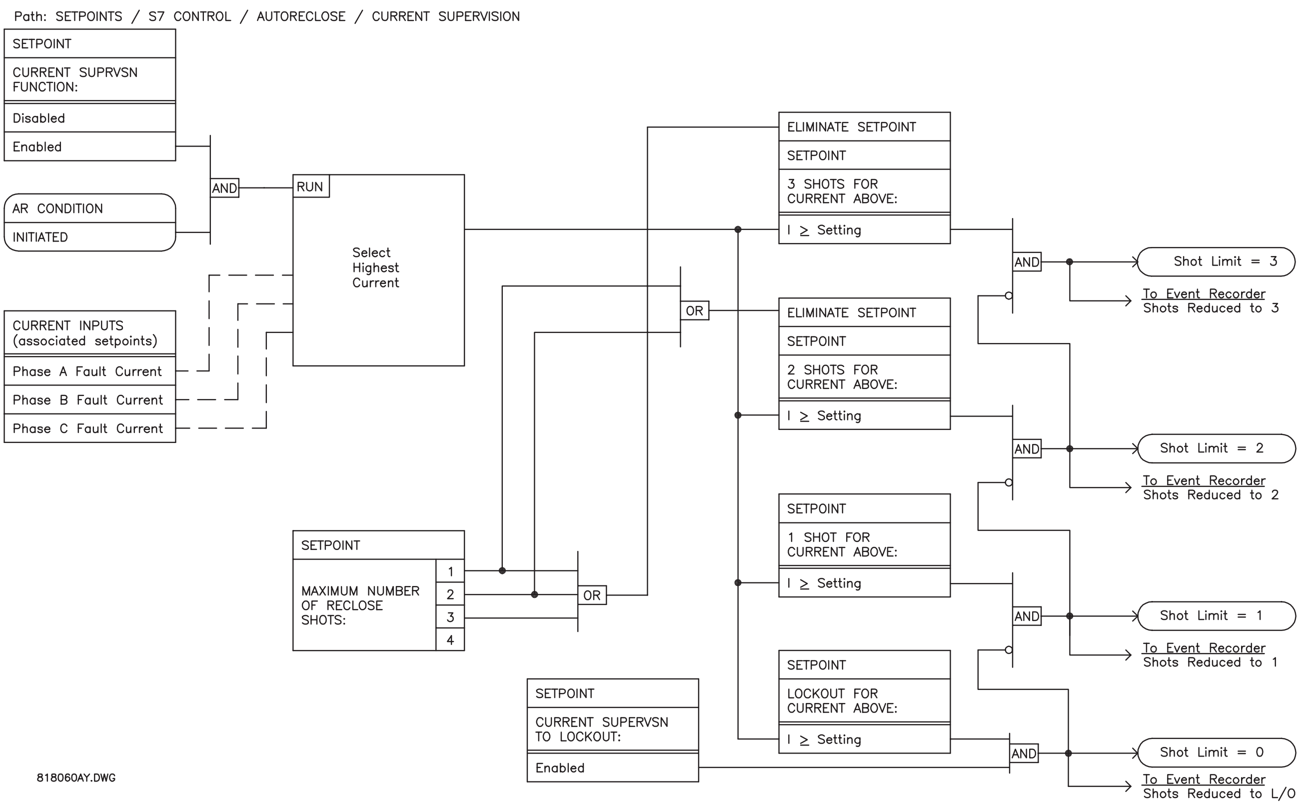

Figure 5–75: AUTORECLOSE CURRENT SUPERVISION LOGIC

e) AUTORECLOSE ZONE COORDINATION

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ AR ⇨⇩ ZONE COORDINATION

■ ZONE COORDINATION ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	ZONE COORDINATION FUNCTION: Disabled	*Range: Enabled, Disabled*
	ESCAPE / MESSAGE ⇳	PHASE CURRENT INCREASE: 1.00 x CT	*Range: 0.00 to 20.00 x CT in steps of 0.01*
	ESCAPE / MESSAGE ⇳	NEUTRAL CURRENT INCREASE: 1.00 x CT	*Range: 0.00 to 20.00 x CT in steps of 0.01*
	ESCAPE / MESSAGE ⇧	MAX FAULT CLEARING TIME: 10 s	*Range: 1 to 1000 s in steps of 1*

The 760 autoreclose scheme can be programmed to maintain coordination of overcurrent elements with a downstream recloser. If a downstream recloser is programmed to use different protection settings for different reclose shots, it may be necessary to change the protection setpoints on the 760 each time the recloser operates. To ensure that protection coordination is maintained, each 760 reclosure shot must be coordinated with each downstream recloser shot. In addition, the 760 reclose shot counter must always match the recloser shot counter. When a fault occurs downstream of the recloser and the 760 feeder breaker does not trip and reclose, the 760 reclosure shot counter must still be incremented.

Once enabled, this scheme assumes an external reclose operation has occurred when the feeder phase or neutral current exhibits a step increase in magnitude, due to fault current, followed by a step decrease in magnitude, due to a recloser opening. After the first detection of an external reclose, the shot counter is incremented by one, protection setpoints are changed, and the autoreclose scheme reset timer is initiated.

If the fault is permanent and the recloser continues to trip and reclose, the coordination feature will continue to increment the shot counter. If this continues to the maximum number of shots programmed in the 760, the autoreclose scheme will go to lockout. If the fault is transient, then the autoreclose scheme and shot counter will eventually be reset by the normal reset mechanism.

The **PHASE CURRENT INCREASE** and **NEUTRAL CURRENT INCREASE** setpoints select the minimum phase and neutral current step increases that signify downstream faults. These currents may be quite low for an end fault on a long feeder with a weak source. The **MAX FAULT CLEARING TIME** setpoint is intended to reset the memory of an increasing current caused by an increase in feeder load since the new load current will not drop to operate the decreasing current detector. This delay must be set longer than the maximum fault clearing time on the recloser.

NOTE

For correct operation of the coordination scheme, the 760 instantaneous protection elements must be set to have time delays longer than the maximum fault clearing time of the downstream recloser. In addition, the autoreclose reset timer must be set longer than the maximum time for the recloser to reach lockout.

5

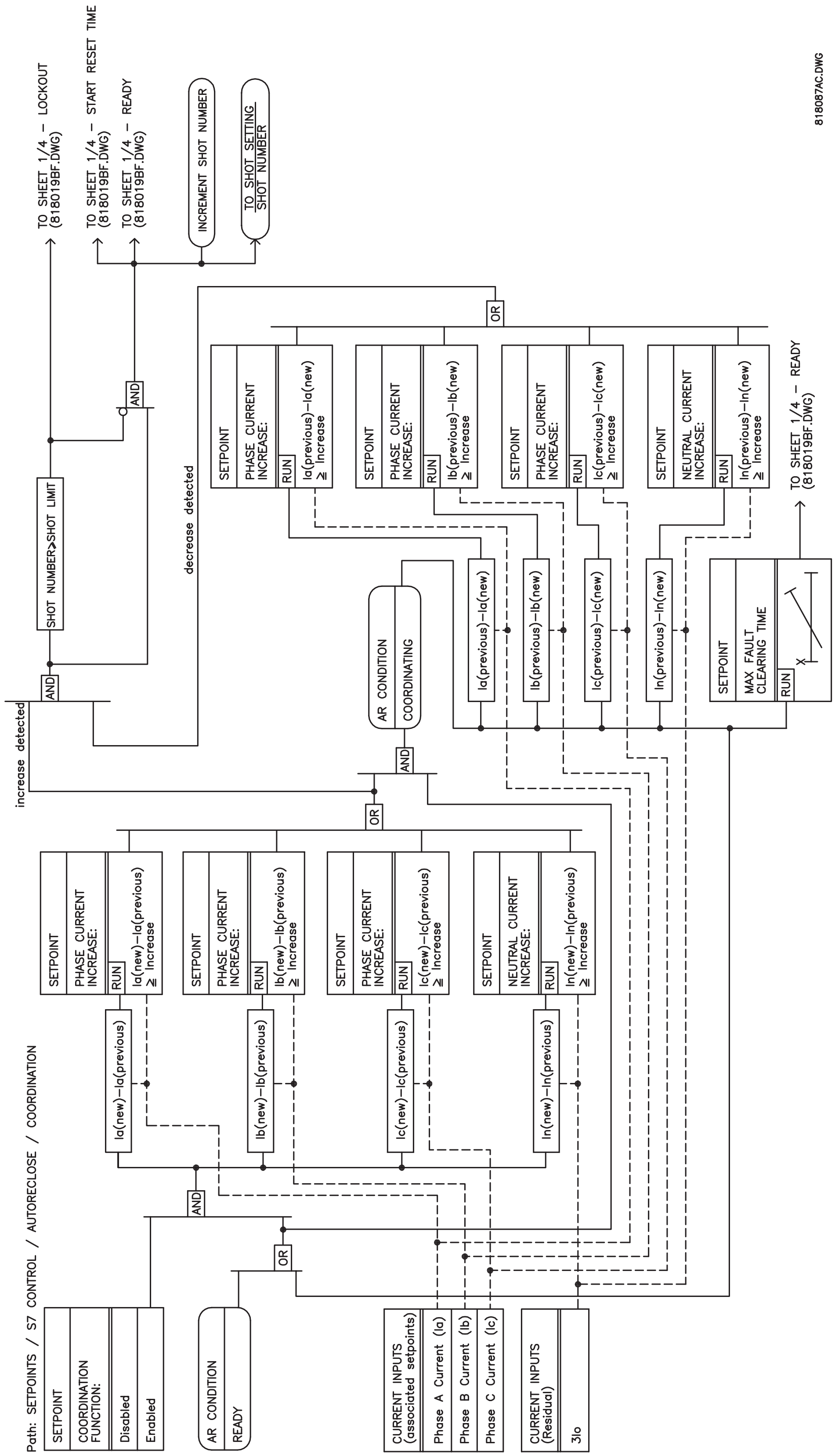

Figure 5–76: AUTORECLOSE ZONE COORDINATION LOGIC

f) RECLOSURE SHOTS 1 TO 4

PATH: SETPOINTS ⇨⇩ S7 CONTROL ⇨⇩ AR ⇨⇩ RECLOSURE 1(4)

■ RECLOSURE 1
■ [ENTER] for more

Display	Range
DEADTIME BEFORE RECLOSURE: 0.50 s	Range: 0.00 to 300.00 s in steps of 0.01
PHASE INST OC 1 BLOCKING: Disabled	Range: Enabled, Disabled
NEUTRAL INST OC 1 BLOCKING: Disabled	Range: Enabled, Disabled
GND INST OC BLOCKING: Disabled	Range: Enabled, Disabled
SENSTV GND INST OC BLOCKING: Disabled	Range: Enabled, Disabled
NEG SEQ INST OC BLOCKING: Disabled	Range: Enabled, Disabled
PHASE TIME OC 1 RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
NEUTRAL TIME OC 1 RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
GND TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
SENSTV GND TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
NEG SEQ TIME OC RAISED PICKUP: 0%	Range: 0 to 100% in steps of 1
SELECT SETPOINT GROUP: Active	Range: Group 1, Group 2, Group 3, Group 4, Active

The above setpoints are programmed independently and are repeated for each of the Reclosure Shots 1 through 4. These setpoints determine the dead time for a given shot and the overcurrent characteristics during that shot. Selections for shots, that are greater than the maximum number of shots programmed in the scheme setup, will not be used by the scheme.

5

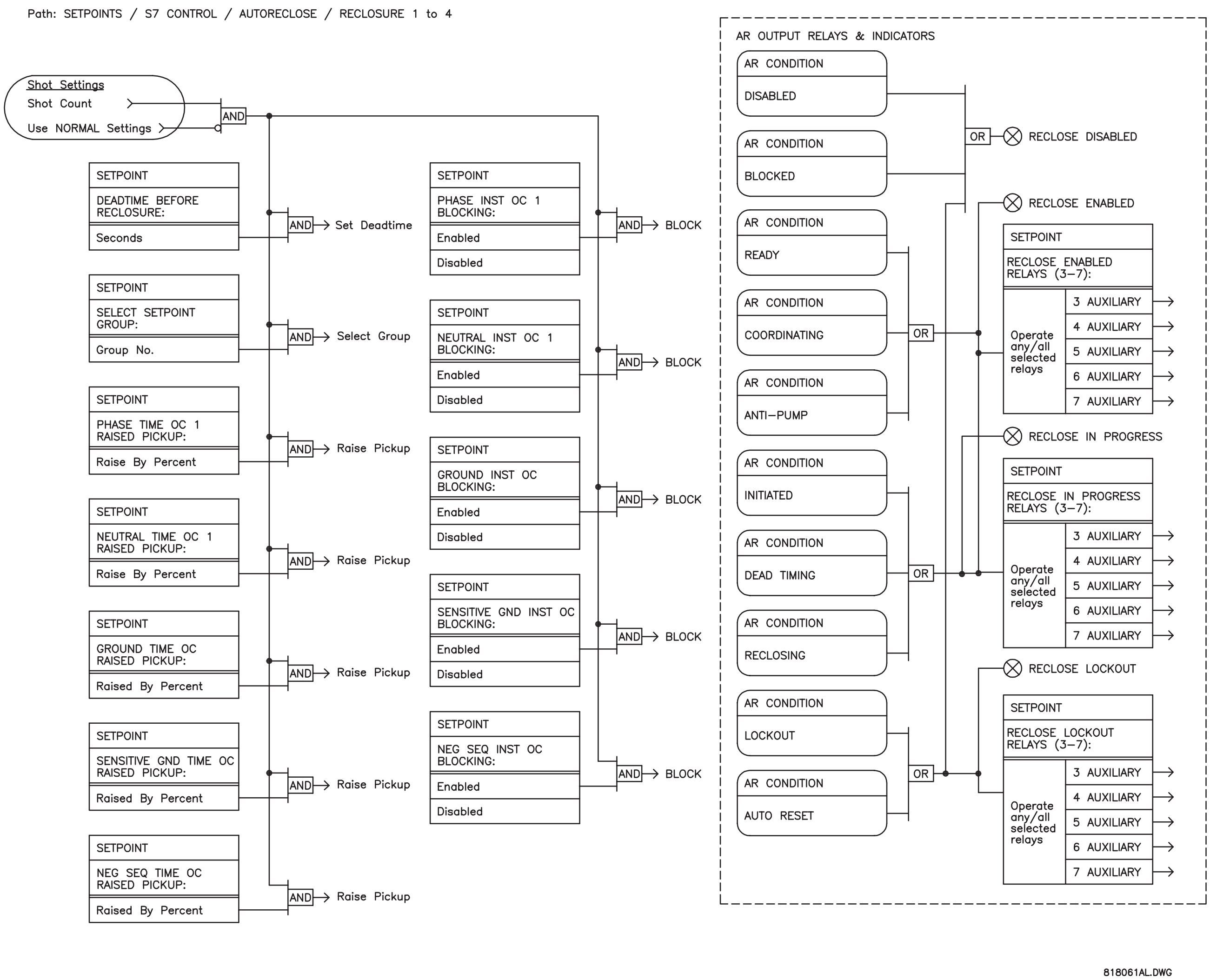

Figure 5–77: AUTORECLOSURE SHOTS 1 TO 4 LOGIC

g) AUTORECLOSURE APPLICATION EXAMPLE

Utility statistics indicate that a large percentage of feeder faults (about 80%) are of a transient nature. Typically, once the feeder is tripped an autorecloser automatically recloses the feeder breaker after a short time delay. If the fault was transient, the entire feeder is returned to normal service and customers experience a very short disturbance. If the fault is permanent and on the load side of another protection point, the reclosure scheme delays another trip of the breaker until this other device clears the fault so that service is disrupted only for loads beyond this other protection point.

A common phase protection scheme uses instantaneous elements in conjunction with automatic reclosing. The design goal is to select setpoints that will detect faults out to the most distant (in impedance terms) point of the feeder and provide fast operation. Typically 'loset' overcurrent elements are programmed to be blocked after the first reclosure. This gives downstream devices, such as fuses, time to interrupt a permanent fault, especially on a feeder tap. Loset elements would then be re-enabled after the scheme is reset. 'Hiset' elements may also be blocked on a subsequent shot with a faster time overcurrent curve selected to allow the fault to burn off. In this case a permanent fault would then cause a time overcurrent trip.

A typical autoreclose scheme as implemented in the 760 would respond to faults as follows:

1. With the breaker closed and protection enabled, a transient fault produces a current above the pickup of both Instantaneous Overcurrent 1 (loset) and Time Overcurrent 1 elements.
2. The Time Overcurrent element begins to time, and the Instantaneous Overcurrent element operates, signaling the breaker to trip and initiate a reclosure.
3. The breaker trips and signals the autoreclose scheme that it is now open. The Instantaneous Overcurrent 1 and Time Overcurrent 1 elements automatically reset because the breaker is open.
4. If all requirements of the autoreclose scheme are fulfilled, autoreclose signals the breaker to close and advances the shot counter. Shot 1 setpoints block the Instantaneous Overcurrent element from further operation.
5. The breaker closes resulting in an inrush current of the feeder loads.
6. If the fault was transient, the current reduces to the load level before a trip occurs. The autoreclose scheme eventually resets and the cycle begins again at Step 1.
7. If the fault is permanent, a current above the pickup of both the Instantaneous Overcurrent 1 and the Time Overcurrent 1 elements is produced. However, the Instantaneous Overcurrent 1 element is blocked from operating.
8. While the Time Overcurrent 1 element is timing, any protection devices between this relay and the fault location are provided an opportunity to isolate the fault.
9. If no protection downstream from the relay clears the fault, the Time Overcurrent 1 element will time-out, signaling the breaker to trip and initiate the autoreclose scheme again.
10. If the shot counter has not reached its maximum allowed value then the cycle begins at step 6 using protection setpoints for the current shot.
11. If the shot counter has reached its maximum then the scheme goes to lockout.

5.9.1 OUTPUT RELAYS

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨ OUTPUT RELAYS

■ OUTPUT RELAYS
■ [ENTER] for more

Message	Range
FORCE OUTPUT RELAYS FUNCTION: Disabled	*Range: Enabled, Disabled*
FORCE 1 TRIP RELAY: De-energized	*Range: Energized, De-energized*
FORCE 2 CLOSE RELAY: De-energized	*Range: Energized, De-energized*
FORCE 3 AUX RELAY: De-energized	*Range: Energized, De-energized*
FORCE 4 AUX RELAY: De-energized	*Range: Energized, De-energized*
FORCE 5 AUX RELAY: De-energized	*Range: Energized, De-energized*
FORCE 6 AUX RELAY: De-energized	*Range: Energized, De-energized*
FORCE 7 AUX RELAY: De-energized	*Range: Energized, De-energized*
FORCE SOLID STATE OUTPUT: De-energized	*Range: Energized, De-energized*

5

For testing purposes, the relay provides the ability to override the normal function of the solid state and output contacts. This is done by forcing each to energize or de-energize.

Set **FORCE OUTPUT RELAYS FUNCTION** to "Enabled" to override the normal operation of the solid state and output contacts, with the state programmed in the messages that follow. Note that this setpoint will always be defaulted to the "Disabled" state at power up.

Select "De-energized" for the remaining setpoints to force the output relays to the de-energized state while **FORCE OUTPUT RELAYS FUNCTION** is set to "Enabled". Selecting "Energized" forces the output relay to the energized state while the **FORCE OUTPUT RELAYS FUNCTION** setpoint is "Enabled".

5.9.2 PICKUP TEST

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ PICKUP TEST

```
■ PICKUP TEST
■ [ENTER] for more
```

[ENTER] ⇨ / ⇦ [ESCAPE]

```
PICKUP TEST
FUNCTION: Disabled
```

Range: Enabled, Disabled
Always defaults to "Disabled" on power-up

[ESCAPE] / [MESSAGE] ⇧

```
PICKUP TEST
RELAYS (3-7): -----
```

Range: Any combination of the 3 to 7 Auxiliary relays

The relay provides the ability to operate any or all of the 3 to 7 Auxiliary output relays upon the pickup of any protection element. The pickup test feature is especially useful for automated testing. Through a 750/760 output contact, test equipment can monitor a pickup threshold.

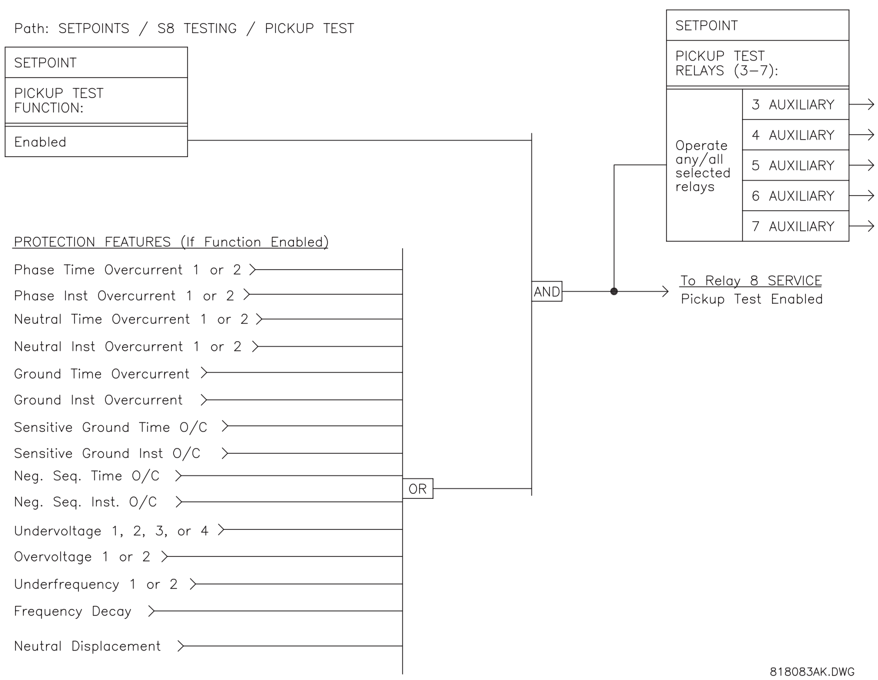

Figure 5–78: PICKUP TEST LOGIC

5.9.3 ANALOG OUTPUTS

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ A/O

```
■ A/O
■ [ENTER] for more
```

[ENTER] ⇨ / ⇦ [ESCAPE]

```
FORCE A/O
FUNCTION: Disabled
```

Range: Enabled, Disabled
Always defaults to "Disabled" on power-up

[ESCAPE] / [MESSAGE] ⇳

```
FORCE A/O 1
  0%
```

Range: 0 to 100% in steps of 1

↓

[ESCAPE] / [MESSAGE] ⇧

```
FORCE A/O 8
  0%
```

Range: 0 to 100% in steps of 1

The relay provides the ability to override the normal function of analog outputs, forcing each to any level from 0 to 100% of the output range. Enter the percentage of the DC mA output range to be signaled by the Analog Output 1 (2 to 8) for the **FORCE A/O 1(8)** setpoints. For example, if the relay has been ordered with 4 to 20 mA analog outputs, setting this value to "100%" will output 20 mA, "0%" will output 4 mA, and "50%" will output 12 mA.

5.9.4 SIMULATION

a) MAIN MENU

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ SIMULATION

■ SIMULATION ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	■ SETUP ■ [ENTER] for more	See page 5–118.
	ESCAPE MESSAGE ⇳	■ PREFAULT VALUES ■ [ENTER] for more	See page 5–121.
	ESCAPE MESSAGE ⇳	■ FAULT VALUES ■ [ENTER] for more	See page 5–121.
	ESCAPE MESSAGE ⇧	■ POSTFAULT VALUES ■ [ENTER] for more	See page 5–123.

CAUTION **when in Simulation Mode, the normal protection and control features are not operational. This is indicated by the 8 Self-Test Warning relay being de-energized. If Simulation Mode is used for field testing on equipment, the operator must provide other means of protection and control.**

A simulation feature is provided for testing the functionality of the relay in response to program conditions, without the need of external AC voltage and current inputs. First time users will find this to be a valuable training tool. System parameters such as currents and voltages, phase angles, and system frequency are entered as setpoints. When placed in simulation mode, the relay suspends reading actual AC inputs, generates samples to represent the programmed phasors, and loads these samples into the memory to be processed by the relay. Both normal and fault conditions can be simulated to exercise a variety of relay features. There are three sets of input parameters used during simulation, each providing a particular state of the system, as shown below:

- **Prefault State**: This state simulates the normal operating condition of a feeder carrying load current, by replacing the normal input parameters with programmed prefault values. Voltages are automatically set to the nominal value programmed in the **BUS VT NOMINAL SECONDARY VOLTAGE** setpoint. The neutral current is set to zero. Phase currents are balanced and set to the value programmed in the **PREFAULT PHASE A/B/C CURRENT** setpoint. The phase angle of each phase current relative to its corresponding phase neutral voltage is set to the value programmed in the **PREFAULT PWR FACTOR ANGLE** setpoint. The frequency of voltages and currents are automatically set to the values programmed in the **NOMINAL FREQ** setpoint.
- **Fault State**: This state simulates the faulted operating condition of a feeder by replacing the normal prefault feeder input parameters with programmed fault values. The magnitude and angle of each bus voltage and current, polarizing current, system frequency and analog input are set to the values programmed under the **FAULT VALUES** setpoints. The neutral current is calculated from the vector sum of the phase currents, and $3V_0$ from the vector sum of the phase voltages.
- **Postfault State**: This state is intended to simulate a feeder that has tripped. Current is automatically set to 0 A. Bus voltages are automatically balanced and set to Phase A-N at 0°, B-N at 120°, and C-N at 240°. The bus voltage magnitude and frequency are set to the entered values. The synchronizing voltage is set to the entered values of magnitude, angle (with respect to phase A-N bus voltage) and frequency.

There are two methods of running simulations. If the feeder circuit breaker is connected to the relay and can be opened and closed, a full operating sequence can be performed. If a breaker is not available, as is often the case, the relay can be made to simulate a breaker and allow the 760 to exercise its autoreclose feature. The operation of each method is described below.

1. If simulation of the feeder breaker is required set the **CIRCUIT BRKR SIMULATION** setpoint to "Enabled". After the required simulation setpoints have been entered, the relay is placed in the Prefault State by setting the **SIMULATION STATE** setpoint to "Prefault". The relay replaces the normal AC inputs with those programmed on the **PREFAULT VALUES** setpoint page. Logic inputs, except for the 52a and 52b contacts, are monitored normally throughout the simulation. The relay's simulation of a circuit breaker is indicated by the status of the Breaker Open and Breaker Closed front panel indicators.

The relay remains in the Prefault State until a command is received to enter the Fault State, either by setting the **SIMULATION STATE** setpoint to the Fault State, or a contact closure on a logic input whose function setpoint is set to Simulate Fault. The logic input makes the measurement of feature operating times possible when output relays are allowed to operate.

In the Fault State, relay features respond to the programmed fault values, generating a trip, alarms, event records, triggers of trace memory and data logger, and front panel indications as necessary. Output relays only operate if permitted by the **ALLOW OPERATION OF RELAYS (3-7)** setpoint. The relay remains in the Fault State until it has detected a trip condition. Note that the Trip Relay is not allowed to operate. At this time the simulated breaker is opened (as indicated by front panel indicators) and the relay is placed in Postfault State.

The relay remains in the Postfault State until either a close command received or the 760 autoreclose scheme has all requirements met and is ready to close. At this time the relay returns to the Prefault State. Note that the Close Relay is not allowed to operate. Setting the **SIMULATION STATE** setpoint to "Disabled" also terminates simulation.

2. If simulation of the feeder breaker is not required set the Circuit Breaker Simulation setpoint to Disabled. After the required simulation setpoints have been entered, the relay is placed in simulation mode by setting the **SIMULATION STATE** setpoint to "Prefault". The relay replaces the normal AC inputs with those programmed on the Prefault Values setpoint page. All logic inputs are monitored normally throughout the simulation including any set to monitor the 52a/52b contacts by which the front panel Breaker Open and Breaker Closed indicators are set.

   Operation is similar to that described in Method 1 above except that the Trip Relay will operate if a trip condition is declared and the Close Relay will operate in response to any form of close request. As well, the Simulation State is controlled by the monitored state of the breaker.

b) SETUP

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ SIMULATION ⇨ SETUP

■ SETUP ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	SIMULATION STATE: Disabled	*Range: Disabled, Prefault, Fault, Postfault*
	ESCAPE / MESSAGE ⇳	CIRCUIT BRKR SIMULATION: Enabled	*Range: Enabled, Disabled*
	ESCAPE / MESSAGE ⇧	ALLOW OPERATION OF RELAYS (3-7): -----	*Range: Any combination of the 3 to 7 Auxiliary relays*

Program **SIMULATION STATE** to “Disabled” if actual system inputs are to be monitored. If programmed to any other value, the relay is in simulation mode and actual system parameters are not monitored. The system parameters simulated by the relay will be those in the section below that corresponds to the programmed value of this setpoint. For example, if programmed to “Fault”, then the system parameters will be set to those defined by the Fault Values setpoints on page 5–132.

NOTE: The simulation state may change due to a change in the operational state of the relay. For example, if set to "Fault" and a trip opens the breaker (either simulated or actual), the simulation state and this setpoint will automatically change to "Postfault".

An operator can use the simulation feature to provide a complete functional test of the relay’s protection features, except for the measurement of external input values. As this feature may be used for on-site testing, provision is made to block the operation of the output relays so the operation of other equipment is prevented. Set **CIRCUIT BRKR SIMULATION** to "Enabled" to block the Trip and Close Relays from operating, and ignore the 52a/52b auxiliary contacts, even if installed. In this mode, the circuit breaker will be simulated. Set **CIRCUIT BRKR SIMULATION** to "Disabled" to allow the Trip and Close Relays to open and close an actual circuit breaker connected to the relay. In this mode, the 52a/52b auxiliary contacts, if installed, will be read for feedback from the breaker.

The Trip and Close relays are allowed to operate by setting **CIRCUIT BRKR SIMULATION** to "Disabled". Auxiliary Relays 3 to 7 can also be allowed to operate if selected by the **ALLOW OPERATION OF RELAYS (3-7)** setpoint. The 8 Self-Test Warning relay is always allowed to operate. Note that the default value blocks the operation of all output relays. For timing tests, a selected output relay can be set to be operational, to provide a signal to stop a timer.

c) PREFAULT VALUES

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ SIMULATION ⇨⇩ PREFAULT VALUES

■ PREFAULT VALUES ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	PHASE A/B/C CURRENT LEVEL: 0.50 x CT	Range: 0.00 to 20.00 x CT in steps of 0.01
	ESCAPE / MESSAGE	PWR FACTOR ANGLE: 0° Lag	Range: 0 to 359° Lag in steps of 1

For proper simulation, values entered here should be below the minimum trip setting of any protection feature. The relay will use these values when in the Prefault State. For delta or wye systems, the relay automatically sets the voltages to the setpoint value of VT nominal secondary voltage, with balanced voltage phase positions.

d) FAULT VALUES

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ SIMULATION ⇨⇩ FAULT VALUES

■ FAULT VALUES ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	PHASE A-N VOLTAGE LEVEL: 1.00 x VT	Range: 0.00 to 2.00 x VT in steps of 0.01
	ESCAPE / MESSAGE	PHASE A-N VOLTAGE POSITION: 0° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	PHASE B-N VOLTAGE LEVEL: 1.00 x VT	Range: 0.00 to 2.00 x VT in steps of 0.01
	ESCAPE / MESSAGE	PHASE B-N VOLTAGE POSITION: 120° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	PHASE C-N VOLTAGE LEVEL: 1.00 x VT	Range: 0.00 to 2.00 x VT in steps of 0.01
	ESCAPE / MESSAGE	PHASE C-N VOLTAGE POSITION: 240° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	PHASE A CURRENT LEVEL: 1.00 x CT	Range: 0.00 to 20.00 x CT in steps of 0.01
	ESCAPE / MESSAGE	PHASE A CURRENT POSITION: 60° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	PHASE B CURRENT LEVEL: 1.00 x CT	Range: 0.00 to 20.00 x CT in steps of 0.01
	ESCAPE / MESSAGE	PHASE B CURRENT POSITION: 180° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	PHASE C CURRENT LEVEL: 1.00 x CT	Range: 0.00 to 20.00 x CT in steps of 0.01
	ESCAPE / MESSAGE	PHASE C CURRENT POSITION: 300° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	GND CURRENT LEVEL: 0.00 x CT	Range: 0.00 to 20.00 x CT in steps of 0.01
	ESCAPE / MESSAGE	GND CURRENT POSITION: 0° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	POLARIZING CURRENT LEVEL: 1.00 x CT	Range: 0.00 to 20.00 x CT in steps of 0.01
	ESCAPE / MESSAGE	POLARIZING CURRENT POSITION: 0° Lag	Range: 0 to 359° Lag in steps of 1

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ESCAPE / MESSAGE	SYSTEM FREQ: 60.00 Hz	Range: 20.00 to 65.00 Hz in steps of 0.01
ESCAPE / MESSAGE	A/I CURRENT: 0.00 mA	Range: 0.00 to 20.00 mA in steps of 0.01

The Fault Simulation State allows adjustment of all current and voltage phasors so that a wide variety of system disturbances can be simulated. The frequency and the analog input values can also be adjusted to give complete flexibility. Fault bus voltage values are always entered as Wye values, even if the relay is set to Delta. The relay will calculate the equivalent line voltages. Voltage magnitudes are entered in per unit values relative to the nominal system voltage that is defined by the **NOMINAL VT SECONDARY VOLTAGE** and **VT RATIO** setpoints. Phase current magnitudes are entered in per unit values relative to the nominal system current that is defined by the **PHASE CT PRIMARY** setpoint. All phasor angles are referenced to the prefault A-N bus voltage at 0°.

e) POSTFAULT VALUES

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ SIMULATION ⇨⇩ POSTFAULT VALUES

■ POSTFAULT VALUES ■ [ENTER] for more	ENTER / ESCAPE	BUS VOLTAGE LEVEL: 1.00 x VT	Range: 0.00 to 2.00 x VT in steps of 0.01
	ESCAPE / MESSAGE	BUS VOLTAGE FREQ: 60.00 Hz	Range: 20.00 to 65.00 Hz in steps of 0.01
	ESCAPE / MESSAGE	SYNC VOLTAGE LEVEL: 1.00 x VT	Range: 0.00 to 2.00 x VT in steps of 0.01
	ESCAPE / MESSAGE	SYNC VOLTAGE POSITION: 0° Lag	Range: 0 to 359° Lag in steps of 1
	ESCAPE / MESSAGE	SYNC VOLTAGE FREQ: 60.00 Hz	Range: 20.00 to 65.00 Hz in steps of 0.01

The Postfault State allows adjustment of the bus and line voltages in order to simulate an open breaker condition and allow testing of the synchrocheck feature. All phasor angles are referenced to the prefault A-N bus voltage at 0°.

5.9.5 FACTORY SERVICE

PATH: SETPOINTS ⇨⇩ S8 TESTING ⇨⇩ FACTORY SERVICE

■ FACTORY SERVICE ■ [ENTER] for more	ENTER / ESCAPE	ENTER FACTORY PASSCODE: ■	Range: Restricted access for GE personnel only

These messages are intended for factory use only, to perform testing and diagnostics. Entering the factory service passcode in the first message allows access to the command messages.

6.1.1 ACTUAL VALUES MAIN MENU

Measured values, maintenance, and fault analysis information are accessed in the actual values mode. Actual value messages are organized into logical groups, or pages, for easy reference as shown in the summary below. All actual value messages are illustrated and described this chapter.

Actual values may be accessed by any of the following three methods.

1. Front panel, using the keys and display.
2. Front program port, and a portable computer running the 750/760PC software supplied with the relay.
3. Rear RS485/RS422 COM 1 port or RS485 COM 2 port with a SCADA system running user-designed software.

■■ ACTUAL VALUES ■■ A1 STATUS	■ VIRTUAL INPUTS ■ [ENTER] for more	See page 6–5.
	■ HARDWARE INPUTS ■ [ENTER] for more	See page 6–5.
	■ LAST TRIP DATA ■ [ENTER] for more	See page 6–6.
	■ FAULT LOCATIONS ■ [ENTER] for more	See page 6–7.
	■ CLOCK ■ [ENTER] for more	See page 6–7.
	■ AR ■ [ENTER] for more	See page 6–7. (760 only)
■■ ACTUAL VALUES ■■ A2 METERING	■ CURRENT ■ [ENTER] for more	See page 6–9.
	■ VOLTAGE ■ [ENTER] for more	See page 6–10.
	■ FREQ ■ [ENTER] for more	See page 6–11.
	■ SYNCHRO VOLTAGE ■ [ENTER] for more	See page 6–11.
	■ PWR ■ [ENTER] for more	See page 6–11.
	■ ENERGY ■ [ENTER] for more	See page 6–12.
	■ DMND ■ [ENTER] for more	See page 6–13.
	■ A/I ■ [ENTER] for more	See page 6–14.
■■ ACTUAL VALUES ■■ A3 MAINTENANCE	■ TRIP COUNTERS ■ [ENTER] for more	See page 6–15.
	■ ARCING CURRENT ■ [ENTER] for more	See page 6–15.

ESCAPE
MESSAGE

```
■■ ACTUAL VALUES
■■ A4 EVENT RECORDER
```

ENTER / ESCAPE

```
■ E128: Mar 16 1997
■ [ENTER] for more
```

See page 6–16.

ESCAPE / MESSAGE

```
■ E127: Mar 15 1997
■ [ENTER] for more
```

↓

ESCAPE / MESSAGE

```
■ E1: Mar 14 1997
■ [ENTER] for more
```

ESCAPE / MESSAGE

```
■ LAST RESET DATE
■ [ENTER] for more
```

See page 6–18.

ESCAPE
MESSAGE

```
■■ ACTUAL VALUES
■■ A5 PRODUCT INFO
```

ENTER / ESCAPE

```
■ TECHNICAL SUPPORT
■ [ENTER] for more
```

See page 6–19.

ESCAPE / MESSAGE

```
■ REV CODES
■ [ENTER] for more
```

See page 6–19.

ESCAPE / MESSAGE

```
■ CAL DATES
■ [ENTER] for more
```

See page 6–19.

The following two figures show block diagrams from the Actual Values messages.

6

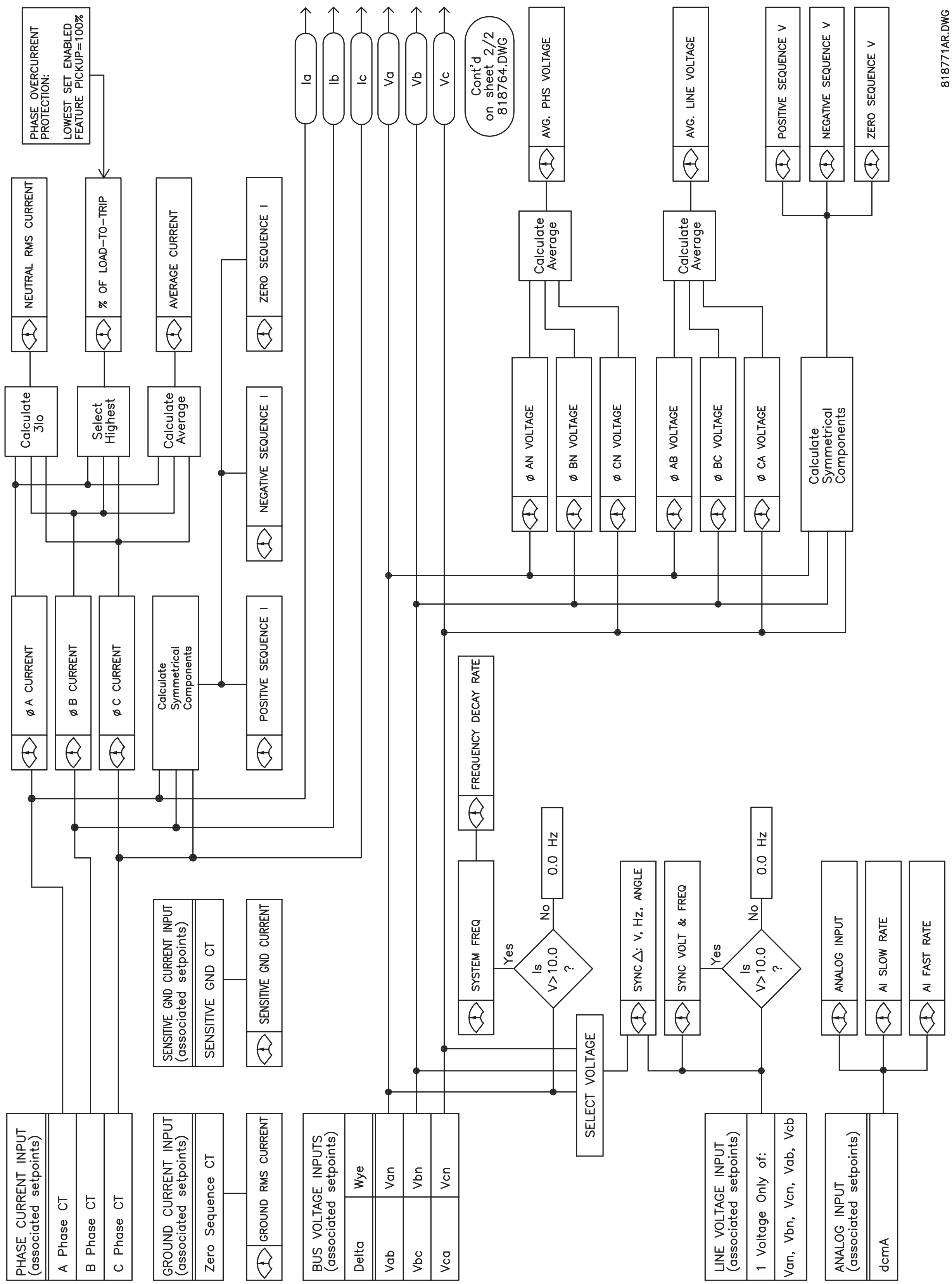

Figure 6–1: ACTUAL VALUES BLOCK DIAGRAM (1 OF 2)

6

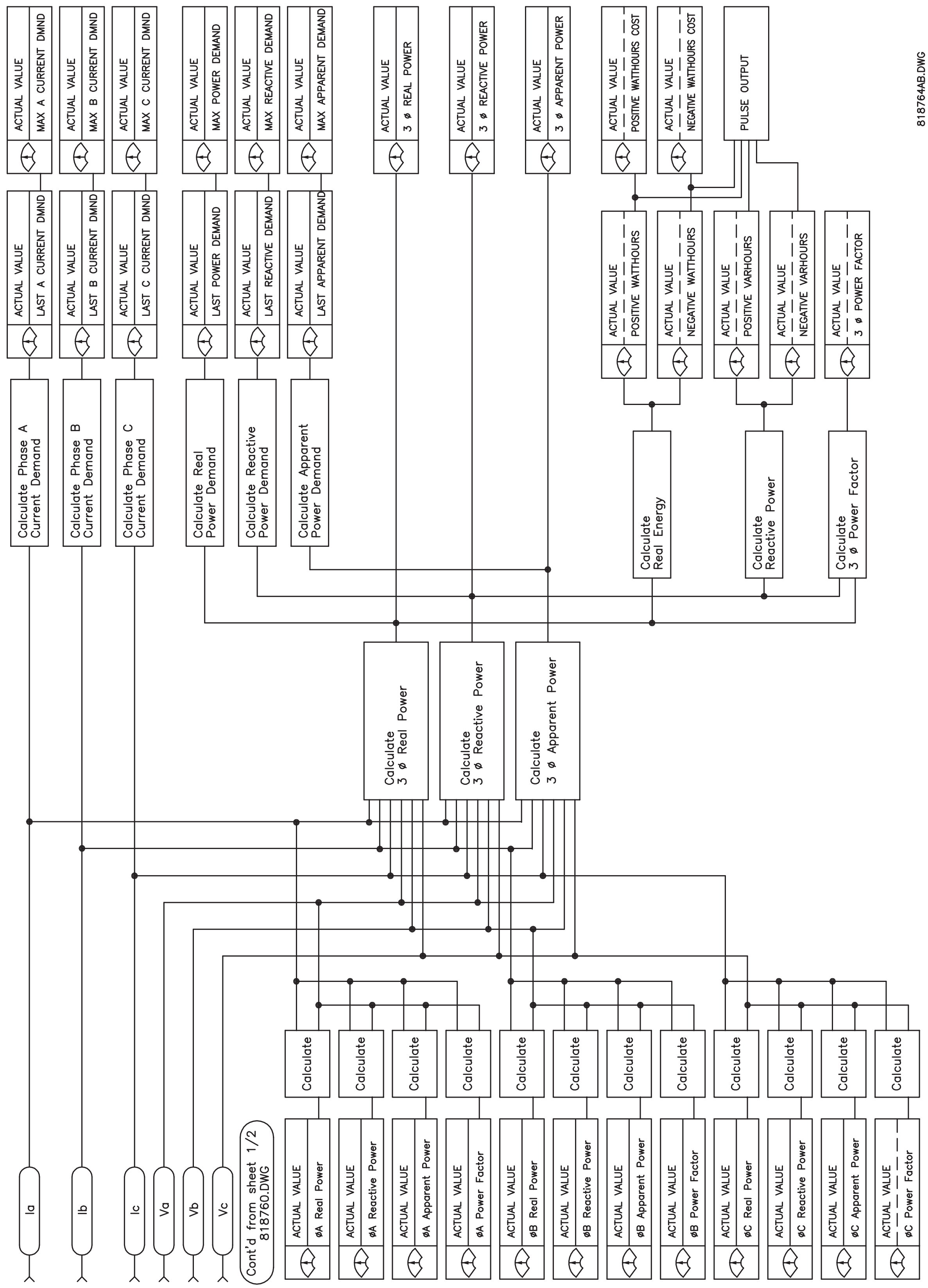

Figure 6–2: ACTUAL VALUES BLOCK DIAGRAM (2 OF 2)

6.2.1 VIRTUAL INPUTS

PATH: ACTUAL VALUES ⇨ A1 STATUS ⇨ VIRTUAL INPUTS

■ VIRTUAL INPUTS ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	2 VIRTUAL INPUTS ARE ACTIVE	*Range: 0 to 20 Virtual Inputs*
	ESCAPE / MESSAGE ⇧	Logic Input 1 Off	*Range: On, Off* *Reflects user-programmed name.*

The state of all active virtual inputs as well as the ability to set their state is displayed here. In some applications, these displays can be used instead of panel switches for controlling operations within the relay. The ability to have user defined names for the inputs allows the operator interface to be easily understood. See Section 5.4: S3 Logic Inputs on page 5–19 for complete details on virtual inputs, their setpoints and application.

The first value displays how many logic inputs have a virtual condition selected as part of their asserted logic. The states of Virtual Inputs 1 through 20 are displayed in this menu. The **Logic Input 1** display heading is user-programmable. Note that only "active" virtual inputs are displayed; active virtual inputs are those that have their **INPUT n ASSERTED LOGIC** setpoint programmed to monitor the state of the virtual input. There are subsequent displays for the remaining virtual inputs.

6.2.2 HARDWARE INPUTS

PATH: ACTUAL VALUES ⇨ A1 STATUS ⇨⇩ HARDWARE INPUTS

■ HARDWARE INPUTS ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	CONTACT 1 STATE: Open	*Range: Open, Closed*
	ESCAPE / MESSAGE ⇳	CONTACT 2 STATE: Open	*Range: Open, Closed*
		↓	
	ESCAPE / MESSAGE ⇳	CONTACT 14 STATE: Open	*Range: Open, Closed*
	ESCAPE / MESSAGE ⇳	SETPOINT ACCESS STATE: Restricted	*Range: Restricted, Allowed*
	ESCAPE / MESSAGE ⇳	Trip Coil Mon STATE: Open	*Range: Open, Closed*
	ESCAPE / MESSAGE ⇧	Close Coil Mon STATE: Open	*Range: Open, Closed*

These messages display the state of all hardware inputs. The top line in the last two values above reflect the names programmed in the **S6 MONITORING ⇨⇩ EQUIPMENT ⇨⇩ COIL 1 MON ⇨ COIL 1 MON NAME** and **COIL 2 MON NAME** setpoints, respectively.

6

6.2.3 LAST TRIP DATA

PATH: ACTUAL VALUES ⇨ A1 STATUS ⇨⇩ LAST TRIP DATA

Display	Keys	Message	Range
■ LAST TRIP DATA ■ [ENTER] for more	ENTER ⇨ / ⇦ ESCAPE	DATE OF LAST TRIP: Mar 16 1997	Range: *Date in format shown*
	ESCAPE / MESSAGE ⇳	TIME OF LAST TRIP: 12:34:56.789	Range: *Time in format shown*
	ESCAPE / MESSAGE ⇳	TRIP: <Φ> <Cause>	Range: *See Section 6.5: A4 Event Recorder on page 6–16 for range details.*
	ESCAPE / MESSAGE ⇳	A: 0 B: 0 C: 0 Amps	Range: *0 to 65535 A*
	ESCAPE / MESSAGE ⇳	GND CURRENT: 0 A	Range: *0 to 65535 A*
	ESCAPE / MESSAGE ⇳	SENSTV GND CURRENT: 0 A	Range: *0 to 655.35 A*
	ESCAPE / MESSAGE ⇳	NEUTRAL CURRENT: 0 A	Range: *0 to 65535 A*
	ESCAPE / MESSAGE ⇳	AN: 0.00 BN: 0.00 CN: 0.00 kVolts	Range: *On, Off. Seen only if* **S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING ⇨⇩ VT CONNECTION TYPE** *is "Wye"*
	ESCAPE / MESSAGE ⇳	AB: 0.00 BC: 0.00 CA: 0.00 kVolts	Range: *On, Off. Not seen if* **S2 SYSTEM SETUP ⇨⇩ BUS VT SENSING ⇨⇩ VT CONNECTION TYPE** *is "Wye"*
	ESCAPE / MESSAGE ⇳	NEUTRAL VOLTAGE: 0.00 kV	Range: *0 to 655.35 kV*
	ESCAPE / MESSAGE ⇳	SYSTEM FREQ: 0.00 Hz	Range: *0.00 to 90.00 Hz*
	ESCAPE / MESSAGE ⇧	A/I: 0 µA	Range: *0 to 655.35 units. Units programmed in* **S6 MONITORING ⇨⇩ A/I ⇨ A/I SETUP ⇨⇩ A/I UNITS**

Independent of the event recorder, the relay captures the system information at the time of the last trip event. This information includes a time and date stamp, trip cause, phase current, ground current, sensitive ground current, neutral current, voltages, system frequency, and the analog input. If more than one protection element trips for a fault (for example, both the Phase and Neutral Instantaneous Overcurrent 1 elements) then only the first trip event detected by the relay will have Last Trip Data captured. This information cannot be cleared; data for a new trip overwrites the previous trip data.

6.2.4 FAULT LOCATIONS

PATH: ACTUAL VALUES ⇨ A1 STATUS ⇨⇩ FAULT LOCATIONS ⇨ FAULT LOCATION 0(9)

■ FAULT LOCATION 0 ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	DATE OF FAULT 0: Mar 16 1997	Range: Date in format shown
	ESCAPE MESSAGE ⇳	TIME OF FAULT 0: 12:34:56.789	Range: Time in format shown
	ESCAPE MESSAGE ⇳	TYPE OF FAULT: n/a	Range: Phase A, Phase B, Phase C, Ground
	ESCAPE MESSAGE ⇳	DISTANCE TO FAULT: 0.00 km	Range: –327.68 to 327.68 km/mi. Seen only if a fault location calculation has been performed.
	ESCAPE MESSAGE ⇧	Zpos (INDUCTIVE) OHM TO FAULT: 0.00	Range: 0.00 to 655.35 Ω. Seen only if a fault location calculation has been performed.

The data for ten faults detected by overcurrent elements is stored under headings beginning with **FAULT LOCATION 0**. This information cannot be cleared; data for new events is always stored as fault 0. The data for each previous fault is shifted to the next highest number, and Event 9 is discarded.

6.2.5 CLOCK

PATH: ACTUAL VALUES ⇨ A1 STATUS ⇨⇩ CLOCK

■ CLOCK ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	CURRENT DATE: November 23 1998	Range: Date in format shown. Displays "Unavailable" if the date has never been programmed.
	ESCAPE MESSAGE ⇧	CURRENT TIME: 16:30:00	Range: Time in format shown. Displays "Unavailable" if the time has never been programmed.

6.2.6 AUTORECLOSE (760 ONLY)

PATH: ACTUAL VALUES ⇨ A1 STATUS ⇨⇩ AR

■ AR ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	AR SHOT NUMBER IN EFFECT: 0	Range: 0 to 4
	ESCAPE MESSAGE ⇳	AR SHOTS REMAINING: 4	Range: 0 to 4
	ESCAPE MESSAGE ⇳	AR SHOT RATE: 0 /hr	Range: 0 to 4
	ESCAPE MESSAGE ⇳	AR SHOT COUNT: 0	Range: 0 to 4
	ESCAPE MESSAGE ⇧	AR SHOT COUNT LAST RESET: Oct 25 1998	Range: Date in format shown. Displays "Unavailable" if the date has never been programmed.

The present shot number which the autoreclose scheme is using to control protection settings is displayed in the **AR SHOT NUMBER IN EFFECT** value. If the scheme has reached Lockout, the display is the shot number after which a trip caused lock-out. The **AR SHOTS REMAINING** value displays the number of reclose shots that can still be performed. After this point, the reclose system will be either reset or locked-out. The value displayed is contained in the Shot Limit memory. Each time a reclose shot is performed, in a given sequence, this Shot Limit is reduced by one. The Shot Limit can also be reduced to any given value less than the programmed value by the current supervision function.

The number of reclosures in the past hour is shown in the **AR SHOT RATE** value. This value will be cleared by a **RESET AR RATE DATA** command via the front panel or communications.

The **AR SHOT COUNT** value shows the total number of reclosures since the **AR SHOT COUNT LAST RESET** date.

6.3.1 METERING CONVENTIONS

The relay measures all RMS currents and voltages, frequency, and an auxiliary analog input. Other values like average and neutral current, average line and phase voltage, symmetrical components, frequency decay rate, synchrocheck delta, power factor, power (real, reactive, apparent), energy (real, reactive), running and maximum demands (current, real power, reactive power, apparent power), and analog input rate of change are derived. All quantities are recalculated every power system cycle and perform protection and monitoring functions. Displayed metered quantities are updated approximately three (3) times a second for readability. All phasors and symmetrical components are referenced to the A-N voltage phasor for wye-connected VTs; to the A-B voltage phasor for delta-connected VTs; or to the phase A current phasor when no voltage signals are present.

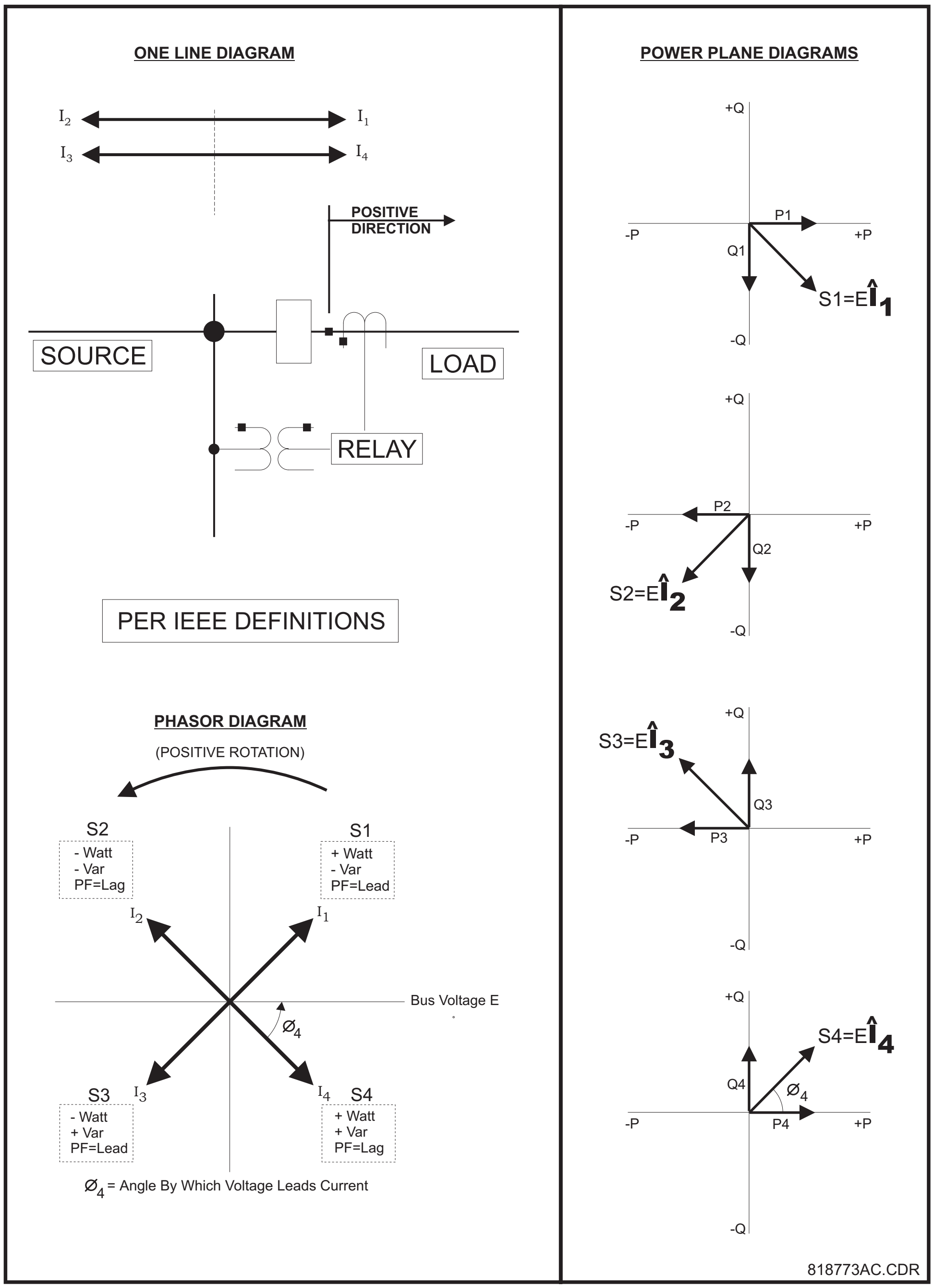

Figure 6–3: POWER QUANTITY RELATIONSHIPS

6.3.2 CURRENT

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨ CURRENT

```
■ CURRENT
■ [ENTER] for more
```

Display	Range
`A: 0 B: 0` / `C: 0 Amps`	Range: 0 to 65535 A
`% OF LOAD-TO-TRIP:` / `0%`	Range: 0 to 2000%
`AVERAGE CURRENT:` / `0 A`	Range: 0 to 655535 A
`PHASE A CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`PHASE B CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`PHASE C CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`NEUTRAL CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`GND CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`SENSTV GND CURRENT:` / `0.00 A 0° Lag`	Range: 0 to 655.35 A, 0 to 359° Lag
`POS SEQ CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`NEG SEQ CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`ZERO SEQ CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag
`POLARIZING CURRENT:` / `0 A 0° Lag`	Range: 0 to 65535 A, 0 to 359° Lag

Measured values of phase current magnitudes and phasors are displayed here. In addition, several calculated values are also displayed. The **AVERAGE CURRENT** displays the calculated averages of the Phase A, B, and C RMS currents:

$$I_{avg} = \frac{(|I_a| + |I_b| + |I_c|)}{3} \qquad \textbf{(EQ 6.1)}$$

The **NEUTRAL CURRENT** value displays the calculated neutral current RMS phasor given by: $3I_0 = I_a + I_b + I_c$ **(EQ 6.2)**

The **POS SEQ CURRENT** displays the calculated positive-sequence current RMS phasor as given by:

$$I_{a1} = \frac{I_a + aI_b + a^2 I_c}{3} \text{ for ABC phase sequence; } I_{a1} = \frac{I_a + a^2 I_b + aI_c}{3} \text{ for ACB phase sequence} \qquad \textbf{(EQ 6.3)}$$

The **NEG SEQ CURRENT** displays the calculated negative-sequence current RMS phasor as given by:

$$I_{a2} = \frac{I_a + a^2 I_b + aI_c}{3} \text{ for ABC phase sequence; } I_{a2} = \frac{I_a + aI_b + a^2 I_c}{3} \text{ for ACB phase sequence} \qquad \textbf{(EQ 6.4)}$$

The **ZERO SEQ CURRENT** displays the calculated zero-sequence current RMS phasor: $I_{a0} = \frac{I_a + I_b + I_c}{3}$ **(EQ 6.5)**

6.3.3 VOLTAGE

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ VOLTAGE

■ VOLTAGE ■ [ENTER] for more	
AB: 0.00 BC: 0.00 CA: 0.00 kV	*Range: 0 to 600.00 kV*
AVERAGE LINE VOLTAGE: 0.00 kV	*Range: 0 to 600.00 kV*
AN: 0.00 BN: 0.00 CN: 0.00 kV	*Range: 0 to 600.00 kV* *Seen only if* **VT CONNECTION TYPE** *is "Wye"*
AVERAGE PHASE VOLTAGE: 0.00 kV	*Range: 0 to 600.00 kV* *Seen only if* **VT CONNECTION TYPE** *is "Wye"*
LINE A-B VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*
LINE B-C VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*
LINE C-A VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*
LINE A-N VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag* *Seen only if* **VT CONNECTION TYPE** *is "Wye"*
LINE B-N VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag* *Seen only if* **VT CONNECTION TYPE** *is "Wye"*
LINE C-N VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag* *Seen only if* **VT CONNECTION TYPE** *is "Wye"*
NEUTRAL VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*
POS SEQ VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*
NEG SEQ VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*
ZERO SEQ VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 600.00 kV, 0 to 359° Lag*

The measured values of line and phase voltage magnitudes and phasors for the Bus VT inputs are displayed along with sequence components. In addition, several calculated values are also displayed. The **AVERAGE LINE VOLTAGE** displays the calculated averages of the RMS line voltages given by: $V_{avg} = (|V_{ab}| + |V_{bc}| + |V_{ca}|)/3$.

The **AVERAGE PHASE VOLTAGE** displays the calculated average of the RMS phase voltages given by:

$$V_{avg} = (|V_{an}| + |V_{bn}| + |V_{cn}|)/3 \quad \textbf{(EQ 6.6)}$$

The **NEUTRAL VOLTAGE** displays the calculated neutral RMS phasor given by: $3V_0 = V_a + V_b + V_c$ **(EQ 6.7)**

The **POS SEQ VOLTAGE** displays the calculated positive-sequence voltage RMS phasor given by:

$$V_{a1} = (V_a + aV_b + a^2V_c)/3 \text{ for ABC phase sequence; } V_{a1} = (V_a + a^2V_b + aV_c)/3 \text{ for ACB phase sequence} \quad \textbf{(EQ 6.8)}$$

The **NEG SEQ VOLTAGE** displays the calculated negative-sequence voltage RMS phasor given by:

$$V_{a2} = (V_a + a^2V_b + aV_c)/3 \text{ for ABC phase sequence; } V_{a2} = (V_a + aV_b + a^2V_c)/3 \text{ for ACB phase sequence} \quad \textbf{(EQ 6.9)}$$

The **ZERO SEQ VOLTAGE** value shows the calculated zero-sequence current RMS phasor: $V_{a0} = (V_a + V_b + V_c)/3$ **(EQ 6.10)**

6.3.4 FREQUENCY

PATH: ACTUAL VALUES ⇨ A2 METERING ⇨⇩ FREQ

■ FREQ ■ [ENTER] for more	SYSTEM FREQ: 0.00 Hz	Range: 0 to 90.00 Hz
	FREQ DECAY RATE: 0.00 Hz/s	Range: –10.00 to 10.00 Hz/s

Frequency is measured with a zero-crossing detector from the V_a voltage. This measured frequency is used for Frequency Tracking (see page 2–3 for details). Both of these values will read zero if the potential across the V_a input terminals is less than 10 V. When the **FREQ DECAY RATE** is positive, the frequency is increasing; when it is negative, the frequency is decreasing.

6.3.5 SYNCHRONIZING VOLTAGE

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ SYNCHRO VOLTAGE

■ SYNCHRO VOLTAGE ■ [ENTER] for more	SYNCHRO VOLTAGE: 0.00 kV 0° Lag	Range: 0 to 600.00 kV, 0 to 359° Lag
	SYNCHRO FREQ: 0.00 Hz	Range: 0 to 90.00 Hz
	SYNCHRO DELTA: 0° 0.00 kV 0.00 Hz	Range: 0 to 359°, 0 to 600.00 kV, 0 to 90.00 Hz

The voltage magnitude, phase angle, frequency, and delta values for the line VT synchronizing voltage input are displayed as shown above. The **SYNCHRO FREQ** value displays the measured frequency of the line VT input; it will be zero if the potential across the line VT input terminals is less than 10.0 V. The **SYNCHRO DELTA** value displays the differences of phase position, voltage magnitude, and frequency between the line VT input and its corresponding bus VT input.

6

6.3.6 POWER

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ PWR

■ PWR ■ [ENTER] for more	3Φ REAL PWR: 0.0 kW	Range: –30000 to 30000 kW. See the Power Quantities table below for further explanation.
	3Φ REACTIVE PWR: 0.0 kvar	Range: –30000 to 30000 kvar. See the Power Quantities table below for further explanation.
	3Φ APPARENT PWR: 0.0 kVA	Range: 0 to 30000 kVA. See the Power Quantities table below for further explanation.
	3Φ PWR FACTOR: 0.00	Range: –0.99 to 1.00
	ΦA REAL PWR: 0.0 kW	Range: –30000 to 30000 kW. See the Power Quantities table below for further explanation.
	ΦA REACTIVE PWR: 0.0 kvar	Range: –30000 to 30000 kvar. See the Power Quantities table below for further explanation.
	ΦA APPARENT PWR: 0.0 kVA	Range: 0 to 30000 kVA. See the Power Quantities table below for further explanation.
	ΦA PWR FACTOR: 0.00	Range: –0.99 to 1.00

The actual values messages for three-phase and Phase A power are shown above. Similar power messages follow for Phases B and C.

The relay calculates and displays the real, reactive, and apparent power of the system. Both three phase and single phase quantities are given. The relationship of these power quantities is illustrated in the power plane, as shown in the power quantity relationships figure that follows. If the **VT CONNECTION TYPE** setpoint "None", all three phase quantities are displayed as zero and all single phase quantities disappear. All power quantities auto-range to show units appropriate to the nominal power which is defined as:

$$P_N = \text{Phase CT Primary} \times \text{VT Secondary Voltage} \times \text{VT Ratio} \quad \textbf{(EQ 6.11)}$$

Table 6–1: POWER QUANTITIES

NOMINAL POWER (P_N)	POWER UNITS	RESOLUTION
P_N < 1 MVA	kW, kvar, kVA, kWhr, kvarhr	1
1 MVA ≤ P_N < 10 MVA	MW, Mvar, MVA, MWhr, Mvarh	0.01
10 MVA ≤ P_N	MW, Mvar, MVA, MWhr, Mvarh	0.1

6.3.7 ENERGY

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ ENERGY

■ ENERGY
■ [ENTER] for more

Message	Range
POSITIVE WATTHOURS: 0.0 MWh	Range: 0 to 4 x 10^6 MWh. See Table 6–1: Power Quantities for further explanation of units.
POSITIVE WATTHOUR COST: $ 0	Range: 0 to $4 x 10^9
NEGATIVE WATTHOURS: 0.0 MWh	Range: 0 to 4 x 10^6 MWh. See Table 6–1: Power Quantities for further explanation of units.
NEGATIVE WATTHOUR COST: $ 0	Range: 0 to $4 x 10^9
POSITIVE VARHOURS: 0.0 Mvarh	Range: 0 to 4 x 10^6 Mvarh. See Table 6–1: Power Quantities for further explanation of units.
NEGATIVE VARHOURS: 0.0 Mvarh	Range: 0 to 4 x 10^6 Mvarh. See Table 6–1: Power Quantities for further explanation of units.
ENERGY USE DATA LAST RESET: Mar 16 1997	Range: Date in format shown

The relay uses three phase power quantities to determine total energy consumption. All energy quantities can be reset to zero with the **S1 RELAY SETUP ⇨⇩ CLEAR DATA ⇨⇩ CLEAR ENERGY USE DATA** setpoint command. Energy cost is also calculated based on the average billing rate programmed in the **S2 SYSTEM SETUP ⇨⇩ PWR SYSTEM ⇨⇩ COST OF ENERGY** setpoint. Although billing rate structures are usually more complex, these values provide approximate costs. Energy quantities auto-range to show units appropriate to the nominal power.

Power quantities in the positive direction are added to the positive values; power quantities in the opposite direction are added to the negative values.

NOTE

The 750/760 is not a revenue class meter and cannot be used for billing purposes.

6.3.8 DEMAND

a) MAIN MENU

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ DMND

```
■ DMND                    ENTER ⇨   ■ PHASE A CURRENT        See below.
■ [ENTER] for more      ⇦ ESCAPE    ■ [ENTER] for more

                          ESCAPE    ■ PHASE B CURRENT
                          MESSAGE ⇳ ■ [ENTER] for more

                          ESCAPE    ■ PHASE C CURRENT
                          MESSAGE ⇳ ■ [ENTER] for more

                          ESCAPE    ■ REAL PWR
                          MESSAGE ⇳ ■ [ENTER] for more

                          ESCAPE    ■ REACTIVE PWR
                          MESSAGE ⇳ ■ [ENTER] for more

                          ESCAPE    ■ APPARENT PWR
                          MESSAGE ⇳ ■ [ENTER] for more

                          ESCAPE    ■ LAST RESET DATE
                          MESSAGE ⇧ ■ [ENTER] for more
```

The relay measures current demand on each phase, and average three phase demand for real, reactive, and apparent power. These parameters can be monitored to reduce supplier demand penalties or for statistical metering purposes. Demand calculations are based on the measurement type selected under **S6 MONITORING ⇨⇩ DMND**. For each quantity, the relay displays the demand over the most recent demand time interval, the maximum demand since the last maximum demand reset, and the time and date stamp of this maximum demand value. Maximum demand quantities can be reset to zero with the **S1 RELAY SETUP ⇨⇩ CLEAR DATA ⇨⇩ CLEAR MAX DMND DATA** setpoint command.

b) PHASE A CURRENT TO APPARENT POWER DEMAND

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ DMND ⇨ PHASE A CURRENT(APPARENT PWR)

```
■ PHASE A CURRENT         ENTER ⇨   LAST PHASE A CURRENT     Range: 0 to 65535 A
■ [ENTER] for more      ⇦ ESCAPE    DMND:       0 A

                          ESCAPE    MAX PHASE A CURRENT      Range: 0 to 65535 A
                          MESSAGE ⇳ DMND:       0 A

                          ESCAPE    LAST PHASE A CURRENT     Range: Date in format shown
                          MESSAGE ⇳ DATE: Mar 16 1997

                          ESCAPE    LAST PHASE A CURRENT     Range: Time in format shown
                          MESSAGE ⇧ TIME: 16:30:00
```

The actual values for Phase A Current Demand are shown above. The actual values displays for Phase B Current, Phase C Current, Real Power, Reactive Power, and Apparent Power Demand are similar to those above.

c) LAST RESET DATE

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ DMND ⇨⇩ LAST RESET DATE

```
■ LAST RESET DATE         ENTER ⇨   DMND DATA LAST           Range: Date in format shown
■ [ENTER] for more      ⇦ ESCAPE    RESET: Mar 16 1997
```

This message displays the last date the maximum demand data was cleared. If the date has never been programmed, this relay will display "Unavailable".

6.3.9 ANALOG INPUT

PATH: ACTUAL VALUES ⇨⇩ A2 METERING ⇨⇩ ANALOG INPUT

Display	Keys	Message	Range
■ A/I ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	A/I: 0 µA	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	A/I: 0 µA /min	Range: 0 to 65535
	ESCAPE MESSAGE ⇧	A/I: 0 µA /hour	Range: 0 to 65535

The relay provides the ability to monitor any external quantity via an auxiliary current input called the analog input.

These first actual value message displays the scaled value of the analog input, as defined in **S6 MONITORING ⇨⇩ A/I ⇨⇩ A/I SETUP**. In this actual values display, the name programmed in setpoint message **S6 MONITORING ⇨⇩ A/I ⇨⇩ A/I SETUP ⇨ A/I NAME** will be displayed instead of the factory default "A/I". The name of the units programmed in the setpoint message **S6 MONITORING ⇨⇩ A/I ⇨⇩ A/I SETUP ⇨⇩ A/I UNITS** will be displayed instead of the factory default "µA".

The subsequent actual value messages display the analog input rate of change in per minutes and per hour.

6.4.1 TRIP COUNTERS

PATH: ACTUAL VALUES ⇨⇩ A3 MAINTENANCE ⇨ TRIP COUNTERS

■ TRIP COUNTERS ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	BRKR TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	GND OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	SENSTV GND OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	NEUTRAL OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	NEG SEQ OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	1Φ PHASE OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	2Φ PHASE OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇳	3Φ PHASE OC TRIPS: 0	Range: 0 to 65535
	ESCAPE MESSAGE ⇧	TRIP COUNTERS LAST RESET: Mar 16 1997	Range: Date in format shown

The total number of trips since the **TRIP COUNTERS LAST RESET** date are displayed. Trip counters are used for scheduling inspections on equipment, for performing qualitative analysis of system problems, and for spotting trends. Any trip condition will increment the **BREAKER TRIPS** counter and one of the more specific trip counters available. A trip condition is generated by any feature or input which signals the Trip Relay to operate. If the logic input assigned to the Block Breaker Statistics function is active, when a trip condition is generated, the trip counters will not be incremented. Trip counter data can be reset to zero with the **S1 RELAY SETUP ⇨⇩ INSTALLATION ⇨⇩ RESET TRIP COUNTER DATA** setpoint.

6

6.4.2 ARCING CURRENT

PATH: ACTUAL VALUES ⇨⇩ A3 MAINTENANCE ⇨⇩ ARCING CURRENT

■ ARCING CURRENT ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	TOTAL ARCING CURRENT ΦA: 0 kA²-cycle	Range: 0 to 65535 kA²-cycle
	ESCAPE MESSAGE ⇳	TOTAL ARCING CURRENT ΦB: 0 kA²-cycle	Range: 0 to 65535 kA²-cycle
	ESCAPE MESSAGE ⇳	TOTAL ARCING CURRENT ΦC: 0 kA²-cycle	Range: 0 to 65535 kA²-cycle
	ESCAPE MESSAGE ⇧	ARCING CURRENT LAST RESET: Mar 16 1997	Range: Date in format shown

The accumulated Phase A, B, and C arcing currents (in kA^2-cycles) since the **ARCING CURRENT LAST RESET** date are displayed. The relay calculates an estimate of the per-phase wear on the breaker contacts. Arcing current data can be reset to zero with the **S1 RELAY SETUP ⇨⇩ INSTALLATION ⇨⇩ RESET ARCING CURRENT DATA** setpoint command.

6.5.1 EVENT RECORDS

PATH: ACTUAL VALUES ⇨⇩ A4 EVENT RECORDER ⇨ E001(128)

■ E128: March 16 1997 ■ [ENTER] for more	ENTER ⇨ ⇦ ESCAPE	TIME OF EVENT: 16:30:00.000	*Range: Time in format shown*
	ESCAPE MESSAGE ⇳	<Event_Type>: <Cause_of_Event>	*Range: See Table 6–2: Event Types on page 6–17 and Table 6–3: Cause of Events on page 6–18.*
	ESCAPE MESSAGE ⇳	PHASE A CURRENT: 0 A 0° Lag	*Range: 0 to 65535 A, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	PHASE B CURRENT: 0 A 0° Lag	*Range: 0 to 65535 A, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	PHASE C CURRENT: 0 A 0° Lag	*Range: 0 to 65535 A, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	GND CURRENT: 0 A 0° Lag	*Range: 0 to 65535 A, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	SENSTV GND CURRENT: 0.00 A 0° Lag	*Range: 0 to 655.35 A, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	LINE A-B VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	LINE B-C VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	LINE C-A VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	LINE A-N VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	LINE B-N VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	LINE C-N VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	SYSTEM FREQ: 0.00 Hz	*Range: 0 to 90.00 Hz*
	ESCAPE MESSAGE ⇳	SYNCHRO VOLTAGE: 0.00 kV 0° Lag	*Range: 0 to 65535 kV, 0 to 359° Lag*
	ESCAPE MESSAGE ⇳	SYNCHRO FREQ: 0.00 Hz	*Range: 0 to 90.00 Hz*
	ESCAPE MESSAGE ⇧	A/I: 0 μA	*Range: 0 to 65535 Analog Input Units*

The 750/760 has an event recorder which runs continuously, capturing and storing the last 128 events. All event recorder information is stored in non-volatile memory so the information is maintained after losing relay control power. The last 128 events are displayed from newest to oldest event. Each event has a header message containing a summary of the event that occurred. Each event is assigned an event number equal to the number of events that have occurred since the recorder was cleared; the event number is incremented for each new event. Event recorder data can be cleared with the **S1 RELAY SETUP ⇨⇩ CLEAR DATA ⇨⇩ CLEAR EVENT RECORDER DATA** setpoint.

Event information is gathered at the instant the event occurs; as such, the current and voltage readings may reflect the transient nature of the event as opposed to steady state values. All messages pertaining to phase voltages AN, BN, and CN are only displayed if **VT CONNECTION TYPE** is programmed to "Wye". If **VT CONNECTION TYPE** is programmed to "Delta", line voltages AB, BC, and CA are displayed.

Events are organized into several different types as shown in the table below. Several event types can be filtered out in order to save space in the event recorder (see Sections 5.2.4: Event Recorder on page 5–10 and Chapter 7 for more details on event filtering). For every event type there are a number of possible causes. The Cause of Events table lists all the event causes according to which event types they can generate.

The following symbols are used in the description of the event messages: **<Φ>** represents the phases involved (e.g. ΦBC) in the event if applicable and **<ON>** represents whether the logic input is asserted (ON) or not asserted (OFF)

Table 6–2: EVENT TYPES

EVENT TYPE	DISPLAY	DESCRIPTION
General Events	None	Events that occur when a specific operation takes place
Pickup Events	PICKUP: <Φ>	These are events that occur when a protection element picks up and starts timing
Trip Events	TRIP: <Φ>	These are events that occur when an element whose function has been programmed to "Trip" or "Trip & AR" operates.
Alarm Events	ALARM: <Φ>	These are events that occur when an element whose function has been programmed to "Alarm" operates or drops out.
Latched Alarm Events	LATCHED ALARM: <Φ>	These are events that occur when an element whose function has been programmed to "Latched Alarm" operates or drops out.
Control Events	CONTROL: <Φ>	These are events that occur when an element whose function has been programmed to "Control" operates or drops out.
Dropout Events	DROPOUT:	These are events that occur when a protection element drops out after a corresponding pickup event.
Contact Events	INPUT C <ON>:	These are events that occur when a contact input is either asserted or de-asserted.
Virtual Input Events	INPUT V <ON>:	These are events that occur when a virtual input is either asserted or de-asserted.
Contact and Virtual Input Events	INPUT CV <ON>:	These are events that occur when both a contact input and virtual input is either asserted or de-asserted.
Self-Test Warning Events	SELF-TEST WARNING:	These are events that occur when a self-test warning is detected or one of the manual testing

The event causes are listed alphabetically by type of event in the following table.

Table 6–3: CAUSE OF EVENTS

GENERAL EVENT CAUSES				
Autoreclose Reset	Breaker Closed	Breaker Not Connected	Breaker Open	Clear Energy Use
Clear Event Record	Clear Max Demand	Close Breaker	Cls From Transfer	Control Power Off
Control Power On	Display Message	Group 1 to 4 Active	Open Breaker	Reclosure 1 to 4
Reclosure Lockout	Reset	Reset AR Count	Reset AR Shot Rate	Reset Arc Current
Reset Trip Counter	Set Date	Set Time	Shots Reduced to 1(3)	Shots Reduced to L/O
Transfer Initiated	Transfer Not Ready	Trigger Data Log	Trigger Trace	Trip From Transfer
PICKUP, TRIP, ALARM, LATCHED ALARM, AND CONTROL EVENT CAUSES				
Analog Rate 1 to 2	Analog Threshold 1 to 2	Apparent Power Demand	Arcing Current	Autoreclose Rate
Breaker Failure	Breaker Operation	Bus Undervoltage 1 to 2	Close Coil Monitor [1]	Cold Load P/U Block
Current Demand	Frequency Decay	Ground Dir Reverse	Ground Inst OC	Ground Time OC
Line Undervoltage 3 to 4	Manual Close Block	Neg Seq Dir Reverse	Neg Seq Inst OC	Neg Seq Time OC
Neg Seq Voltage	Neutral Current Level	Neutral Dir Reverse	Neutral Displacement	Neutral Inst OC 1 and 2
Neutral Time OC 1 and 2	Out of Sync	Overfrequency	Overvoltage 1 and 2	Phase Current Level
Phase Dir Reverse	Phase Inst OC 1 and 2	Phase Time OC 1	Phase Time OC 2	Power Factor 1
Power Factor 2	Pulse Output [2]	Reactive Power Demand	Real Power Demand	Sens Gnd Dir Reverse
Senstv Gnd Time OC	Senstv Gnd Inst OC	Trip Coil Monitor	Trip Counter	UFreq Restore Init
Underfrequency 1	Underfrequency 2	User Input A to T [3]	UVolt Restore Init	VT Failure
LOGIC INPUT EVENT CAUSES				
52a Contact	52b Contact	Block 1 Trip	Block 2 Close	Block All OC
Block Freq Decay	Block Gnd Inst OC	Block Gnd Time OC	Block Ground OC	Block Neg Seq Inst
Block Neg Seq Time	Block Neg Seq Volt	Block Neutral Disp	Block Neutral Inst OC 1	Block Neutral Inst OC 2
Block Neutral OC	Block Neutral Time OC 1	Block Neutral Time OC 2	Block Phase Inst OC 1	Block Phase Inst OC 2
Block Phase OC	Block Phase Time OC 1	Block Phase Time OC 2	Block Reclosure	Block Reset
Block Restoration	Block Sens Gnd Inst OC	Block Sens Gnd OC	Block Sens Gnd Time OC	Block Transfer
Block Trip Count	Block Undervolt 1 to 4	Block Underfreq 1 and 2	Breaker Connected	Bus Tie Closed
Bus Tie Connected	Bypass Synchrocheck	Cancel Reclosure	Cls From Incomer 1	Cls From Incomer 2
Cold Load Pickup	Incomer 1 Closed	Incomer 2 Closed	Initiate Reclosure	Local Mode
Remote Close	Remote Open	Remote Reset	Selected To Trip	Setpoint Group 2
Setpoint Group 3	Setpoint Group 4	Simulate Fault	Source Trip	Start Demand Interval
Trigger Data Log	Trigger Trace	User Input A to T [3]	UV On Other Source	Xmfr Lockout
WARNING EVENT CAUSES				
A/D Virtual Ground	Analog Output +32V	Clock Not Set	Dry Contact +32V	EEPROM Corrupt
Factory Service	FLASH Corrupt	Force Analog Out	Force Relays	Internal RS485
Internal Temp	IRIG-B Failure	Not Calibrated	Pickup Test	Prototype Software
Relay Not Ready	RTC Crystal	Simulation Mode		

[1] The coil monitor name as programmed is displayed.
[2] The pulse output quantity name as programmed is displayed.
[3] For User Input A through T, the user-defined name is displayed

6.5.2 LAST RESET DATE

PATH: ACTUAL VALUES ⇨⇩ A4 EVENT RECORDER ⇨⇩ LAST RESET DATE

```
■ LAST RESET DATE          ENTER ⇨   EVENT RECORDER LAST
■ [ENTER] for more       ⇦ ESCAPE    RESET: Mar 16 1997
```

Range: Date in format shown

After the header message for the last event is a message indicating when the event recorder was last cleared.

6.6.1 TECHNICAL SUPPORT

PATH: ACTUAL VALUES ⇨⇩ A5 PRODUCT INFO ⇨ TECHNICAL SUPPORT

■ TECHNICAL SUPPORT ■ [ENTER] for more	ENTER / ESCAPE	GE Multilin 215 Anderson Ave.	*The address for GE Multilin is indicated here.*
	ESCAPE / MESSAGE	Markham, Ontario Canada, L6E 1B3	
	ESCAPE / MESSAGE	Tel: (905) 294-6222 Fax: (905) 201-2098	*The telephone and fax numbers for GE Multilin are indicated here.*
	ESCAPE / MESSAGE	Internet Address: www.GEmultilin.com	*The GE Multilin web page address is indicated here.*

This page has information on where to obtain technical support for your relay.

6.6.2 REVISION CODES

PATH: ACTUAL VALUES ⇨⇩ A5 PRODUCT INFO ⇨⇩ REV CODES

■ REV CODES ■ [ENTER] for more	ENTER / ESCAPE	GE Multilin 750 REVISION 4.00	*The product name and software revision are indicated.*
	ESCAPE / MESSAGE	HARDWARE REV: H	*Displays the hardware revision of the relay.*
	ESCAPE / MESSAGE	S/W REV: 400	*Displays the software revision of the relay.*
	ESCAPE / MESSAGE	VERSION NUMBER: 000	*Displays the version number of the relay, indicating any special modification number.*
	ESCAPE / MESSAGE	ORDER CODE: 760- P5-G5-S5-HI-A20-R	*Displays the relay order code and installed options.*
	ESCAPE / MESSAGE	BOOTWARE REV: 300	*Displays the relay's boot software revision*
	ESCAPE / MESSAGE	SERIAL NUMBER: 400	*Displays the software revision of the relay.*
	ESCAPE / MESSAGE	MANUFACTURING DATE: Oct 25 1997	*Displays the manufacture date in the format shown.*

This page specifies hardware revision and configuration, software revision, and serial number. This information is primarily intended for GE Multilin service personnel.

6.6.3 CALIBRATION DATES

PATH: ACTUAL VALUES ⇨⇩ A5 PRODUCT INFO ⇨⇩ CAL DATES

■ CAL DATES ■ [ENTER] for more	ENTER / ESCAPE	FACTORY CAL DATE: Oct 25 1997	*Displays the initial calibration date in the format shown.*
	ESCAPE / MESSAGE	LAST CAL DATE: Oct 25 1997	*Displays the last calibration date in the format shown.*

This information is primarily intended for GE Multilin service personnel.

7.1.1 PROTOCOLS

The GE Multilin 750/760 Feeder Management Relay communicates with other computerized equipment such as programmable logic controllers, personal computers, or plant master computers using either the AEG Modicon Modbus protocol or the Harris Distributed Network Protocol (DNP), Version 3.0. Following are some general notes:

- The 750/760 relay always act as slave devices meaning that they never initiate communications; they only listen and respond to requests issued by a master computer.
- For Modbus, a subset of the Remote Terminal Unit (RTU) format of the protocol is supported which allows extensive monitoring, programming and control functions using read and write register commands.
- For DNP, the functionality is restricted to monitoring of essential relay data and control of important relay functions. A complete description of the services available via DNP may be found in the Device Profile Document which is included in this chapter.

DNP is a complex protocol. As a consequence, it is not possible within the scope of this manual to provide a description of the protocol's operation in anything approaching the detail required to understand how to use it to communicate with the relay. It is strongly recommended that interested users contact the DNP Users Group at `www.dnp.org` to obtain further information:

Members of the DNP Users Group are eligible to receive complete descriptions of all aspects of the protocol. The Users Group also operates a website (`www.dnp.org`) where technical information and support is available.

7.1.2 PHYSICAL LAYER

Both the Modbus and DNP protocols are hardware-independent so that the physical layer can be any of a variety of standard hardware configurations including RS232, RS422, RS485, fiber optics, etc. The 750/760 includes a front panel RS232 port and two rear terminal RS485 ports, one of which can also be configured as RS422. Data flow is half duplex in all configurations. See Section 3.2.10: RS485 and RS422 Communications on page 3–16 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 is 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, and 19200 are available. Even, odd, and no parity are available. See Section 5.2.2: Communications on page 5–7 for further details.

The master device in any system must know the address of the slave device with which it is to communicate. The 750/760 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 setpoint selects the slave address used for all ports with the exception that for the front panel port the relay will accept any address when the Modbus protocol is used. The slave address is otherwise the same regardless of the protocol in use, but note that the broadcast address is 0 for Modbus and 65535 for DNP. The relay recognizes and processes a master request (under conditions that are protocol-specific) if the broadcast address is used but never returns a response.

DNP may be used on, at most, one of the communications ports. Any port(s) not selected to use DNP will communicate using Modbus. The **S1 RELAY SETUP ⇨⇩ COMMUNICATIONS ⇨⇩ DNP ⇨ DNP PORT** setpoint is used to select which port will communicate using DNP.

The maximum time for a 750/760 relay to return a response to any (non-broadcast) master request never exceeds 1 second.

7

7.2.1 DESCRIPTION

This section is dedicated to discussion of details of the Modbus protocol. As noted above, specifics of DNP are best obtained directly from the DNP Users Group. Along with the Device Profile Document, the DNP specification provides sufficient information for a user to develop an interface should DNP wish to be used for communications with the relay.

7.2.2 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 of both transmit and receive packets. For exact details on packet formatting refer to subsequent sections describing each function code.

The Modbus packet format is a set of five sequential information blocks as shown below:

BLOCK	SIZE
Slave Address	1 byte
Function Code	1 byte
Data	*n* bytes, $n \geq 1$
Cyclic Redundancy Check (CRC)	2 bytes
Dead Time	3.5 bytes transmission time

Each block of the Modbus packet is described below:

- **Slave Address**: This is the address of the slave device intended to receive the packet sent by the master and perform the desired action. Each slave device on a communication bus must have a unique address to prevent bus contention. All the relay ports have the same address which is programmable from 1 to 254 (see Port Setup on page 5–8). Only the addressed slave will respond to a packet that starts with its address. Note that the front port is an exception to this rule; it will act on a message containing any slave address.

  A master transmit packet with a slave address of 0 indicates a broadcast command. All slaves on the communication link will take action based on the packet, but none will respond to the master. Broadcast mode is only recognized when associated with Function Codes 05h, 06h, and 10h. For any other function code, a packet with broadcast mode slave address 0 will be ignored. See Section 7.3.3: Clock Synchronization of Multiple Relays on page 7–8 for an example of broadcast mode.

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- **Function Code**: This is one of the supported functions codes of the 750/760 which tells the slave what action to perform. See page 7–4 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 page 7–7 for further details.
- **Data**: This will be a variable number of bytes depending on the function code. This may include actual values, setpoints, or addresses sent by the master to the slave or by the slave to the master.
- **Cyclic Redundancy Check (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 GE Multilin 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 following section for a description of how to calculate 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 baud, 2 ms at 19200 baud). 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.

7.2.3 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.

Symbols:

-->	data transfer
A	16 bit working register
A_{low}	low order byte of A
A_{high}	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_i	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 (the 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_i `(+)` A_{low} `-->` A_{low}
5. `j + 1 --> j`
6. `shr (A)`
7. `Is there a carry?` `No: go to step 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`

NOTE: GE Multilin will provide a C programming language implementation of this algorithm upon request.

7.2.4 MESSAGE TIMING

Communication message synchronization is maintained by timing constraints. The receiving device must measure the time between the reception of characters. If three and one half character times elapse without a new character or completion of the message, then the communication link must be reset (i.e. all slaves start listening for a new query message from the master). Thus at 1200 baud a delay of greater than $3.5 \times 1 / 1200 \times 10 = 29.2$ ms will cause the communication link to be reset. At 9600 baud a delay of greater than $3.5 \times 1 / 9600 \times 10 = 3.6$ ms will cause the communication link to be reset. Most master query messages will be responded to in less than 50 ms.

7.3.1 MODBUS FUNCTION CODES

a) SUPPORTED FUNCTION CODES

Modbus officially defines function codes from 1 to 127 though only a small subset is generally needed. The 750/760 relays support some of these functions, as summarized in the following table. Subsequent sections describe each function code in detail.

Table 7–1: GE MULTILIN MODBUS FUNCTION CODES

FUNCTION CODE		DEFINITION	DESCRIPTION	SUBSTITUTE
HEX	DEC			
01	1	READ BINARY STATUS	Read one or more consecutive binary status bits from the 750/760.	---
02	2			---
03	3	READ ACTUAL VALUES OR SETPOINTS	Read actual value or setpoint registers from one or more consecutive memory map register addresses.	04H
04	4			03H
05	5	EXECUTE OPERATION	Perform 750/760 specific operations.	10H
06	6	STORE SINGLE SETPOINT	Write a specific value into a single setpoint register.	10H
10	16	STORE MULTIPLE SETPOINTS	Write specific values into one or more consecutive setpoint registers.	---

b) FUNCTION CODE 01H/02H: READ BINARY STATUS

These function codes allow the master to read one or more consecutive binary status bits from an 750/760. The status bits are packed into bytes with the first addressed bit occupying the least significant bit position of the first returned byte. Enough bytes are returned to contain all requested status bits. The last byte is zero-padded as required. The maximum number of status bits that can be read in a single request is 1920 (although this greatly exceeds the number of status bits defined in the 750/760).

The addresses of the bits that can be read using these functions are the same as the point indices defined for the DNP Binary Input objects (e.g., address zero references the “Relay In Service” status). Refer to the Device Profile Document on page 7–49 for the definition of all binary status data. Note that function codes 01H and 02H are identical in their operation.

The following table shows the format of the master and slave packets. The example shows a master device requesting 10 status bit values starting at address 13h from slave device 11; the slave device responds with the bit values 1, 0, 1, 1, 0, 0, 1, 0, 0 and 1 from binary status addresses 13h through 1Ch inclusive. Note that two bytes are required to contain the response data. The first byte contains the first eight data bits stored in the least significant to the most significant bit position. The second byte contains the last two data bits stored in the least two significant bit positions. Note that the rest of the second byte is zero-filled.

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MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	01	read binary status
DATA STARTING ADDRESS: high order byte, low order byte	00 13	data starting at address 0013h
NUMBER OF DATA BITS: high order byte, low order byte	00 0A	10 data bits
CRC: low order byte, high order byte	4F 58	computed cyclic redundancy check

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	01	read binary status
BYTE COUNT	02	2 bytes total
DATA BYTES: high order byte, low order byte	4D 02	register value in address 0013h = 4D02h
CRC: low order byte, high order byte	CC AE	computed cyclic redundancy check code

c) FUNCTION CODE 03H/04H: READ ACTUAL VALUES / SETPOINTS

This function code allows the master to read one or more consecutive data registers (actual values or setpoints) from an 750/760. Data registers are always 16 bit (two byte) values transmitted high order byte first. The maximum number of registers that can be read in a single packet is 120. See the Modbus Memory Map for exact details on the data registers.

Since some PLC implementations of Modbus only support one of function codes 03h and 04h, the 750/760 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 200h from slave device 11; the slave device responds with the values 555, 0, and 100 from registers 200h, 201h, and 202h respectively.

MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	03	read register values
DATA STARTING ADDRESS: high order byte, low order byte	02 00	data starting at address 0200
NUMBER OF REGISTERS: high order byte, low order byte	00 03	3 register values = 6 bytes total
CRC: low order byte, high order byte	06 E3	computed cyclic redundancy check

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	03	read register values
BYTE COUNT	06	3 register values = 6 bytes total
DATA #1: high order byte, low order byte	02 2B	register value in address 0200 = 022B
DATA #2: high order byte, low order byte	00 00	register value in address 0201 = 0000
DATA #3: high order byte, low order byte	00 64	register value in address 0202 = 0064
CRC: low order byte, high order byte	C8 BA	computed cyclic redundancy check code

d) FUNCTION CODE 05H: EXECUTE OPERATION

This function code allows the master to perform various operations in the 750/760. Available operations are shown in Table 7–2: Summary of Operation Codes for Function 05h.

The following table shows the format of the master and slave packets. The example shows a master device requesting the slave device 11 to perform a reset. The hi and lo Code Value bytes always have the values FFh and 00h, respectively and are a remnant of the original Modbus definition of this function code.

MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	05	execute operation
OPERATION CODE: high order byte, low order byte	00 01	remote reset
CODE VALUE: high order byte, low order byte	FF 00	perform operation
CRC: low order byte, high order byte	DF 6A	computed cyclic redundancy check

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	05	execute operation
OPERATION CODE: high order byte, low order byte	00 01	remote reset
CODE VALUE: high order byte, low order byte	FF 00	perform operation
CRC: low order byte, high order byte	DF 6A	computed cyclic redundancy check code

Table 7–2: 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 front panel RESET key.
0002	OPEN BREAKER	Performs the same function as the front panel OPEN key. The 760 must be in Remote Mode for this operation to be effective.
0003	CLOSE BREAKER	Performs the same function as the front panel CLOSE key. The 760 must be in Remote Mode for this operation to be effective.
0004	SET TIME	Sets the internal clock time. See page 7–8 for details.
0005	SET DATE	Sets the internal clock date. See page 7–8 for details.
0006	TRIGGER TRACE MEMORY	Performs the same function as the logic input function **TRIGGER TRACE MEMORY**.
0007	CLEAR ENERGY USE DATA	Performs the same function as **CLEAR ENERGY USE DATA** command.
0008	CLEAR MAX DEMAND DATA	Performs the same function as the **CLEAR MAX DMD DATA** command.
0009	CLEAR EVENT RECORDER DATA	Performs the same function as the **CLEAR EVENT RECORDER DATA** command.
000A	RESET TRIP COUNTER DATA	Performs the same function as the **RESET TRIP COUNTER DATA** command.
000B	RESET ARCING CURRENT DATA	Performs the same function as the **RESET ARCING CURRENT DATA** command.
000C	DISPLAY OVERRIDE PACKET	Displays the 40 character (20 register) *Override_Packet* (addresses 10B1 to 10C4 hex) for the time specified in *Override_Time* (address 10B0 hex).
000D	TRIGGER DATA LOGGER	Performs the same function as the logic input function **TRIGGER DATA LOGGER**.
000E	RESET TRACE MEMORY	Resets the Trace Memory oscillography data by clearing the number of captured events to zero.
000F	RESET DATA LOGGER	Resets the Data Logger by clearing the number of captured events to zero.
0010	RESET AR COUNT DATA	Resets the Autoreclose Count by setting the **AR SHOT COUNT** to zero.
0011	RESET AR RATE DATA	Resets the Autoreclose Shot Rate by setting **AR SHOT RATE** to zero.

e) FUNCTION CODE 06H: STORE SINGLE SETPOINT

This function code allows the master to modify the contents of a single setpoint register in a 750/760. Setpoint registers are always 16 bit (two byte) values transmitted high order byte first (see the Memory Map on page 7–13 for details). The following table shows the format of the master and slave packets. It shows a master device storing the value 200 at memory map address 1100h to slave device 11.

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MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	06	store single setpoint value
DATA STARTING ADDRESS: high order byte, low order byte	11 00	data starting at address 1100
DATA: high order byte, low order byte	00 C8	data for address 1100 = 00C8
CRC: low order byte, high order byte	8F F0	CRC computed by master

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	06	store single setpoint value
DATA STARTING ADDRESS: high order byte, low order byte	11 00	data starting at address 1100
DATA: high order byte, low order byte	00 C8	data for address 1100 = 00C8
CRC: low order byte, high order byte	8F F0	CRC computed by slave

f) FUNCTION CODE 10H: STORE MULTIPLE SETPOINTS

This function code allows the master to modify the contents of a one or more consecutive setpoint registers in a 750/760. Setpoint registers are 16 bit (two byte) values transmitted high order byte first. The maximum number of setpoint registers that can be stored in a single packet is 60. The table below shows the format of the master and slave packets. It shows a master device storing the value 200 at memory map address 1100h, and the value 1 at memory map address 1101h to slave device 11.

MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte, low order byte	11 00	data starting at address 1100
NUMBER OF SETPOINTS: high order byte, low order byte	00 02	2 setpoint values = 4 bytes total
BYTE COUNT	04	4 bytes of data
DATA #1: high order byte, low order byte	00 C8	data for address 1100 = 00C8
DATA #2: high order byte, low order byte	00 01	data for address 1101 = 0001
CRC: low order byte, high order byte	27 01	CRC computed by master

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte, low order byte	11 00	data starting at address 1100
NUMBER OF SETPOINTS: high order byte, low order byte	00 02	2 setpoint values = 4 bytes total
CRC: low order byte, high order byte	46 64	CRC computed by slave

7.3.2 EXCEPTION RESPONSES

Programming or operation errors happen because of illegal data in a packet, hardware or software problems in the slave device, etc. These errors result in an exception response from the slave. The GE Multilin 750/760 implements the error codes listed below. 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.

MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	39	unsupported function code – error
CRC: low order byte, high order byte	CD F2	CRC computed by master

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	B9	return unsupported function code with high-order bit set
ERROR CODE	01	illegal function
CRC: low order byte, high order byte	93	CRC computed by slave

Table 7–3: EXCEPTION RESPONSE ERROR CODES

ERROR CODE	MODBUS DEFINITION	GE MULTILIN IMPLEMENTATION
01	ILLEGAL FUNCTION	The function code of the master query message is not supported by the slave.
02	ILLEGAL DATA ADDRESS	The address referenced in the data field of the master query message is not an address supported by the slave.
03	ILLEGAL DATA VALUE	The value referenced in the data field of the master query message is not allowable in the addressed slave location.
04	FAILURE IN ASSOCIATED DEVICE	An external device connected to the addressed slave device has failed and the data requested cannot be sent. This response will be returned if a GE Multilin device connected to the RS485 external device port of the 745 has failed to respond to the 750/760.
05*	ACKNOWLEDGE	The addressed slave device has accepted and is processing a long duration command. Poll for status.
06*	BUSY, REJECTED MESSAGE	The message was received without error, but the slave device is engaged in processing a long duration command. Retransmit later, when the slave device may be free.
07*	NAK - NEGATIVE ACKNOWLEDGE	The message was received without error, but the request could not be performed, because this version of the 750/760 does not have the requested operation available.

* Some Modbus implementations may not support these exception responses

7.3.3 CLOCK SYNCHRONIZATION OF MULTIPLE RELAYS

The time and date of multiple relays on the same communication link can be synchronized so that time stamping of events on different relays can be correlated. The following procedure describes how to synchronize the clocks of multiple relays. Since the clock is accurate to 1 minute per month, performing this procedure every 10 minutes will result in synchronization accuracy of ±10 ms.

1. Store values for the date and time setpoints Set Date and Set Time at locations 1006h and 1008h in the Memory Map respectively into each slave device.
2. Broadcast (via slave address 0) the Set Date operation code via function code 05h to all connected slaves to synchronize the dates.
3. Broadcast (via slave address 0) the Set Time operation code via function code 05h to all connected slaves to synchronize the times. If synchronizing to an external clock source then this command should be sent when the time is equal to the value stored in Set Time.

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The following table shows the format of the master and slave packets for a master device storing the date of June 10, 1994 and time of 2:15:30 PM to slave device 11 as required by step one of the procedure.

MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte, low order byte	10 06	data starting at address 1100h
NUMBER OF SETPOINTS: high order byte, low order byte	00 04	4 setpoint values = 8 bytes total
BYTE COUNT	08	8 bytes of data
DATA #1: high order byte, low order byte	06 0A	Month = 06h (June), Day = 0Ah (10th)
DATA #2: high order byte, low order byte	07 CA	Year = 07CAh (1994)
DATA #3: high order byte, low order byte	0E 0F	Time (hour: minute) = 0Eh:0Fh (14:15)
DATA #4: high order byte, low order byte	75 30	Time (ms) = 7530h (30000 ms = 30 seconds)
CRC: low order byte, high order byte	37 0C	CRC computed by master

SLAVE RESPONSE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	response message from slave 11
FUNCTION CODE	10	store multiple setpoint values
DATA STARTING ADDRESS: high order byte, low order byte	10 06	data starting at address 1006h
NUMBER OF BYTES: high order byte, low order byte	00 08	4 setpoint values = 8 bytes total
CRC: low order byte, high order byte	27 9B	CRC computed by slave

The following table shows the format of the master and slave packets for a master device sending the Store Time operation code to all slave devices on the communications link as required by step three of the procedure.

MASTER QUERY MESSAGE:	EXAMPLE (HEX):	
SLAVE ADDRESS	11	query message for slave 11
FUNCTION CODE	05	execute operation
OPERATION CODE: high order byte, low order byte	00 04	set time
CODE VALUE: high order byte, low order byte	FF 00	perform operation
CRC: low order byte, high order byte	CC 2A	computed cyclic redundancy check

SLAVE RESPONSE:	EXAMPLE (HEX):
No response from slave	

7.3.4 READING THE EVENT RECORDER

All Event Recorder data can be read from Modbus registers found in the address range 2000h to 20FFh.

The 'Number of Events Since Last Clear' register at address 2001h is incremented by one every time a new event occurs. The register is cleared to zero when the Event Recorder is cleared. When a new event occurs, it is assigned an 'event number' which is equal to the incremented value of this register; the newest event will have an event number equal to the Number of Events. This register can be used to determine if any new events have occurred by periodically reading the register to see if the value has changed. If the Number of Events has increased then there are new events available.

Only the data for a single event can be read from the Modbus memory map in a single data packet. The 'Event Number Selector' register at address 2000h selects the event number for which data can be read from the memory map. For example, to read the data for event number 123, the value 123 must first be written to this register. All the data for event number 123 can now be read from the 'Event Record Data' registers at addresses 2010h to 201Dh. Only the last 128 events are actually stored in the relay's memory. Attempting to retrieve data for elder events that are not stored will result in a Modbus exception response when writing to the 'Event Number Selector'.

The following example illustrates how information can be retrieved from the Event Recorder:

A SCADA system polls the Number of Events register once every minute. It now reads a value of 27 from the register when previously the value was 24 which means that three new events have occurred. The SCADA system writes a value of 25 to the Event Number Selector register. It then reads the data for event number 25 from the Event Record Data registers and stores the data to permanent memory for retrieval by an operator. The system now writes the value 26 to the selector and then reads the data for event number 26. Finally, the value 27 is written to the selector followed by reading the data for this event. All the data for the new events has now been retrieved by the SCADA system so it resumes polling the Number of Events register.

The data for an event should be straightforward to interpret from the information given in the Memory Map except for the 'Cause of Event' register. Data format F24 describes the event cause register which contains several 'fields' of information. The 'Event Type' field determines how to interpret the remainder of the register. Interpreting the event cause register is most easily described with several examples.

EVENT CAUSE REGISTER VALUE	EVENT CAUSE INTERPRETATION
1003h	Breaker Opened
3501h	A-C Phase Time Overcurrent 1 Trip
8501h	A-C Phase Time Overcurrent 1 Dropout
4212h	B Overvoltage 1 Alarm
6514h	User Input A Asserted via Contact Input
7009h	Clock Not Set

7.3.5 READING TRACE MEMORY

All Trace Memory waveform data can be read from Modbus registers found in the address range 2100h to 215Fh. In order to understand the following description, familiarity with the settings for Trace Memory is required; refer to Section 5.2.5: Trace Memory on page 5–11.

The ‘Number of Trace Memory Triggers Since Last Clear’ register is incremented by one every time a new Trace Memory is triggered. This register is cleared to zero when Trace Memory is cleared. When a new trigger occurs, the associated waveform data is assigned a ‘Trace Memory Number’ which is equal to the incremented value of this register; the newest data will have a number equal to the Number of Trace Memory Triggers. 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 of Trace Memory Triggers has increased then there is new data available.

The Trace Memory Buffer Organization setpoint determines the number of samples that are captured per channel for each separate trigger. This setpoint also determines how many data triggers are stored in memory. For example if the setting is 4x1024 then there are 1024 samples per channel per trigger and the last three data triggers can be read from memory. Note that only 64 samples of one data channel for a single waveform can be read from the Modbus memory map in a single data packet. The ‘Trace Memory Selectors’ registers determine which waveform data can be read from the memory map.

The ‘Trace Memory Number Selector’ determines which Trace Memory can be read. For example, to read the data for Trace Memory number 3, the value 3 must first be written to this register. Data for Trace Memory number 3 can now be read from the ‘Trace Memory Information’ registers at addresses 2111h to 2119h. These registers include a trigger cause (see the previous section for a description of the data format), a trigger time and date stamp, and the sampling frequency. There is also the ‘Start Index’ and ‘Trigger Index’ which determine how to ‘unravel’ the data samples; see the description of the circular data structure below.

The ‘Trace Memory Channel Selector’ determines which data channel samples can be read from the ‘Trace Memory Samples’ registers at addresses 2120h to 215Fh; refer to format F26 for a complete listing of the available data channels. For example, to read Vc voltage samples a value of 6 is written to this register. Note that this register also determines the data format of the samples.

The ‘Trace Memory Sample Selector’ (TMSS) determines which block of 64 samples can be read from the ‘Trace Memory Samples’ registers. The number of samples stored for one channel is variable and depends on the ‘Buffer Organization’ setpoint. The ‘Number of Trace Memory Samples Stored’ register indicates the number of samples that have already been accumulated for the selected Trace Memory Number; this register may have a value less than the total number of samples that can be stored if a trigger just occurred and there are an appreciable number of post-trigger samples to capture.

The samples are stored in a circular buffer; the figure below shows how a waveform might be stored for one channel. The ‘Trace Memory Start Index’ determines where the waveform begins in the buffer. Likewise, the ‘Trace memory Trigger Index’ determines where the trigger point is. In this example the Start Index is 96 and the Trigger Index is 224; note that the indices are always a multiple of sixteen.

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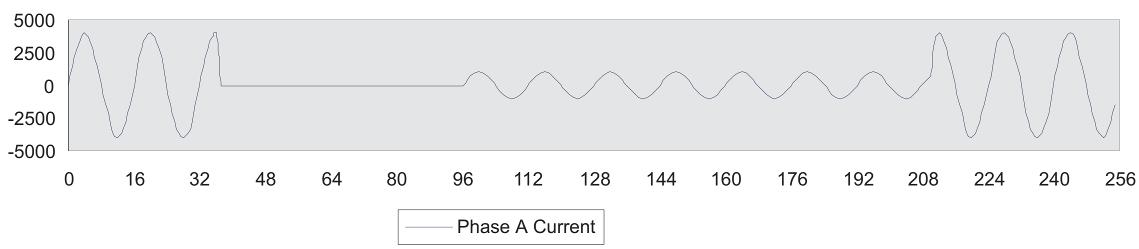

Figure 7–1: TRACE MEMORY CIRCULAR BUFFER

The following example illustrates how information can be retrieved from Trace Memory:

1. A SCADA system polls the Number of Trace Memory Triggers register once every minute. It now reads a value of 4 from the register where previously the value was 3 which means that a new data has been captured. The SCADA system proceeds with the following steps to read all the waveform data. After these steps it resumes polling the Number of Trace Memory Triggers register.
2. Read the TRACE MEMORY BUFFER ORGANIZATION setpoint
3. Write a value of 4 to the Trace Memory Number Selector.
4. Read all the Trace Memory Information registers and store to SCADA memory.

5. Set variables TMCS and TMSS to 0.
6. Write TMCS to Trace Memory Channel Selector.
7. Write TMSS to Trace Memory Sample Selector.
8. Read 64 samples from Trace Memory Samples and store to SCADA memory.
9. Increment TMSS by 64.
10. If TMSS < Total Number of Samples then go to Step 5.
11. Increment CS by 1.
12. If TMCS < total number of channels available then go to Step 4.
13. Done.

All the Trace Memory data for the most recent trigger is now stored to SCADA memory. The SCADA software could now 'unravel' the circular buffers using the Start Index and Trigger Index registers that were read in Step 3 and store them permanently to file or perhaps generate a graphical picture.

7.3.6 READING THE DATA LOGGER

All Data Logger information can be read from Modbus registers found in the address range 2200h to 22ffh. In order to understand the following description, familiarity with the settings for the Data Logger is required; refer to Section 5.2.6: Data Logger on page 5–12. Reading the Data Logger is very similar to reading Trace Memory and the description for the latter should be used with note of the exceptions described below.

The data channels in the Data Logger are programmable and are determined by the Channel 1 to 8 Source setpoints. These setpoints determine the format of data samples for a given channel.

In Continuous mode:

- The Number of Data Log Triggers Since Last Clear is always equal to one.
- The Data Logger only maintains one buffer of 4096 samples for each channel. Since the buffer is being continuously updated the 'Data Log Start Index' will change once the buffer is full and new data is added (overwriting old data and thus moving the location of the starting index). At slow sampling rates this is less important but when sampling is performed at a high rate it is very likely that the start index will move between subsequent reads of the memory map.
- The "Data Log Trigger Index" will always index the last sample added to the buffer. Thus, it too, will also be quickly and continuously changing if the sampling rate is high.
- The "Data Log Trigger Cause" will be set to zero and the time and date are when the last sample data was written to the buffer.

7.3.7 ACCESSING DATA VIA THE USER MAP

The 750/760 has a powerful feature, called the User Map, which allows a computer to read up to 120 non-consecutive data registers (setpoints or actual values) by using one Modbus packet. It is often necessary for a master computer to continuously poll various values in each of the connected slave relays. If these values are scattered throughout the memory map, reading them would require numerous transmissions and would burden the communication link. The User Map can be programmed to join any memory map address to one in the block of consecutive User Map locations, so that they can be accessed by reading these consecutive locations.

The User Map feature consists of User Map Addresses #1 to #120 at locations 0180h to 01F7h in the Memory Map. These are the setpoints which store the memory map addresses of the values that are to be accessed. The data registers are read from the User Map Values #1 to #120 at locations 0100h to 0177h in the Memory Map. Reading the register at the location of User Map Value #1 returns the value at the address stored in User Map Address #1, User Map Value #2 the value at User Map Address #2, and so on. Storing registers is not allowed using the User Map.

The following table shows the register addresses to store in the User Map Addresses #1 to #6 so that several different data registers can be read in one continuous block from User Map Value #1 to #6. Reading the User Map Values is done via function code 03h or 04h.

NOTE

The User Memory Map is only intended to be used to READ data in a proficient manner for the master computer. The communication system should not be configured in a manner that generates WRITES to these locations continuously, as these settings are stored in the EEPROM that has a maximum of 100000 program/erase cycles.

Table 7–4: USER MAP REGISTER ADDRESSES

DATA REGISTER DESCRIPTION	VALUES TO STORE IN USER MAP ADDRESSES	LOCATIONS IN USER MAP VALUES TO READ DATA
General Status	Store 0200h at 0180h	0100h
Active Condition	Store 0210h at 0181h	0101h
Phase A RMS Current	Store 0300h at 0182h	0102h
Phase B RMS Current	Store 0301h at 0183h	0103h
Phase C RMS Current	Store 0302h at 0184h	0104h
Phase CT Primary	Store 1100h at 0185h	0105h

7.3.8 MEMORY MAP ORGANIZATION

The 750/760 Memory Map describes all the data registers that can be accessed via serial communications. The Memory Map address range is grouped into several categories as outlined in the following table. All memory map locations are two byte (16 bit) values. The remaining pages of this chapter list all locations of the Memory Map. Addresses for all locations are shown in hexadecimal. Consult the range, step, units, and the data format (listed after the memory map) to interpret register values.

NOTE

Many Modbus communications drivers add 40001d to the actual address of the register addresses. For example, if address 0h was to be read, then 40001d would be the address required by the Modbus communications driver; similarly, if address 320h (800d) was to be read, then 40801d would be the address required by the Modbus communications driver.

Table 7–5: MEMORY MAP ORGANIZATION

MEMORY MAP SECTION	ADDRESS RANGE	DESCRIPTION
Product ID	0000h to 007Fh	Identification and revision information.
Commands	0080h to 00FFh	Substitute command locations. Read and write access.
User Map	0100h to 01FFh	User Map Values and Addresses. See the previous section for details.
Actual Values	0200h to 0FFFh	Actual values data. Read Only.
Setpoints	1000h to 1FFFh	Setpoints data. Read and Write.
Event Recorder, Trace Memory, Data Logger	2000h to 2FFFh	See relevant sections in this chapter for details.
Reserved	3000h to 3FFFh	Reserved for future use.
Factory Service Data	4000h to FFFFh	Reserved.

7.4.1 MEMORY MAP

Table 7–6: MODBUS MEMORY MAP (SHEET 1 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
A5	**PRODUCT ID**				**READ ONLY**
0000	GE Multilin Product Device Code	---	---	F1	---
0001	Hardware Revision	1 to 26	---	F13	---
0002	Software Revision	---	---	F14	---
0003	Version Number	000 to 999	---	F1	---
0004	Bootware Revision	---	---	F14	---
0005	Installed Options	---	---	F15	---
0006	Serial Number (4 words)	---	---	F33	---
000A	Date Of Manufacture (2 words)	---	---	F23	---
	COMMANDS				**READ/WRITE**
0080	Command Operation Code	---	---	F19	0
0081[1]	Simulate Front Panel Key Press	---	---	F55	---
0088	Communications Port Passcode (4 words)	---	---	F33	---
S8	**VIRTUAL INPUTS**				**READ/WRITE**
0090	Reserved				
0091	Virtual Input 1	---	---	F66	Not Asserted
0092	Virtual Input 2	---	---	F66	Not Asserted
↓	↓	↓	↓	↓	↓
00A4	Virtual Input 20	---	---	F66	Not Asserted
	SET TIME / DATE				**READ/WRITE**
00F0[1]	Set Time (2 words)	---	---	F22	---
00F2[1]	Set Date (2 words)	---	---	F23	---
	USER MAP VALUES				**READ ONLY**
0100	User Map Value #1	---	---	---	---
0101	User Map Value #2	---	---	---	---
↓	↓	↓	↓	↓	↓
0177	User Map Value #120	---	---	---	---
	USER MAP ADDRESSES				**READ/WRITE**
0180	User Map Address #1	0000 to FFFF	hex	F1	0
0181	User Map Address #2	0000 to FFFF	hex	F1	0
↓	↓	↓	↓	↓	↓
01F7	User Map Address #120	0000 to FFFF	hex	F1	0
A1	**SYSTEM STATUS**				**READ ONLY**
0200	General Status	---	---	F21	---
0201	760 Operation Status	---	---	F44	---
0202	Communications Port Setpoint Access Status	---	---	F30	---
0203	Reserved				
0204	Contact Input Status	---	---	F46	---
0205	Coil Monitor Status	---	---	F47	---
0206	Output Relay Status	---	---	F40	---
0207	Date (2 words)	---	---	F23	---
0209	Time (2 words)	---	---	F22	---
020B	Active Setpoint Group	---	---	F79	---
020C	Edit Setpoint Group	---	---	F79	---
	ACTIVE CONDITION QUEUE				**READ ONLY**
0210	Active Condition #1	---	---	F24	---
0211	Active Condition #2	---	---	F24	---
↓	↓	↓	↓	↓	↓
022F	Active Condition #32	---	---	F24	---

1 2 3 4 5 6 7 8 9 For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 2 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
	LATCHED CONTACT INPUT STATE				**READ ONLY**
0230	Contact In Status (Closed Contacts Latched until read via Comms)	---	---	F46	---
	LATCHED OUTPUT RELAY STATE				**READ ONLY**
0231[8]	Output Rly Status (Asserted Outputs Latched until read via Comms)	---	---	F40	---
A1	**LOGIC INPUT STATES**				**READ ONLY**
0240	Reserved	---	---	---	---
0241	Logic Input 1 State	---	---	F69	---
0242	Logic Input 2 State	---	---	F69	---
↓	↓	↓	↓	↓	↓
0254	Logic Input 20 State	---	---	F69	---
A1	**AUTORECLOSE STATUS - 760 ONLY**				**READ ONLY**
0260	Autoreclose Shot Number	---	---	F1	---
0261	Autoreclose Shots Remaining	---	---	F1	---
0262	Manual Close Blocking	---	---	F30	---
0263	Reserved	---	---	---	---
0264[8]	Recloses per hour	---	---	F1	---
A1	**AUTORECLOSE STATUS - 760 ONLY**				**READ ONLY**
0270[8]	Reclosure Count	---	---	F1	---
0271[8]	Reclosure Count Last Reset Date (2 words)	---	---	F23	---
A1	**LAST TRIP DATA**				**READ ONLY**
02E0	Date of Last Trip (2 words)	---	---	F23	---
02E2	Time of Last Trip (2 words)	---	---	F22	---
02E4	Cause of Last Trip	---	---	F24	---
02E5	Last Trip Phase A Current	0 to 65535	A	F1	---
02E6	Last Trip Phase B Current	0 to 65535	A	F1	---
02E7	Last Trip Phase C Current	0 to 65535	A	F1	---
02E8	Last Trip Ground Current	0 to 65535	A	F1	---
02E9	Last Trip A-N (A-B) Voltage	0.00 to 600.00	kV	F3	---
02EA	Last Trip B-N (B-C) Voltage	0.00 to 600.00	kV	F3	---
02EB	Last Trip C-N (C-A) Voltage	0.00 to 600.00	kV	F3	---
02EC	Last Trip System Frequency	0.00 to 90.00	Hz	F3	---
02ED	Last Trip Analog Input	0 to 65535	Units	F1	---
02EE	Last Trip Neutral Current	0 to 65535	A	F1	---
02EF[3]	Last Trip Sensitive Ground Current	0.00 to 655.35	A	F3	---
02F0[5]	Last Trip Neutral Voltage	0.00 to 655.35	kV	F3	---
A2	**CURRENT AND VOLTAGE**				**READ ONLY**
02FE[5]	Neutral Voltage	0.00 to 655.35	kV	F3	---
02FF[3]	Sensitive Ground Current	0.00 to 655.35	A	F3	---
0300	Phase A RMS Current	0 to 65535	A	F1	---
0301	Phase B RMS Current	0 to 65535	A	F1	---
0302	Phase C RMS Current	0 to 65535	A	F1	---
0303	Percent of Load-to-Trip	0 to 2000	%	F1	---
0304	Ground Current	0 to 65535	A	F1	---
0305	A-N RMS Voltage	0.00 to 600.00	kV	F3	---
0306	B-N RMS Voltage	0.00 to 600.00	kV	F3	---
0307	C-N RMS Voltage	0.00 to 600.00	kV	F3	---
0308	A-B RMS Voltage	0.00 to 600.00	kV	F3	---
0309	B-C RMS Voltage	0.00 to 600.00	kV	F3	---
030A	C-A RMS Voltage	0.00 to 600.00	kV	F3	---
030B[3]	Reserved for Polarizing Current	---	---	---	---
030C	Average Current	0 to 65535	A	F1	---
030D	Average Line Voltage	0.00 to 600.00	kV	F3	---
030E	Average Phase Voltage	0.00 to 600.00	kV	F3	---

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 3 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
030F	Neutral Current	0 to 65535	A	F1	---
A2	**3ϕ POWER, FREQUENCY**				READ ONLY
0310[2]	3ϕ Real Power	-30000 to 30000	kW	F86	---
0311[2]	3ϕ Reactive Power	-30000 to 30000	kvar	F86	---
0312[2]	3ϕ Apparent Power	0 to 30000	kVA	F86	---
0313	3ϕ Power Factor	-0.99 to +1.00	---	F6	---
0314	System Frequency	0.00 to 90.00	Hz	F3	---
0315[1]	System Frequency Decay Rate	-10.00 to 10.00	Hz/s	F6	---
0316[1]	Auto Ranging Power / Energy Multiplier	1 to 100	---	F1	---
A2	**SYNCHRONIZING VOLTAGE**				**READ ONLY**
0318	Synchronizing RMS Voltage	0.00 to 600.00	kV	F3	---
0319	Synchronizing RMS Voltage Frequency	0.00 to 90.00	Hz	F3	---
031A	Synchronizing Voltage Difference	0.00 to 600.00	kV	F3	---
031B	Synchronizing Phase Difference	0 to 359	°	F1	---
031C	Synchronizing Frequency Difference	0.00 to 90.00	Hz	F3	---
031D	Synchronizing Voltage Angle	0 to 359	° Lag	F1	---
A2	**ENERGY USE**				**READ ONLY**
0320[2]	Positive Watthours (2 words)	0 to 4e9	kWh	F86	---
0322	Positive Watthour Cost (2 words)	0 to 4e9	$	F7	---
0324[2]	Negative Watthours (2 words)	0 to 4e9	kWh	F86	---
0326	Negative Watthour Cost (2 words)	0 to 4e9	$	F7	---
0328[2]	Positive Varhours (2 words)	0 to 4e9	kvarh	F86	---
032A[2]	Negative Varhours (2 words)	0 to 4e9	kvarh	F86	---
032C	Energy Use Data Last Reset (2 words)	---	---	F23	---
A2	**LAST DEMAND**				**READ ONLY**
0330	Last Phase A Current Demand	0 to 65535	A	F1	---
0331	Last Phase B Current Demand	0 to 65535	A	F1	---
0332	Last Phase C Current Demand	0 to 65535	A	F1	---
0333[2]	Last Real Power Demand	-30000 to 30000	kW	F86	---
0334[2]	Last Reactive Power Demand	-30000 to 30000	kvar	F86	---
0335[2]	Last Apparent Power Demand	0 to 30000	kVA	F86	---
A2	**MAXIMUM DEMAND**				**READ ONLY**
0340	Maximum Phase A Current Demand	0 to 65535	A	F1	---
0341	Maximum Phase A Current Date (2 words)	---	---	F23	---
0343	Maximum Phase A Current Time (2 words)	---	---	F22	---
0345	Maximum Phase B Current Demand	0 to 65535	A	F1	---
0346	Maximum Phase B Current Date (2 words)	---	---	F23	---
0348	Maximum Phase B Current Time (2 words)	---	---	F22	---
034A	Maximum Phase C Current Demand	0 to 65535	A	F1	---
034B	Maximum Phase C Current Date (2 words)	---	---	F23	---
034D	Maximum Phase C Current Time (2 words)	---	---	F22	---
034F[2]	Maximum Real Power Demand	-30000 to 30000	kW	F86	---
0350	Maximum Real Power Date (2 words)	---	---	F23	---
0352	Maximum Real Power Time (2 words)	---	---	F22	---
0354[2]	Maximum Reactive Power Demand	-30000 to 30000	kvar	F86	---
0355	Maximum Reactive Power Date (2 words)	---	---	F23	---
0357	Maximum Reactive Power Time (2 words)	---	---	F22	---
0359[2]	Maximum Apparent Power Demand	0 to 30000	kVA	F86	---
035A	Maximum Apparent Power Date (2 words)	---	---	F23	---
035C	Maximum Apparent Power Time (2 words)	---	---	F22	---
035E	Demand Data Last Reset (2 words)	---	---	F23	---
A2	**1ϕ POWER**				**READ ONLY**
0360[1]	ϕA Real Power	-30000 to 30000	kW	F86	---

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 4 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
0361[1]	ϕA Reactive Power	-30000 to 30000	kvar	F86	---
0362[1]	ϕA Apparent Power	0 to 30000	kVA	F86	---
0363[1]	ϕA Power Factor	-0.99 to +1.00	---	F6	---
0364[1]	ϕB Real Power	-30000 to 30000	kW	F86	---
0365[1]	ϕB Reactive Power	-30000 to 30000	kvar	F86	---
0366[1]	ϕB Apparent Power	0 to 30000	kVA	F86	---
0367[1]	ϕB Power Factor	-0.99 to +1.00	---	F6	---
0368[1]	ϕC Real Power	-30000 to 30000	kW	F86	---
0369[1]	ϕC Reactive Power	-30000 to 30000	kvar	F86	---
036A[1]	ϕC Apparent Power	0 to 30000	kVA	F86	---
036B[1]	ϕC Power Factor	-0.99 to +1.00	---	F6	---
A2	**ANALOG INPUT**				**READ ONLY**
0370	Analog Input	0 to 65535	Units	F1	---
0371	Analog Input Fast Rate of Change	---	Units / min.	F5	---
0372	Analog Input Slow Rate of Change	---	Units / hr.	F5	---
A3	**TRIP COUNTERS**				**READ ONLY**
0380	Breaker Trips	0 to 65535	---	F1	---
0381	Ground Overcurrent Trips	0 to 65535	---	F1	---
0382	Neutral Overcurrent Trips	0 to 65535	---	F1	---
0383	One Phase Overcurrent Trips	0 to 65535	---	F1	---
0384	Two Phase Overcurrent Trips	0 to 65535	---	F1	---
0385	Three Phase Overcurrent Trips	0 to 65535	---	F1	---
0386	Trip Counters Last Reset Date (2 words)	---	---	F23	---
0388	Negative Sequence Overcurrent Trips	0 to 65535	---	F1	---
0389[3]	Sensitive Ground Overcurrent Trips	0 to 65535	---	F1	---
A3	**TOTAL ARCING CURRENT**				**READ ONLY**
03A0	Total Arcing Current Phase A	0 to 65535	kA^{2}cyc	F1	---
03A1	Total Arcing Current Phase B	0 to 65535	kA^{2}cyc	F1	---
03A2	Total Arcing Current Phase C	0 to 65535	kA^{2}cyc	F1	---
03A3	Total Arcing Current Last Reset (2 words)	---	---	F23	---
A1	**FAULT LOCATION 1**				**READ ONLY**
03B0	Date of Fault (2 words)	---	---	F23	---
03B2	Time of Fault (2 words)	---	---	F22	---
03B4	Type of Fault	---	---	F76	---
03B5	Distance to Fault	-327.68 to 327.67	km, mi	F52	---
03B6	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 2**				**READ ONLY**
03B8	Date of Fault (2 words)	---	---	F23	---
03BA	Time of Fault (2 words)	---	---	F22	---
03BC	Type of Fault	---	---	F76	---
03BD	Distance to Fault	-327.68 to 327.67	km	F52	---
03BE	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 3**				**READ ONLY**
03C0	Date of Fault (2 words)	---	---	F23	---
03C2	Time of Fault (2 words)	---	---	F22	---
03C4	Type of Fault	---	---	F76	---
03C5	Distance to Fault	-327.68 to 327.67	km	F52	---
03C6	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 4**				**READ ONLY**
03C8	Date of Fault (2 words)	---	---	F23	---
03CA	Time of Fault (2 words)	---	---	F22	---
03CC	Type of Fault	---	---	F76	---
03CD	Distance to Fault	-327.68 to 327.67	km	F52	---

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 5 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
03CE	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 5**				**READ ONLY**
03D0	Date of Fault (2 words)	---	---	F23	---
03D2	Time of Fault (2 words)	---	---	F22	---
03D4	Type of Fault	---	---	F76	---
03D5	Distance to Fault	-327.68 to 327.67	km	F52	---
03D6	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 6**				**READ ONLY**
03D8	Date of Fault (2 words)	---	---	F23	---
03DA	Time of Fault (2 words)	---	---	F22	---
03DC	Type of Fault	---	---	F76	---
03DD	Distance to Fault	-327.68 to 327.67	km	F52	---
03DE	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 7**				**READ ONLY**
03E0	Date of Fault (2 words)	---	---	F23	---
03E2	Time of Fault (2 words)	---	---	F22	---
03E4	Type of Fault	---	---	F76	---
03E5	Distance to Fault	-327.68 to 327.67	km	F52	---
03E6	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 8**				**READ ONLY**
03E8	Date of Fault (2 words)	---	---	F23	---
03EA	Time of Fault (2 words)	---	---	F22	---
03EC	Type of Fault	---	---	F76	---
03ED	Distance to Fault	-327.68 to 327.67	km	F52	---
03EE	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 9**				**READ ONLY**
03F0	Date of Fault (2 words)	---	---	F23	---
03F2	Time of Fault (2 words)	---	---	F22	---
03F4	Type of Fault	---	---	F76	---
03F5	Distance to Fault	-327.68 to 327.67	km	F52	---
03F6	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A1	**FAULT LOCATION 10**				**READ ONLY**
03F8	Date of Fault (2 words)	---	---	F23	---
03FA	Time of Fault (2 words)	---	---	F22	---
03FC	Type of Fault	---	---	F76	---
03FD	Distance to Fault	-327.68 to 327.67	km	F52	---
03FE	Line Z1 to Fault (magnitude)	0.00 to 655.35	Ω	F53	---
A2	**CURRENT PHASE ANGLES**				**READ ONLY**
0400	Phase A Current Angle	0 to 359	° Lag	F1	---
0401	Phase B Current Angle	0 to 359	° Lag	F1	---
0402	Phase C Current Angle	0 to 359	° Lag	F1	---
0403	Neutral Current Angle	0 to 359	° Lag	F1	---
0404	Ground Current Angle	0 to 359	° Lag	F1	---
0405[3]	Reserved Polarizing Current Angle	---	---	---	---
0406[3]	Sensitive Ground Current Angle	0 to 359	° Lag	F1	---
A2	**VOLTAGE PHASE ANGLES**				**READ ONLY**
0410	A-N Voltage Angle	0 to 359	° Lag	F1	---
0411	B-N Voltage Angle	0 to 359	° Lag	F1	---
0412	C-N Voltage Angle	0 to 359	° Lag	F1	---
0413	A-B Voltage Angle	0 to 359	° Lag	F1	---
0414	B-C Voltage Angle	0 to 359	° Lag	F1	---
0415	C-A Voltage Angle	0 to 359	° Lag	F1	---
0416[5]	Neutral Voltage Angle	0 to 359	° Lag	F1	---

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 6 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
A2	**SYMMETRICAL COMPONENTS**				**READ ONLY**
0420	Positive Sequence Current Magnitude	0 to 65535	A	F1	---
0421	Positive Sequence Current Angle	0 to 359	° Lag	F1	---
0422	Negative Sequence Current Magnitude	0 to 65535	A	F1	---
0423	Negative Sequence Current Angle	0 to 359	° Lag	F1	---
0424	Zero Sequence Current Magnitude	0 to 65535	A	F1	---
0425	Zero Sequence Current Angle	0 to 359	° Lag	F1	---
0426	Positive Sequence Voltage Magnitude	0.00 to 600.00	kV	F3	---
0427	Positive Sequence Voltage Angle	0 to 359	° Lag	F1	---
0428	Negative Sequence Voltage Magnitude	0.00 to 600.00	kV	F3	---
0429	Negative Sequence Voltage Angle	0 to 359	° Lag	F1	---
042A	Zero Sequence Voltage Magnitude	0.00 to 600.00	kV	F3	---
042B	Zero Sequence Voltage Angle	0 to 359	° Lag	F1	---
	PROTECTION FUNCTION STATES				**READ ONLY**
0600	Reserved				
0601[2]	Phase Time Overcurrent 1	---	---	F49	---
0602[2]	Phase Instantaneous Overcurrent 1	---	---	F49	---
0603[2]	Phase Instantaneous Overcurrent 2	---	---	F49	---
0604[2]	Ground Time Overcurrent	---	---	F49	---
0605[2]	Ground Instantaneous Overcurrent	---	---	F49	---
0606[2]	Neutral Time Overcurrent 1	---	---	F49	---
0607[2]	Neutral Time Overcurrent 2	---	---	F49	---
0608[2]	Neutral Instantaneous Overcurrent 1	---	---	F49	---
0609[2]	Neutral Instantaneous Overcurrent 2	---	---	F49	---
060A[2]	Phase Directional is Reverse	---	---	F49	---
060B[2]	Neutral Directional is Reverse	---	---	F49	---
060C	Manual Close Blocking	---	---	F49	---
060D	Cold Load Pickup Blocking	---	---	F49	---
060E	Bus Undervoltage 1	---	---	F49	---
060F	Bus Undervoltage 2	---	---	F49	---
0610	Line Undervoltage 3	---	---	F49	---
0611	Line Undervoltage 4	---	---	F49	
0612	Overvoltage 1	---	---	F49	---
0613	Overvoltage 2	---	---	F49	---
0614	Underfrequency 1	---	---	F49	---
0615	Underfrequency 2	---	---	F49	---
0616	Phase Current Level	---	---	F49	---
0617	Neutral Current Level	---	---	F49	---
0618	Power Factor 1	---	---	F49	---
0619	Power Factor 2	---	---	F49	---
061A	Synchrocheck Block (Not In Sync)	---	---	F49	---
061B	Current Demand	---	---	F49	---
061C	Real Power Demand	---	---	F49	---
061D	Reactive Power Demand	---	---	F49	---
061E	Apparent Power Demand	---	---	F49	---
061F	Analog Input Threshold 1	---	---	F49	---
0620	Analog Input Threshold 2	---	---	F49	---
0621	Analog Input Rate of Change 1	---	---	F49	---
0622	Analog Input Rate of Change 2	---	---	F49	---
0623	Overfrequency	---	---	F49	---
0624	Trip Counter	---	---	F49	---
0625	Arcing Current	---	---	F49	---
0626	VT Failure	---	---	F49	---

1 2 3 4 5 6 7 8 9 For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 7 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
0627	Breaker Failure	---	---	F49	---
0628	Breaker Operation Failure	---	---	F49	---
0629	Trip Coil Monitor	---	---	F49	---
062A	Close Coil Monitor	---	---	F49	---
062B	User Input A	---	---	F49	---
062C	User Input B	---	---	F49	---
062D	User Input C	---	---	F49	---
062E	User Input D	---	---	F49	---
062F	User Input E	---	---	F49	---
0630	User Input F	---	---	F49	---
0631	User Input G	---	---	F49	---
0632	User Input H	---	---	F49	---
0633	Negative Sequence Instantaneous O/C	---	---	F49	---
0634	Negative Sequence Time O/C	---	---	F49	---
0635	Negative Sequence Overvoltage	---	---	F49	---
0636	Undervoltage Restoration	---	---	F49	---
0637	Underfrequency Restoration	---	---	F49	---
0638[1]	Phase Time Overcurrent 2	---	---	F49	---
0639[1]	Frequency Decay	---	---	F49	---
063A[3]	Negative Sequence Directional is Reverse	---	---	F49	---
063B[3]	Sensitive Ground Instantaneous O/C	---	---	F49	---
063C[3]	Sensitive Ground Time O/C	---	---	F49	---
063D[3]	Sensitive Ground Directional is Reverse	---	---	F49	---
063E[5]	Reverse Power (requires Mod 008)	---	---	F49	---
063F[5]	Neutral Displacement	---	---	F49	---
0640[5]	Pulse Output Positive Watthours	---	---	F49	---
0641[5]	Pulse Output Negative Watthours	---	---	F49	---
0642[5]	Pulse Output Positive Varhours	---	---	F49	---
0643[5]	Pulse Output Negative Varhours	---	---	F49	---
0644[6]	Ground Directional is Reverse	---	---	F49	---
0645[7]	Reserved for MOD 010	---	---	F49	---
0646[8]	User Input I	---	---	F49	---
0647[8]	User Input J	---	---	F49	---
0648[8]	User Input K	---	---	F49	---
0649[8]	User Input L	---	---	F49	---
064A[8]	User Input M	---	---	F49	---
064B[8]	User Input N	---	---	F49	---
064C[8]	User Input O	---	---	F49	---
064D[8]	User Input P	---	---	F49	---
064E[8]	User Input Q	---	---	F49	---
064F[8]	User Input R	---	---	F49	---
0650[8]	User Input S	---	---	F49	---
0651[8]	User Input T	---	---	F49	---
0652[8]	Autoreclose Rate Supervision	---	---	F49	---
0653[8]	Restricted Earth Fault	---	---	F49	---
S1	**750/760 SETUP**				**READ/WRITE**
1000	Reserved				
1001	Flash Message Time	0.5 to 10.0	s	F2	4.0 s
1002	Default Message Timeout	10 to 900	s	F1	300 s
1003	Default Message Intensity (25, 50, 75, or100)	25 to 100	%	F1	25%
1004[1]	Display Filter Constant	0 to 255	---	F1	0
1005	Reserved				
1006	Set Date (2 words)	---	---	F23	01/01/1993

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 8 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1008	Set Time (2 words)	---	---	F22	00:00:00.000
100A	760 Operation	---	---	F29	Not Ready
100B[2]	IRIG-B Signal Type	---	---	F43	None
100C	Encrypted Passcode (4 words)	---	---	F33	"AIKFBAIK"
S1	**EVENT RECORDER SETUP**				**READ/WRITE**
1010	Event Recorder Function	---	---	F30	Enabled
1011	Recording of Trip Events	---	---	F30	Enabled
1012	Recording of Alarm Events	---	---	F30	Enabled
1013	Recording of Control Events	---	---	F30	Disabled
1014	Recording of Logic Input Events	---	---	F30	Enabled
1015	Recording of Pickup Events	---	---	F30	Enabled
1016	Recording of Dropout Events	---	---	F30	Enabled
1017[8]	Recording of Set Time/Date Events	---	---	F30	Enabled
S1	**TRACE MEMORY SETUP**				**READ/WRITE**
1018	Buffer Organization	---	---	F81	16 x 256
1019	Trigger Position	0 to 100	%	F1	25%
101A	Trigger Source	---	---	F82	Pickup & Trip
S1	**DEFAULT MESSAGES**				**READ/WRITE**
1020	Number Of Messages Selected (read only)	0 to 20	---	F1	3
1021	Default Message #1	---	---	F32	---
1022	Default Message #2	---	---	F32	---
1023	Default Message #3	---	---	F32	---
↓	↓	↓	↓	↓	↓
103E	Default Message #30	---	---	F32	---
S1	**USER TEXT MESSAGES**				**READ/WRITE**
1040	User Text Message 1 (20 words)	---	---	F33	"Text 1"
1054	User Text Message 2 (20 words)	---	---	F33	"Text 2"
1068	User Text Message 3 (20 words)	---	---	F33	"Text 3"
107C	User Text Message 4 (20 words)	---	---	F33	"Text 4"
1090	User Text Message 5 (20 words)	---	---	F33	"Text 5"
S1	**OVERRIDE MESSAGE**				**READ/WRITE**
10B0	Override Message Display Time	0 to 9000	s	F1	0 s
10B1	Override Message (20 words)	---	---	F33	"This is a test"
S1	**COMMUNICATIONS**				**READ/WRITE**
10D0	Slave Address	1 to 254	---	F1	254
10D1	COM1 Baud Rate	---	---	F31	9600
10D2	COM1 Parity	---	---	F27	None
10D3	COM1 Communication Hardware	---	---	F17	RS485
10D4	Front Panel RS232 Baud Rate	---	---	F31	9600
10D5	Front Panel RS232 Parity	---	---	F27	None
10D6	Reserved				
10D7	Reserved				
10D8	COM2 Baud Rate	---	---	F31	9600
10D9	COM2 Parity	---	---	F27	None
10DA	DNP Port	---	---	F62	None
10DB	DNP Point Mapping	---	---	F30	Disabled
S1	**DATA LOGGER**				**READ/WRITE**
10E0	Sample Rate	---	---	F74	1 cycle
10E1	Continuous Mode	---	---	F30	Disabled
10E2	Buffer Organization	---	---	F81	16 x 256
10E3	Trigger Position	0 to 100	%	F1	25%
10E4	Trigger Source	---	---	F82	Pickup & Trip
10E5	Channel 1 Source	---	---	F77	I_a

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 9 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
10E6	Channel 2 Source	---	---	F77	I_b
10E7	Channel 3 Source	---	---	F77	I_c
10E8	Channel 4 Source	---	---	F77	I_g
10E9	Channel 5 Source	---	---	F77	V_{an}
10EA	Channel 6 Source	---	---	F77	V_{bn}
10EB	Channel 7 Source	---	---	F77	V_{cn}
10EC	Channel 8 Source	---	---	F77	Frequency
S1[8]	**DNP COMMUNICATIONS**				**READ/WRITE**
10F0[8]	Transmission Delay	0 to 65000	ms	F1	0 ms
10F1[8]	Data Link Confirmation Mode	---	---	F89	Never
10F2[8]	Data Link Confirmation Timeout	1 to 65000	ms	F1	1000 ms
10F3[8]	Data Link Confirmation Retries	0 to 100	---	F1	3
10F4[8]	Select/Operate Arm Timer Duration	1 to 65000	ms	F1	10000 ms
10F5[8]	Write Time Interval	0 to 65000	ms	F1	0 ms
10F6[8]	Inhibit Cold Restart	---	---	F30	Disabled
10F7[9]	3 Key Reset of Max Demand Values	---	---	F30	Disabled
S2	**SYSTEM SETUP**				**READ/WRITE**
1100	Phase CT Primary	1 to 50000	A	F1	1000 A
1101	Reserved				
1102	Ground CT Primary	1 to 50000	A	F1	50 A
1103	Bus VT Connection Type	---	---	F28	Wye
1104	Bus Nominal VT Secondary Voltage	50.0 to 240.0	V	F2	120.0 V
1105	Bus VT Ratio	1.0 to 5000.0	xxx: 1	F2	120.0:1
1106	Nominal Frequency	25 to 60	Hz	F1	60 Hz
1107	Cost of energy	1.0 to 25.0	¢/kWh	F2	5.0 ¢/kWh
1108[3]	Reserved for Polarizing CT Primary	---	---	---	---
1109	Line VT Connection	---	---	F18	V_{bn}
110A	Line Nominal VT Secondary Voltage	50.0 to 240.0	V	F2	120.0 V
110B	Line VT Ratio	1.0 to 5000.0	xxx: 1	F1	120.0:1
110C[1]	Phase Sequence	---	---	F83	ABC
110D[3]	Sensitive Ground CT Primary	1 to 50000	A	F1	1000 A
S3	**LOGIC INPUT ASSERTED LOGIC**				**READ/WRITE**
1140[2]	Logic Input 1 Asserted Logic	---	---	F63	Contact Close
1141[2]	Logic Input 2 Asserted Logic	---	---	F63	Contact Close
1142[2]	Logic Input 3 Asserted Logic	---	---	F63	Contact Close
↓	↓	↓	↓	↓	↓
114D[2]	Logic Input 14 Asserted Logic	---	---	F63	Contact close
114E[1]	Logic Input 15 Asserted Logic	---	---	F64	Disabled
114F[1]	Logic Input 16 Asserted Logic	---	---	F64	Disabled
↓	↓	↓	↓	↓	↓
1153[1]	Logic Input 20 Asserted Logic	---	---	F64	Disabled
S3	**BREAKER FUNCTIONS**				**READ/WRITE**
1160	52a Contact	---	---	F65	Disabled
1161	52b Contact	---	---	F65	Disabled
1162	Breaker Connected	---	---	F65	Disabled
S3	**CONTROL FUNCTIONS**				**READ/WRITE**
1170	Local Mode	---	---	F65	Disabled
1171	Remote Reset	---	---	F65	Disabled
1172	Remote Open	---	---	F65	Disabled
1173	Remote Close	---	---	F65	Disabled
1174	Cold Load Pickup	---	---	F65	Disabled
1175	Setpoint Group 2	---	---	F65	Disabled
1176	Setpoint Group 3	---	---	F65	Disabled

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 10 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1177	Setpoint Group 4	---	---	F65	Disabled
S3	**USER INPUT A**				**READ/WRITE**
1180	User Input A Name (9 registers)	---	---	F33	User Input A
1189	User Input A Source	---	---	F65	Disabled
118A	User Input A Function	---	---	F37	Disabled
118B	User Input A Relays	---	---	F57	None
118C	User Input A Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT B**				**READ/WRITE**
1190	User Input B Name (9 registers)	---	---	F33	User Input B
1199	User Input B Source	---	---	F65	Disabled
119A	User Input B Function	---	---	F37	Disabled
119B	User Input B Relays	---	---	F57	None
119C	User Input B Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT C**				**READ/WRITE**
11A0	User Input C Name (9 registers)	---	---	F33	User Input C
11A9	User Input C Source	---	---	F65	Disabled
11AA	User Input C Function	---	---	F37	Disabled
11AB	User Input C Relays	---	---	F57	None
11AC	User Input C Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT D**				**READ/WRITE**
11B0	User Input D Name (9 registers)	---	---	F33	User Input D
11B9	User Input D Source	---	---	F65	Disabled
11BA	User Input D Function	---	---	F37	Disabled
11BB	User Input D Relays	---	---	F57	None
11BC	User Input D Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT E**				**READ/WRITE**
11C0	User Input E Name (9 registers)	---	---	F33	User Input E
11C9	User Input E Source	---	---	F65	Disabled
11CA	User Input E Function	---	---	F37	Disabled
11CB	User Input E Relays	---	---	F57	None
11CC	User Input E Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT F**				**READ/WRITE**
11D0	User Input F Name (9 registers)	---	---	F33	User Input F
11D9	User Input F Source	---	---	F65	Disabled
11DA	User Input F Function	---	---	F37	Disabled
11DB	User Input F Relays	---	---	F57	None
11DC	User Input F Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT G**				**READ/WRITE**
11E0	User Input G Name (9 registers)	---	---	F33	User Input G
11E9	User Input G Source	---	---	F65	Disabled
11EA	User Input G Function	---	---	F37	Disabled
11EB	User Input G Relays	---	---	F57	None
11EC	User Input G Delay	0.00 to 600.00	s	F3	0.00 s
S3	**USER INPUT H**				**READ/WRITE**
11F0	User Input H Name (9 registers)	---	---	F33	User Input H
11F9	User Input H Source	---	---	F65	Disabled
11FA	User Input H Function	---	---	F37	Disabled
11FB	User Input H Relays	---	---	F57	None
11FC	User Input H Delay	0.00 to 600.00	s	F3	0.00 s
S3	**BLOCKING FUNCTIONS**				**READ/WRITE**
1240	Block 1 TRIP Relay	---	---	F65	Disabled
1241	Block 2 CLOSE Relay	---	---	F65	Disabled
1242	Block Reset	---	---	F65	Disabled

1 2 3 4 5 6 7 8 9 For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 11 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1243	Block Undervoltage 1	---	---	F65	Disabled
1244	Block Undervoltage 2	---	---	F65	Disabled
1245	Block Undervoltage 3	---	---	F65	Disabled
1246	Block Undervoltage 4	---	---	F65	Disabled
1247	Block Underfrequency 1	---	---	F65	Disabled
1248	Block Underfrequency 2	---	---	F65	Disabled
1249	Bypass Synchrocheck	---	---	F65	Disabled
124A[2]	Block Breaker Statistics	---	---	F65	Disabled
124B	Block Negative Sequence Voltage	---	---	F65	Disabled
124C	Block Restoration	---	---	F65	Disabled
124D	Block Frequency Decay	---	---	F65	Disabled
124E[5]	Block Reverse Power (requires Mod 008)	---	---	F65	Disabled
124F[5]	Block Neutral Displacement	---	---	F65	Disabled
S3	**OVERCURRENT BLOCKING FUNCTIONS**				**READ/WRITE**
1260	Block All Overcurrent	---	---	F65	Disabled
1261	Block All Phase Overcurrent	---	---	F65	Disabled
1262	Block All Ground Overcurrent	---	---	F65	Disabled
1263	Block All Neutral Overcurrent	---	---	F65	Disabled
1264[2]	Block Phase Time Overcurrent 1	---	---	F65	Disabled
1265[2]	Block Phase Instantaneous Overcurrent 1	---	---	F65	Disabled
1266[2]	Block Phase Instantaneous Overcurrent 2	---	---	F65	Disabled
1267[2]	Block Ground Time Overcurrent	---	---	F65	Disabled
1268[2]	Block Ground Instantaneous Overcurrent	---	---	F65	Disabled
1269[2]	Block Neutral Time Overcurrent 1	---	---	F65	Disabled
126A[2]	Block Neutral Time Overcurrent 2	---	---	F65	Disabled
126B[2]	Block Neutral Instantaneous Overcurrent 1	---	---	F65	Disabled
126C[2]	Block Neutral Instantaneous Overcurrent 2	---	---	F65	Disabled
126D	Block Negative Sequence Time Overcurrent	---	---	F65	Disabled
126E	Block Negative Sequence Instantaneous Overcurrent	---	---	F65	Disabled
126F	Block Phase Time Overcurrent 2	---	---	F65	Disabled
1270[3]	Block All Sensitive Ground Overcurrent	---	---	F65	Disabled
1271[3]	Block Sensitive Ground Instantaneous O/C	---	---	F65	Disabled
1272[3]	Block Sensitive Ground Time O/C	---	---	F65	Disabled
S3	**TRANSFER FUNCTIONS**				**READ/WRITE**
1280	Selected To Trip	---	---	F65	Disabled
1281	Undervoltage on Other Source	---	---	F65	Disabled
1282	Incomer 1 Breaker Closed	---	---	F65	Disabled
1283	Incomer 2 Breaker Closed	---	---	F65	Disabled
1284	Tie Breaker Connected	---	---	F65	Disabled
1285	Tie Breaker Closed	---	---	F65	Disabled
1286	Block Transfer	---	---	F65	Disabled
1287	Transformer Lockout	---	---	F65	Disabled
1288	Source Trip	---	---	F65	Disabled
1289	Close From Incomer 1	---	---	F65	Disabled
128A	Close From Incomer 2	---	---	F65	Disabled
S3	**AUTORECLOSE FUNCTIONS (760 ONLY)**				**READ/WRITE**
1290	Initiate Reclosure	---	---	F65	Disabled
1291	Cancel Reclosure	---	---	F65	Disabled
1292	Block Reclosure	---	---	F65	Disabled
S3	**MISCELLANEOUS FUNCTIONS**				**READ/WRITE**
12A0	Trigger Trace Memory	---	---	F65	Disabled
12A1	Simulate Fault	---	---	F65	Disabled
12A2	Trigger Data Logger	---	---	F65	Disabled

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 12 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
12A3[8]	Start Demand Interval	---	---	F65	Disabled
S4	**RELAY 1 TRIP**				**READ/WRITE**
1300[8]	Relay 1 TRIP Seal In Time	0.00 to 9.99	s	F3	0.04s
S4	**RELAY 2 CLOSE**				**READ/WRITE**
1310[8]	Relay 2 CLOSE Seal In Time	0.00 to 9.99	s	F3	0.04 s
S4	**RELAY 3 AUXILIARY**				**READ/WRITE**
1320	Relay 3 AUXILIARY Name (8 words)	---	---	F33	"AUXILIARY"
1328	Relay 3 AUXILIARY Non-operated State	---	---	F34	De-energized
1329	Relay 3 AUXILIARY Output Type	---	---	F35	Self-resetting
132A	Relay 3 AUXILIARY Pulse Dwell Time	0.1 to 6000.0	s	F2	0.1 s
S4	**RELAY 4 AUXILIARY**				**READ/WRITE**
1330	Relay 4 AUXILIARY Name (8 words)	---	---	F33	"AUXILIARY"
1338	Relay 4 AUXILIARY Non-operated State	---	---	F34	De-energized
1339	Relay 4 AUXILIARY Output Type	---	---	F35	Self-resetting
133A	Relay 4 AUXILIARY Pulse Dwell Time	0.1 to 6000.0	s	F2	0.1 s
S4	**RELAY 5 AUXILIARY**				**READ/WRITE**
1340	Relay 5 AUXILIARY Name (8 words)	---	---	F33	"AUXILIARY"
1348	Relay 5 AUXILIARY Non-operated State	---	---	F34	De-energized
1349	Relay 5 AUXILIARY Output Type	---	---	F35	Self-resetting
134A	Relay 5 AUXILIARY Pulse Dwell Time	0.1 to 6000.0	s	F2	0.1 s
S4	**RELAY 6 AUXILIARY**				**READ/WRITE**
1350	Relay 6 AUXILIARY Name (8 words)	---	---	F33	"AUXILIARY"
1358	Relay 6 AUXILIARY Non-operated State	---	---	F34	De-energized
1359	Relay 6 AUXILIARY Output Type	---	---	F35	Self-resetting
135A	Relay 6 AUXILIARY Pulse Dwell Time	0.1 to 6000.0	s	F2	0.1 s
S4	**RELAY 7 AUXILIARY**				**READ/WRITE**
1360	Relay 7 AUXILIARY Name (8 words)	---	---	F33	"AUXILIARY"
1368	Relay 7 AUXILIARY Non-operated State	---	---	F34	De-energized
1369	Relay 7 AUXILIARY Output Type	---	---	F35	Self-resetting
136A	Relay 7 AUXILIARY Pulse Dwell Time	0.1 to 6000.0	s	F2	0.1 s
S3[8]	**USER INPUT I**				**READ/WRITE**
1370[8]	User Input I Name (9 registers)	---	---	F33	User Input I
1379[8]	User Input I Source	---	---	F65	Disabled
137A[8]	User Input I Function	---	---	F37	Disabled
137B[8]	User Input I Relays	---	---	F57	None
137C[8]	User Input I Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT J**				**READ/WRITE**
1380[8]	User Input J Name (9 registers)	---	---	F33	User Input J
1389[8]	User Input J Source	---	---	F65	Disabled
138A[8]	User Input J Function	---	---	F37	Disabled
138B[8]	User Input J Relays	---	---	F57	None
138C[8]	User Input J Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT K**				**READ/WRITE**
1390[8]	User Input K Name (9 registers)	---	---	F33	User Input K
1399[8]	User Input K Source	---	---	F65	Disabled
139A[8]	User Input K Function	---	---	F37	Disabled
139B[8]	User Input K Relays	---	---	F57	None
139C[8]	User Input K Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT L**				**READ/WRITE**
13A0[8]	User Input L Name (9 registers)	---	---	F33	User Input L
13A9[8]	User Input L Source	---	---	F65	Disabled
13AA[8]	User Input L Function	---	---	F37	Disabled
13AB[8]	User Input L Relays	---	---	F57	None

1 2 3 4 5 6 7 8 9 For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 13 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
13AC[8]	User Input L Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT M**				**READ/WRITE**
13B0[8]	User Input M Name (9 registers)	---	---	F33	User Input M
13B9[8]	User Input M Source	---	---	F65	Disabled
13BA[8]	User Input M Function	---	---	F37	Disabled
13BB[8]	User Input M Relays	---	---	F57	None
13BC[8]	User Input M Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT N**				**READ/WRITE**
13C0[8]	User Input N Name (9 registers)	---	---	F33	User Input N
13C9[8]	User Input N Source	---	---	F65	Disabled
13CA[8]	User Input N Function	---	---	F37	Disabled
13CB[8]	User Input N Relays	---	---	F57	None
13CC[8]	User Input N Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT O**				**READ/WRITE**
13D0[8]	User Input O Name (9 registers)	---	---	F33	User Input O
13D9[8]	User Input O Source	---	---	F65	Disabled
13DA[8]	User Input O Function	---	---	F37	Disabled
13DB[8]	User Input O Relays	---	---	F57	None
13DC[8]	User Input O Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT P**				**READ/WRITE**
13E0[8]	User Input P Name (9 registers)	---	---	F33	User Input P
13E9[8]	User Input P Source	---	---	F65	Disabled
13EA[8]	User Input P Function	---	---	F37	Disabled
13EB[8]	User Input P Relays	---	---	F57	None
13EC[8]	User Input P Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT Q**				**READ/WRITE**
13F0[8]	User Input Q Name (9 registers)	---	---	F33	User Input Q
13F9[8]	User Input Q Source	---	---	F65	Disabled
13FA[8]	User Input Q Function	---	---	F37	Disabled
13FB[8]	User Input Q Relays	---	---	F57	None
13FC[8]	User Input Q Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT R**				**READ/WRITE**
1400[8]	User Input R Name (9 registers)	---	---	F33	User Input R
1409[8]	User Input R Source	---	---	F65	Disabled
140A[8]	User Input R Function	---	---	F37	Disabled
140B[8]	User Input R Relays	---	---	F57	None
140C[8]	User Input R Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT S**				**READ/WRITE**
1410[8]	User Input S Name (9 registers)	---	---	F33	User Input S
1419[8]	User Input S Source	---	---	F65	Disabled
141A[8]	User Input S Function	---	---	F37	Disabled
141B[8]	User Input S Relays	---	---	F57	None
141C[8]	User Input S Delay	0.00 to 600.00	s	F3	0.00 s
S3[8]	**USER INPUT T**				**READ/WRITE**
1420[8]	User Input T Name (9 registers)	---	---	F33	User Input T
1429[8]	User Input T Source	---	---	F65	Disabled
142A[8]	User Input T Function	---	---	F37	Disabled
142B[8]	User Input T Relays	---	---	F57	None
142C[8]	User Input T Delay	0.00 to 600.00	s	F3	0.00 s
S2	**FLEXCURVE A TRIP TIMES**				**READ/WRITE**
1430	FlexCurve A Trip Time at 1.03 x PU	0 to 65535	ms	F1	0 ms
1431	FlexCurve A Trip Time at 1.05 x PU	0 to 65535	ms	F1	0 ms
1432	FlexCurve A Trip Time at 1.10 x PU	0 to 65535	ms	F1	0 ms

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 14 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1433	FlexCurve A Trip Time at 1.20 x PU	0 to 65535	ms	F1	0 ms
1434	FlexCurve A Trip Time at 1.30 x PU	0 to 65535	ms	F1	0 ms
1435	FlexCurve A Trip Time at 1.40 x PU	0 to 65535	ms	F1	0 ms
1436	FlexCurve A Trip Time at 1.50 x PU	0 to 65535	ms	F1	0 ms
1437	FlexCurve A Trip Time at 1.60 x PU	0 to 65535	ms	F1	0 ms
1438	FlexCurve A Trip Time at 1.70 x PU	0 to 65535	ms	F1	0 ms
1439	FlexCurve A Trip Time at 1.80 x PU	0 to 65535	ms	F1	0 ms
143A	FlexCurve A Trip Time at 1.90 x PU	0 to 65535	ms	F1	0 ms
143B	FlexCurve A Trip Time at 2.00 x PU	0 to 65535	ms	F1	0 ms
143C	FlexCurve A Trip Time at 2.10 x PU	0 to 65535	ms	F1	0 ms
143D	FlexCurve A Trip Time at 2.20 x PU	0 to 65535	ms	F1	0 ms
143E	FlexCurve A Trip Time at 2.30 x PU	0 to 65535	ms	F1	0 ms
143F	FlexCurve A Trip Time at 2.40 x PU	0 to 65535	ms	F1	0 ms
1440	FlexCurve A Trip Time at 2.50 x PU	0 to 65535	ms	F1	0 ms
1441	FlexCurve A Trip Time at 2.60 x PU	0 to 65535	ms	F1	0 ms
1442	FlexCurve A Trip Time at 2.70 x PU	0 to 65535	ms	F1	0 ms
1443	FlexCurve A Trip Time at 2.80 x PU	0 to 65535	ms	F1	0 ms
1444	FlexCurve A Trip Time at 2.90 x PU	0 to 65535	ms	F1	0 ms
1445	FlexCurve A Trip Time at 3.00 x PU	0 to 65535	ms	F1	0 ms
1446	FlexCurve A Trip Time at 3.10 x PU	0 to 65535	ms	F1	0 ms
1447	FlexCurve A Trip Time at 3.20 x PU	0 to 65535	ms	F1	0 ms
1448	FlexCurve A Trip Time at 3.30 x PU	0 to 65535	ms	F1	0 ms
1449	FlexCurve A Trip Time at 3.40 x PU	0 to 65535	ms	F1	0 ms
144A	FlexCurve A Trip Time at 3.50 x PU	0 to 65535	ms	F1	0 ms
144B	FlexCurve A Trip Time at 3.60 x PU	0 to 65535	ms	F1	0 ms
144C	FlexCurve A Trip Time at 3.70 x PU	0 to 65535	ms	F1	0 ms
144D	FlexCurve A Trip Time at 3.80 x PU	0 to 65535	ms	F1	0 ms
144E	FlexCurve A Trip Time at 3.90 x PU	0 to 65535	ms	F1	0 ms
144F	FlexCurve A Trip Time at 4.00 x PU	0 to 65535	ms	F1	0 ms
1450	FlexCurve A Trip Time at 4.10 x PU	0 to 65535	ms	F1	0 ms
1451	FlexCurve A Trip Time at 4.20 x PU	0 to 65535	ms	F1	0 ms
1452	FlexCurve A Trip Time at 4.30 x PU	0 to 65535	ms	F1	0 ms
1453	FlexCurve A Trip Time at 4.40 x PU	0 to 65535	ms	F1	0 ms
1454	FlexCurve A Trip Time at 4.50 x PU	0 to 65535	ms	F1	0 ms
1455	FlexCurve A Trip Time at 4.60 x PU	0 to 65535	ms	F1	0 ms
1456	FlexCurve A Trip Time at 4.70 x PU	0 to 65535	ms	F1	0 ms
1457	FlexCurve A Trip Time at 4.80 x PU	0 to 65535	ms	F1	0 ms
1458	FlexCurve A Trip Time at 4.90 x PU	0 to 65535	ms	F1	0 ms
1459	FlexCurve A Trip Time at 5.00 x PU	0 to 65535	ms	F1	0 ms
145A	FlexCurve A Trip Time at 5.10 x PU	0 to 65535	ms	F1	0 ms
145B	FlexCurve A Trip Time at 5.20 x PU	0 to 65535	ms	F1	0 ms
145C	FlexCurve A Trip Time at 5.30 x PU	0 to 65535	ms	F1	0 ms
145D	FlexCurve A Trip Time at 5.40 x PU	0 to 65535	ms	F1	0 ms
145E	FlexCurve A Trip Time at 5.50 x PU	0 to 65535	ms	F1	0 ms
145F	FlexCurve A Trip Time at 5.60 x PU	0 to 65535	ms	F1	0 ms
1460	FlexCurve A Trip Time at 5.70 x PU	0 to 65535	ms	F1	0 ms
1461	FlexCurve A Trip Time at 5.80 x PU	0 to 65535	ms	F1	0 ms
1462	FlexCurve A Trip Time at 5.90 x PU	0 to 65535	ms	F1	0 ms
1463	FlexCurve A Trip Time at 6.00 x PU	0 to 65535	ms	F1	0 ms
1464	FlexCurve A Trip Time at 6.50 x PU	0 to 65535	ms	F1	0 ms
1465	FlexCurve A Trip Time at 7.00 x PU	0 to 65535	ms	F1	0 ms
1466	FlexCurve A Trip Time at 7.50 x PU	0 to 65535	ms	F1	0 ms
1467	FlexCurve A Trip Time at 8.00 x PU	0 to 65535	ms	F1	0 ms

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 15 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1468	FlexCurve A Trip Time at 8.50 x PU	0 to 65535	ms	F1	0 ms
1469	FlexCurve A Trip Time at 9.00 x PU	0 to 65535	ms	F1	0 ms
146A	FlexCurve A Trip Time at 9.50 x PU	0 to 65535	ms	F1	0 ms
146B	FlexCurve A Trip Time at 10.0 x PU	0 to 65535	ms	F1	0 ms
146C	FlexCurve A Trip Time at 10.5 x PU	0 to 65535	ms	F1	0 ms
146D	FlexCurve A Trip Time at 11.0 x PU	0 to 65535	ms	F1	0 ms
146E	FlexCurve A Trip Time at 11.5 x PU	0 to 65535	ms	F1	0 ms
146F	FlexCurve A Trip Time at 12.0 x PU	0 to 65535	ms	F1	0 ms
1470	FlexCurve A Trip Time at 12.5 x PU	0 to 65535	ms	F1	0 ms
1471	FlexCurve A Trip Time at 13.0 x PU	0 to 65535	ms	F1	0 ms
1472	FlexCurve A Trip Time at 13.5 x PU	0 to 65535	ms	F1	0 ms
1473	FlexCurve A Trip Time at 14.0 x PU	0 to 65535	ms	F1	0 ms
1474	FlexCurve A Trip Time at 14.5 x PU	0 to 65535	ms	F1	0 ms
1475	FlexCurve A Trip Time at 15.0 x PU	0 to 65535	ms	F1	0 ms
1476	FlexCurve A Trip Time at 15.5 x PU	0 to 65535	ms	F1	0 ms
1477	FlexCurve A Trip Time at 16.0 x PU	0 to 65535	ms	F1	0 ms
1478	FlexCurve A Trip Time at 16.5 x PU	0 to 65535	ms	F1	0 ms
1479	FlexCurve A Trip Time at 17.0 x PU	0 to 65535	ms	F1	0 ms
147A	FlexCurve A Trip Time at 17.5 x PU	0 to 65535	ms	F1	0 ms
147B	FlexCurve A Trip Time at 18.0 x PU	0 to 65535	ms	F1	0 ms
147C	FlexCurve A Trip Time at 18.5 x PU	0 to 65535	ms	F1	0 ms
147D	FlexCurve A Trip Time at 19.0 x PU	0 to 65535	ms	F1	0 ms
147E	FlexCurve A Trip Time at 19.5 x PU	0 to 65535	ms	F1	0 ms
147F	FlexCurve A Trip Time at 20.0 x PU	0 to 65535	ms	F1	0 ms
S2	**FLEXCURVE B**				**READ/WRITE**
1480	FlexCurve B (80 words - see FlexCurve A)	0 to 65535	ms	F1	0 ms
S5	**PHASE TIME OVERCURRENT 1**				**READ/WRITE**
1500	Phase Time Overcurrent 1 Function	---	---	F37	Trip
1501	Phase Time Overcurrent 1 Relays	---	---	F57	None
1502[2]	Phase Time Overcurrent 1 Curve	---	---	F36	Ext Inverse
1503	Phase Time Overcurrent 1 Voltage Restraint	---	---	F30	Disabled
1504[1]	Phase Time Overcurrent 1 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1505[1]	Phase Time Overcurrent 1 Multiplier	0.00 to 100.00	---	F3	1.00
1506[1]	Phase Time Overcurrent 1 Reset Time	---	---	F68	Instantaneous
1507[1]	Phase Time Overcurrent 1 Direction	---	---	F84	Disabled
S5	**PHASE INSTANTANEOUS OVERCURRENT 1**				**READ/WRITE**
1508[2]	Phase Instantaneous Overcurrent 1 Function	---	---	F37	Disabled
1509[2]	Phase Instantaneous Overcurrent 1 Relays	---	---	F57	None
150A[2]	Phase Instantaneous Overcurrent 1 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
150B[2]	Phase Instantaneous Overcurrent 1 Delay	0.00 to 600.00	s	F3	0.00 s
150C	Phases Required for Operation	---	---	F41	Any One
150D[1]	Phase Instantaneous Overcurrent 1 Direction	---	---	F84	Disabled
S5	**PHASE INSTANTANEOUS OVERCURRENT 2**				**READ/WRITE**
1510[2]	Phase Instantaneous Overcurrent 2 Function	---	---	F37	Disabled
1511[2]	Phase Instantaneous Overcurrent 2 Relays	---	---	F57	None
1512[2]	Phase Instantaneous Overcurrent 2 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1513[2]	Phase Instantaneous Overcurrent 2 Delay	0.00 to 600.00	s	F3	0.00 s
1514	Phases Required for Operation	---	---	F41	Any One
1515[1]	Phase Instantaneous Overcurrent 2 Direction	---	---	F84	Disabled
S5	**PHASE DIRECTIONAL**				**READ/WRITE**
1520	Phase Directional Function	---	---	F38	Disabled
1521	Phase Directional Maximum Torque Angle	0 to 359	° Lead	F1	30° Lead
1522[1]	Minimum Polarizing Voltage	0.00 to 1.25	x VT	F3	0.05 x VT

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 16 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1523	Phase Directional Relays	---	---	F57	None
1524[4]	Block OC When Voltage Memory Expires	---	---	F30	Disabled
S5	**PHASE TIME OVERCURRENT 2**				**READ/WRITE**
1530[1]	Phase Time Overcurrent 2 Function	---	---	F37	Disabled
1531[1]	Phase Time Overcurrent 2 Relays	---	---	F57	None
1532[1]	Phase Time Overcurrent 2 Curve	---	---	F36	Ext. Inverse
1533[1]	Phase Time Overcurrent 2 Voltage Restraint	---	---	F30	Disabled
1534[1]	Phase Time Overcurrent 2 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1535[1]	Phase Time Overcurrent 2 Multiplier	0.00 to 100.00	---	F3	1.00
1536[1]	Phase Time Overcurrent 2 Reset Time	---	---	F68	Instantaneous
1537[1]	Phase Time Overcurrent 2 Direction	---	---	F84	Disabled
S5	**GROUND TIME OVERCURRENT**				**READ/WRITE**
1600	Ground Time Overcurrent Function	---	---	F37	Disabled
1601	Ground Time Overcurrent Relays	---	---	F57	None
1602	Ground Time Overcurrent Curve	---	---	F36	Ext. Inverse
1603[1]	Ground Time Overcurrent Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1604[1]	Ground Time Overcurrent Multiplier	0.00 to 100.00	---	F3	1.00
1605[1]	Ground Time Overcurrent Reset Time	---	---	F68	Instantaneous
1606[6]	Ground Time Overcurrent Direction	---	---	F84	Disabled
S5	**GROUND INSTANTANEOUS OVERCURRENT**				**READ/WRITE**
1608[2]	Ground Instantaneous Overcurrent Function	---	---	F37	Disabled
1609[2]	Ground Instantaneous Overcurrent Relays	---	---	F57	None
160A[2]	Ground Instantaneous Overcurrent Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
160B[2]	Ground Instantaneous Overcurrent Delay	0.00 to 600.00	s	F3	0.00 s
160C[6]	Ground Instantaneous Overcurrent Direction	---	---	F84	Disabled
S5	**GROUND DIRECTIONAL**				**READ/WRITE**
160E[6]	Ground Directional Function	---	---	F38	Disabled
160F[6]	Ground Directional Maximum Torque Angle	0 to 359	° Lead	F1	315°
1610[6]	Ground Directional Minimum Polarizing Voltage	0.00 to 1.25	x VT	F3	0.05 x VT
1611[6]	Ground Directional Polarizing	---	---	F50	Voltage
1612[6]	Ground Directional Relays	---	---	F57	None
S5	**NEUTRAL TIME OVERCURRENT 1**				**READ/WRITE**
1630	Neutral Time Overcurrent 1 Function	---	---	F37	Disabled
1631	Neutral Time Overcurrent 1 Relays	---	---	F57	None
1632	Neutral Time Overcurrent 1 Curve	---	---	F36	Ext. Inverse
1633[1]	Neutral Time Overcurrent 1 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1634[1]	Neutral Time Overcurrent 1 Multiplier	0.00 to 100.00	---	F3	1.00
1635[1]	Neutral Time Overcurrent 1 Reset Time	---	---	F68	Instantaneous
1636[1]	Neutral Time Overcurrent 1 Direction	---	---	F84	Disabled
S5	**NEUTRAL INSTANANEOUS OVERCURRENT 1**				**READ/WRITE**
1640[2]	Neutral Instantaneous Overcurrent 1 Function	---	---	F37	Disabled
1641[2]	Neutral Instantaneous Overcurrent 1 Relays	---	---	F57	None
1642[2]	Neutral Instantaneous Overcurrent 1 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1643[2]	Neutral Instantaneous Overcurrent 1 Delay	0.00 to 600.00	s	F3	0.00 s
1644[1]	Neutral Instantaneous Overcurrent 1 Direction	---	---	F84	Disabled
S5	**NEUTRAL INSTANTANEOUS OVERCURRENT 2**				**READ/WRITE**
1650[2]	Neutral Instantaneous Overcurrent 2 Function	---	---	F37	Disabled
1651[2]	Neutral Instantaneous Overcurrent 2 Relays	---	---	F57	None
1652[2]	Neutral Instantaneous Overcurrent 2 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1653[2]	Neutral Instantaneous Overcurrent 2 Delay	0.00 to 600.00	s	F3	0.00 s
1654[1]	Neutral Instantaneous Overcurrent 2 Direction	---	---	F84	Disabled
S5	**NEUTRAL TIME OVERCURRENT 2**				**READ/WRITE**
1660[1]	Neutral Time Overcurrent 2 Function	---	---	F37	Disabled

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 17 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1661[1]	Neutral Time Overcurrent 2 Relays	---	---	F57	None
1662[1]	Neutral Time Overcurrent 2 Curve	---	---	F36	Ext. Inverse
1663[1]	Neutral Time Overcurrent 2 Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1664[1]	Neutral Time Overcurrent 2 Multiplier	0.00 to 100.00	---	F3	1.00
1665[1]	Neutral Time Overcurrent 2 Reset Time	---	---	F68	Instantaneous
1666[1]	Neutral Time Overcurrent 2 Direction	---	---	F84	Disabled
S5	**NEUTRAL DIRECTIONAL**				**READ/WRITE**
1670[1]	Neutral Directional Function	---	---	F38	Disabled
1671[1]	Neutral Directional Maximum Torque Angle	0 to 359	°	F1	315°
1672[1]	Minimum Polarizing Voltage	0.00 to 1.25	x VT	F3	0.05 x VT
1674[1]	Neutral Directional Polarizing	---	---	F50	Voltage
1675[1]	Neutral Directional Relays	---	---	F57	None
S5	**NEGATIVE SEQUENCE TIME OVERCURRENT**				**READ/WRITE**
1700	Negative Sequence Time Overcurrent Function	---	---	F37	Disabled
1701	Negative Sequence Time Overcurrent Relays	---	---	F57	None
1702[1]	Negative Sequence Time Overcurrent Curve	---	---	F36	Ext. Inverse
1703[1]	Negative Sequence Time Overcurrent Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1704[1]	Negative Sequence Time Overcurrent Multiplier	0.00 to 100.00	---	F3	1.00
1705[1]	Negative Sequence Time Overcurrent Reset Time	---	---	F68	Instantaneous
1706[1]	Negative Sequence Time Overcurrent Direction	---	---	F84	Disabled
S5	**NEGATIVE SEQUENCE INST OVERCURRENT**				**READ/WRITE**
1710	Negative Sequence Inst Overcurrent Function	---	---	F37	Disabled
1711	Negative Sequence Instantaneous Overcurrent Relays	---	---	F57	None
1712	Negative Sequence Instantaneous Overcurrent Pickup	0.05 to 20.00	x CT	F3	1.00 x CT
1713	Negative Sequence Instantaneous Overcurrent Delay	0.00 to 600.00	s	F3	0.00 s
1714[1]	Negative Sequence Inst Overcurrent Direction	---	---	F84	Disabled
S5	**NEGATIVE SEQUENCE VOLTAGE**				**READ/WRITE**
1720	Negative Sequence Voltage Function	---	---	F39	Disabled
1721	Negative Sequence Voltage Relays	---	---	F57	None
1722[2]	Negative Sequence Voltage Pickup	0.00 to 1.25	x VT	F3	0.10
1723	Negative Sequence Voltage Delay	0.0 to 6000.0	s	F2	2.0 s
S5	**NEGATIVE SEQUENCE DIRECTIONAL**				**READ/WRITE**
1730[1]	Negative Sequence Directional Function	---	---	F38	Disabled
1731[1]	Neg Seq Directional Maximum Torque Angle (MTA)	0 to 359	°	F1	315°
1732[1]	Minimum Polarizing Voltage	0.00 to 1.25	x VT	F3	0.05 x VT
1733[1]	Negative Sequence Directional Relays	---	---	F57	None
S5	**SENSITIVE GROUND INSTANTANEOUS OC**				**READ/WRITE**
1740[3]	Sensitive Ground Instantaneous Overcurrent Function	---	---	F37	Disabled
1741[3]	Sensitive Ground Instantaneous Overcurrent Relays	---	---	F57	None
1742[3]	Sensitive Ground Instantaneous Overcurrent Pickup	0.005 to 1.000	x CT	F70	0.100 x CT
1743[3]	Sensitive Ground Instantaneous Overcurrent Delay	0.00 to 600.00	s	F3	0.00 s
1744[3]	Sensitive Ground Instantaneous Overcurrent Direction	---	---	F84	Disabled
S5	**SENSITIVE GROUND TIME OC**				**READ/WRITE**
1750[3]	Sensitive Ground Time Overcurrent Function	---	---	F37	Disabled
1751[3]	Sensitive Ground Time Overcurrent Relays	---	---	F57	None
1752[3]	Sensitive Ground Time Overcurrent Curve	---	---	F36	Ext. Inverse
1753[3]	Sensitive Ground Time Overcurrent Pickup	0.005 to 1.000	x CT	F70	0.100 x CT
1754[3]	Sensitive Ground Time Overcurrent Multiplier	0.00 to 100.00	---	F3	1.00
1755[3]	Sensitive Ground Time Overcurrent Reset Time	---	---	F68	Instantaneous
1756[3]	Sensitive Ground Time Overcurrent Direction	---	---	F84	Disabled
S5	**SENSITIVE GROUND DIRECTIONAL**				**READ/WRITE**
1760[3]	Sensitive Ground Directional Function	---	---	F38	Disabled
1761[3]	Sensitive Ground Directional Maximum Torque Angle	0 to 359	°	F1	315°

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 18 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1762[3]	Minimum Polarizing Voltage	0.00 to 1.25	x VT	F3	0.05 x VT
1763[3]	Sensitive Ground Directional Polarizing	---	---	F50	Voltage
1764[3]	Sensitive Ground Directional Relays	---	---	F57	None
S5[7]	**RESERVED FOR MOD 010**				**READ/WRITE**
1767[7]	Reserved for MOD 010				
1768[7]	Reserved for MOD 010				
1769[7]	Reserved for MOD 010				
176A[7]	Reserved for MOD 010				
176B[7]	Reserved for MOD 010				
S5	**RESTRICTED EARTH FAULT (REF)**				**READ/WRITE**
1770[8]	Restricted Earth Fault Function	---	---	F39	Disabled
1771[8]	Restricted Earth Fault Relays	---	---	F57	None
1772[8]	Restricted Earth Fault Pickup	0.005 to 1.000	x CT	F70	0.100 x CT
1773[8]	Restricted Earth Fault Delay	0.00 to 600.00	s	F3	0.00 s
S5	**BUS UNDERVOLTAGE 1**				**READ/WRITE**
1780	Bus Undervoltage 1 Function	---	---	F39	Disabled
1781	Bus Undervoltage 1 Relays	---	---	F57	None
1782[2]	Bus Undervoltage 1 Pickup	0.00 to 1.25	x VT	F3	0.75 x VT
1783	Bus Undervoltage 1 Delay	0.0 to 6000.0	s	F2	2.0 s
1784	Bus Undervoltage 1 Phases Required for Operation	---	---	F41	All Three
1785[2]	Bus Undervoltage 1 Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.30 x V
1786	Bus Undervoltage 1 Curve	---	---	F45	Definite Time
S5	**BUS UNDERVOLTAGE 2**				**READ/WRITE**
1788	Bus Undervoltage 2 Function	---	---	F39	Disabled
1789	Bus Undervoltage 2 Relays	---	---	F57	None
178A[2]	Bus Undervoltage 2 Pickup	0.00 to 1.25	x VT	F3	0.75 x VT
178B	Bus Undervoltage 2 Delay	0.0 to 6000.0	s	F2	2.0 s
178C	Bus Undervoltage 2 Phases Required for Operation	---	---	F41	All Three
178D[2]	Bus Undervoltage 2 Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.30 x V
178E	Bus Undervoltage 2 Curve	---	---	F45	Definite Time
S5	**OVERVOLTAGE 1**				**READ/WRITE**
1790	Overvoltage 1 Function	---	---	F39	Disabled
1791	Overvoltage 1 Relays	---	---	F57	None
1792[2]	Overvoltage 1 Pickup	0.00 to 1.25	x VT	F3	1.25 x VT
1793	Overvoltage 1 Delay	0.0 to 6000.0	s	F2	2.0 s
1794	Overvoltage 1 Phases Required for Operation	---	---	F41	All Three
S5	**OVERVOLTAGE 2**				**READ/WRITE**
1798	Overvoltage 2 Function	---	---	F39	Disabled
1799	Overvoltage 2 Relays	---	---	F57	None
179A[2]	Overvoltage 2 Pickup	0.00 to 1.25	x VT	F3	1.25 x VT
179B	Overvoltage 2 Delay	0.0 to 6000.0	s	F2	2.0 s
179C	Overvoltage 2 Phases Required for Operation	---	---	F41	All Three
S5	**UNDERFREQUENCY 1**				**READ/WRITE**
17A0	Underfrequency 1 Function	---	---	F39	Disabled
17A1	Underfrequency 1 Relays	---	---	F57	None
17A2	Underfrequency 1 Pickup	20.00 to 65.00	Hz	F3	59.00 Hz
17A3	Underfrequency 1 Delay	0.00 to 600.00	s	F3	2.00 s
17A4[2]	Underfrequency 1 Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.70 x VT
17A5[1]	Underfrequency 1 Minimum Operating Current	0.00 to 20.00	x CT	F3	0.20 x CT
S5	**UNDERFREQUENCY 2**				**READ/WRITE**
17A8	Underfrequency 2 Function	---	---	F39	Disabled
17A9	Underfrequency 2 Relays	---	---	F57	None
17AA	Underfrequency 2 Pickup	20.00 to 65.00	Hz	F3	58.00 Hz

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 19 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
17AB	Underfrequency 2 Delay	0.00 to 600.00	s	F3	3.00 s
17AC[2]	Underfrequency 2 Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.70 x VT
17AD[1]	Underfrequency 2 Minimum Operating Current	0.00 to 20.00	x CT	F3	0.20 x CT
S5	**LINE UNDERVOLTAGE 3**				**READ/WRITE**
17B0	Line Undervoltage 3 Function	---	---	F39	Disabled
17B1	Line Undervoltage 3 Relays	---	---	F57	None
17B2[2]	Line Undervoltage 3 Pickup	0.00 to 1.25	x VT	F3	0.75 x VT
17B3	Line Undervoltage 3 Delay	0.0 to 6000.0	s	F2	2.0 s
17B4[2]	Line Undervoltage 3 Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.30 x V
17B5	Line Undervoltage 3 Curve	---	---	F45	Definite Time
S5	**LINE UNDERVOLTAGE 4**				**READ/WRITE**
17B8	Line Undervoltage 4 Function	---	---	F39	Disabled
17B9	Line Undervoltage 4 Relays	---	---	F57	None
17BA[2]	Line Undervoltage 4 Pickup	0.00 to 1.25	x VT	F3	0.75 x VT
17BB	Line Undervoltage 4 Delay	0.0 to 6000.0	s	F2	2.0 s
17BC[2]	Line Undervoltage 4 Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.30 x V
17BD	Line Undervoltage 4 Curve	---	---	F45	Definite Time
S5	**FREQUENCY DECAY**				**READ/WRITE**
17C0[1]	Frequency Decay Function	---	---	F39	Disabled
17C1[1]	Frequency Decay Relays	---	---	F57	None
17C2[1]	Frequency Decay Rate	0.1 to 5.0	Hz/s	F2	1.0 Hz/s
17C3[1]	Frequency Decay Pickup	20.00 to 65.00	Hz	F3	59.50 Hz
17C4[1]	Frequency Decay Delay	0.00 to 600.00	s	F3	2.00 s
17C5[1]	Frequency Decay Minimum Operating Voltage	0.00 to 1.25	x VT	F3	0.70 x VT
17C6[1]	Frequency Decay Minimum Operating Current	0.00 to 20.00	x CT	F3	0.00 x CT
S5[5]	**REVERSE POWER (requires Mod 008)**				**READ/WRITE**
17C8	Reverse Power Function	---	---	F39	Disabled
17C9	Reverse Power Relays	---	---	F57	None
17CA	Reverse Power Pickup	0.015 to 0.600	x RATED	F70	0.050 x RATED
17CB	Reverse Power Delay	0.0 to 6000.0	s	F2	10.0 s
S5[5]	**NEUTRAL DISPLACEMENT**				**READ/WRITE**
17CE	Neutral Displacement Function	---	---	F39	Disabled
17CF	Neutral Displacement Relays	---	---	F57	None
17D0	Neutral Displacement Pickup	0.00 to 1.25	x VT	F3	1.00 x VT
17D1	Neutral Displacement Multiplier	0.00 to 100.00	---	F3	1.00
17D2	Neutral Displacement Curve	---	---	F36	Ext. Inverse
17D3	Neutral Displacement Reset Time	---	---	F68	Instantaneous
S6	**PHASE CURRENT LEVEL**				**READ/WRITE**
1800	Phase Current Level Function	---	---	F38	Disabled
1801	Phase Current Level Relays	---	---	F57	None
1802	Phase Current Level Pickup	0.05 to 20.00	x CT	F3	1.10 x CT
1803	Phase Current Level Delay	0 to 60,000	s	F1	2 s
S6	**NEUTRAL CURRENT LEVEL**				**READ/WRITE**
1808	Neutral Current Level Function	---	---	F38	Disabled
1809	Neutral Current Level Relays	---	---	F57	None
180A	Neutral Current Level Pickup	0.05 to 20.00	x CT	F3	1.10 x CT
180B	Neutral Current Level Delay	0 to 60,000	s	F1	2 s
S6	**POWER FACTOR 1**				**READ/WRITE**
1810	Power Factor 1 Function	---	---	F38	Disabled
1811	Power Factor 1 Relays	---	---	F57	None
1812	Power Factor 1 Pickup (+ Lag, - Lead)	-0.99 to +1.00	---	F6	0.80 Lag
1813	Power Factor 1 Dropout (+ Lag, - Lead)	-0.99 to +1.00	---	F6	1
1814	Power Factor 1 Delay	0 to 60,000	s	F1	50 s

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 20 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
S6	**POWER FACTOR 2**				**READ/WRITE**
1818	Power Factor 2 Function	---	---	F38	Disabled
1819	Power Factor 2 Relays	---	---	F57	None
181A	Power Factor 2 Pickup (+ Lag, - Lead)	-0.99 to +1.00	---	F6	0.80 Lag
181B	Power Factor 2 Dropout (+ Lag, - Lead)	-0.99 to +1.00	---	F6	1
181C	Power Factor 2 Delay	0 to 60,000	s	F1	50 s
S6	**FAULT LOCATOR**				**READ/WRITE**
1830	Length of Feeder	0.1 to 99.9	km, mi	F2	0.1
1831	Units of Length	---	---	F75	km
1832	Zpos (Resistive) of Feeder	0.01 to 99.99	Ω	F3	0.01 Ω
1833	Zpos (Inductive) of Feeder	0.01 to 99.99	Ω	F3	0.01 Ω
1834	Zzero (Resistive) of Feeder	0.01 to 99.99	Ω	F3	0.01 Ω
1835	Zzero (Inductive) of Feeder	0.01 to 99.99	Ω	F3	0.01 Ω
1836[1]	Fault Type Output to Relays 4 to 7	---	---	F30	Disabled
1837[9]	Fault Location After Trip	----	----	F30	Disabled
S6	**CURRENT DEMAND**				**READ/WRITE**
1840	Current Demand Function	---	---	F38	Disabled
1841	Current Demand Measurement Type	---	---	F58	Thermal Exp.
1842	Current Demand Thermal 90% Response	---	---	F16	15 min.
1843	Current Demand Time Interval	---	---	F16	20 min.
1844	Current Demand Relays	---	---	F57	None
1845	Current Demand Pickup	10 to 10000	A	F1	1000 A
S6	**REAL POWER DEMAND**				**READ/WRITE**
1848	Real Power Demand Function	---	---	F38	Disabled
1849	Real Power Demand Measurement Type	---	---	F58	Block Interval
184A	Real Power Demand Thermal 90% Response	---	---	F16	15 min.
184B	Real Power Demand Time Interval	---	---	F16	20 min.
184C	Real Power Demand Relays	---	---	F57	None
184D[2]	Real Power Demand Pickup	1 to 3000.0	MW	F86	100 MW
S6	**REACTIVE POWER DEMAND**				**READ/WRITE**
1850	Reactive Power Demand Function	---	---	F38	Disabled
1851	Reactive Power Demand Measurement Type	---	---	F58	Block Interval
1852	Reactive Power Demand Thermal 90% Response	---	---	F16	15 min.
1853	Reactive Power Demand Time Interval	---	---	F16	20 min.
1854	Reactive Power Demand Relays	---	---	F57	None
1855[2]	Reactive Power Demand Pickup	1 to 3000.0	Mvar	F86	100 Mvar
S6	**APPARENT POWER DEMAND**				**READ/WRITE**
1858	Apparent Power Demand Function	---	---	F38	Disabled
1859	Apparent Power Demand Measurement Type	---	---	F58	Block Interval
185A	App. Power Demand Thermal 90% Response	---	---	F16	15 min.
185B	Apparent Power Demand Time Interval	---	---	F16	20 min.
185C	Apparent Power Demand Relays	---	---	F57	None
185D[2]	Apparent Power Demand Pickup	1 to 3000.0	MVA	F86	100 MVA
S6[5]	**PULSE OUTPUT**				**READ/WRITE**
1860	Pulse Output Function	---	---	F38	Disabled
1861	Positive Watthours Pulse Output Relays	---	---	F57	None
1862	Positive Watthours Pulse Interval	0 to 6553.5	MWh	F86	100 MWh
1863	Negative Watthours Pulse Output Relays	---	---	F57	None
1864	Negative Watthours Pulse Interval	0 to 6553.5	MWh	F86	100 MWh
1865	Positive Varhours Pulse Output Relays	---	---	F57	None
1866	Positive Varhours Pulse Interval	0 to 6553.5	Mvarh	F86	100 Mvarh
1867	Negative Varhours Pulse Output Relays	---	---	F57	None
1868	Negative Varhours Pulse Interval	0 to 6553.5	Mvarh	F86	100 Mvarh

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 21 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
S6	**ANALOG INPUT SETUP**				**READ/WRITE**
1880	Analog Input Name (10 words)	---	---	F33	“ANALOG INPUT”
188A	Analog Input Units (3 words)	---	---	F33	"μA"
188D	Analog Input Range	---	---	F42	0-20 mA
188E	Analog Input Minimum Value	0 to 65535	Units	F1	0
188F	Analog Input Maximum Value	0 to 65535	Units	F1	20000
S6	**ANALOG INPUT THRESHOLD 1**				**READ/WRITE**
18A0[9]	Analog Threshold 1 Function	---	---	F38	Disabled
18A1	Analog Threshold 1 Relays	---	---	F57	None
18A2	Analog Threshold 1 Pickup	0 to 65535	Units	F1	100
18A3	Analog Threshold 1 Delay	0 to 60000	s	F1	100 s
18A4[1]	Analog Threshold 1 Pickup Type	---	---	F85	Over
S6	**ANALOG INPUT THRESHOLD 2**				**READ/WRITE**
18A8	Analog Threshold 2 Function	---	---	F38	Disabled
18A9	Analog Threshold 2 Relays	---	---	F57	None
18AA	Analog Threshold 2 Pickup	0 to 65535	Units	F1	100
18AB	Analog Threshold 2 Delay	0 to 60000	s	F1	100 s
18AC[1]	Analog Threshold 2 Pickup Type	---	---	F85	Over
S6	**ANALOG INPUT RATE 1**				**READ/WRITE**
18B0	Analog In Rate 1 Function	---	---	F38	Disabled
18B1	Analog In Rate 1 Relays	---	---	F57	None
18B2	Analog In Rate 1 Pickup	–1000.0 to 1000.0	Units / hr.	F5	10.0 μA/hr.
18B3	Analog In Rate 1 Delay	0 to 60000	s	F1	0 s
S6	**ANALOG INPUT RATE 2**				**READ/WRITE**
18B8	Analog In Rate 2 Function	---	---	F38	Disabled
18B9	Analog In Rate 2 Relays	---	---	F57	None
18BA	Analog In Rate 2 Pickup	–1000.0 to 1000.0	Units / hr.	F5	10.0 μA/hr.
18BB	Analog In Rate 2 Delay	0 to 60000	s	F1	0 s
S6	**ANALOG OUTPUT 1**				**READ/WRITE**
18C0	Analog Output 1 Parameter	---	---	F77	Disabled
18C1	Analog Output 1 Minimum	---	---	F78	0
18C2	Analog Output 1 Maximum	---	---	F78	0
S6	**ANALOG OUTPUT 2**				**READ/WRITE**
18C4	Analog Output 2 Parameter	---	---	F77	Disabled
18C5	Analog Output 2 Minimum	---	---	F78	0
18C6	Analog Output 2 Maximum	---	---	F78	0
S6	**ANALOG OUTPUT 3**				**READ/WRITE**
18C8	Analog Output 3 Parameter	---	---	F77	Disabled
18C9	Analog Output 3 Minimum	---	---	F78	0
18CA	Analog Output 3 Maximum	---	---	F78	0
S6	**ANALOG OUTPUT 4**				**READ/WRITE**
18CC	Analog Output 4 Parameter	---	---	F77	Disabled
18CD	Analog Output 4 Minimum	---	---	F78	0
18CE	Analog Output 4 Maximum	---	---	F78	0
S6	**ANALOG OUTPUT 5**				**READ/WRITE**
18D0	Analog Output 5 Parameter	---	---	F77	Disabled
18D1	Analog Output 5 Minimum	---	---	F78	0
18D2	Analog Output 5 Maximum	---	---	F78	0
S6	**ANALOG OUTPUT 6**				**READ/WRITE**
18D4	Analog Output 6 Parameter	---	---	F77	Disabled
18D5	Analog Output 6 Minimum	---	---	F78	0
18D6	Analog Output 6 Maximum	---	---	F78	0

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 22 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
S6	**ANALOG OUTPUT 7**				**READ/WRITE**
18D8	Analog Output 7 Parameter	---	---	F77	Disabled
18D9	Analog Output 7 Minimum	---	---	F78	0
18DA	Analog Output 7 Maximum	---	---	F78	0
S6	**ANALOG OUTPUT 8**				**READ/WRITE**
18DC	Analog Output 8 Parameter	---	---	F77	Disabled
18DD	Analog Output 8 Minimum	---	---	F78	0
18DE	Analog Output 8 Maximum	---	---	F78	0
S6	**OVERFREQUENCY**				**READ/WRITE**
18E0	Overfrequency Function	---	---	F38	Disabled
18E1	Overfrequency Relays	---	---	F57	None
18E2	Overfrequency Pickup	20.00 to 65.00	Hz	F3	60.50 Hz
18E3	Overfrequency Delay	0.0 to 6000.0	s	F2	5.0 s
S6	**TRIP COUNTER**				**READ/WRITE**
1900	Trip Counter Function	---	---	F38	Disabled
1901	Trip Counter Relays	---	---	F57	None
1902	Trip Counter Limit	1 to 10000	---	F1	10000 Trips
S6	**TOTAL ARCING CURRENT**				**READ/WRITE**
1908	Total Arcing Current Function	---	---	F38	Disabled
1909	Total Arcing Current Relays	---	---	F57	None
190A	Total Arcing Current Start Delay	0 to 100	ms	F1	32 ms
190B	Total Arcing Current Limit	1 to 50000	kA^2-cyc	F1	1000 kA^2cyc
S6	**VT FAILURE**				**READ/WRITE**
1918	VT Failure Function	---	---	F38	Disabled
1919	VT Failure Relays	---	---	F57	None
191A	VT Failure Delay	0 to 60,000	s	F1	10 s
S8	**SIMULATION SETUP**				**READ/WRITE**
1920	Simulation Status	---	---	F48	Disabled
1921	Circuit Breaker Simulation	---	---	F30	Enabled
1922	Allow Operation of Relays	---	---	F57	None
S8	**SIMULATION PRE-FAULT VALUES**				**READ/WRITE**
1930	Prefault Phase A/B/C Current Level	0.00 to 20.00	x CT	F3	0.50 x CT
1931	Prefault Power Factor Angle	0 to 359	° Lag	F1	0° Lag
S8	**SIMULATION FAULT VALUES**				**READ/WRITE**
1940	Fault Phase A-N Voltage Level	0.00 to 2.00	x VT	F3	1.00 x VT
1941	Fault Phase A-N Voltage Position	0 to 359	° Lag	F1	0° Lag
1942	Fault Phase B-N Voltage Level	0.00 to 2.00	x T	F3	1.00 x VT
1943	Fault Phase B-N Voltage Position	0 to 359	° Lag	F1	120° Lag
1944	Fault Phase C-N Voltage Level	0.00 to 2.00	x T	F3	1.00 x VT
1945	Fault Phase C-N Voltage Position	0 to 359	° Lag	F1	240° Lag
1946	Fault Phase A Current Level	0.00 to 20.00	x CT	F3	1.00 x CT
1947	Fault Phase A Current Position	0 to 359	° Lag	F1	60° Lag
1948	Fault Phase B Current Level	0.00 to 20.00	x CT	F3	1.00 x CT
1949	Fault Phase B Current Position	0 to 359	° Lag	F1	180° Lag
194A	Fault Phase C Current Level	0.00 to 20.00	x CT	F3	1.00 x CT
194B	Fault Phase C Current Position	0 to 359	° Lag	F1	300° Lag
194C	Fault System Frequency	20.00 to 65.00	Hz	F3	60.00 Hz
194D	Fault Analog Input Current	0.00 to 20.00	mA	F3	0.00 mA
194E[3]	Reserved for Fault Polarizing Current Level	0.00 to 20.00	x CT	F70	1.00 x CT
194F[3]	Reserved for Fault Polarizing Current Position	0 to 359	° Lag	F1	0°
1950	Fault Ground Current Level	0.00 to 20.00	x CT	F3	0.00 x CT
1951	Fault Ground Current Position	0 to 359	° Lag	F1	0°
1952[3]	Fault Sensitive Ground Current Level	0.005 to 1.000	x CT	F70	0.100 x CT

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 23 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1953[3]	Fault Sensitive Ground Current Position	0 to 359	° Lag	F1	0°
S8	**SIMULATION POST-FAULT VALUES**				**READ/WRITE**
1960	Postfault Bus Voltage Level	0.00 to 2.00	x VT	F3	1.00 x VT
1961	Postfault Bus Voltage Frequency	20.00 to 65.00	Hz	F3	60.00 Hz
1962	Postfault Synchronous Voltage Level	0.00 to 2.00	x VT	F3	1.00 x VT
1963	Postfault Synchronous Voltage Position	0 to 359	° Lag	F1	0°
1964	Postfault Synchronous Voltage Frequency	20.00 to 65.00	Hz	F3	60.00 Hz
S5	**BREAKER FAILURE**				**READ/WRITE**
1980	Breaker Failure Function	---	---	F38	Disabled
1981	Breaker Failure Relays	---	---	F57	None
1982	Breaker Failure Delay 1	0.03 to 1.00	s	F3	0.10 s
1983	Breaker Failure Current	0.05 to 20.00	x CT	F3	1.00 x CT
1984	Breaker Failure Delay 2	0.00 to 1.00	s	F3	0.00 s
S6	**BREAKER OPERATION**				**READ/WRITE**
1988	Breaker Operation Function	---	---	F38	Disabled
1989	Breaker Operation Relays	---	---	F57	None
198A	Breaker Operation Delay	0.03 to 1.00	s	F3	0.10 s
S6	**COIL MONITOR 1**				**READ/WRITE**
1990	Coil Monitor 1 Function	---	---	F38	Disabled
1991	Coil Monitor 1 Relays	---	---	F57	None
1992	Breaker State Bypass	---	---	F30	Disabled
1993[8]	Coil Monitor 1 Delay	5 to 100	s	F1	5 s
1994[8]	Coil Monitor 1 Type	---	---	F90	Trip
S6	**COIL MONITOR 2**				**READ/WRITE**
1998	Coil Monitor 2 Function	---	---	F38	Disabled
1999	Coil Monitor 2 Relays	---	---	F57	None
199A	Breaker State Bypass	---	---	F30	Disabled
199B[8]	Coil Monitor 2 Delay	5 to 100	s	F1	5 s
199C[8]	Coil Monitor 2 Type	---	---	F90	Close
S6[8]	**COIL MONITOR NAMES**				**READ/WRITE**
19A0[8]	Coil Monitor 1 Name (9 registers)	---	---	F33	Trip Coil Monitor
19A9[8]	Coil Monitor 2 Name (9 registers)	---	---	F33	Close Coil Monitor
S6[8]	**ANALOG INPUT THRESHOLD NAMES**				**READ/WRITE**
19B2[8]	Analog Input Threshold 1 Name (9 registers)	---	---	F33	Analog Threshld 1
19BB[8]	Analog Input Threshold 2 Name (9 registers)	---	---	F33	Analog Threshld 2
S8	**FORCE OUTPUT RELAYS**				**READ/WRITE**
1A00	Force Output Relays Function	---	---	F30	Disabled
1A01	Force 1 TRIP Relay	---	---	F34	De-energized
1A02	Force 2 CLOSE Relay	---	---	F34	De-energized
1A03	Force 3 ALARM Relay	---	---	F34	De-energized
1A04	Force 4 AUXILIARY Relay	---	---	F34	De-energized
1A05	Force 5 AUXILIARY Relay	---	---	F34	De-energized
1A06	Force 6 AUXILIARY Relay	---	---	F34	De-energized
1A07	Force 7 AUXILIARY Relay	---	---	F34	De-energized
1A08	Force 8 SELF-TEST WARNING Relay	---	---	F34	De-energized
1A09	Force Solid State Output	---	---	F34	De-energized
S8	**FORCE ANALOG OUTPUTS**				**READ/WRITE**
1A10	Force Analog Outputs Function	---	---	F30	Disabled
1A11	Force Analog Output 1	0 to 100	%	F1	0%
1A12	Force Analog Output 2	0 to 100	%	F1	0%
1A13	Force Analog Output 3	0 to 100	%	F1	0%
1A14	Force Analog Output 4	0 to 100	%	F1	0%
1A15	Force Analog Output 5	0 to 100	%	F1	0%

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

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Table 7–6: MODBUS MEMORY MAP (SHEET 24 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1A16	Force Analog Output 6	0 to 100	%	F1	0%
1A17	Force Analog Output 7	0 to 100	%	F1	0%
1A18	Force Analog Output 8	0 to 100	%	F1	0%
S8	**PICKUP TEST**				**READ/WRITE**
1A20	Pickup Test Function	---	---	F30	Disabled
1A21	Pickup Test Relays	---	---	F57	None
S7	**SETPOINT GROUP**				**READ/WRITE**
1B00	Active Setpoint Group	---	---	F79	Group 1
1B01	Edit Setpoint Group	---	---	F80	Active Group
1B02	Breaker Open Inhibit	---	---	F30	Disabled
1B03	Overcurrent Pickup Inhibit	---	---	F30	Disabled
1B04	Overvoltage Pickup Inhibit	---	---	F30	Disabled
1B05	Undervoltage Pickup Inhibit	---	---	F30	Disabled
1B06	Underfrequency Pickup Inhibit	---	---	F30	Disabled
S7	**SYNCHROCHECK**				**READ/WRITE**
1B10	Synchrocheck Function	---	---	F38	Disabled
1B11	Dead Source Permissive	---	---	F20	OFF
1B12[2]	Dead Bus Maximum Voltage	0.00 to 1.25	x VT	F3	0.20 x VT
1B13[2]	Dead Line Maximum Voltage	0.00 to 1.25	x VT	F3	0.20 x VT
1B14[2]	Live Bus Minimum Voltage	0.00 to 1.25	x VT	F3	0.80 x VT
1B15[2]	Live Line Minimum Voltage	0.00 to 1.25	x VT	F3	0.80 x VT
1B16[2]	Maximum Voltage Difference	0.01 to 100.00	kV	F3	2.00 kV
1B17	Maximum Angle Difference	0 to 100	°	F1	24°
1B18	Maximum Frequency Difference	0 to 5.00	Hz	F3	2.00 Hz
1B19	Synchrocheck Relays	---	---	F57	None
S7	**MANUAL CLOSE FEATURE BLOCKING**				**READ/WRITE**
1B20	Manual Close Feature Blocking Function	---	---	F38	Disabled
1B21	Manual Close Relays	---	---	F57	None
1B22[2]	Manual Close Block Time	1 to 1000	s	F1	5 s
1B23[1]	Select Setpoint Group	---	---	F80	Active Group
1B24[2]	Overcurrent Blocking Flags	---	---	F59	None blocked
1B25[2]	Phase Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1B26[2]	Neutral Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1B27[2]	Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1B28[2]	Negative Sequence Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1B29[3]	Sensitive Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
S7	**COLD LOAD FEATURE BLOCKING**				**READ/WRITE**
1B40	Cold Load Pickup Feature Blocking Function	---	---	F38	Disabled
1B41	Cold Load Pickup Relays	---	---	F57	None
1B42	Outage Time Before Cold Load	1 to 1000	min.	F1	100 min.
1B43[2]	Cold Load Pickup Block Time	1 to 1000	s	F1	5 s
1B44[1]	Select Setpoint Group	---	---	F80	Active Group
1B45[2]	Overcurrent Blocking Flags	---	---	F59	None blocked
1B46[2]	Phase Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1B47[2]	Neutral Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1B48[2]	Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1B49[2]	Negative Sequence Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1B4A[3]	Sensitive Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
S7	**UNDERVOLTAGE RESTORATION**				**READ/WRITE**
1B60	Undervoltage Restoration Function	---	---	F38	Disabled
1B61	Undervoltage Restoration Relays	---	---	F57	None
1B62	Undervoltage Restoration Phases Required for Operation	---	---	F41	All Three
1B63[2]	Undervoltage Restoration Minimum Voltage	0.00 to 1.25	x VT	F3	0.90 x V

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 25 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1B64	Undervoltage Restoration Delay	0 to 10000	s	F1	10 s
1B65	Undervoltage Restoration Incomplete Sequence Time	1 to 10,000	min.	F1	100 min.
1B66[3]	Undervoltage Restoration Source	---	---	F87	Bus
S7	**UNDERFREQUENCY RESTORATION**				**READ/WRITE**
1B70	Underfrequency Restoration Function	---	---	F38	Disabled
1B71	Underfrequency Restoration Relays	---	---	F57	None
1B72[2]	Underfrequency Restoration Minimum Voltage	0.00 to 1.25	x VT	F3	0.90 x V
1B73[8]	Underfrequency Restoration Minimum Frequency	20.00 to 65.00	Hz	F3	59.90 Hz
1B74	Underfrequency Restoration Delay	0 to 10000	s	F1	10 s
1B75	Underfrequency Restoration Incomplete Sequence Time	1 to 10,000	min.	F1	100 min.
S7	**TRANSFER**				**READ/WRITE**
1B80	Transfer Function	---	---	F56	Disabled
1B81	Transfer Delay This Source	0.0 to 10.0	s	F2	1.0 s
1B82	Transfer Delay Other Source	0.0 to 10.0	s	F2	3.0 s
1B83	Block Trip On Double Loss	---	---	F30	Disabled
S7	**AUTORECLOSE SETUP - 760 ONLY**				**READ/WRITE**
1BA0	Autoreclose Function	---	---	F30	Disabled
1BA1	Number of Reclosure Shots	1 to 4	1	F1	1
1BA2	Autoreclose Reset Time	1 to 1000	s	F1	60 s
1BA3	Autoreclose Block Time Upon Manual Close	0 to 200	s	F1	10 s
1BA4	Incomplete Sequence Time	1 to 1000	s	F1	30 s
1BA5	Reclosure Enabled Relays	---	---	F57	None
1BA6	Reclose In Progress Relays	---	---	F57	None
1BA7	Reclosure Lockout Relays	---	---	F57	None
1BA8[8]	Autoreclose External Close Logic	---	---	F30	Disabled
S7	**AUTORECLOSE RATE SUPERVISION - 760 ONLY**				**READ/WRITE**
1BAA[8]	Rate Supervision Function	---	---	F38	Disabled
1BAB[8]	Max Autoreclose Rate	1 to 50	/hr.	F1	25
1BAC[8]	Rate Supervision Relays	---	---	F57	None
S7	**CURRENT SUPERVISION - 760 ONLY**				**READ/WRITE**
1BB0	Current Supervision Function	---	---	F30	Disabled
1BB1[2]	3 Shots For Current Above	0.00 to 20.00	x CT	F3	17.00 x CT
1BB2[2]	2 Shots For Current Above	0.00 to 20.00	x CT	F3	18.00 x CT
1BB3[2]	1 Shot For Current Above	0.00 to 20.00	x CT	F3	19.00 x CT
1BB4	Current Supervision To Lockout	---	---	F30	Disabled
1BB5[2]	Lockout For Current Above	0.00 to 20.00	x CT	F3	20.00 x CT
S7	**ZONE COORDINATION - 760 ONLY**				**READ/WRITE**
1BB8[1]	Zone Coordination Function	---	---	F30	Disabled
1BB9[1]	Phase Current Increase	0.05 to 20.00	x CT	F3	1.00 x CT
1BBA[1]	Neutral Current Increase	0.05 to 20.00	x CT	F3	1.00 x CT
1BBB[1]	Maximum fault Clearing Time	1 to 1000	s	F1	10 s
S7	**RECLOSURE SHOT 1 - 760 ONLY**				**READ/WRITE**
1BC0[2]	Deadtime Before Reclosure 1	0.00 to 300.00	s	F3	0.50 s
1BC1[1]	Select Setpoint Group	---	---	F80	Active Group
1BC2[2]	Overcurrent Blocking Flags	---	---	F59	None blocked
1BC3[1]	Phase Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BC4[1]	Neutral Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BC5[1]	Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BC6[1]	Negative Sequence Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BC7[3]	Sensitive Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
S7	**RECLOSURE SHOT 2 - 760 ONLY**				**READ/WRITE**
1BD0[2]	Deadtime Before Reclosure 2	0.00 to 300.00	s	F3	3.00 s
1BD1[1]	Select Setpoint Group	---	---	F80	Active Group

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 26 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
1BD2[2]	Overcurrent Blocking Flags	---	---	F59	None blocked
1BD3[1]	Phase Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BD4[1]	Neutral Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BD5[1]	Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BD6[1]	Negative Sequence Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BD7[3]	Sensitive Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
S7	**RECLOSURE SHOT 3 - 760 ONLY**				**READ/WRITE**
1BE0[2]	Deadtime Before Reclosure 3	0.00 to 300.00	s	F3	4.00 s
1BE1[1]	Select Setpoint Group	---	---	F80	Active Group
1BE2[2]	Overcurrent Blocking Flags	---	---	F59	None blocked
1BE3[1]	Phase Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BE4[1]	Neutral Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BE5[1]	Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BE6[1]	Negative Sequence Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BE7[3]	Sensitive Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
S7	**RECLOSURE SHOT 4 - 760 ONLY**				**READ/WRITE**
1BF0[2]	Deadtime Before Reclosure 4	0.00 to 300.00	s	F3	5.00 s
1BF1[1]	Select Setpoint Group	---	---	F80	Active Group
1BF2[2]	Overcurrent Blocking Flags	---	---	F59	None blocked
1BF3[1]	Phase Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BF4[1]	Neutral Time Overcurrent 1 Raised Pickup	0 to 100	%	F1	0%
1BF5[1]	Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BF6[1]	Negative Sequence Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
1BF7[3]	Sensitive Ground Time Overcurrent Raised Pickup	0 to 100	%	F1	0%
S3	**LOGIC INPUTS NAMES**				**READ/WRITE**
1C00[1]	Logic Input 1 Name (9 words = 18 characters)	---	---	F33	Logic Input 1
1C09[1]	Logic Input 2 Name (9 words = 18 characters)	---	---	F33	Logic Input 2
↓	↓	↓	↓	↓	↓
1CAB[1]	Logic Input 20 Name (9 words = 18 characters)	---	---	F33	Logic Input 20
A4	**EVENT RECORD SELECTOR**				**READ/WRITE**
2000	Event Number Selector	0 to 65535	---	F1	0
A4	**EVENT RECORDOR INFORMATION**				**READ ONLY**
2001	Number of Events Since Clear	0 to 65535	---	F1	0
2002	Event Recorder Last Cleared (2 words)	---	---	F23	---
A4	**EVENT RECORD DATA**				**READ ONLY**
2010	Record #N Date of Event (2 words)	---	---	F23	---
2012	Record #N Time of Event (2 words)	---	---	F22	---
2014	Record #N Cause of Event	---	---	F24	---
2015	Record #N Phase A Current Magnitude	0 to 65535	A	F1	---
2016	Record #N Phase B Current Magnitude	0 to 65535	A	F1	---
2017	Record #N Phase C Current Magnitude	0 to 65535	A	F1	---
2018	Record #N Ground Current Magnitude	0 to 65535	A	F1	---
2019	Record #N A-N (A-B) Voltage Magnitude	0.00 to 600.00	kV	F3	---
201A	Record #N B-N (B-C) Voltage Magnitude	0.00 to 600.00	kV	F3	---
201B	Record #N C-N (C-A) Voltage Magnitude	0.00 to 600.00	kV	F3	---
201C	Record #N System Frequency	0.00 to 90.00	Hz	F3	---
201D	Record #N Analog Input	0 to 65535	Units	F1	---
201E[1]	Record #N Phase A Current Angle	0 to 359	° Lag	F1	---
201F[1]	Record #N Phase B Current Angle	0 to 359	° Lag	F1	---
2020[1]	Record #N Phase C Current Angle	0 to 359	° Lag	F1	---
2021[1]	Record #N Ground Current Angle	0 to 359	° Lag	F1	---
2022[1]	Record #N A-N (A-B) Voltage Angle	0 to 359	° Lag	F1	---
2023[1]	Record #N B-N (C-B) Voltage Angle	0 to 359	° Lag	F1	---

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

Table 7–6: MODBUS MEMORY MAP (SHEET 27 OF 27)

ADDR	DESCRIPTION	RANGE	UNITS	TYPE	DEFAULT
2024[1]	Record #N C-N Voltage Angle	0 to 359	° Lag	F1	---
2025[1]	Record #N Synchronizing RMS Voltage Magnitude	0.00 to 600.00	kV	F3	---
2026[1]	Record #N Synchronizing Voltage Angle	0 to 359	° Lag	F1	---
2027[1]	Record #N Synchronizing RMS Voltage Frequency	0.00 to 90.00	Hz	F3	---
2028[3]	Record #N Sensitive Ground Current Magnitude	0.00 to 655.35	A	F3	---
2029[3]	Record #N Sensitive Ground Current Angle	0 to 359	° Lag	F1	---
	TRACE MEMORY SELECTORS				**READ/WRITE**
2100	Trace Memory Number Selector	0 to 65535	---	F1	0
2101	Trace Memory Channel Selector	---	---	F26	I_a
2102	Trace Memory Sample Selector (TMSS)	0 to 4095	---	F1	0
	TRACE MEMORY INFORMATION				**READ ONLY**
2110	Number of Trace Memory Triggers Since Clear	0 to 65535	---	F1	---
2111	Number of Trace Memory Samples Stored	0 to 4096	---	F1	---
2112	Trace Memory Start Index	0 to 4095	---	F1	---
2113	Trace Memory Trigger Index	0 to 4095	---	F1	---
2114	Trace Memory Trigger Cause	---	---	F24	---
2115	Trace Memory Trigger Date	---	---	F23	---
2117	Trace Memory Trigger Time	---	---	F22	---
2119	Trace Memory Sampling Frequency	16.00 to 65.00	Hz	F3	---
	TRACE MEMORY SAMPLES				**READ ONLY**
2120	Trace Memory Sample TMSS+0	---	---	F25	---
2121	Trace Memory Sample TMSS+1	---	---	F25	---
↓	↓	↓	↓	↓	↓
215F	Trace Memory Sample TMSS+63	---	---	F25	---
	DATA LOG SELECTORS				**READ/WRITE**
2200	Data Log Number Selector	0 to 65535	---	F1	0
2201	Data Log Channel Selector	0 to 7	---	F1	0
2202	Data Log Sample Selector (DLSS)	0 to 4095	---	F1	0
	DATA LOG INFORMATION				**READ ONLY**
2210	Number of Data Log Triggers Since Clear	0 to 65535	---	F1	---
2211	Number of Data Log Samples Stored	0 to 4096	---	F1	---
2212	Data Log Start Index	0 to 4095	---	F1	---
2213	Data Log Trigger Index	0 to 4095	---	F1	---
2214	Data Log Trigger Cause	---	---	F24	---
2215	Data Log Trigger Date	---	---	F23	---
2217	Data Log Trigger Time	---	---	F22	---
	DATA LOG SAMPLES				**READ ONLY**
2220	Data Log Sample DLSS+0	---	---	F78	---
2221	Data Log Sample DLSS+1	---	---	F78	---
↓	↓	↓	↓	↓	↓
225F	Data Log Sample DLSS+63	---	---	F78	---

[1 2 3 4 5 6 7 8 9] For explanation of Table footnotes, see the Memory Map Notes at the end of this table.

MEMORY MAP NOTES:

1 These registers are new for version 2.10
2 These registers have been changed from version 2.00 to 2.10
3 These registers are new or have changed for version 3.00
4 These registers are new or have changed for version 3.10
5 These registers are new or have changed for version 3.20
6 These registers are new for version 3.30
7 These registers are new or have changed for version 3.40 MOD 010
8 These registers are new or have changed for version 3.60
9 These registers are new or have changed for version 3.70

7.4.2 DATA FORMATS

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 1 OF 17)

TYPE	VALUE	DESCRIPTION
F1	**UNSIGNED VALUE (16 bits)**	
	Example: 1234 stored as 1234	
F2	**UNSIGNED VALUE, 1 DECIMAL PLACE (16 bits)**	
	Example: 123.4 stored as 1234	
F3	**UNSIGNED VALUE, 2 DECIMAL PLACES (16 bits)**	
	Example: 12.34 stored as 1234	
F4	**2's COMPLEMENT SIGNED VALUE (16 bits)**	
	Example: -1234 stored as -1234	
F5	**2's COMPLEMENT SIGNED, 1 DECIMAL PLACE (16 bits)**	
	Example: -123.4 stored as -1234	
F6	**2's COMPLEMENT SIGNED, 2 DECIMAL PLACES (16 bits)**	
	Example: -12.34 stored as -1234	
F7	**UNSIGNED LONG VALUE (32 bits)**	
	High order word of long value stored in 1st 16 bits Low order word of long value stored in 2nd 16 bits Example: 123456 stored as 123456	
F8	**UNSIGNED LONG VALUE, 1 DECIMAL PLACE (32 bits)**	
	High order word of long value stored in 1st 16 bits Low order word of long value stored in 2nd 16 bits Example: 12345.6 stored as 123456	
F9	**UNSIGNED LONG VALUE, 2 DECIMAL PLACES (32 bits)**	
	High order word of long value stored in 1st 16 bits Low order word of long value stored in 2nd 16 bits Example: 1234.56 stored as 123456	
F10	**2's COMPLEMENT SIGNED LONG VALUE (32 bits)**	
	High order word of long value stored in 1st 16 bits Low order word of long value stored in 2nd 16 bits Example: -123456 stored as -123456	
F11	**2's COMP SIGNED LONG VALUE, 1 DEC PLACE (32 bits)**	
	High order word of long value stored in 1st 16 bits Low order word of long value stored in 2nd 16 bits Example: -12345.6 stored as -123456	
F12	**2's COMP SIGNED LONG VALUE, 2 DEC PLACES (32 bits)**	
	High order word of long value stored in 1st 16 bits Low order word of long value stored in 2nd 16 bits Example: -1234.56 stored as -123456	
F13	**HARDWARE REVISION**	
	1	A
	2	B
	↓	↓
	26	Z
F14	**SOFTWARE REVISION**	
	0F00h	Major Revision Number (0 to 9 in steps of 1)
	00F0h	Minor Revision Number (0 to 9 in steps of 1)
	000Fh	Ultra Minor Revision No. (0 to 9 in steps of 1)
	Example: Revision 2.83 stored as 0283 hex	
F15	**INSTALLED OPTIONS**	
	0001h	Phase Current Inputs (0 = 1 A, 1 = 5 A)
	0002h	Ground Current Input (0 = 1 A, 1 = 5 A)
	0004h[3]	Sens Ground Current Input (0 = 1 A, 1 = 5 A)
	0030h	Power Supply (0 = LO, 1 = MID, 2 = HI)
	0080h	Breaker Closed LED (0 = Red, 1 = Green)
	0F00h	Analog Outputs (0 = A1, 1 = A5, 2 = A20, 3 = A10)
	8000h	750/760 Product Selector (0=750, 1=760)

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 2 OF 17)

TYPE	VALUE	DESCRIPTION
F16	**DEMAND INTERVAL/RESPONSE**	
	0	5 min.
	1	10 min.
	2	15 min.
	3	20 min.
	4	30 min.
	5	60 min.
F17	**COMMUNICATION HARDWARE**	
	0	RS485
	1	RS422
F18	**LINE VT CONNECTION**	
	0	V_{an}
	1	V_{bn}
	2	V_{cn}
	3	V_{ab}
	4	V_{cb}
F19	**COMMAND OPERATION CODE**	
	0	NO OPERATION
	1	RESET
	2	OPEN BREAKER
	3	CLOSE BREAKER
	4	SET TIME
	5	SET DATE
	6	TRIGGER TRACE MEMORY
	7	CLEAR ENERGY USE DATA
	8	CLEAR MAX DEMAND DATA
	9	CLEAR EVENT RECORDER DATA
	10	RESET TRIP COUNTER DATA
	11	RESET ARCING CURRENT DATA
	12	DISPLAY OVERRIDE MESSAGE
	13	TRIGGER DATA LOGGER
	14	RESET TRACE MEMORY
	15	RESET DATA LOGGER
	16 [7]	RESET AR SHOT COUNT DATA (760 only!)
	17 [7]	RESET AR SHOT RATE DATA (760 only!)
F20	**DEAD SOURCE PERMISSIVE**	
	0	Off
	1	DB **&** DL
	2	LL **&** DB
	3	DL **&** LB
	4	DB **|** DL
	5	DB **X** DB
F21	**GENERAL STATUS**	
	0001h	Relay In Service (0 = Not In Svc, 1 = In Svc)
	0002h	Trip (0 = No Active Trips, 1 = Active Trip)
	0004h	Alarm (0 = No Active Alarms, 1 = Active Alrm)
	0008h	Pickup (0 = No Protection, 1 = Protection)
	0010h	Setpoint Group 1 (0 = Disabled, 1 = Enabled)
	0020h	Setpoint Group 2 (0 = Disabled, 1 = Enabled)
	0040h	Setpoint Group 3 (0 = Disabled, 1 = Enabled)

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

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Table 7–7: MEMORY MAP DATA FORMATS (SHEET 3 OF 17)

TYPE	VALUE	DESCRIPTION
F21 ctd.	0080h	Setpoint Group 4 (0 = Disabled, 1 = Enabled)
	0100h	Breaker Open (0 = Closed, 1 = Open)
	0200h	Breaker Closed (0 = Open, 1 = Closed)
	0400h	Reclosure (0=Disabled, 1=Enabled), **760 only**
	0800h	Reclosure (0=Enabled, 1=Disabled), **760 only**
	1000h	Reclosure In Progress (0 = Not In Progress, 1 = In Progress) – **760 only!**
	2000h	Reclosure Lockout (0 = Not In Lockout, 1 = In Lockout) **– 760 only!**
	4000h	Local Mode (0 = Enabled, 1 = Disabled)
	8000h	Message (0 = No Diagnostic Message, 1 = Diagnostic Messages)
F22	**TIME (32 bits)**	
	Hours / Minutes (HH:MM:xx.xxx) 1st 16 bits	
	FF00h	Hours (0= 12am, 1=1am,..., 23=11pm)
	00FFh	Minutes (0 to 59 in steps of 1)
	Seconds (xx:xx:SS.SSS) (2nd 16 bits)	
	FFFFh	(0 = 00.000 s, 1=00.001 s, 59999=59.999 s)
	NOTE: If the time has never been set then all 32 bits will be 1.	
F23	**DATE (32 bits)**	
	Month / Day (MM/DD/xxxx) (2nd 16 bits)	
	FF00h	Month (1 = January,..., 12 = December)
	00FFh	Day (1 to 31 in steps of 1)
	Year (xx/xx/YYYY) (2nd 16 bits)	
	FFFFh	1990 to 2089 in steps of 1
	NOTE: If the date has never been set then all 32 bits will be 1.	
F24	**EVENT TYPE**	
	F000h	**EVENT TYPE (first 4 bits)**
	1	General
	2	Pickup
	3	Trip
	4 [8]	Alarm
	5	Control
	6	Logic Input
	7	Self-Test Warning
	8	Dropout
	The format for the rest of the register depends on Event Type	
	GENERAL EVENT TYPE	
	00FFh	**EVENT CAUSE (last 8 bits)**
	1	Control Power Off
	2	Control Power On
	3	Breaker Opened
	4	Breaker Closed
	5	Breaker Not Connected
	6	Reset
	7	Open Breaker
	8	Close Breaker
	9	Set Time
	10	Set Date
	11	Trigger Trace Memory
	12	Clear Energy Use
	13	Clear Max Demand
	14	Clear Event Recorder
	15	Reset Trip Counter

[1] [2] [3] [4] [5] [6] [7] [8] [9] For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 4 OF 17)

TYPE	VALUE	DESCRIPTION
F24 ctd.	16	Reset Arcing Current
	17	Display Override Message
	18	Trigger Data Logger
	20	Transfer Initiated
	21	Transfer Not Ready
	22	Close From Transfer
	23	Trip From Transfer
	30	Reclosure 1 **760 only!**
	31	Reclosure 2 **760 only!**
	32	Reclosure 3 **760 only!**
	33	Reclosure 4 **760 only!**
	34	Reclosure Lockout **760 only!**
	35	Shots Reduced to 3 **760 only!**
	36	Shots Reduced to 2 **760 only!**
	37	Shots Reduced to 1 **760 only!**
	38	Shots Reduced to L/O **760 only!**
	39	Autoreclose Reset **760 only!**
	40	Setpoint Group 1 Active
	41	Setpoint Group 2 Active
	42	Setpoint Group 3 Active
	43	Setpoint Group 4 Active
	44 [7]	Reset AR Count **760 only!**
	45 [7]	Reset AR Shot Rate **760 only!**
	PICKUP / TRIP / ALARM LATCHED ALARM / CONTROL / DROPOUT EVENT TYPES	
	FF00h	**PHASES (first 8 bits)**
	0100h	Phase A (0 = No Fault, 1 = Fault)
	0200h	Phase B (0 = No Fault, 1 = Fault)
	0400h	Phase C (0 = No Fault, 1 = Fault)
	00FFh	**CAUSE OF EVENT (last 8 bits)**
	1 [2]	Phase Time Overcurrent 1
	2 [2]	Phase Instantaneous Overcurrent 1
	3 [2]	Phase Instantaneous Overcurrent 2
	4 [2]	Ground Time Overcurrent
	5 [2]	Ground Instantaneous Overcurrent
	6 [2]	Neutral Time Overcurrent 1
	7 [2]	Neutral Time Overcurrent 2
	8 [2]	Neutral Instantaneous Overcurrent 1
	9 [2]	Neutral Instantaneous Overcurrent 2
	10 [2]	Phase Directional is Reverse
	11 [2]	Neutral Directional is Reverse
	12 [2]	Manual Close Feature Blocking
	13	Cold Load Pickup Feature Blocking
	14	Bus Undervoltage 1
	15	Bus Undervoltage 2
	16	Line Undervoltage 3
	17	Line Undervoltage 4
	18	Overvoltage 1
	19	Overvoltage 2
	20	Underfrequency 1
	21	Underfrequency 2
	22	Phase Current Level
	23 [1]	Neutral Current Level

[1] [2] [3] [4] [5] [6] [7] [8] [9] For explanation of footnotes, see notes of end of Table.

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Table 7–7: MEMORY MAP DATA FORMATS (SHEET 5 OF 17)

TYPE	VALUE	DESCRIPTION
F24 ctd.	24	Power Factor 1
	25	Power Factor 2
	26	Out Of Synchronization
	27	Current Demand
	28	Real Power Demand
	29	Reactive Power Demand
	30	Apparent Power Demand
	31	Analog Input Threshold 1
	32	Analog Input Threshold 2
	33	Analog Input Rate of Change 1
	34	Analog Input Rate of Change 2
	35	Overfrequency
	36	Trip Counter
	37	Arcing Current
	38	VT Failure
	39	Breaker Failure
	40	Breaker Operation
	41	Trip Coil Monitor
	42	Close Coil Monitor
	43	User Input A
	44	User Input B
	45	User Input C
	46	User Input D
	47	User Input E
	48	User Input F
	49	User Input G
	50	User Input H
	51	Negative Sequence Instantaneous OC
	52	Negative Sequence Time Overcurrent
	53	Negative Sequence Overvoltage
	54	Undervoltage Restoration
	55	Underfrequency Restoration
	56	Phase Time Overcurrent 2
	57 [1]	Frequency Decay
	58 [1]	Negative Sequence is Reverse
	59 [3]	Sensitive Ground Instantaneous Overcurrent
	60 [3]	Sensitive Ground Time Overcurrent
	61 [3]	Sensitive Ground Direction is Reverse
	62 [4]	Reverse Power (requires Mod 008)
	63 [4]	Neutral Displacement
	64 [4]	Positive Watthours Pulse Output
	65 [4]	Negative Watthours Pulse Output
	66 [4]	Positive Varhours Pulse Output
	67 [4]	Negative Varhours Pulse Output
	68 [5]	Ground Directional is Reverse
	69 [6]	Reserved for MOD 010
	70 [7]	User Input I
	71 [7]	User Input J
	72 [7]	User Input K
	73 [7]	User Input L
	74 [7]	User Input M
	75 [7]	User Input N
	76 [7]	User Input O

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 6 OF 17)

TYPE	VALUE	DESCRIPTION
F24 ctd.	77 [7]	User Input P
	78 [7]	User Input Q
	79 [7]	User Input R
	80 [7]	User Input S
	81 [7]	User Input T
	82 [7]	Autoreclose Rate **760 ONLY!**
	83 [7]	Restricted Earth Fault
	LOGIC INPUT EVENT TYPE	
	FF00h	**STATES (first 8 bits)**
	0100h	Contact State (0 = Open, 1 = Closed)
	0200h	Virtual State (0 = Off, 1 = On)
	0400h	Logic Input (0 = Not Asserted, 1 = Asserted)
	00FFh	**INPUT FUNCTION (last 8 bits)**
	1	52a Contact
	2	52b Contact
	3	Breaker Connected
	10	Local Mode
	11	Remote Reset
	12	Remote Open
	13	Remote Close
	14	Cold Load Pickup
	15	Setpoint Group 2
	16	Setpoint Group 3
	17	Setpoint Group 4
	20	User Input A
	21	User Input B
	22	User Input C
	23	User Input D
	24	User Input E
	25	User Input F
	26	User Input G
	27	User Input H
	30	Block 1 TRIP
	31	Block 2 CLOSE
	32	Block Reset
	33	Block Undervolt 1
	34	Block Undervolt 2
	35	Block Undervolt 3
	36	Block Undervolt 4
	37	Block Underfreq 1
	38	Block Underfreq 2
	39	Bypass Synchrocheck
	40	Block Trip Count
	41	Block Negative Sequence Overvoltage
	42	Block Restoration
	43 [1]	Block Freq Decay
	50	Block All OC
	51	Block Phase OC
	52	Block Ground OC
	53	Block Neutral OC
	54 [2]	Block Phase Time OC 1
	55 [2]	Block Phase Instantaneous OC 1
	56 [2]	Block Phase Instantaneous OC 2

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 7 OF 17)

TYPE	VALUE	DESCRIPTION
F24 ctd.	57 [2]	Block Ground Time OC
	58 [2]	Block Ground Instantaneous OC
	59 [2]	Block Neutral Time OC 2
	60 [2]	Block Neutral Time OC 1
	61 [2]	Block Neutral Instantaneous OC 1
	62 [2]	Block Neutral Instantaneous OC 2
	63	Block Negative Sequence Instantaneous OC
	64	Block Negative Sequence Time Overcurrent
	65 [1]	Block Phase Time OC 2
	70	Selected To Trip
	71	UV On Other Source
	72	Incomer 1 Closed
	73	Incomer 2 Closed
	74	BusTie Connected
	75	Bus Tie Closed
	76	Block Transfer
	77	Xmfr Lockout
	78	Source Trip
	79	Cls From Incomer 1
	80	Cls From Incomer 2
	90	Initiate Reclosure
	91	Cancel Reclosure
	92	Block Reclosure
	100	Trigger Trace Memory
	101	Simulate Fault
	102	Trigger Data Log
	103 [3]	Block All Sensitive Ground Overcurrent
	104 [3]	Block Sensitive Ground Instantaneous O/C
	105 [3]	Block Sensitive Ground Time O/C
	106 [4]	Block Reverse Power (requires Mod 008)
	107 [4]	Block Neutral Displacement
	108 [7]	User Input I
	109 [7]	User Input J
	110 [7]	User Input K
	111 [7]	User Input L
	112 [7]	User Input M
	113 [7]	User Input N
	114 [7]	User Input O
	115 [7]	User Input P
	116 [7]	User Input Q
	117 [7]	User Input R
	118 [7]	User Input S
	119 [7]	User Input T
	120 [7]	Start Demand Interval
	SELF-TEST WARNING EVENT TYPE	
	00FFh	**EVENT CAUSE (last 8 bits)**
	1	Relay Not Ready
	2	Analog Output +32V
	3	FLASH Corrupt
	4	EEPROM Corrupt
	5	Dry Contact +32V
	6	A/D Virtual Ground
	7	Internal RS485

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 8 OF 17)

TYPE	VALUE	DESCRIPTION
F24 ctd.	8	Internal Temperature
	9	Clock Not Set
	10	Prototype Software
	11	Not Calibrated
	12	Force Relays
	13	Force Analog Out
	14	Simulation Mode
	15	Pickup Test
	16	Factory Service Mode
	17	IRIG-B Failure
	18 [7]	Not Used
	19 [7]	Not Used
	20 [7]	RTC Crystal
F25	**2's COMPLEMENT SIGNED VALUE**	
	To convert phase currents to Amps, multiply by ‘Phase CT Primary’ and divide by 1000. To convert ground current to Amps, multiply by ‘Ground CT Primary’ and divide by 1000. To convert sensitive ground current to Amps, multiply by ‘Sensitive Ground CT Primary’ and divide by 10000. To convert to voltages to Volts, multiply by ‘VT Ratio’, multiply by ‘VT Secondary Voltage’ and divide by 1000.	
F26	**TRACE MEMORY CHANNEL SELECTOR**	
	The contents of the Trace Memory Samples depends on the value contained in the Trace Memory Channel Selector as follows:	
	0	Phase A Current (Format F25)
	1	Phase B Current (Format F25)
	2	Phase C Current (Format F25)
	3	Ground Current (Format F25)
	4	A-N (A-B) Voltage (Format F25)
	5	B-N Voltage (Format F25)
	6	C-N (C-B) Voltage (Format F25)
	7	Line Voltage (Format F25)
	8	Output Relay States (Format F40)
	9	Logic Input States (Format F46)
	10 [3]	Sensitive Ground Current (Format F25)
F27	**COMMUNICATIONS PARITY**	
	0	None
	1	Odd
	2	Even
F28	**VT CONNECTION TYPE**	
	0	None
	1	Wye
	2	Delta
F29	**760 OPERATION**	
	0	Not Ready
	1	Ready
F30	**ENABLED/DISABLED**	
	0	0 = Disabled
	1	1 = Enabled
F31	**BAUD RATE**	
	0	300 Baud
	1	1200 Baud
	2	2400 Baud
	3	4800 Baud
	4	9600 Baud

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 9 OF 17)

TYPE	VALUE	DESCRIPTION
F31 ctd.	5	19200 Baud
F32	**DEFAULT MESSAGE**	
		Internally Defined
F33	**ASCII TEXT CHARACTERS**	
	00FFh	Second ASCII Character
	FF00h	First ASCII Character
F34	**RELAY NON-OPERATED STATE**	
	0	De-energized
	1	Energized
F35	**RELAY OUTPUT TYPE**	
	0	Self-Resetting
	1	Latched
	2	Pulsed
F36	**OVERCURRENT CURVE SHAPE**	
	0	Extremely Inverse
	1	Very Inverse
	2	Normally Inverse
	3	Moderately Inverse
	4	Definite Time
	5	IEC Curve A
	6	IEC Curve B
	7	IEC Curve C
	8	FlexCurve A
	9	FlexCurve B
	10	IAC Extreme Inverse
	11	IAC Very Inverse
	12	IAC Inverse
	13	IAC Short Inverse
	14	IEC Short Inverse
F37	**TRIP/ALARM/CONTROL FUNCTION**	
	0	Disabled
	1	Trip
	2	Trip & Autoreclose **760 only!**
	3	Alarm
	4	Control
	5 [8]	Latched Alarm
F38	**ALARM/CONTROL FUNCTION**	
	0	Disabled
	3	Alarm
	4	Control
	5 [8]	Latched Alarm
	6 [9]	Blk Thrsh 1 (Analog Input Threshold 2 only)
F39	**TRIP/ALARM/CONTROL FUNCTION**	
	0	Disabled
	1	Trip
	3	Alarm
	4	Control
	5 [8]	Latched Alarm
F40	**OUTPUT RELAY STATUS**	
	0001h	Relay 1 Trip (0 = not operated, 1 = operated)
	0002h	Rly 2 Close (0 = not operated, 1 = operated)
	0004h	Rly 3 Alarm (0 = not operated, 1 = operated)
	0008h	Relay 4 Aux (0 = not operated, 1 = operated)

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 10 OF 17)

TYPE	VALUE	DESCRIPTION
F40 ctd.	0010h	Relay 5 Aux (0 = not operated, 1 = operated)
	0020h	Relay 6 Aux (0 = not operated, 1 = operated)
	0040h	Relay 7 Aux (0 = not operated, 1 = operated)
	0080h	Relay 8 Aux (0 = not operated, 1 = operated)
F41	**CURRENT/VOLTAGE PHASES**	
	1	Any One
	2	Any Two
	3	All Three
F42[2]	**ANALOG INPUT RANGE**	
	0	0-1 mA
	1	0-5 mA
	2	4-20 mA
	3	0-20 mA
	4[1]	0-10 mA
F43[2]	**IRIG-B SIGNAL TYPE**	
	0	None
	1	DC Shift
	2	Amplitude Modulated
F44	**OUT OF SERVICE STATES**	
	0001h	Major Internal Failure (0=disabled, 1=enabled)
	0002h	Minor Internal Failure (0=disabled, 1=enabled)
	0004h	Testing Mode (0=Disabled, 1=Enabled)
	0020h	Code Programming Mode (0=Disabled, 1=Enabled)
F45	**UNDERVOLTAGE CURVE TYPE**	
	0	Definite Time
	1	Inverse Time
F46	**CONTACT INPUT STATUS**	
	0001h	Contact Input 1 State (0=Open, 1=Closed)
	0002h	Contact Input 2 State (0=Open, 1=Closed)
	0004h	Contact Input 3 State (0=Open, 1=Closed)
	0008h	Contact Input 4 State (0=Open, 1=Closed)
	0010h	Contact Input 5 State (0=Open, 1=Closed)
	0020h	Contact Input 6 State (0=Open, 1=Closed)
	0040h	Contact Input 7 State (0=Open, 1=Closed)
	0080h	Contact Input 8 State (0=Open, 1=Closed)
	0100h	Contact Input 9 State (0=Open, 1=Closed)
	0200h	Contact Input 10 State (0=Open, 1=Closed)
	0400h	Contact Input 11 State (0=Open, 1=Closed)
	0800h	Contact Input 12 State (0=Open, 1=Closed)
	1000h	Contact Input 13 State (0=Open, 1=Closed)
	2000h	Contact Input 14 State (0=Open, 1=Closed)
	4000h	Setpoint Access (0=Restricted, 1=Allowed)
F47	**TRIP/CLOSE COIL STATUS**	
	0001h	Coil Monitor 1 Circuit (0=Open, 1=Closed)
	0002h	Coil Monitor 2 Circuit (0=Open, 1=Closed)
F48	**SIMULATION STATUS**	
	0	Disabled
	1	Prefault State
	2	Fault State
	3	Postfault State
F49	**PROTECTION FUNCTION STATE**	
	1000h	Pickup (0=Not picked up, 1=Picked up)

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 11 OF 17)

TYPE	VALUE	DESCRIPTION
F49 ctd.	2000h	Operate (0=Not operating, 1=Operating)
	4000h	Latched (0=Not latched, 1=Latched)
	8000h	Latched Alarm (0=Not latched, 1=Latched)
	0100h	Phase A (0=Phase A is not picked up/ operating, 1= Phase A is picked up/operating)
	0200h	Phase B (0=Phase B is not picked up/ operating, 1= Phase B is picked up/operating)
	0400h	Phase C (0=Phase C is not picked up/ operating, 1= Phase C is picked up/operating)
F50	**POLARIZATION**	
	0	Voltage
	1	Current
	2	Dual
F51	**A100 SELF-TEST ERRORS**	
	0001h	+32V Analog Out Volt Monitor (0 = OK, 1 = Fail)
	0002h	+32V Switch In Volt Monitor (0 = OK, 1 = Failed)
	0004h	Real Time Clock (0 = OK, 1 = Unable to Start)
	0008h	Not Used
	0010h	EEPROM Failure (0 = OK, 1 = Failed)
	0020h	Internal Temperature (-40 to 70 °C) (0 = OK, 1= Out of Range)
	0040h	A/D Virtual Ground (0 = OK, 1 = Out of Spec)
	0080h	Not Calibrated (0 = OK, 1 = Not Calibrated)
	0100h [7]	Not Used
	8000h	Prototype Unit (0 = OK, 1 = Installed)
F52	**2's COMPLEMENT SIGNED VALUE, 2 DECIMAL PLACES DISTANCE TO FAULT**	
	Example: -12.34 stored as -1234. Note: a value of 327.67 indicates that the distance could not be calculated.	
F53	**UNSIGNED VALUE, 2 DEC PLACES - LINE Z1 TO FAULT**	
	Example: 12.34 stored as 1234. Note: a value of 655.35 indicates that the impedance could not be calculated	
F54	**FORCE LED STATE**	
	0001h	LED #1 (Top) (0 = Off, 1 = On)
	0002h	LED #2 (0 = Off, 1 = On)
	0004h	LED #3 (0 = Off, 1 = On)
	0008h	LED #4 (0 = Off, 1 = On)
	0010h	LED #5 (0 = Off, 1 = On)
	0020h	LED #6 (0 = Off, 1 = On)
	0040h	LED #7 (0 = Off, 1 = On)
	0080h	LED #8 (Bottom) (0 = Off, 1 = On)
F55	**FRONT PANEL KEY**	
	0	'0'
	1	'1'
	2	'2'
	3	'3'
	4	'4'
	5	'5'
	6	'6'
	7	'7'
	8	'8'
	9	'9'
	10	'.'
	13	'Value Up'
	14	'Value Down'
	15	'Message Up'

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 12 OF 17)

TYPE	VALUE	DESCRIPTION
F55 ctd.	16	'Message Down'
	17	'Next'
	18	'Enter'
	19	'Escape'
	20	'Setpoints'
	21	'Actual'
	22	'Reset'
	23	'Open'
	24	'Close'
	25	'Help'
	31	No Key
F56	**TRANSFER FUNCTION**	
	0	Disabled
	1	Incomer 1
	2	Incomer 2
	3	Bus Tie
F57	**OUTPUT RELAYS (3-7)**	
	0004h	3 Alarm (0 = Do Not Operate, 1 = Operate)
	0008h	4 Auxiliary (0 = Do Not Operate, 1 = Operate)
	0010h	5 Auxiliary (0 = Do Not Operate, 1 = Operate)
	0020h	6 Auxiliary (0 = Do Not Operate, 1 = Operate)
	0040h	7 Auxiliary (0 = Do Not Operate, 1 = Operate)
F58	**DEMAND MEASUREMENT TYPE**	
	0	Thermal Exponential
	1	Block Interval
	2	Rolling Demand
F59 [2]	**OVERCURRENT BLOCKING FLAGS**	
	0001h [2]	Phase Inst OC 1 (0 = Do Not Block, 1= Block)
	0002h [2]	Neutral Inst OC 1 (0 = Do Not Block, 1= Block)
	0004h [2]	Ground Inst OC (0 = Do Not Block, 1= Block)
	0008h [2]	Neg Seq Inst OC (0 = Do Not Block, 1= Block)
	0010h [3]	Sens Gnd Inst OC (0 = Do Not Block, 1= Block)
F61	**C400 SELF TEST ERRORS**	
	0001h	A100 Communications (0 = OK, 1 = Failing)
	8000h	Prototype Unit (0 = OK, 1 = Installed)
F62	**PORT USED FOR DNP**	
	0	None
	1	COM1
	2	COM2
	3	Front
F63 [2]	**INPUTS 1-14 ASSERTED LOGIC**	
	0 [1]	Disabled
	1 [1]	Contact Close
	2 [1]	Contact Open
	3 [1]	Virtual On
	4 [1]	Virtual Off
	5 [1]	Closed **&** V_{on}
	6 [1]	Closed **&** V_{off}
	7 [1]	Open **&** V_{on}
	8 [1]	Open **&** V_{off}
	9 [1]	Closed **|** V_{on}
	10 [1]	Closed **|** V_{off}
	11 [1]	Open **|** V_{on}

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 13 OF 17)

TYPE	VALUE	DESCRIPTION
F63 [2] ctd.	12 [1]	Open **|** V_{off}
	13 [1]	Closed **X** V_{on}
	14 [1]	Closed **X** V_{off}
	15 [1]	Open **X** V_{on}
	16 [1]	Open **X** V_{off}
F64 [2]	**INPUTS 15-20 ASSERTED LOGIC**	
	0 [1]	Disabled
	1 [1]	Virtual On
	2 [1]	Virtual Off
F65	**LOGIC INPUT FUNCTION**	
	0	Disabled
	1	Input 1
	2	Input 2
	3	Input 3
	↓	↓
	20	Input 20
F66	**LOGIC INPUT STATE**	
	0	Off
	1	On
F68	**RESET TIME MODEL**	
	0	Instantaneous
	1	Linear
F69	**LOGIC INPUT STATE**	
	0100h	Contact State (0 = Open, 1 = Closed)
	0200h	Virtual State (0 = Off, 1 = On)
	0400h	Logic Input (0 = Not Asserted, 1 = Asserted)
F70	**UNSIGNED VALUE, 3 DECIMAL PLACES**	
	Example: 1.234 stored as 1234	
F71	**FACTORY SERVICE COMMANDS**	
	0	Clear Any Pending Commands
	1	Load Factory Default Setpoints
	2	Load Factory Default Calibration Data
	3	Clear Diagnostic Data
F72	**FORCE HARDWARE**	
	0001h	LED's (0=Normal, 1=Use LED force codes)
	0002h [8]	Reserved
	0004h	A100 Output Relay Watchdog (0=Normal, 1=Stop Updating)
	0008h	C400 Watchdog (0=Normal, 1=Stop Updating)
	0010h	485 Communication Port (0=Normal, 1=Echo)
	0020h	E485 Comm Port (0=Normal, 1=Echo)
	0040h	A100 Watchdog (0=Normal, 1=Stop Updating)
F73	**DYNAMIC OVERCURRENT PRIORITY**	
	0	No Priority Adjustment
	1	Voltage Restraint
	2	Manual Close
	3	Cold Load
	4	Autoreclose
F74	**DATA LOGGER SAMPLE RATE**	
	0	1 cycle
	1	1 second
	2	1 minute
	3	5 minutes

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 14 OF 17)

TYPE	VALUE	DESCRIPTION
F74 ctd.	4	10 minutes
	5	15 minutes
	6	20 minutes
	7	30 minutes
	8	60 minutes
F75	**UNITS OF LENGTH**	
	0	km
	1	Miles
F76	**TYPE OF FAULT**	
	0001h	øA (0=Not involved, 1= Involved)
	0002h	øB (0=Not involved, 1= Involved)
	0004h	øC (0=Not involved, 1= Involved)
	0008h	Ground (0=Not involved, 1= Involved)
	Example: øB to øC to Ground = 000Eh	
F77 [2]	**ANALOG OUTPUT PARAMETER TYPE**	
	0	Disabled
	1	Phase A Current
	2	Phase B Current
	3	Phase C Current
	4	Average Phase Current
	5	% of Load to Trip
	6	Neutral Current
	7	Phase A-N Voltage
	8	Phase B-N Voltage
	9	Phase C-N Voltage
	10	Average Phase Voltage
	11	Line A-B Voltage
	12	Line B-C Voltage
	13	Line C-A Voltage
	14	Average Line Voltage
	15	Frequency
	16	3ϕ Real Power (MW)
	17	3ϕ Reactive Power (Mvar)
	18	3ϕ Apparent Power (MVA)
	19	3ϕ Power Factor
	20	Last Phase A Current Demand
	21	Last Phase B Current Demand
	22	Last Phase C Current Demand
	23	Last Real Power Demand
	24	Last Reactive Power Demand
	25	Last Apparent Power Demand
	26	Analog Input
	27	Last Fault Location
	28	Positive Watthours
	29	Negative Watthours
	30	Positive Varhours
	31	Negative Varhours
	32	Ground Current
	33 [1]	ϕA Real Power (MW)
	34 [1]	ϕA Reactive Power (Mvar)
	35 [1]	ϕA Apparent Power (MVA)
	36 [1]	ϕA Power Factor
	37 [1]	ϕB Real Power (MW)

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 15 OF 17)

TYPE	VALUE	DESCRIPTION
F77 [2] ctd.	38 [1]	ϕB Reactive Power (Mvar)
	39 [1]	ϕB Apparent Power (MVA)
	40 [1]	ϕB Power Factor
	41 [1]	ϕC Real Power (MW)
	42 [1]	ϕC Reactive Power (Mvar)
	43 [1]	ϕC Apparent Power (MVA)
	44 [1]	ϕC Power Factor
	45 [1]	Synchro Voltage
	46 [1]	Synchro Frequency
	47 [1]	Synchro Voltage Angle
	48 [1]	Sychro Voltage Difference
	49 [1]	Sychro Angle Difference
	50 [1]	Sychro Frequency Difference
	51 [1]	Frequency Decay Rate
	52 [3]	Polarizing Current
	53 [1]	Phase A Current Angle
	54 [1]	Phase B Current Angle
	55 [1]	Phase C Current Angle
	56 [1]	Neutral Current Angle
	57 [1]	Ground Current Angle
	58 [3]	Polarizing Current Angle
	59 [1]	A-N Voltage Angle
	60 [1]	B-N Voltage Angle
	61 [1]	C-N Voltage Angle
	62 [1]	A-B Voltage Angle
	63 [1]	B-C Voltage Angle
	64 [1]	C-A Voltage Angle
	65 [1]	Positive Sequence Current Magnitude
	66 [1]	Positive Sequence Current Angle
	67 [1]	Negative Sequence Current Magnitude
	68 [1]	Negative Sequence Current Angle
	69 [1]	Zero Sequence Current Magnitude
	70 [1]	Zero Sequence Current Angle
	71 [1]	Positive Sequence Voltage Magnitude
	72 [1]	Positive Sequence Voltage Angle
	73 [1]	Negative Sequence Voltage Magnitude
	74 [1]	Negative Sequence Voltage Angle
	75 [1]	Zero Sequence Voltage Magnitude
	76 [1]	Zero Sequence Voltage Angle
	77 [3]	Sensitive Ground Current
	78 [3]	Sensitive Ground Current Angle
	79 [4]	Neutral Voltage
	80 [4]	Neutral Voltage Angle

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 16 OF 17)

TYPE	VALUE	DESCRIPTION
F78 [2]	**ANALOG OUTPUT MINIMUM / MAXIMUM**	
	The Range, Step Value, and Units for the Analog Output Minimum and Maximum depends upon the parameter type programmed for the output. The following table shows the format for a given parameter type:	

PARAMETER	RANGE	STEP	UNITS
All currents	0 to 65535	1	Amps
All voltages	0.00 to 655.35	0.01	kV
% Load to Trip	0 to 2000	1	%
Frequency	20.00 to 65.00	0.01	Hz
All Power / Energy	see F86		
Power Factor	-0.99 to +1.00	0.01	---
Analog Input	0 to 65535	1	units
Fault Location	-1000.0 to +1000.0	0.1	km / mi
Frequency Delay	-10.00 to +10.00	0.01	Hz/s
All Angles	0 to 359	1	° Lag

TYPE	VALUE	DESCRIPTION
F79	**SETPOINT GROUP**	
	0	Group 1
	1	Group 2
	2	Group 3
	3	Group 4
F80	**EDIT SETPOINT GROUP**	
	0	Group 1
	1	Group 2
	2	Group 3
	3	Group 4
	4	Active Group
F81	**TRACE MEMORY / DATA LOGGER BUFFER**	
	0	2 x 2048
	1	4 x 1024
	2	8 x 512
	3	16 x 256
F82	**TRACE MEMORY / DATA LOGGER TRIGGER**	
	0x0001	Trigger on pickup
	0x0002	Trigger on dropout
	0x0004	Trigger on trip
	0x0008	Trigger on alarm
	0x0010	Trigger on control
F83 [1]	**PHASE SEQUENCE**	
	0	ABC
	1	ACB
F84 [1]	**OVERCURRENT DIRECTION**	
	0	Disabled
	1	Forward
	2	Reverse
F85 [1]	**PICKUP TYPE**	
	0	Over
	1	Under

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Table 7–7: MEMORY MAP DATA FORMATS (SHEET 17 OF 17)

TYPE	VALUE	DESCRIPTION
F86 [1]	**AUTO-RANGING POWER / ENERGY**	
	All power quantities auto-range to display units relative to the nominal power of the system as defined below. Multiply the power quantity in question by the multiplier in register 0316h to yield the correct reading. The SI prefix for all power and energy quantities before scaling by the multiplier is ‘k’. All power quantities are signed, single word registers (F4). All energy quantities are unsigned, double word registers (F7). The multiplier is determined from the nominal power which is defined as the product of three setpoints: P_N = Phase CT Primary x Bus VT Secondary Voltage x Bus VT Ratio NOMINAL POWER P_N / MULTIPLIER: P_N < 1 MVA — 1 1 MVA ≤ P_N < 10 MVA — 10 10 MVA ≤ P_N — 100 Example: If the 3ϕ Real Power register (0310) has a value of ‘123’ and the Multiplier register (0316) has a value of ‘10’ then the value to display is 1230 kW.	
F87 [3]	**UNDERVOLTAGE RESTORATION SOURCE**	
	0	Bus
	1	Line
F88 [6]	**RESERVED FOR MOD 010**	
	0	
	1	
F89 [7]	**DNP DATA LINK CONFIRMATION MODE**	
	0	Never
	1	Sometimes
	2	Always
F90 [7]	**COIL MONITOR TYPE**	
	0	Trip
	1	Close

1 2 3 4 5 6 7 8 9 For explanation of footnotes, see notes of end of Table.

Data Formats Notes:

1 New for version 2.10
2 Changed from version 2.00 to 2.10
3 New or have changed for version 3.00
4 New or have changed for version 3.20
5 New for version 3.30
6 New for version 3.31 MOD 010
7 New or have changed for version 3.60
8 New or have changed for version 3.70
9 New or have changed for version 4.00

7.5.1 DEVICE PROFILE DOCUMENT

DNP 3.0
DEVICE PROFILE DOCUMENT

Vendor Name: General Electric Multilin Inc.

Device Name: 750/760 Feeder Management Relay

Highest DNP Level Supported:

For Requests: Level 2
For Responses: Level 2

Device Function:

❒ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

Binary Input (Object 1, Variations 1 and 2)
Binary Output (Object 10, Variation 2)
Analog Input (Object 30, Variations 1, 2, 3 and 4)
Analog Input Change (Object 32, Variations 1, 2, 3 and 4)
Warm Restart (Function code 14)

Maximum Data Link Frame Size (octets):

Transmitted: 292
Received: 292

Maximum Application Fragment Size (octets):

Transmitted: 2048
Received: 2048

Maximum Data Link Re-tries:

❒ None
❒ Fixed
☒ Configurable (Note 1)

Maximum Application Layer Re-tries:

☒ None
❒ Configurable

Requires Data Link Layer Confirmation:

❒ Never
❒ Always
❒ Sometimes
☒ Configurable (Note 1)

Requires Application Layer Confirmation:

❒ Never
❒ Always
☒ When reporting Event Data
❒ When sending multi-fragment responses
❒ Sometimes
❒ Configurable

Timeouts while waiting for:

Data Link Confirm	❒ None	❒ Fixed	❒ Variable	☒ Configurable (Note 1)
Complete Appl. Fragment	☒ None	❒ Fixed	❒ Variable	❒ Configurable
Application Confirm	☒ None	❒ Fixed	❒ Variable	❒ Configurable
Complete Appl. Response	☒ None	❒ Fixed	❒ Variable	❒ Configurable
Others:	(None)			

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DNP 3.0
DEVICE PROFILE DOCUMENT (CONTINUED)

Executes Control Operations:

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT/OPERATE	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Count > 1	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Pulse On	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse Off	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Latch Off	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Trip/Close	☐ Never	☐ Always	☒ Sometimes	☐ Configurable

(For an explanation of the above, refer to the discussion accompanying Binary Output/Control Relay Output point list)

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Reports Binary Input Change Events when no specific variations requested:

- ☐ Never
- ☒ Only time-tagged
- ☐ Only non-time-tagged
- ☐ Configurable to send both, one or the other

Reports time-tagged Binary Input Change Events when no specific variation requested:

- ☐ Never
- ☒ Binary Input Change With Time
- ☐ Binary Input Change With Relative Time
- ☐ Configurable

Sends Unsolicited Responses:

- ☒ Never
- ☐ Configurable
- ☐ Only certain objects
- ☐ Sometimes
- ☐ ENABLE/DISABLE UNSOLICITED Function codes supported

Sends Static Data in Unsolicited Responses:

- ☒ Never
- ☐ When Device Restarts
- ☐ When Status Flags Change

Default Counter Object/Variation:

- ☒ No Counters Reported
- ☐ Configurable
- ☐ Default Object
  Default Variation
- ☐ Point-by-point list attached

Counters Roll Over at:

- ☒ No Counters Reported
- ☐ Configurable
- ☐ 16 Bits
- ☐ 32 Bits
- ☐ Other Value
- ☐ Point-by-point list attached

Sends Multi-Fragment Responses: ☐ Yes ☒ No

Table Notes:

1. The data link layer confirmation mode, confirmation time-out, and number of retries are all configurable. Refer to DNP Configuration on page 5–9 for more details.

7.5.2 DNP IMPLEMENTATION

The table below gives a list of all objects recognized and returned by the relay. Additional information is provided on the following pages including a list of the default variations returned for each object and lists of defined point numbers for each object.

IMPLEMENTATION TABLE						
OBJECT			REQUEST		RESPONSE	
OBJ	VAR	DESCRIPTION	FUNC. CODES	QUAL CODES (HEX)	FUNC. CODES	QUAL CODES (HEX)
1	0	Binary Input - All Variations	1	06		
1	1	Binary Input	1	00, 01, 06	129	00, 01
1	2	Binary Input With Status	1	00, 01, 06	129	00, 01
2	0	Binary Input Change - All Variations	1	06, 07, 08		
2	1	Binary Input Change Without Time	1	06, 07, 08	129	17, 28
2	2	Binary Input Change With Time	1	06, 07, 08	129	17, 28
10	0	Binary Output - All Variations	1	06		
10	2	Binary Output Status	1	00, 01, 06	129	00, 01
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	17, 28
30	0	Analog Input - All Variations	1	06		
30	1	32-Bit Analog Input With Flag	1	00, 01, 06	129	00, 01
30	2	16-Bit Analog Input With Flag	1	00, 01, 06	129	00, 01
30	3	32-Bit Analog Input Without Flag	1	00, 01, 06	129	00, 01
30	4	16-Bit Analog Input Without Flag	1	00, 01, 06	129	00, 01
32	0	Analog Input Change - All Variations	1	06, 07, 08		
32	1	32-Bit Analog Input Change Without Time	1	06, 07, 08	129	17, 28
32	2	16-Bit Analog Input Change Without Time	1	06, 07, 08	129	17, 28
32	3	32-Bit Analog Input Change With Time	1	06, 07, 08	129	17, 28
32	4	16-Bit Analog Input Change With Time	1	06, 07, 08	129	17, 28
50	1	Time and Date	1, 2	07 (Note 1)	129	07
60	1	Class 0 Data (Note 2)	1	06	129	
60	2	Class 1 Data (Note 3)	1	06, 07, 08	129	
60	3	Class 2 Data (Note 3)	1	06, 07, 08	129	
60	4	Class 3 Data (Note 3)	1	06, 07, 08	129	
80	1	Internal Indications	2	00 (Note 4)	129	
		No object	13			
		No object	14			
		No object	23			

Table Notes:

1. For this object, the quantity specified in the request must be exactly 1 as there is only one instance of this object defined in the relay.
2. All static input data known to the relay is returned in response to a request for Class 0. This includes all objects of type 1 (Binary Input), type 10 (Binary Output) and type 30 (Analog Input).
3. The point tables for Binary Input and Analog Input objects contain a field which defines to which event class the corresponding static data has been assigned.
4. For this object, the qualifier code must specify an index of 7 only.

The following table specifies the default variation for all objects returned by the relay. These are the variations that will be returned for the object in a response when no specific variation is specified in a request.

DEFAULT VARIATIONS		
OBJECT	DESCRIPTION	DEFAULT VARIATION
1	Binary Input - Single Bit	1
2	Binary Input Change With Time	2
10	Binary Output Status	2
30	16-Bit Analog Input Without Flag	4
32	16-Bit Analog Input Change Without Time	2

7.5.3 DNP POINT LISTS

a) BINARY INPUT / BINARY INPUT CHANGE

BINARY INPUT (OBJECT 01); BINARY INPUT CHANGE (OBJECT 02)		
INDEX	DESCRIPTION	EVENT CLASS ASSIGNED
0	Relay In Service	Class 1
1	Trip Condition(s) Active	Class 1
2	Alarm Condition(s) Active	Class 1
3	Protection Picked Up	Class 1
4	Setpoint Group 1 Active	Class 1
5	Setpoint Group 2 Active	Class 1
6	Setpoint Group 3 Active	Class 1
7	Setpoint Group 4 Active	Class 1
8	Breaker Is Open	Class 1
9	Breaker Is Closed	Class 1
10	Reclosure Enabled [1]	Class 1
11	Reclosure Disabled [1]	Class 1
12	Reclosure In Progress [1]	Class 1
13	Reclosure Locked Out [1]	Class 1
14	Local Mode Active	Class 1
15	Diagnostic Message(s) Active	Class 1
16	Major Internal Failure	Class 1
17	Minor Internal Failure	Class 1
18	Testing Mode Active	Class 1
19	Contact Input 1 Closed	Class 1
20	Contact Input 2 Closed	Class 1
21	Contact Input 3 Closed	Class 1

BINARY INPUT (OBJECT 01); BINARY INPUT CHANGE (OBJECT 02)		
INDEX	DESCRIPTION	EVENT CLASS ASSIGNED
22	Contact Input 4 Closed	Class 1
23	Contact Input 5 Closed	Class 1
24	Contact Input 6 Closed	Class 1
25	Contact Input 7 Closed	Class 1
26	Contact Input 8 Closed	Class 1
27	Contact Input 9 Closed	Class 1
28	Contact Input 10 Closed	Class 1
29	Contact Input 11 Closed	Class 1
30	Contact Input 12 Closed	Class 1
31	Contact Input 13 Closed	Class 1
32	Contact Input 14 Closed	Class 1
33	Setpoint Access Jumper Present	Class 1
34	Coil Monitor 1 Circuit Closed	Class 1
35	Coil Monitor 2 Circuit Closed	Class 1
36	Relay 1 TRIP Operated	Class 1
37	Relay 2 CLOSE Operated	Class 1
38	Relay 3 AUXILIARY Operated	Class 1
39	Relay 4 AUXILIARY Operated	Class 1
40	Relay 5 AUXILIARY Operated	Class 1
41	Relay 6 AUXILIARY Operated	Class 1
42	Relay 7 AUXILIARY Operated	Class 1
43	Relay 8 SERVICE Operated	Class 1

Notes:

1. Any detected change in the state of any point will cause the generation of an event object.
2. An event object will be generated as a result of any change in any point.

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b) BINARY OUTPUT / CONTROL RELAY OUTPUT

BINARY OUTPUT (OBJECT 10) CONTROL RELAY OUTPUT BLOCK (OBJECT 12)	
INDEX	**DESCRIPTION**
0	Reset
1	Open Breaker
2	Close Breaker
3	Virtual Input 1
4	Virtual Input 2
5	Virtual Input 3
6	Virtual Input 4
7	Virtual Input 5
8	Virtual Input 6
9	Virtual Input 7
10	Virtual Input 8
11	Virtual Input 9

BINARY OUTPUT (OBJECT 10) CONTROL RELAY OUTPUT BLOCK (OBJECT 12)	
INDEX	**DESCRIPTION**
12	Virtual Input 10
13	Virtual Input 11
14	Virtual Input 12
15	Virtual Input 13
16	Virtual Input 14
17	Virtual Input 15
18	Virtual Input 16
19	Virtual Input 17
20	Virtual Input 18
21	Virtual Input 19
22	Virtual Input 20
23	Breaker Control

The following restrictions should be observed when using object 12 to control the points listed in the above table.

1. The *Count* field is checked first. If it is zero, the command will be accepted but no action will be taken. If this field is non-zero, the command will be executed exactly once regardless of its value.
2. The *Control Code* field of object 12 is then inspected:
   - The Queue, and Clear sub-fields are ignored.
   - If the Code sub-field is NUL, then the command will be accepted without any action being taken.
   - A Code sub-field of “Pulse On” (1) is valid only for points 0 through 2. This is used to activate the function (e.g., Reset) associated with the point.
   - A Code sub-field of “Pulse On” (1) in combination with a value in the Trip/Close sub-field form a “Trip” or “Close” value. A “Trip” value consists of a “Pulse On” (1) in the Code sub-field and a 2 in the Trip/Close sub-field. This results in a value of 81 (hex) in the Control Code field. A “Close” value consists of a “Pulse On” (1) in the Code sub-field and a 1 in the Trip/Close sub-field. This results in a value of 41 (hex) in the Control Code field.
   - A Code sub-field of “Latch On” (3) or “Latch Off” (4) is valid for all virtual input points (i.e., points 3 through 22). This is used to set the associated Virtual Input on (“Latch On”) or off (“Latch Off”). As well, a “Close” value in the Control Code field will cause the virtual input to be turned on while a “Trip” value in this field will cause the virtual input to be turned off.
   - The “Breaker Control” point (23) will only accept a “Trip” or “Close” value. A value of “Trip” will activate the “Breaker Open” function. Similarly, a value of “Close” will activate the “Breaker Close” function.
   - All operations not defined above are invalid and will be rejected.
3. The *On Time* and *Off Time* fields are ignored. A "Pulse On” Code takes effect immediately when received, therefore timing is irrelevant.
4. The *Status* field in the response will reflect the success or failure of the control attempt thus:
   - A Status of “Request Accepted” (0) will be returned if the command was accepted.
   - A Status of “Request not Accepted due to Formatting Errors” (3) will be returned if the Control Code field was incorrectly formatted or an invalid Code was present in the command.
   - A Status of “Control Operation not Supported for this Point” (4) will be returned if an attempt was made to operate the “Open Breaker” (1), “Close Breaker” (2) or “Breaker Control” (23) points and the relay is in local mode (this status is indicated by Object 1, Point 14).

Setting or clearing a Virtual Input will always succeed, however an operate of the Reset, Open Breaker, Close Breaker or Breaker Control points may fail (even if the command is accepted) due to other inputs or conditions (e.g., blocks) existing at the time. To verify the success or failure of an operate of these points it is necessary that the associated Binary Input(s) be examined after the control attempt is performed.

When using object 10 to read the status of a Binary Output, a read of points 0 through 2 and 23 will always return zero. For other points, the current state of the corresponding Virtual Input will be returned.

c) ANALOG INPUT / ANALOG INPUT CHANGE

In the following table, the entry in the “Format” column indicates that the format of the associated data point can be determined by looking up the entry in the Memory Map Data Formats table. For example, an “F1” format is described in that table as a (16-bit) unsigned value without any decimal places. Therefore, the value read should be interpreted in this manner.

ANALOG INPUT (OBJECT 30); ANALOG INPUT CHANGE (OBJECT 32)					
(NOTE 5) INDEX WHEN POINT MAPPING IS:		FORMAT	DESCRIPTION	EVENT CLASS ASSIGNED	NOTES
DISABLED	ENABLED				
n/a	0	-	User Map Value 1		
n/a	1	-	User Map Value 2		
↓	↓	↓	↓		
n/a	118	-	User Map Value 119		
n/a	119	-	User Map Value 120		
0	120	F49	Phase Time Overcurrent 1	Class 1	
1	121	F49	Phase Instantaneous Overcurrent 1	Class 1	
2	122	F49	Phase Instantaneous Overcurrent 2	Class 1	
3	123	F49	Ground Time Overcurrent	Class 1	
4	124	F49	Ground Instantaneous Overcurrent	Class 1	
5	125	F49	Neutral Time Overcurrent 1	Class 1	
6	126	F49	Neutral Time Overcurrent 2	Class 1	
7	127	F49	Neutral Instantaneous Overcurrent 1	Class 1	
8	128	F49	Neutral Instantaneous Overcurrent 2	Class 1	
9	129	F49	Phase Directional Is Reverse	Class 1	
10	130	F49	Neutral Directional Is Reverse	Class 1	
11	131	F49	Manual Close Blocking	Class 1	
12	132	F49	Cold Load Pickup Blocking	Class 1	
13	133	F49	Bus Undervoltage 1	Class 1	
14	134	F49	Bus Undervoltage 2	Class 1	
15	135	F49	Line Undervoltage 3	Class 1	
16	136	F49	Line Undervoltage 4	Class 1	
17	137	F49	Overvoltage 1	Class 1	
18	138	F49	Overvoltage 2	Class 1	
19	139	F49	Underfrequency 1	Class 1	
20	140	F49	Underfrequency 2	Class 1	
21	141	F49	Phase Current Level	Class 1	
22	142	F49	Neutral Current Level	Class 1	
23	143	F49	Power Factor 1	Class 1	
24	144	F49	Power Factor 2	Class 1	
25	145	F49	Synchrocheck Block (Not In Sync)	Class 1	
26	146	F49	Current Demand	Class 1	
27	147	F49	Real Power Demand	Class 1	
28	148	F49	Reactive Power Demand	Class 1	

ANALOG INPUT (OBJECT 30); ANALOG INPUT CHANGE (OBJECT 32) (CONTINUED)					
(NOTE 5) INDEX WHEN POINT MAPPING IS:		FORMAT	DESCRIPTION	EVENT CLASS ASSIGNED	NOTES
DISABLED	ENABLED				
29	149	F49	Apparent Power Demand	Class 1	
30	150	F49	Analog Input Threshold 1	Class 1	
31	151	F49	Analog Input Threshold 2	Class 1	
32	152	F49	Analog Input Rate of Change 1	Class 1	
33	153	F49	Analog Input Rate of Change 2	Class 1	
34	154	F49	Overfrequency	Class 1	
35	155	F49	Trip Counter	Class 1	
36	156	F49	Arcing Current	Class 1	
37	157	F49	VT Failure	Class 1	
38	158	F49	Breaker Failure	Class 1	
39	159	F49	Breaker Operation Failure	Class 1	
40	160	F49	Trip Coil Monitor	Class 1	
41	161	F49	Close Coil Monitor	Class 1	
42	162	F49	User Input A	Class 1	
43	163	F49	User Input B	Class 1	
44	164	F49	User Input C	Class 1	
45	165	F49	User Input D	Class 1	
46	166	F49	User Input E	Class 1	
47	167	F49	User Input F	Class 1	
48	168	F49	User Input G	Class 1	
49	169	F49	User Input H	Class 1	
50	170	F49	Negative Sequence Instantaneous Overcurrent	Class 1	
51	171	F49	Negative Sequence Time Overcurrent	Class 1	
52	172	F49	Negative Sequence Overvoltage	Class 1	
53	173	F49	Undervoltage Restoration	Class 1	
54	174	F49	Underfrequency Restoration	Class 1	
55	175	F49	Phase Time Overcurrent 2	Class 1	
56	176	F49	Frequency Decay	Class 1	
57	177	F49	Negative Sequence Directional Is Reverse	Class 1	
58	178	F49	Sensitive Ground Instantaneous Overcurrent	Class 1	
59	179	F49	Sensitive Ground Time Overcurrent	Class 1	
60	180	F49	Sensitive Ground Directional Is Reverse	Class 1	
61	181	F1	Phase A RMS Current	Class 2	Note 3
62	182	F1	Phase B RMS Current	Class 2	Note 3
63	183	F1	Phase C RMS Current	Class 2	Note 3
64	184	F1	Percent Of Load-To-Trip	Class 2	Note 3
65	185	F1	Ground Current	Class 2	Note 3
66	186	F3	Phase A-Neutral RMS Voltage	Class 2	Note 3
67	187	F3	Phase B-Neutral RMS Voltage	Class 2	Note 3
68	188	F3	Phase C-Neutral RMS Voltage	Class 2	Note 3
69	189	F3	Phase A-Phase B RMS Voltage	Class 2	Note 3
70	190	F3	Phase B-Phase C RMS Voltage	Class 2	Note 3
71	191	F3	Phase C-Phase A RMS Voltage	Class 2	Note 3
72	192	F3	Sensitive Ground Current	Class 2	Note 3
73	193	F1	Average Current	Class 2	Note 3
74	194	F3	Average Line Voltage	Class 2	Note 3

ANALOG INPUT (OBJECT 30); ANALOG INPUT CHANGE (OBJECT 32) (CONTINUED)					
(NOTE 5) INDEX WHEN POINT MAPPING IS:		FORMAT	DESCRIPTION	EVENT CLASS ASSIGNED	NOTES
DISABLED	ENABLED				
75	195	F3	Average Phase Voltage	Class 2	Note 3
76	196	F1	Neutral Current	Class 2	Note 3
77	197	F86	3ϕ Real Power	Class 2	Note 3
78	198	F86	3ϕ Reactive Power	Class 2	Note 3
79	199	F86	3ϕ Apparent Power	Class 2	Note 3
80	200	F6	3ϕ Power Factor	Class 2	Note 3
81	201	F3	System Frequency	Class 2	Note 4
82	202	F1	Analog Input	Class 2	Note 3
83	203	F23	Date Of Last Trip (Upper 16 Bits - See Note 1)	Class 1	Note 1
84	204	F23	Date Of Last Trip (Lower 16 Bits - See Note 1)	Class 1	Note 1
85	205	F22	Time Of Last Trip (Upper 16 Bits - See Note 1)	Class 1	Note 1
86	206	F22	Time Of Last Trip (Lower 16 Bits - See Note 1)	Class 1	Note 1
87	207	F24	Cause Of Last Trip	Class 1	
88	208	F1	Last Trip Phase A RMS Current	Class 1	
89	209	F1	Last Trip Phase B RMS Current	Class 1	
90	210	F1	Last Trip Phase C RMS Current	Class 1	
91	211	F1	Last Trip Ground Current	Class 1	
92	212	F3	Last Trip Sensitive Ground Current	Class 1	
93	213	F3	Last Trip A-N (A-B) RMS Voltage	Class 1	
94	214	F3	Last Trip B-N (B-C) RMS Voltage	Class 1	
95	215	F3	Last Trip C-N (C-A) RMS Voltage	Class 1	
96	216	F3	Last Trip System Frequency	Class 1	
97	217	F1	Last Trip Analog Input	Class 1	
98	218	F1	Last Trip Neutral Current	Class 1	
99	219	F23	Date Of Fault 1 (Upper 16 Bits - See Note 1)	Class 3	Note 1
100	220	F23	Date Of Fault 1 (Lower 16 Bits - See Note 1)	Class 3	Note 1
101	221	F22	Time Of Fault 1 (Upper 16 Bits - See Note 1)	Class 3	Note 1
102	222	F22	Time Of Fault 1 (Lower 16 Bits - See Note 1)	Class 3	Note 1
103	223	F76	Type Of Fault 1	Class 3	
104	224	F52	Distance To Fault 1	Class 3	
105	225	F53	Line Z1 To Fault 1 (Magnitude)	Class 3	
106	226	F23	Date Of Fault 2 (Upper 16 Bits - See Note 1)		Note 1
107	227	F23	Date Of Fault 2 (Lower 16 Bits - See Note 1)		Note 1
108	228	F22	Time Of Fault 2 (Upper 16 Bits - See Note 1)		Note 1
109	229	F22	Time Of Fault 2 (Lower 16 Bits - See Note 1)		Note 1
110	230	F76	Type Of Fault 2		
111	231	F52	Distance To Fault 2		
112	232	F53	Line Z1 To Fault 2 (Magnitude)		
113	233	F23	Date Of Fault 3 (Upper 16 Bits - See Note 1)		Note 1
114	234	F23	Date Of Fault 3 (Lower 16 Bits - See Note 1)		Note 1
115	235	F22	Time Of Fault 3 (Upper 16 Bits - See Note 1)		Note 1
116	236	F22	Time Of Fault 3 (Lower 16 Bits - See Note 1)		Note 1
117	237	F76	Type Of Fault 3		
118	238	F52	Distance To Fault 3		
119	239	F53	Line Z1 To Fault 3 (Magnitude)		
120	240	F23	Date Of Fault 4 (Upper 16 Bits - See Note 1)		Note 1

ANALOG INPUT (OBJECT 30); ANALOG INPUT CHANGE (OBJECT 32) (CONTINUED)					
(NOTE 5) INDEX WHEN POINT MAPPING IS:		FORMAT	DESCRIPTION	EVENT CLASS ASSIGNED	NOTES
DISABLED	ENABLED				
121	241	F23	Date Of Fault 4 (Lower 16 Bits - See Note 1)		Note 1
122	242	F22	Time Of Fault 4 (Upper 16 Bits - See Note 1)		Note 1
123	243	F22	Time Of Fault 4 (Lower 16 Bits - See Note 1)		Note 1
124	244	F76	Type Of Fault 4		
125	245	F52	Distance To Fault 4		
126	246	F53	Line Z1 To Fault 4 (Magnitude)		
127	247	F23	Date Of Fault 5 (Upper 16 Bits - See Note 1)		Note 1
128	248	F23	Date Of Fault 5 (Lower 16 Bits - See Note 1)		Note 1
129	249	F22	Time Of Fault 5 (Upper 16 Bits - See Note 1)		Note 1
130	250	F22	Time Of Fault 5 (Lower 16 Bits - See Note 1)		Note 1
131	251	F76	Type Of Fault 5		
132	252	F52	Distance To Fault 5		
133	253	F53	Line Z1 To Fault 5 (Magnitude)		
134	254	F23	Date Of Fault 6 (Upper 16 Bits - See Note 1)		Note 1
135	255	F23	Date Of Fault 6 (Lower 16 Bits - See Note 1)		Note 1
136	256	F22	Time Of Fault 6 (Upper 16 Bits - See Note 1)		Note 1
137	257	F22	Time Of Fault 6 (Lower 16 Bits - See Note 1)		Note 1
138	258	F76	Type Of Fault 6		
139	259	F52	Distance To Fault 6		
140	260	F53	Line Z1 To Fault 6 (Magnitude)		
141	261	F23	Date Of Fault 7 (Upper 16 Bits - See Note 1)		Note 1
142	262	F23	Date Of Fault 7 (Lower 16 Bits - See Note 1)		Note 1
143	263	F22	Time Of Fault 7 (Upper 16 Bits - See Note 1)		Note 1
144	264	F22	Time Of Fault 7 (Lower 16 Bits - See Note 1)		Note 1
145	265	F76	Type Of Fault 7		
146	266	F52	Distance To Fault 7		
147	267	F53	Line Z1 To Fault 7 (Magnitude)		
148	268	F23	Date Of Fault 8 (Upper 16 Bits - See Note 1)		Note 1
149	269	F23	Date Of Fault 8 (Lower 16 Bits - See Note 1)		Note 1
150	270	F22	Time Of Fault 8 (Upper 16 Bits - See Note 1)		Note 1
151	271	F22	Time Of Fault 8 (Lower 16 Bits - See Note 1)		Note 1
152	272	F76	Type Of Fault 8		
153	273	F52	Distance To Fault 8		
154	274	F53	Line Z1 To Fault 8 (Magnitude)		
155	275	F23	Date Of Fault 9 (Upper 16 Bits - See Note 1)		Note 1
156	276	F23	Date Of Fault 9 (Lower 16 Bits - See Note 1)		Note 1
157	277	F22	Time Of Fault 9 (Upper 16 Bits - See Note 1)		Note 1
158	278	F22	Time Of Fault 9 (Lower 16 Bits - See Note 1)		Note 1
159	279	F76	Type Of Fault 9		
160	280	F52	Distance To Fault 9		
161	281	F53	Line Z1 To Fault 9 (Magnitude)		
162	282	F23	Date Of Fault 10 (Upper 16 Bits - See Note 1)		Note 1
163	283	F23	Date Of Fault 10 (Lower 16 Bits - See Note 1)		Note 1
164	284	F22	Time Of Fault 10 (Upper 16 Bits - See Note 1)		Note 1
165	285	F22	Time Of Fault 10 (Lower 16 Bits - See Note 1)		Note 1
166	286	F76	Type Of Fault 10		

ANALOG INPUT (OBJECT 30); ANALOG INPUT CHANGE (OBJECT 32) (CONTINUED)					
(NOTE 5) INDEX WHEN POINT MAPPING IS:		FORMAT	DESCRIPTION	EVENT CLASS ASSIGNED	NOTES
DISABLED	ENABLED				
167	287	F52	Distance To Fault 10		
168	288	F53	Line Z1 To Fault 10 (Magnitude)		
169	289	F49	Reserved for MOD 008	Class 1	
170	290	F49	Neutral Displacement	Class 1	
171	291	F49	Ground Directional is Reverse	Class 1	
172	292	F49	Reserved For MOD 010	Class 1	
173	293	F49	User Input I	Class 1	
174	294	F49	User Input J	Class 1	
175	295	F49	User Input K	Class 1	
176	296	F49	User Input L	Class 1	
177	297	F49	User Input M	Class 1	
178	298	F49	User Input N	Class 1	
179	299	F49	User Input O	Class 1	
180	300	F49	User Input P	Class 1	
181	301	F49	User Input Q	Class 1	
182	302	F49	User Input R	Class 1	
183	303	F49	User Input S	Class 1	
184	304	F49	User Input T	Class 1	
185	305	F49	Autoreclose Rate Supervision	Class 1	
186	306	F49	Restricted Earth Fault	Class 1	
187	307	F1	Auto Ranging Power / Energy Multiplier	Class 2	
188	308	F3	Neutral Voltage	Class 2	Note 3
189	309	F3	Last Trip Neutral Voltage	Class 1	

Notes:

1. To support existing SCADA hardware that is not capable of 32-bit data reads, the upper and lower 16-bit portions of all time and date values have been assigned to separate points. To read a date or time, it is necessary to read both the upper and lower 16-bit portions, concatenate these two values to form a 32-bit value and interpret the result in the format associated with the point (i.e., F22 for time, F23 for date).
2. Points which have an assigned event class will generate an event object as a result of any change in the point's value unless otherwise noted.
3. An event object will be generated if the point's value changes by a minimum of 2% of its previous value.
4. An event object will be generated if the system frequency changes by 0.04 Hz or more.
5. There are two defined maps for Analog Output points. The map that is used is specified by the setting of the "DNP Point Mapping" setpoint at Modbus address 10DBh. This setpoint may be set to a value of "Disabled" or "Enabled". When "Disabled", only the preassigned Analog Output points are available beginning at point index 0.

   When "Enabled", the User Map Values are assigned to points 0 through 119 with the preassigned Analog Outputs following beginning with Point Index 120. The value read from points 0 through 119 will depend upon the value programmed into the corresponding User Map Address setpoint (note that programming of these setpoints can only be accomplished via Modbus). Refer to Section 7.3.7: Accessing Data via the User Map on page 7–11 for more information.

Please note that changes in User Map Values never generate event objects.

8.1.1 SAFETY PRECAUTIONS

CAUTION **HAZARD may result if the product is not used for its intended purposes**

CAUTION **Dangerously high voltages are present on the rear terminals of the relay. The voltages are capable of causing DEATH or SERIOUS INJURY. Use extreme caution and follow all safety rules when handling, testing, or adjusting the equipment.**

CAUTION **Do not open the secondary circuit of a live CT, since the high voltage produced is capable of causing DEATH or SERIOUS INJURY, or damage to the CT insulation.**

CAUTION **The relay uses components that are sensitive to electrostatic discharges. When handling the unit, care must be taken to avoid contact with terminals at the rear of the relay.**

CAUTION **Ensure that the control power applied to the relay, and the AC current and voltage input, match the ratings specified on the relay nameplate. Do not apply current to the CT inputs in excess of the Time × Current specified limits.**

CAUTION **Ensure that the Logic Input wet contacts are connected to voltages less than the maximum voltage specification of 300 V DC.**

8.1.2 REQUIREMENTS

The following procedures can be used to verify the proper operation of the 750/760 Feeder Management Relay. Although not a total functional verification, the tests in this chapter check the major operating points. Before commissioning the relay, users should read Chapter 3 which provides important information about wiring, mounting, and safety concerns. One should also become familiar with the relay as described in Chapters 2 and 5.

The test procedures outlined in this section are for field verification that the relay is operational and programmed as required for the application. It is not necessary to field test every characteristic of every relay feature. The various features are implemented in software, which is thoroughly tested at the factory. Our recommendation is to field test all of the input, display, and output hardware, and features which are to be operational in the specific application.

The setpoints considered for the measurement of parameters and the operation of features are shown on the logic diagrams. All settings must be set to the application requirement by the user before beginning the tests. To facilitate testing it is recommended that all functions be initially set to "Disabled". Every feature which will be used in the application should be set to the required function for the test, then returned to "Disabled" at completion. Each feature can then be testing without complications caused by operations of other features. At the completion of all tests each feature is then set as required.

The procedures for testing of common operations will not be repeated in every test. The common features, and the test procedure location are as follows:

- Thermal Exponential Demand Characteristic: Measurement of Current Demand
- Block Interval Demand Characteristic: Measurement of Current Demand
- Rolling Interval Demand Characteristic: Measurement of Current Demand
- Feature Function as "Trip", "Alarm", or "Control": Phase Time Overcurrent 1
- Fixed Delay Timing: Phase Time Overcurrent 1
- Front Panel RESET Key Resetting: Phase Time Overcurrent 1
- Logic Input Resetting: Phase Time Overcurrent 1
- Feature Blocking from Logic Inputs: Phase Time Overcurrent 1
- Element Operation of Output Relays: Phase Time Overcurrent 1
- Number Of Faulted Phases: Phase Instantaneous Overcurrent 1
- Feature Function as "Trip + AR": Autoreclose (760 Only)

We also recommend that the procedures outlined in Section 8.7: Placing the Relay In Service on page 8–56 be performed for all installations to verify proper operation and function of the equipment.

8.1.3 CONVENTIONS

The following conventions are used for the remainder of this chapter:

- It is assumed the VT and CT inputs are wired in accordance with Figure 3–9: Typical Wiring Diagram on page 3–7. With these connections, and assumed where phase angles are noted, a unity power factor current in the primary circuit flows into the relay marked terminal, with no phase shift with respect to the corresponding phase-neutral voltage.
- The phase rotation of the relay test set is ABC.
- A current that lags a voltage has a *positive* phase angle.
- Phase A to neutral voltage is indicated by V_{an} (arrowhead on the "a").
- Phase A to B voltage is indicated by V_{ab} (arrowhead on the "a").
- The sign convention for power parameters is as shown in Figure 6–3: Power Quantity Relationships on page 6–8.
- The actual value display at the beginning of some sections is the display for the measured parameter. All actual values are mentioned with their “path” as a means of specifying where to find the particular message. For instance, the analog input, which in the message structure is located under actual values page **A2 METERING** as the first message under subheading **A/I**, would be written as: **A2 METERING** ⇨⇩ **A/I** ⇨ **A/I**.

8.1.4 TEST EQUIPMENT

Excluding data acquisition testing, tests may be performed using the simulation feature, eliminating the need of external AC voltage and current inputs. System parameters, such as current and voltage information, are entered as setpoints. When placed in simulation mode, the relay suspends reading actual AC inputs and uses the programmed phasors to generate sample values that are placed in the Trace Memory. All metering calculations and logic associated with protection, monitoring, and control, are performed normally, using phasors calculated from the samples placed in the memory instead of phasors generated from the input parameter data acquisition system. The advantage of simulation is that all metering calculations can be verified without the inaccuracies associated with current and voltage sources.

If simulation is not used, the following equipment is necessary to perform any test included in this chapter:

GENERAL PURPOSE:

Three-phase variable AC current and voltage source (V, A, phase, Hz).
Three-phase power multimeter (V, A, phase, Hz, W, var, VA, Wh, varh, PF).
Variable DC mA source.
An accurate timing device and multimeters.

SPECIFIC PURPOSE:

Synchrocheck requires two single phase variable voltage sources with adjustable frequency and phase.
Underfrequency requires a dynamic relay test set with at least two preset modes.
Distance-to-fault: requires a dynamic relay test set with at least three preset modes.
Analog Input Rate of Change requires a DC current generator with the capacity to generate current ramps adjustable for durations from 1 minute to 2 hours, and from 0 to 20 mA.

OPTIONAL:

PC running the 750/760PC software.

8.1.5 INSTALLATION CHECKS

1. Check the relay phase current inputs, specified on the nameplate, are correct for the connected current transformers.
2. Check the relay ground current input, specified on the nameplate, is correct for the connected CT (if applicable).
3. Check that the relay auxiliary voltage, specified on the nameplate, is correct for the supplied voltage.
4. Check that the installed relay agrees with the drawings, particularly the Analog Output range.
5. Check that the external wiring is correct.
6. Check that all grounding terminals of the relay are properly connected to the ground bus.

8.1.6 WIRING DIAGRAMS

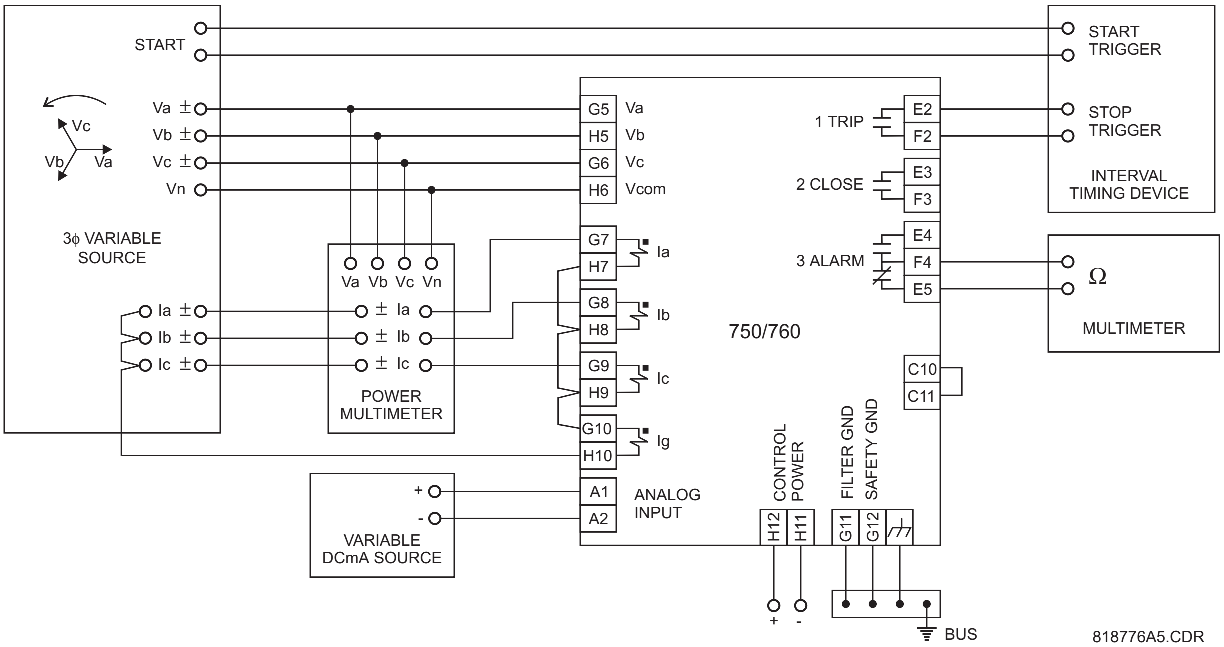

Figure 8–1: RELAY TEST WIRING – WYE CONNECTION

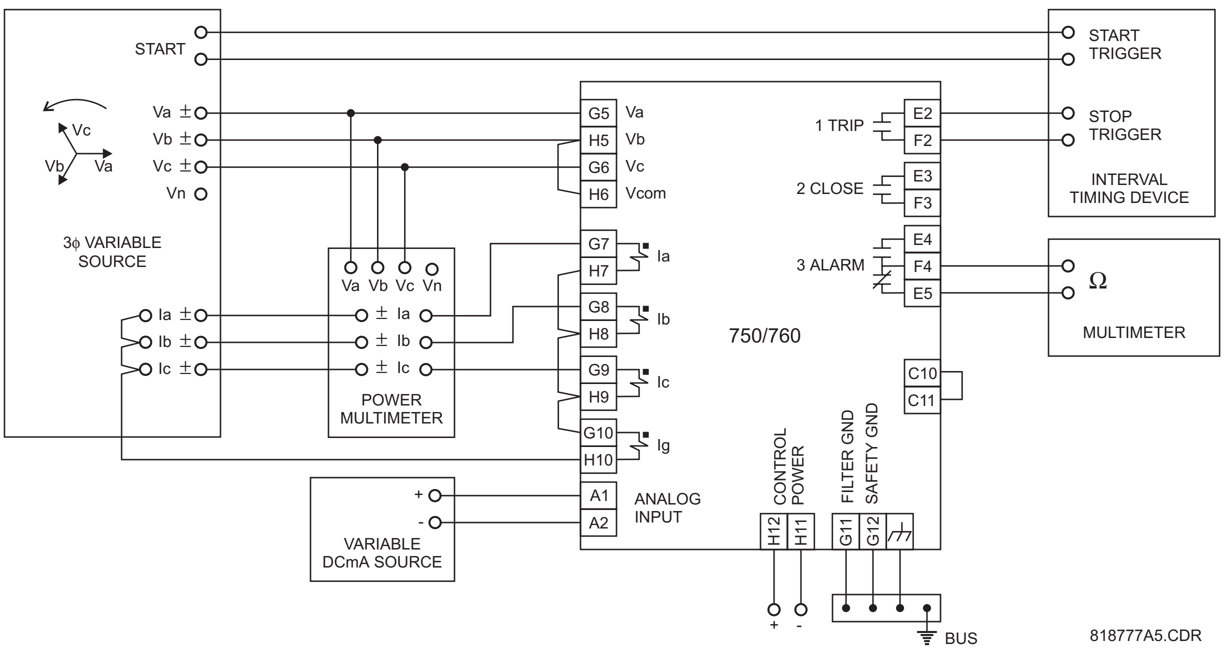

Figure 8–2: RELAY TEST WIRING – DELTA CONNECTION

8.2.1 LOGIC/VIRTUAL INPUTS 1 TO 14

a) ACTUAL VALUES DISPLAY

For these first tests, the **INPUT 1 (14) ASSERTED LOGIC** setpoints should be programmed as "Closed | Von". Under the **A1 STATUS ⇨⇩ VIRTUAL INPUTS ⇨ LOGIC INPUT 1 (14)** subheading,

1. Turn on this input and check that the display shows this state.
2. Turn off this input and check that the display shows this state.

Under the **A1 STATUS ⇨⇩ HARDWARE INPUTS ⇨⇩ CONTACT 1 (14) STATE** subheading:

1. Close the contact connected to this input and check that the display shows this state.
2. Open the contact connected to this input and check that the display shows this state.

b) USER INPUT A SETPOINT SET TO "ALARM"

1. Set all inputs 1 through 14, both contact and virtual, to the de-asserted state.
2. Enter (example) settings under subheading **S3 LOGIC INPUTS ⇨⇩ USER INPUT A**

   USER INPUT A NAME: "User Input A"
   USER INPUT A SOURCE: "Input 1"
   USER INPUT A FUNCTION: "Alarm"
   USER INPUT A RELAYS (3-7): "3----"
   USER INPUT A DELAY: "0.00 s"
3. For **INPUT ASSERTED LOGIC** setpoints set to "Contact Close",
   - 3.1. Check that there is no logic input diagnostic message on the display.
   - 3.2. Set the monitored contact for the logic input programmed in setpoint **USER INPUT A SOURCE** to the closed state. Note that the corresponding virtual input will have no affect.
   - 3.3. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.
   - 3.4. Set the monitored contact for the logic input programmed in setpoint **USER INPUT A SOURCE** to the open state. Again note that the corresponding virtual input will have no affect.
   - 3.5. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.
   - 3.6. Repeat Steps 3.1 through 3.7 for all functions programmed to be asserted by a Contact Close input.
4. For **INPUT ASSERTED LOGIC** setpoints set to "Contact Open":
   - 4.1. Check that there is no logic input diagnostic message on the display.
   - 4.2. Set the monitored contact for the logic input programmed in the **USER INPUT A SOURCE** setpoint to the open state. Note that the corresponding virtual input will have no affect.
   - 4.3. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.
   - 4.4. Set the monitored contact for the logic input programmed in setpoint User Input A Source to the closed state. Again note that the corresponding virtual input will have no affect.
   - 4.5. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.
   - 4.6. Repeat steps 4.3 through 4.7 for all functions programmed to be asserted by a Contact Open input.
5. For **INPUT ASSERTED LOGIC** setpoints set to "Virtual On":
   - 5.1. Check that there is no logic input diagnostic message on the display.
   - 5.2. Set the monitored virtual input for the logic input programmed in setpoint message **USER INPUT A SOURCE** to the on state. Note that the corresponding contact input will have no affect.

5.3. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

5.4. Set the virtual input for the logic input programmed in setpoint message **USER INPUT A SOURCE** to the off state. Again note that the corresponding contact input will have no affect.

5.5. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

5.6. Repeat steps 5.3 through 5.7 for all functions programmed to be asserted by a Virtual On input.

6. For **INPUT ASSERTED LOGIC** setpoints set to "Virtual Off":

6.1. Check that there is no logic input diagnostic message on the display.

6.2. Set the monitored virtual input for the logic input programmed in setpoint message User Input A Source to the off state. Note that the corresponding contact input will have no affect.

6.3. Check that the diagnostic message, either "User Input A" or the name programmed in setpoint **USER INPUT A NAME**, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

6.4. Set the virtual input for the logic input programmed in setpoint message **USER INPUT A SOURCE** to the on state. Again note that the corresponding contact input will have no affect.

6.5. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

6.6. Repeat steps 6.3 through 6.7 for all functions programmed to be asserted by a Virtual Off input.

7. For **INPUT ASSERTED LOGIC** setpoints set to "Closed & Von":

7.1. Check that there is no logic input diagnostic message on the display.

7.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the open state and the virtual input to the off state. Check that no diagnostic message is on the display with the 3 auxiliary LED and relay deactivated.

7.3. Set the monitored contact to the closed state with the virtual input remaining in the off state. Check that no diagnostic message is on the display with the Auxiliary LED and relay deactivated.

7.4. Leave the monitored contact in the closed state and put the virtual input in the on state. Check that the diagnostic message, either "User Input A" or the name programmed in **USER INPUT A NAME**, appears on the display with the Auxiliary LED and relay activated. Check the event recorder that the selected function has been invoked.

7.5. Set the monitored contact to the open state and the virtual input to the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

7.6. Repeat steps 7.3 through 7.7 for all functions programmed to be asserted by a "Closed & Von" input.

8. For **INPUT ASSERTED LOGIC** setpoints set to "Closed & Voff":

8.1. Check that there is no logic input diagnostic message on the display.

8.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the open state and the virtual input to the on state. Check that no diagnostic message is on the display with the 3 auxiliary LED and relay deactivated.

8.3. Set the monitored contact to the closed state with the virtual input remaining in the on state. Check that no diagnostic message is on the display with the Auxiliary LED and relay deactivated.

8.4. Leave the monitored contact in the closed state and put the virtual input in the off state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

8.5. Set the monitored contact to the open state and the virtual input to the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

8.6. Repeat steps 8.3 through 8.7 for all functions programmed to be asserted by a Closed & Voff input.

9. For **INPUT ASSERTED LOGIC** setpoints set to "Open & Von":

9.1. Check that there is no logic input diagnostic message on the display.

9.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the closed state and the virtual input to the off state. Check that no diagnostic message is on the display with the Auxiliary LED and relay deactivated.

9.3. Set the monitored contact to the open state with the virtual input remaining in the off state. Check that no diagnostic message is on the display with the Auxiliary LED and relay deactivated.

9.4. Leave the monitored contact in the open state and put the virtual input in the on state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

9.5. Set the monitored contact to the closed state and the virtual input to the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

9.6. Repeat steps 9.3 through 9.7 for all functions programmed to be asserted by a Open & Von input.

10. For **INPUT ASSERTED LOGIC** setpoints set to "Open & Voff":

10.1. Check that there is no logic input diagnostic message on the display.

10.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the closed state and the virtual input to the on state. Check that no diagnostic message is on the display with the 3 auxiliary LED and relay deactivated.

10.3. Set the monitored contact to the open state with the virtual input remaining in the on state. Check that no diagnostic message is on the display with the Auxiliary LED and relay deactivated.

10.4. Leave the monitored contact in the open state and put the virtual input in the off state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

10.5. Set the monitored contact to the closed state and the virtual input to the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

10.6. Repeat steps 10.3 through 10.7 for all functions programmed to be asserted by a Open & Voff input.

11. For **INPUT ASSERTED LOGIC** setpoints set to "Closed | Von":

11.1. Check that there is no logic input diagnostic message on the display.

11.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the closed state and the virtual input to the off state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

11.3. Leave the monitored contact in the closed state and put the virtual input in the on state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

11.4. Set the monitored contact to the open state and leave the virtual input in the on state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

11.5. Leave the monitored contact in the open state and put the virtual input in the off state. Check that the diagnostic message is removed from the display with the 3 Auxiliary LED and relay deactivated.

11.6. Repeat steps 11.3 through 11.7 for all functions programmed to be asserted by a Closed | Von input.

12. For **INPUT ASSERTED LOGIC** setpoints set to "Closed | Voff":

12.1. Check that there is no logic input diagnostic message on the display.

12.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the closed state and the virtual input to the on state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

12.3. Leave the monitored contact in the closed state and put the virtual input in the off state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

12.4. Set the monitored contact to the open state and leave the virtual input in the off state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

12.5. Leave the monitored contact in the open state and put the virtual input in the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

12.6. Repeat steps 12.3 through 12.7 for all functions programmed to be asserted by a Closed | Voff input.

13. For **INPUT ASSERTED LOGIC** setpoints set to "Open | Von":

13.1. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the open state and the virtual input to the off state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

13.2. Leave the monitored contact in the open state and put the virtual input in the on state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

13.3. Set the monitored contact to the closed state and leave the virtual input in the on state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

13.4. Leave the monitored contact in the closed state and put the virtual input in the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

13.5. Repeat steps 13.3 through 13.7 for all functions programmed to be asserted by a Open | Von input.

14. For **INPUT ASSERTED LOGIC** setpoints set to "Open | Voff":

14.1. Check that there is no logic input diagnostic message on the display.

14.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the open state and the virtual input to the on state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

14.3. Leave the monitored contact in the open state and put the virtual input in the off state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

14.4. Set the monitored contact to the closed state and leave the virtual input in the off state. Check that the diagnostic message, the Auxiliary LED and relay remain activated.

14.5. Leave the monitored contact in the closed state and put the virtual input in the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

14.6. Repeat steps 14.3 through 14.7 for all functions programmed to be asserted by a Open| Voff input.

15. For **INPUT ASSERTED LOGIC** setpoints set to "Closed X Von":

15.1. Check that there is no logic input diagnostic message on the display.

15.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the closed state and the virtual input to the off state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

15.3. Leave the monitored contact in the closed state and put the virtual input in the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

15.4. Set the monitored contact to the open state and leave the virtual input in the on state. Check that the diagnostic message appears on the display with the Auxiliary LED and relay activated.

15.5. Leave the monitored contact in the open state and put the virtual input in the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

15.6. Repeat steps 15.3 through 15.7 for all functions programmed to be asserted by a Closed X Von input.

16. For **INPUT ASSERTED LOGIC** setpoints set to "Closed X Voff":

16.1. Check that there is no logic input diagnostic message on the display.

16.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the closed state and the virtual input to the on state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

16.3. Leave the monitored contact in the closed state and put the virtual input in the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

16.4. Set the monitored contact to the open state and leave the virtual input in the off state. Check that the diagnostic message appears on the display with the Auxiliary LED and relay activated.

16.5. Leave the monitored contact in the open state and put the virtual input in the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

16.6. Repeat steps 16.3 through 16.7 for all functions programmed to be asserted by a Closed X Voff input.

17. For **INPUT ASSERTED LOGIC** setpoints set to Open X Von:

17.1. Check that there is no logic input diagnostic message on the display.

17.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the open state and the virtual input to the off state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

17.3. Leave the monitored contact in the open state and put the virtual input in the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

17.4. Set the monitored contact to the closed state and leave the virtual input in the on state. Check that the diagnostic message appears on the display with the Auxiliary LED and relay activated.

17.5. Leave the monitored contact in the closed state and put the virtual input in the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

17.6. Repeat steps 17.3 through 17.7 for all functions programmed to be asserted by a Open X Von input.

18. For **INPUT ASSERTED LOGIC** setpoints set to "Open X Voff":

18.1. Check that there is no logic input diagnostic message on the display.

18.2. Set the monitored contact for the logic input programmed in setpoint message User Input A Source to the open state and the virtual input to the on state. Check that the diagnostic message, either User Input A or the name programmed in setpoint User Input A Name, appears on the display with the Auxiliary LED and relay activated. Check in the Event Recorder that the selected function has been invoked.

18.3. Leave the monitored contact in the open state and put the virtual input in the off state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

18.4. Set the monitored contact to the closed state and leave the virtual input in the off state. Check that the diagnostic message appears on the display with the Auxiliary LED and relay activated.

18.5. Leave the monitored contact in the closed state and put the virtual input in the on state. Check that the diagnostic message is removed from the display with the Auxiliary LED and relay deactivated.

18.6. Repeat steps 18.3 through 18.7 for all functions programmed to be asserted by a Open X Voff input.

c) USER INPUT A FUNCTION SET TO "CONTROL"

The procedure to test this element is identical to that outlined for User Input A Function setpoint set to Alarm, with the following exceptions: there will not be any diagnostic message or Alarm LED.

d) USER INPUT A FUNCTION SET TO "TRIP"

The procedure to test this element is identical to that outlined for User Input A Function setpoint set to Alarm, with the following exceptions. The Trip Relay and LED will activate along with the Auxiliary Relay and LED. At the end of each test, a reset must be performed in order to clear the trip diagnostic message and Trip LED.

8.2.2 VIRTUAL INPUTS 15 TO 20

Follow the Virtual On and Virtual Off Input Asserted Logic procedures outlined for Logic/Virtual Inputs 1 to 14 in the previous section.

8.2.3 OUTPUT RELAYS

1. Enter the following settings under the **S8 TESTING ⇨ OUTPUT RELAYS** subheading:

   FORCE OUTPUT RELAYS FUNCTION: "Enabled"
   FORCE 1 TRIP RELAY: "De-energized"
   FORCE 2 CLOSE RELAY: "De-energized"
   FORCE 3 AUXILIARY RELAY: "De-energized"
   FORCE 4 AUXILIARY RELAY: "De-energized"
   FORCE 5 AUXILIARY RELAY: "De-energized"
   FORCE 6 AUXILIARY RELAY: "De-energized"
   FORCE 7 AUXILIARY RELAY: "De-energized"
   FORCE 8 SELF-TEST RELAY: "De-energized"
   FORCE SOLID STATE OUTPUT: "De-energized"
2. Using a multimeter, check that all output relays are de-energized (i.e. N.O. contacts open, N.C. contacts closed).
3. Make the following setting change: **S8 TESTING ⇨ OUTPUT RELAYS ⇨⇩ FORCE 1 TRIP RELAY**: "Energized".
4. Check that the Trip output is energized (i.e. N.O. contacts closed), and the Trip LED is illuminated.
5. Make the following setting change: **S8 TESTING ⇨ OUTPUT RELAYS ⇨⇩ FORCE 1 TRIP RELAY**: "De-energized".
6. Repeat Steps 3 through 5 for Output Relays 2 through 8 inclusive.
7. Observing polarity, connect a minimum 5 V DC source in series with a limiting resistor that will permit a minimum current of 100 mA, in series with the Solid State output. Observing polarity, connect a DC voltmeter across the limiting resistor. Check there is no voltage displayed on the voltmeter.
8. Change setting to: **S8 TESTING ⇨ OUTPUT RELAYS ⇨⇩ FORCE SOLID STATE OUTPUT**: "Energized".
9. Check that a voltage has appeared on the voltmeter. Turn off the source and disconnect the test wiring.
10. Change setting to: **S8 TESTING ⇨ OUTPUT RELAYS ⇨⇩ FORCE SOLID STATE OUTPUT**: "De-energized".
11. Change setting to: **S8 TESTING ⇨ OUTPUT RELAYS ⇨ FORCE OUTPUT RELAYS FUNCTION**: "Disabled".

8.3.1 CURRENT METERING

a) PHASE CURRENT INPUTS

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

For 1 A CTs: ±0.01 A for 0.01 to 1.99 A; ±0.2 A for 2.00 to 20.00 A
For 5 A CTs: ±0.05 A for 0.05 to 9.99 A; ±1.0 A for 10.00 to 100.00 A

Use the following procedure to test Phase and Neutral Current Inputs:

1. The relevant actual values displays are located under subheading **A2 METERING ⇨⇩ CURRENT** and are:

   A: B: C: (Magnitude)
   AVERAGE CURRENT: (Magnitude)
   PHASE A CURRENT: (Phasor)
   PHASE B CURRENT: (Phasor)
   PHASE C CURRENT: (Phasor)
   NEUTRAL CURRENT: (Phasor)
   POS SEQ CURRENT: (Phasor)
   NEG SEQ CURRENT: (Phasor)
   ZERO SEQ CURRENT: (Phasor)

2. Inject 1-phase current of various values into the relay phase current input one phase at a time, and observe the magnitude. Note that the average, positive-sequence, negative-sequence and zero-sequence magnitudes are 1/3 of the phase current magnitude for this test. The neutral current will match the phase current magnitude.
3. Inject 3-phase current of various values and angles into the relay phase current input and note the measured current phasors and symmetrical components.

Use the following procedure for Ground and Sensitive Ground Current Inputs:

The relevant actual values displays are located under subheading **A2 METERING ⇨⇩ CURRENT** as follows:

GND CURRENT: (Phasor)
SENSTV GND CURRENT: (Phasor)

1. Inject current of various values into the relay ground input, Terminals G10–H10, and note the current.
2. Inject current of various values into the relay sensitive ground input, Terminals G3–H3, and note the current.

b) PERCENT OF LOAD-TO-TRIP

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Expected Accuracy: equivalent to that of phase current inputs

The relevant actual values displays are shown below:

A2 METERING ⇨⇩ CURRENT ⇨⇩ % OF LOAD-TO-TRIP

NOTE

Percent of load-to-trip is calculated from the phase with the highest current reading. It is the ratio of this current to the lowest pickup setting among the phase time and instantaneous overcurrent protection features. If all of these features are disabled, the value displayed will be "0".

1. Inject current of various values into Phase A.
2. Verify that percent load-to-trip is calculated as the correct percentage of the most sensitive operational Phase Overcurrent element and displayed.
3. Repeat for phases B and C.

8.3.2 VOLTAGE METERING

a) BUS VOLTAGE

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Phase-neutral voltages: ±0.68 V for 50 to 130 V; ±2.18 V for other voltages within specified limits
Phase-phase voltages (V_{ab} and V_{cb}): ±0.68 V for 50 to 130 V; ±2.18 V for all other voltages within the specified limits.
Phase-phase voltages (calculated V_{ac}): ±1.36 V for 50 to 130 V; ±4.36 V for other voltages within the specified limits.

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The procedure for testing the metered bus voltage is as follows:

1. The relevant actual values displays are located under subheading **A2 METERING ⇨⇩ VOLTAGE** and are:

   AB: BC: CA: (Magnitude)
   AVERAGE LINE VOLTAGE: (Magnitude)
   AN: BN: CN: (Magnitude) (not available when connected Delta)
   AVERAGE PHASE VOLTAGE: (Magnitude) (not available when connected Delta)
   LINE A-B VOLTAGE: (Phasor)
   LINE B-C VOLTAGE: (Phasor)
   LINE C-A VOLTAGE: (Phasor)
   PHASE A-N VOLTAGE: (Phasor) (not available when connected Delta)
   PHASE B-N VOLTAGE: (Phasor) (not available when connected Delta)
   PHASE C-N VOLTAGE: (Phasor) (not available when connected Delta)
   POS SEQ VOLTAGE: (Phasor)
   NEG SEQ VOLTAGE: (Phasor)
   ZERO SEQ VOLTAGE: (Phasor)
   NEUTRAL (3VO) VOLTAGE: (Phasor)

2. Inject 1-phase voltage of various values into the relay bus voltage input one phase at a time, and observe the magnitude. Note that for Wye VTs the positive sequence, negative sequence and zero sequence magnitudes are 1/3 of the phase voltage magnitude for this test. For Delta VTs the zero sequence voltage will be displayed as 0. The positive sequence and negative sequence magnitudes will be $\sqrt{3}$ of the line voltage magnitude.

3. Inject 3-phase voltage of various values and angles into the relay bus voltage input and note the measured voltage phasors & symmetrical components. For Delta VTs the zero sequence voltage will be shown as 0.

b) BUS VOLTAGE FREQUENCY

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Frequency: ±0.02 Hz of injected value within the range 16.00 to 90.00 Hz
Undervoltage Inhibit: 10 V secondary

The procedure for testing the metered bus voltage frequency is as follows:

1. The relevant actual values display is located as follows: **A2 METERING ⇨⇩ FREQ ⇨⇩ SYSTEM FREQ**.
2. Inject a voltage of nominal value at nominal frequency into Phase A. Check that the frequency is measured and displayed.
3. Check the undervoltage inhibit level by slowly reducing the voltage until the frequency is no longer measured, and "0.00 Hz" is displayed.
4. Return the voltage to nominal. Adjust the frequency above and below nominal, and note the frequency measured by the relay.

The procedure for testing the metered frequency decay rate is as follows:

1. The relevant actual values display is located as follows: **A2 METERING ⇨⇩ FREQ ⇨⇩ FREQ DECAY RATE**
2. Vary the frequency of the phase A voltage and verify the measured frequency decay rate.

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c) SYNCHRO VOLTAGE AND FREQUENCY

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Voltage: ±0.68 V for 50 to 130 V
Frequency: ±0.02 Hz of injected value within the range 16.00 to 90.00 Hz

The procedure for testing the metered synchro voltage and frequency is as follows:

1. The relevant actual values displays are located under subheading **A2 METERING ⇨⇩ SYNCHRO VOLTAGE** and are:

   SYNCHRO VOLTAGE: (Phasor)
   SYNCHRO FREQ:
   SYNCHRO DELTA ∆F: ∆V: ∆F:

2. Inject voltage of various magnitudes and frequencies into the line voltage input and verify the displays.

8.3.3 POWER METERING

a) REAL POWER AND WATTHOURS

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Real Power: ±1% of full scale at currents 5 to 199% of nominal and voltages from 50 to 130 V
Watthours: ±2% of full scale at currents 5 to 199% of nominal and voltages from 50 to 130 V

The procedure for testing the metered real power and watthours is as follows.

1. The relevant actual values displays are located as shown below:

   A2 METERING ⇨⇩ PWR ⇨⇩ 3Φ REAL PWR:
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦA REAL PWR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦB REAL PWR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦC REAL PWR: (not available when connected Delta)

   A2 METERING ⇨⇩ ENERGY ⇨⇩ POSITIVE WATTHOURS:
   A2 METERING ⇨⇩ ENERGY ⇨⇩ NEGATIVE WATTHOURS:

2. To reduce the time required for watthour measurements, set the input VT and CT ratios to high values. Inject 3-phase voltage and current of various values and angles into the relay. Note that real power is measured and displayed.
3. Maintain voltage and current at various settings for a time sufficient to achieve a minimum of 20 MWh for each test interval. Check that watthours is measured and displayed. Note that watthours for load in the positive direction and negative directions are stored in separate registers. The procedure should be performed for loads in each direction.

b) REACTIVE POWER AND VARHOURS

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Reactive Power: ±1% of full scale, currents 5 to 199% of nominal, voltages 50 to 130 V
Varhours: ± 2% of full scale, currents 5 to 199% of nominal, voltages 50 to 130 V

The procedure for metered reactive power and energy is as follows:

1. The relevant actual values displays are shown below:

   A2 METERING ⇨⇩ PWR ⇨⇩ 3Φ REACTIVE PWR:
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦA REACTIVE PWR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦB REACTIVE PWR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦC REACTIVE PWR: (not available when connected Delta)

   A2 METERING ⇨⇩ ENERGY ⇨⇩ POSITIVE VARHOURS:
   A2 METERING ⇨⇩ ENERGY ⇨⇩ NEGATIVE VARHOURS:

2. To reduce the time required for varhour measurements, set the input VT and CT ratios to high values. Inject 3-phase voltage and current of various values and angles into the relay. Note that reactive power is measured and displayed.
3. Maintain voltage and current at various settings for a time sufficient to achieve a minimum of 20 Mvarh for each test interval. Check that varhours are measured and displayed. Note that varhours for load in the positive direction and negative directions are stored in separate registers. The procedure should be performed for loads in each direction.

c) APPARENT POWER

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Apparent Power: ±1% of full scale, currents 5 to 199% of nominal, voltages 50 to 130 V

The procedure for metered apparent power is as follows:

1. The relevant actual values displays are shown below:

   A2 METERING ⇨⇩ PWR ⇨⇩ 3Φ APPARENT PWR:
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦA APPARENT PWR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦB APPARENT PWR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦC APPARENT PWR: (not available when connected Delta)

2. Inject 3-phase voltage and current of various values and angles into the relay. Note that reactive power is measured and displayed.

d) POWER FACTOR

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Power Factor: ±0.02 of injected values, currents 5 to 199% of nominal, voltages 50 to 130 V

The procedure for metered apparent power is as follows:

1. The relevant actual values displays are shown below:

   A2 METERING ⇨⇩ PWR ⇨⇩ 3Φ PWR FACTOR:
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦA PWR FACTOR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦB PWR FACTOR: (not available when connected Delta)
   A2 METERING ⇨⇩ PWR ⇨⇩ ΦC PWR FACTOR: (not available when connected Delta)

2. Inject 3-phase voltage and current of various values and angles into the relay. Verify that the power factor is measured and displayed correctly for each phase. Note that:

$$\text{3-phase PF} = \frac{\text{total 3-phase real power}}{\text{total 3-phase apprarent power}} \quad \textbf{(EQ 8.1)}$$

8.3.4 DEMAND METERING

a) CURRENT DEMAND

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Expected Accuracy: ±2.0% of full scale

To reset the "Last Demand" reading to 0 between tests, cycle the relay power source off and then on.

Block Interval and Rolling demand measurement types must be tested in synchronization with the internal clock. Both of these measurements start with the first interval of the day at 12:00:00.000 midnight. To synchronize, preset the injection levels, then turn the current off. Select the relay display (not the 750/760PC software) to **A1 STATUS ⇨⇩ CLOCK ⇨⇩ CURRENT TIME**. Apply the test current when the clock is at the beginning of an interval measurement period, as determined by the **TIME INTERVAL** setpoint for the element.

The relevant actual values displays are shown below:

A2 METERING ⇨⇩ DMND ⇨ PHASE A CURRENT ⇨ LAST PHASE A CURRENT DMND
A2 METERING ⇨⇩ DMND ⇨ PHASE A CURRENT ⇨⇩ MAX PHASE A CURRENT DMND
A2 METERING ⇨⇩ DMND ⇨ PHASE A CURRENT ⇨⇩ MAX PHASE A CURRENT DATE
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE A CURRENT ⇨⇩ MAX PHASE A CURRENT TIME
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE B CURRENT ⇨ LAST PHASE B CURRENT DMND
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE B CURRENT ⇨⇩ MAX PHASE B CURRENT DMND
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE B CURRENT ⇨⇩ MAX PHASE B CURRENT DATE
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE B CURRENT ⇨⇩ MAX PHASE B CURRENT TIME
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE C CURRENT ⇨ LAST PHASE C CURRENT DMND
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE C CURRENT ⇨⇩ MAX PHASE C CURRENT DMND
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE B CURRENT ⇨⇩ MAX PHASE C CURRENT DATE
A2 METERING ⇨⇩ DMND ⇨⇩ PHASE B CURRENT ⇨⇩ MAX PHASE C CURRENT TIME

For Thermal Exponential Demand (for example, a response time setting of 5 minutes), the procedure is as follows:

1. Clear demand data registers by setting **S1 RELAY SETUP ⇨⇩ CLEAR DATA ⇨⇩ CLEAR MAX DMND DATA** to "Yes".
2. Inject a fixed value of current into Phase A. Record the measured current demand at 1, 2, 3, 4, 5 and 10 minutes after the application of current. The demand, in percent of injected current, should be as follows:

TIME (MIN.)	1	2	3	4	6	10
Demand (% of Input)	36.9	60.1	74.8	84.1	90.0	99.0

3. For other response time settings, multiply the Row 1 times above by [selected response time / 5].
4. Check that the maximum current demand, including date and time of occurrence, is recorded and displayed.
5. Repeat Steps 2 to 4 for Phases B and C.

For Block Interval Demand: (for example, a time interval setting of 5 minutes), the procedure is as follows:

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1. Repeat Steps 2 to 5 above.
2. Record the measured current demand at 1, 2, 3, 4, 5 and 6 minutes after the application of current. The demand, in percent of injected current, should be as follows:

TIME (MIN.)	1	2	3	4	5	6
Demand (% of Input)	0.0	0.0	0.0	0.0	100.0	100.0

For Rolling Demand (for example, a time interval setting of 5 minutes), the procedure is as follows:

1. Repeat Steps 2 to 5 above from Thermal Exponential Demand above.
2. Record the measured current demand at 1, 2, 3, 4, 5 and 6 minutes after the application of current. The demand, in percent of injected current, should be as follows:

TIME (MIN.)	1	2	3	4	5	6
Demand (% of Input)	20.0	40.0	60.0	80.0	100.0	100.0

b) REAL POWER DEMAND

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Expected Accuracy: ±2.0% of full scale

The relevant actual values displays are shown below:

A2 METERING ⇨⇩ DMND ⇨⇩ REAL PWR ⇨ LAST REAL PWR DMND
A2 METERING ⇨⇩ DMND ⇨⇩ REAL PWR ⇨⇩ MAX REAL PWR DMND
A2 METERING ⇨⇩ DMND ⇨⇩ REAL PWR ⇨⇩ MAX REAL PWR DATE
A2 METERING ⇨⇩ DMND ⇨⇩ REAL PWR ⇨⇩ MAX REAL PWR TIME

Follow the procedure in Current Demand on page 8–13, except that the injected and monitored parameter is watts.

c) REACTIVE POWER DEMAND

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Expected Accuracy: ±2.0% of full scale

The relevant actual values displays are shown below:

A2 METERING ⇨⇩ DMND ⇨⇩ REACTIVE PWR ⇨ LAST REACTIVE PWR DMND
A2 METERING ⇨⇩ DMND ⇨⇩ REACTIVE PWR ⇨⇩ MAX REACTIVE PWR DMND
A2 METERING ⇨⇩ DMND ⇨⇩ REACTIVE PWR ⇨⇩ MAX REACTIVE PWR DATE
A2 METERING ⇨⇩ DMND ⇨⇩ REACTIVE PWR ⇨⇩ MAX REACTIVE PWR TIME

Follow the procedure in Current Demand on page 8–13, except that the injected and monitored parameter is vars.

d) APPARENT POWER DEMAND

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Expected Accuracy: ±2.0% of full scale

The relevant actual values displays are shown below:

A2 METERING ⇨⇩ DMND ⇨⇩ APPARENT PWR ⇨ LAST APPARENT PWR DMND
A2 METERING ⇨⇩ DMND ⇨⇩ APPARENT PWR ⇨⇩ MAX APPARENT PWR DMND
A2 METERING ⇨⇩ DMND ⇨⇩ APPARENT PWR ⇨⇩ MAX APPARENT PWR DATE
A2 METERING ⇨⇩ DMND ⇨⇩ APPARENT PWR ⇨⇩ MAX APPARENT PWR TIME

Follow the procedure in Current Demand on page 8–13, except that the injected and monitored parameter is VA.

8.3.5 ANALOG INPUT METERING

For these tests, refer to the figures on page 8–3 for test connections. The expected accuracy is as follows:

Expected Accuracy: ±1.0% of full scale

The relevant actual values displays are shown below:

A2 METERING ⇨⇩ A/I ⇨ A/I
A2 METERING ⇨⇩ A/I ⇨⇩ A/I (/MIN)
A2 METERING ⇨⇩ A/I ⇨⇩ A/I (/HOUR)

The procedure for testing the Analog Input metering is shown below:

1. Inject steady values of DC current (in mA) of various values into relay terminals A1(+) and A2(–). Verify that the analog input is correctly measured and displayed in the **A/I** value.
2. Inject a fixed rate of ramping DC current (in mA) of various values into relay terminals A1(+) and A2(–) for at least 2 minutes. At the end of this time, verify that the analog input is correctly measured and displayed in the **A/I (/MIN)** value.
3. Inject a fixed rate of ramping DC current (in mA) of various values into relay terminals A1(+) and A2(–) for at least 2 hours. At the end of this time, verify that the analog input is correctly measured and displayed in the **A/I (/HOUR)** value.

8.4.1 SETPOINT GROUPS

The Active setpoint group is indicated by a continuously illuminated LED, and the Edit group by an intermittently illuminated LED on the relay faceplate. When changing settings for testing be careful to check the correct group is adjusted and selected as the active group.

Verify that settings in a particular setpoint group are being used by the protection elements when the particular group is selected to be active. There are three alternative strategies that can be used to provide this verification:

- Test any one protection element that has different settings in different groups
- Test a random selection of protection elements in different groups
- Test all protection elements that are not disabled in every group

Once one of the above strategies is selected, the following procedures are used to test protection elements.

8.4.2 PHASE OVERCURRENT

a) PHASE TOC 1

For these tests, refer to the figures on page 8–3 for test connections.

NOTE: The following procedures, other than the check for Linear Reset Timing, are based on the "Instantaneous" reset time characteristic. If the “Linear” reset time characteristic is required, ensure that there is sufficient time between test current injections, or cycle relay power OFF and ON to discharge the energy measurement accumulator to 0.

The following procedure checks Pickup with one phase for operation:

1. Inject current at a level below the pickup level into Phase A.
2. Slowly increase the current until the Pickup LED comes on. Note the pickup value.
3. Slowly reduce the current until the Pickup LED goes out. Note the dropout level, which should be 2% of CT less than pickup when pickup ≤ CT or 97 to 98% of pickup when pickup > CT.
4. Repeat Steps 1 through 3 for Phases B and C.

The following procedure checks indications and operations caused by a Trip function, with front panel RESET key resetting:

1. Inject current to cause a pickup and wait until the element times to Trip.
2. Check that the Trip and Message LEDs are flashing, the Last Trip message is displayed, and the Output Relay 1 and any others programmed to operate (as well as their associated LED indicators) operate.
3. Slowly reduce the current until the Pickup LED goes out. Check that the Trip and Message LEDs are flashing, and that the Output Relay 1 and any others programmed to operate (as well as their associated LEDs) reset.
4. Press the front panel RESET key. Check that the Trip and Message LEDs go off, and the Last Trip message is no longer displayed. Turn current off.

The following procedure checks indications and operations caused by a Trip function, with Logic Input resetting:

1. Ensure that the reset logic input control function has been assigned to a logic input.
2. Inject current to cause a pickup and wait until the element times to Trip.
3. Check that the Trip and Message LEDs are flashing, the Last Trip message is displayed, and the Output Relay 1 and any others programmed to operate (as well as their associated LED indicators) operate.
4. Slowly reduce the current until the Pickup LED goes out. Check that the Trip and Message LEDs are flashing, and that the Output Relay 1 and any others programmed to operate (as well as their associated LEDs) reset.
5. Assert a logic input to provide a reset. Check that the Trip and Message LEDs are now off, and the Last Trip message is no longer displayed. Turn current off.

The following procedure checks indications and operations caused by an Alarm function:

1. Inject current to cause a pickup and wait until the element times to Alarm.
2. Check that the Alarm and Message LEDs are flashing, the Active Alarm message is displayed, and any output relays programmed to operate (as well as their associated LEDs) operate.

3. Slowly reduce the current until the Pickup LED goes out.
4. Verify that the Alarm and Message LEDs go off, and that any output relays programmed to operate (as well as their associated LEDs) reset, and the Active Alarm message is no longer displayed.
5. Turn current off.

The following procedure checks indications and operations caused by a Control function:

1. Inject current to cause a pickup and wait until the element times-out. Check that any output relays programmed to operate (as well as their associated LED indicators) operate.
2. Slowly reduce the current until the Pickup LED goes out. Check that any output relays programmed to operate (as well as their associated LED indicators) reset.
3. Turn current off.

The following procedure checks indications and operations caused by a Latched Alarm function, with RESET key resetting:

1. Inject current to cause a pickup and wait until the element times to Alarm.
2. Check that the Alarm and Message LEDs are flashing, the Active Alarm message is displayed, and any output relays programmed to operate (as well as their associated LEDs) operate.
3. Slowly reduce the current until the Pickup LED goes out. Check that the Alarm and Message LEDs are flashing, and that any output relays programmed to operate (as well as their associated LEDs) reset.
4. Press the front panel RESET key. Check that the Alarm and Message LEDs go off, and the Active Alarm message is no longer displayed.
5. Turn current off.

The following procedure checks blocking From Logic Inputs. Note that this procedure is different for Phase TOC2; see the next section for details.

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Phase Time 1". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Phase O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

The following procedure checks timing:

1. Connect the Stop Trigger.
2. Preset the injection current level to 2.0 x pickup. Turn the current off, and reset the timer.
3. Inject the preset current into Phase A and note the measured delay time. Check this time against the time established by the settings and reset the timer.
4. Preset the injection current level to 4.0 x pickup. Turn the current off, and reset the timer.
5. Inject the preset current into Phase B and note the measured delay time. Check this time against the time established by the settings and reset the timer.
6. Preset the injection current level to 7.0 x pickup. Turn the current off, and reset the timer.
7. Inject the preset current into Phase C and note the measured delay time. Check this time against the time established by the settings.
8. Turn current off and disconnect the Stop Trigger.

The following procedure checks Linear Reset Timing:

1. To confirm that the TOC element is using linear reset timing, if so programmed, inject a current above the pickup level for approximately half the time required to Trip.
2. Turn the current off, reset the interval timer, and then re-apply immediately.
3. The time-to-trip should be much less than the trip-time established by the settings.

The following procedure checks the voltage restrained Phase TOC function:

1. Apply three-phase nominal voltage to the relay.

2. Inject current below the pickup level into Phase A and slowly increase until the Pickup LED is on. Note the pickup value is the pickup current of the Curve in use.
3. Slowly reduce the current into Phase A until the Pickup LED goes off and note the dropout level, which should be 2% of CT less than pickup when pickup ≤ CT or 97 to 98% of pickup when pickup > CT.
4. Reduce the current to zero.
5. Repeat Steps 2 to 4 for current injected into Phases B and C.
6. Set all input voltages to 0 and slowly increase Phase A current until the Pickup LED comes on. Check that this current is 9 to 11% of the measured full voltage pickup current.
7. Increase input voltage V_{ab} until the Pickup LED goes out. This should be at 9 to 11% of the nominal phase-phase voltage. This test establishes the lower knee of the operating characteristic.
8. With the Pickup LED still off, increase voltage V_{ab} to 60% of the nominal phase-phase voltage.
9. Increase the Phase A current until the Pickup LED comes on. This should be at 59 to 61% of the full voltage measured pickup current.
10. With the Pickup LED still off, increase voltage V_{ab} to 130% of nominal.
11. Increase Phase A current to 90% of normal pickup and hold this value. Slowly decrease V_{ab} until the Pickup LED just comes on. This should be at 89 to 91% of nominal V_{ab}. This establishes the upper knee of the characteristic, and shows the pickup is not altered above 90% voltage.
12. Reduce current and voltages to 0.
13. Repeat Steps 6 through 12 for current injected in Phase B and controlling voltage V_{cb}.
14. Repeat Steps 6 through 12 for current injected in Phase C and controlling voltage V_{ca}.

To check trip timing with voltage restraint, set the input voltage to a given level, establishing a new pickup current, and then following the procedure outlined earlier under Timing.

b) PHASE TOC 2

The procedure to test this element is identical to that for Phase TOC 1, except for the blocking from logic inputs, in which case the following procedure should be used:

1. Inject current to cause a Pickup.
2. Assert a logic input to provide a "Block Phase Time 2". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Phase O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

c) PHASE IOC 1

The procedure to test this element is identical for Phase TOC 1, except for the procedures below. Pickup, indication and operation are subject to the "phases required for operation" test, but not subject to the "linear reset timing" and "voltage restrained Phase TOC" tests.

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The following procedure checks pickup with two phases for operation:

1. Inject current into Phase B at 150% of pickup.
2. Inject current at a level below the pickup level into Phase A.
3. Slowly increase the Phase A current until the Pickup LED comes on and note the pickup value.
4. Slowly reduce the Phase A current until the Pickup LED goes out. Note the dropout level, which should be 2% of CT less than pickup when pickup ≤ CT or 97 to 98% of pickup when pickup > CT.
5. Repeat Steps 1 through 4 for phase pair B and C and phase pair C and A.

The following procedure checks pickup with three phases for operation:

1. Inject current into Phases B and C at 150% of pickup.
2. Inject current at a level below the pickup level into Phase A.
3. Slowly increase the Phase A current until the Pickup LED comes on and note the pickup value.

4. Slowly reduce the Phase A current until the Pickup LED goes out and note the dropout level, which should be 2% of CT less than pickup when pickup ≤ CT, or 97 to 98% of pickup when pickup > CT.
5. Repeat Steps 1 through 4 for current at 150% in Phases C and A and adjusted in B.
6. Repeat Steps 1 through 4 for current at 150% in Phases B and A and adjusted in C.

The following procedure checks the blocking from logic inputs:

1. Inject current into the required number of phases to cause a pickup.
2. Assert a logic input to provide a "Block Phase Inst 1". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Phase O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

The following procedure checks Phase IOC 1 timing:

1. Connect the Stop Trigger to the interval timer.
2. Preset the current source to a minimum of 110% of pickup current, then turn the current off and reset the timer.
3. Inject the preset current into the required number of phases and note the delay time, then reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals.
5. Reset the relay and disconnect the “Stop Trigger.”

d) PHASE IOC 2

The procedures to test this element are identical to those outlined for Phase IOC 1 above, with the exception of the blocking from logic inputs check, which is performed as follows:

1. Inject current into the required number of phases to cause a pickup.
2. Assert a logic input to provide a "Block Phase Inst 2" and verify the Pickup LED immediately turns off.
3. Repeat Steps 1 and 2 for logic inputs "Block Phase O/C", "Block All O/C" and “Block 1 TRIP Relay” as required.

e) PHASE DIRECTIONAL OC

A plot of the operating characteristic of the phase directional feature for various settings of MTA for Phase A is shown below. Other characteristics for specific MTA settings can be deduced from this diagram. Note that the diagram is plotted for the phase current referred to both the system phase-neutral voltage and the polarizing voltage used for Phase A (the polarizing voltages for Phases B and C are Vca and Vab respectively).

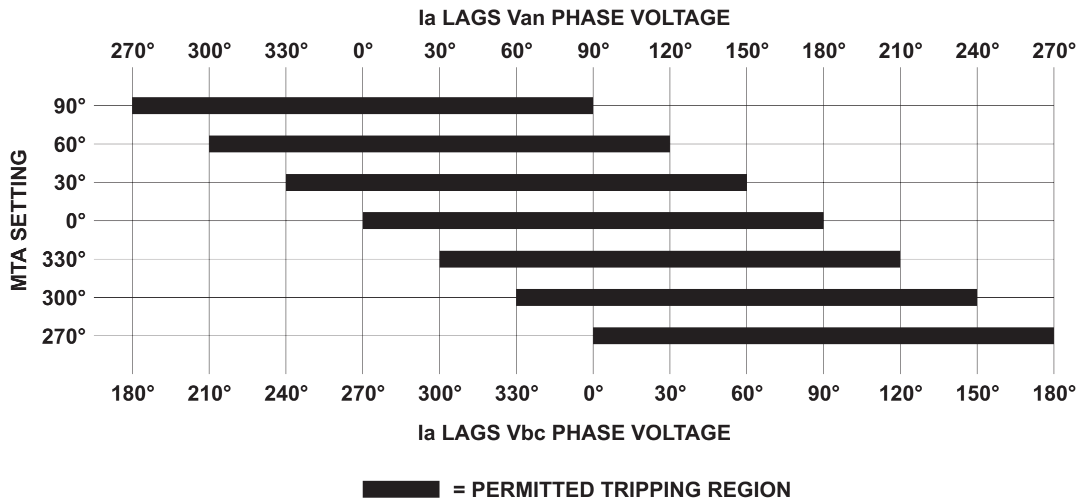

Figure 8–3: PHASE DIRECTIONAL – PHASE A FORWARD OPERATING REGIONS

NOTE

The following descriptions present angles with reference to the polarizing voltage and assume an MTA setting of 180°. For an MTA setting other than 180° alter the noted angles to those established by the programmed MTA.

For forward tripping and Wye connected VTs, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3 and use the following procedure:

1. Set V_{an} = V_{bn} = V_{cn} > **MIN POLARIZING VOLTAGE** setpoint at 0°, 120°, and 240°, respectively. Inject Phase A current of 0.2 x CT at an angle which is in phase with the polarizing voltage. This angle is outside the tripping region, so tripping should be blocked. If the function is set to “Control”, check that any output relays programmed for this condition are operated. If the function is set to “Alarm”, check that the Alarm and Message LEDs are flashing, the correct Phase Directional Reverse alarm message is displayed, and any output relays programmed for this condition are operated.
2. Slowly increase the angle of the Phase A current in the lagging direction. The directional element should detect current flow in the tripping direction when the Phase A current is lagging the polarizing voltage by more than 90° ±2°. The alarm and output relays should reset.
3. Continue to increase the lagging angle until the alarm is again raised. The Phase A current should be lagging the polarizing voltage by an angle of 270° ± 2°.
4. Continue to increase the angle until the Phase A current is once again in phase with the polarizing voltage. The alarm should remain.
5. Repeat the above Steps 1 through 4 for current angle adjusted in each of Phases B and C.

For forward tripping and Delta connected VTs, use the test connections specified in Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3 and use the following procedure:

1. Set V_{ab} = V_{bc} = V_{ca} > **MIN POLARIZING VOLTAGE** setpoint at 0°, 120°, and 240°, respectively. Inject Phase A current of 0.2 x CT at an angle which is in phase with the polarizing voltage. This angle is outside the tripping region, so tripping should be blocked. If the function is set to “Control”, check that any output relays programmed for this condition are operated. If the function is set to “Alarm”, check that the Alarm and Message LEDs are flashing, the correct Phase Directional Reverse alarm message is displayed, and any output relays programmed for this condition are operated.
2. Slowly increase the angle of the Phase A current in the lagging direction. The directional element should detect current flow in the tripping direction when the Phase A current is lagging the polarizing voltage by more than 90° ±2°. The alarm and output relays should reset.
3. Continue to increase the lagging angle until the alarm is again raised. The Phase A current should be lagging the polarizing voltage by an angle of 270° ±2°.
4. Continue to increase the angle until the Phase A current is once again in phase with the polarizing voltage. The alarm should remain.
5. Repeat the above Steps 1 through 4 for current angle adjusted in each of Phases B and C.

8.4.3 NEUTRAL OVERCURRENT

a) NEUTRAL TOC 1

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into any one phase, and the element is not subject to the “phases required for operation” and “voltage restrained time overcurrent” tests.

8

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert logic input to provide a "Block Neutral Time 1". The Pickup LED should immediately turn off.
3. Repeat Steps 1 and 2 for logic inputs "Block Neutral O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

b) NEUTRAL TOC 2

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into any one phase, and the element is not subject to the “phases required for operation” and “voltage restrained time overcurrent” checks.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert logic input to provide a "Block Neutral Time 2". The Pickup LED should immediately go out.

3. Repeat Steps 1 and 2 for logic inputs "Block Neutral O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

c) NEUTRAL IOC 1

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into any one phase, and the element is not subject to the “phases required for operation”, “linear reset timing”, and “voltage restrained time overcurrent” tests.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Neutral Inst 1". The Pickup LED should immediately go out.
3. Repeat 1 and 2 for logic inputs "Block Neutral O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

d) NEUTRAL IOC 2

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into any one phase, and the element is not subject to the “phases required for operation”, “linear reset timing”, and “voltage restrained time overcurrent” checks.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Neutral Inst 2". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Neutral O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

e) NEUTRAL DIRECTIONAL OC

If dual polarizing is required, check the operation of the voltage and current polarized elements individually as outlined below, then check the overall dual polarized response as outlined at the end of this section.

A plot of the operating characteristic of the voltage polarized neutral directional feature for various settings of MTA is shown below. Other characteristics for specific MTA settings can be deduced from this diagram. Note that the diagram is plotted for the residual current referred to the system faulted-phase phase-to-neutral voltage.

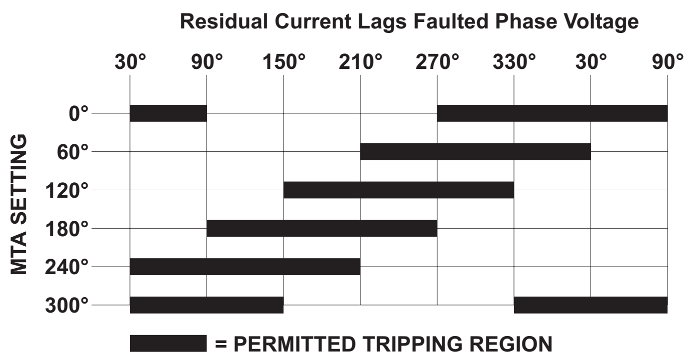

Figure 8–4: NEUTRAL DIRECTIONAL – VOLTAGE POLARIZED FORWARD OPERATING REGIONS

NOTE

The following descriptions present angles with reference to the faulted phase voltage and assume an MTA setting of 180°. For an MTA setting other than 180° alter the noted angles to those established by the programmed MTA.

To test forward tripping with voltage polarization, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3 and follow the procedure below:

1. Set V_{an} = V_{bn} = V_{cn} = nominal voltage at 0°, 120°, and 240° respectively. Set a current of 0.2 of nominal to lag V_{an} by 180° (in the tripping direction) and inject into Phase A. Note that $-V_0$ is less than the MIN POLARIZING VOLTAGE.
2. Reduce V_{an} until $-V_0$ is greater than the MIN POLARIZING VOLTAGE.
3. Slowly increase the angle of the Phase A current in the lagging direction. At an angle lagging Van by 270° ±2°, any output relays programmed for this condition should operate if the function is set to “Control”. If the function is set to

"Alarm", check that the Alarm and Message LEDs are flashing, the Neutral Directional Reverse alarm message is displayed, and any output relays programmed for this condition are operated.

4. Continue to increase the lagging angle through 0°, until the block message disappears at an angle lagging V_{an} by 90° ±2°. Turn the current off.
5. If desired, repeat the above Steps 1 through 4 for Phases B and C using I_b with faulted phase voltage V_{bn} and I_c with faulted phase voltage V_{cn}.

To test forward tripping with current polarization, use the test connections specified and procedure specified below:

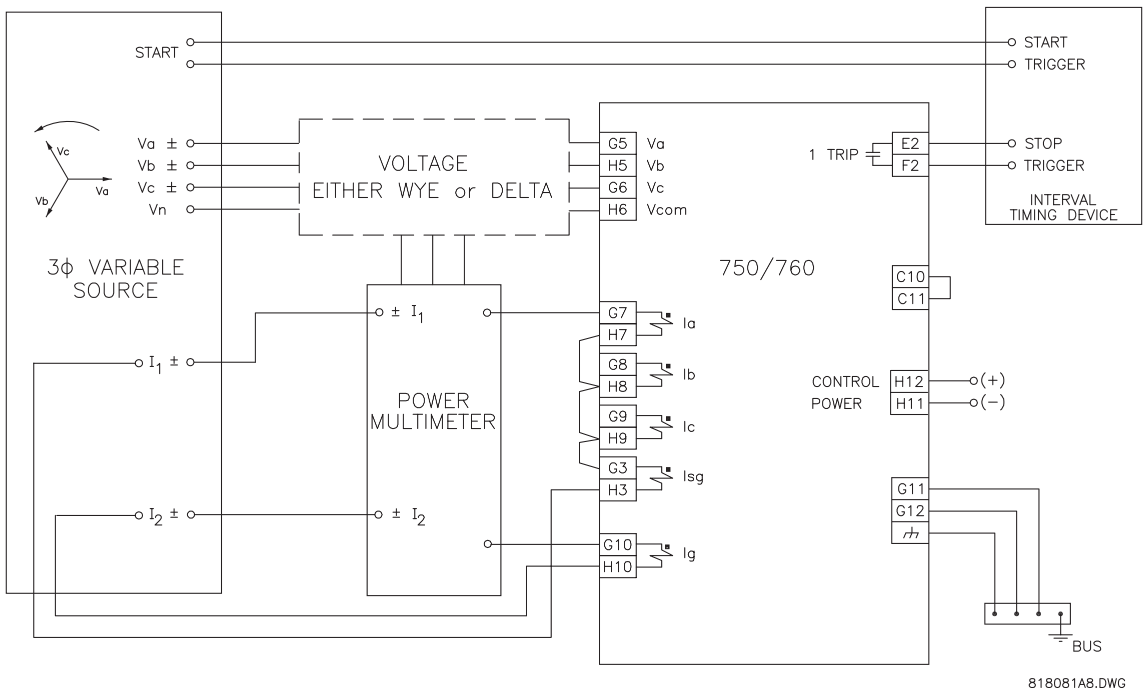

Figure 8–5: NEUTRAL DIRECTIONAL TEST CONNECTION FOR POLARIZING CURRENT

NOTE **The following description presents angles with reference to the polarizing current.**

1. Set a current of 0.2 of nominal and inject into the ground current input (Terminals G10 and H10).
2. Set a $3I_0$ current to 0.2 of nominal and in-phase with the ground current (this is the trip direction) and inject into the relay via the phase current inputs.
3. Increase the lagging angle of 3Io. At an angle lagging the ground current by 90° ±2°, any output relays programmed for this condition should operate if the function is set to "Control". If the function is set to "Alarm", check that the Alarm and Message LEDs are flashing, the Neutral Directional Reverse alarm message is displayed, and any output relays programmed for this condition are operated.
4. Continue to increase the lagging angle until the block message disappears at an angle lagging the ground current by 270° ±2°. Turn the current off.

To check forward tripping with dual polarization, use the test connections specified in Figure 8–5: Neutral Directional Test Connection for Polarizing Current and follow the procedure below. As operations of each neutral directional sensing element have been checked under voltage and current polarization, it is only necessary to check that both directional elements are operational, and that either element can block tripping for reverse faults.

1. Set V_{an} to 60%, and V_{bn} = V_{cn} to 100% nominal voltage at phase angles of 0°, 120°, and 240°, respectively.
2. Inject a current of 0.2 x nominal into the phase current input of the relay ($3I_0$) at an angle outside the tripping region of the set MTA, as compared to faulted phase voltage V_{an}. The Neutral Directional Reverse alarm should appear.

3. Inject a current of 0.2 x nominal, lagging the $3I_0$ current by 180°, into the ground current input. The block alarm should remain.
4. Increase the angle of the ground current lagging $3I_0$ current through a complete 360° rotation back to the original angle of lagging by 180°. The block alarm should remain throughout the rotation as the voltage polarized element is still blocking.
5. Maintaining the ground current angle lagging $3I_0$ by 180° increase the angle of $3I_0$ lagging the V_{an} voltage through a complete 360° rotation back to the original angle. The block alarm should remain throughout the rotation as the current polarized element is still blocking.
6. Increase the angle of the ground current lagging $3I_0$ current until the currents are in-phase. The block alarm should remain.
7. Maintaining the ground current angle in-phase with $3I_0$ increase the angle of $3I_0$ lagging the V_{an} voltage until into the permitted region. The block alarm should disappear when the angle reaches the tripping region.

8.4.4 GROUND OVERCURRENT

a) GROUND TOC

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into the ground input terminals and the element is not subject to the “phases required for operation” and “voltage restrained time overcurrent” checks.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Ground Time". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Ground O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

b) GROUND IOC

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into the ground input terminals, and the element is not subject to the “phases required for operation”, “linear reset timing”, and “voltage restrained time overcurrent” tests.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Ground Inst". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Ground O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

c) GROUND DIRECTIONAL OC

The procedure to test this element is identical to that outlined in Neutral Directional OC on page 8–21, except that the operating current is the ground current. Also, Ground Directional may only be voltage polarized.

d) SENSITIVE GROUND TOC

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into the sensitive ground input terminals, and the element is not subject to the “phases required for operation” and “voltage restrained time overcurrent” tests.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Blk Sens Gnd Time". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Sens Gnd O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

e) SENSITIVE GROUND IOC

The procedure to test this element is identical to that outlined in Phase IOC 1 on page 8–18, except that the current is injected into the sensitive ground input terminals, and the element is not subject to the “phases required for operation”, “linear reset timing”, and “voltage restrained time overcurrent” tests.

The blocking from logic inputs check is different from that for Phase IOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Blk Sens Gnd Inst". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic inputs "Block Sens Gnd O/C", "Block All O/C" and “Block 1 Trip Relay” as required.

f) SENSITIVE GROUND DIRECTIONAL OC

The procedure to test this element is identical to that outlined in Neutral Directional OC on page 8–21, except that the operating current is the sensitive ground current.

8.4.5 NEGATIVE-SEQUENCE OVERCURRENT AND VOLTAGE

a) NEGATIVE-SEQUENCE TOC

The procedure to test this element is identical to that outlined in Phase TOC 1 on page 8–16, except that current is injected into any one phase of the phase input terminals and the negative sequence current magnitude is 1/3rd of the injected current. The element is not subject to the “phases required for operation” or “voltage restrained time overcurrent” tests.

The blocking from logic inputs check is different from that for Phase TOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Neg Seq Time". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input "Block All O/C" and “Block 1 Trip Relay” as required.

b) NEGATIVE-SEQUENCE IOC

The procedure to test this element is identical to that outlined in Phase IOC 1 on page 8–18, except that current is injected into any one phase of the phase input terminals and the negative sequence current magnitude is 1/3rd of the injected current. The element is not subject to the “phases required for operation”, “linear reset timing”, and “voltage restrained time overcurrent” tests.

The blocking from logic inputs check is different from that for Phase IOC 1 and is performed as follows:

1. Inject current to cause a pickup.
2. Assert a logic input to provide a "Block Neg Seq Inst". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input "Block All O/C" and “Block 1 Trip Relay” as required.

c) NEGATIVE-SEQUENCE DIRECTIONAL OC

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The procedure to test this element is identical to that outlined in Phase Directional OC on page 8–19, except the injected current must be a negative sequence current.

d) NEGATIVE-SEQUENCE VOLTAGE

For Wye VTs, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3. A negative sequence voltage can be created by injecting a single phase voltage or a set of three single-phase voltages with a known negative sequence component. For single phase injection, the negative sequence voltage magnitude is the injected voltage divided by $\sqrt{3}$.

To test pickup for Wye VTs, use the following procedure:

1. Inject a negative sequence voltage of 0 into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly raise the voltage until the Pickup LED comes on. This is the pickup level.
3. Lower the voltage until the Pickup LED goes out. This is the reset voltage, which should be 2% of VT less than the pickup level.

For Delta VTs, use the test connections specified in Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. A negative sequence voltage can be created by injecting a single phase-phase voltage, or a set of two phase-phase voltages with a known negative sequence component. For a single phase-phase injection the negative sequence voltage magnitude is the injected voltage divided by $\sqrt{3}$.

To test Pickup for Delta VTs, use the following procedure:

1. Inject a negative sequence voltage of 0 into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly raise the voltage until the Pickup LED comes on. This is the pickup level.
3. Lower the voltage until the Pickup LED goes out. This is the reset voltage, which should be 2% of VT less than the pickup level.

Indications and Operations are the same as those outlined in Phase TOC 1 on page 8–16.

The following procedure checks blocking from logic inputs for Delta VTs:

1. Inject voltage to cause a pickup.
2. Assert a logic input to provide a "Block Neg Seq Voltage". The Pickup LED should immediately go out.
3. Repeat steps 1 and 2 for logic input “Block 1 TRIP Relay” as required.

The following procedure checks negative-sequence voltage timing for Delta VTs:

1. Connect the “Stop Trigger".
2. Set the voltage source to the required test voltage, then turn off the voltage.
3. Reset the timer. Turn the voltage on and measure the operating time.
4. Repeat Steps 2 and 3 four more times and obtain an average of the time intervals.
5. Reset the relay and disconnect the “Stop Trigger".

8.4.6 VOLTAGE

a) BUS UNDERVOLTAGE (WYE VTS ONLY)

To test Bus Undervoltage for Wye VTs, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3.

The following procedure checks Pickup with One Phase For Operation:

1. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly lower V_{an} until the Pickup LED comes on. This is the pickup voltage.
3. Continue to lower V_{an} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** level minus 2% of VT.
4. Raise V_{an} until the Pickup LED comes on, and continue to increase until the indicator goes out. This is the reset voltage, which should be the pickup value plus 2% of VT.
5. Repeat Steps 1 through 4 except adjust V_{bn} and V_{cn} in turn.

The following procedure checks Pickup with Two Phases For Operation:

1. Inject V_{cn} = nominal voltage and V_{an} = V_{bn} = a voltage between the **MIN OPERATING VOLTAGE** and the pickup voltage into the bus voltage input of the relay. The Pickup LED should be on.
2. Slowly raise V_{an} until the Pickup LED goes out. This is the reset voltage, which should be the pickup plus 2% of VT.
3. Reduce V_{an} until the Pickup LED comes on. This is the pickup voltage of V_{an}.
4. Continue to lower V_{an} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** of V_{an} minus 2% of VT.
5. Slowly raise V_{an} until the Pickup LED comes on, then reduce V_{bn} until the Pickup LED goes out. This is the programmed **MIN OPERATING VOLTAGE** of V_{bn} minus 2% VT.
6. Slowly raise V_{bn} until the Pickup LED first comes on and then goes out. This is the reset voltage, which should be the pickup value plus 2% of VT.
7. Lower V_{bn} until the Pickup LED comes on. This is the pickup voltage of V_{bn}.
8. Repeat Steps 1 through 7, substituting V_{cn} for V_{an}, V_{an} for V_{bn} and V_{bn} for V_{cn}.

9. Repeat Steps 1 through 7, substituting V_{bn} for V_{an}, V_{cn} for V_{bn} and V_{an} for V_{cn}.

The following procedure checks Pickup with Three Phases For Operation:

1. Inject V_{an} = V_{bn} = V_{cn} = a voltage between the **MIN OPERATING VOLTAGE** and the pickup voltage into the bus voltage input of the relay. The Pickup LED should be on.
2. Slowly raise V_{an} until the Pickup LED goes out. This reset voltage should be the pickup value plus 2% of VT.
3. Reduce V_{an} until the Pickup LED comes on. This is the pickup voltage of V_{an}.
4. Slowly raise V_{bn} until the Pickup LED goes out. This reset voltage should be the pickup value plus 2% of VT.
5. Reduce V_{bn} until the Pickup LED comes on. This is the pickup voltage of V_{bn}
6. Slowly raise V_{cn} until the Pickup LED goes out. This reset voltage should be the pickup value plus 2% of VT.
7. Reduce V_{cn} until the Pickup LED comes on. This is the pickup voltage of V_{cn}.
8. Lower V_{an} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** of V_{an} minus 2% of VT.
9. Slowly raise V_{an} until the Pickup LED comes on. This is the **MIN OPERATING VOLTAGE** level.
10. Reduce V_{bn} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** of V_{bn} minus 2% of VT.
11. Slowly raise V_{bn} until the Pickup LED comes on. This is the **MIN OPERATING VOLTAGE** level.
12. Reduce V_{cn} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** of V_{cn} minus 2% of VT.
13. Slowly raise V_{cn} until the Pickup LED comes on. This is the **MIN OPERATING VOLTAGE** level.

b) BUS UNDERVOLTAGE (DELTA VTS ONLY)

To test Bus Undervoltage for Delta VTs, use the test connections specified in Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3.

The following procedure tests Pickup with One Phase For Operation:

1. Inject V_{ab} = V_{cb} = nominal voltage into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly lower V_{ab} until the Pickup LED comes on. This is the pickup voltage.
3. Continue to lower V_{ab} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** minus 2% of VT.
4. Raise V_{ab} until the Pickup LED comes on, and continue to increase until the indicator goes out. This is the reset voltage, which should be the pickup value plus 2% of VT.
5. Repeat Steps 1 through 4 except adjust V_{bc}.

The following procedure tests Pickup with Two or Three Phases For Operation:

1. Inject V_{ab} = nominal voltage and V_{cb} = a voltage between the **MIN OPERATING VOLTAGE** and the pickup voltage into the bus voltage input of the relay. The Pickup LED should be on.
2. Slowly raise V_{cb} until the Pickup LED goes out. This reset voltage should be the pickup value plus 2% of VT.
3. Reduce V_{cb} until the Pickup LED comes on. This is the pickup voltage of V_{cb}.
4. Continue to lower V_{cb} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** of Vcb minus 2% of VT.
5. Slowly raise V_{cb} until the Pickup LED comes on. This is the **MIN OPERATING VOLTAGE** level.
6. Reduce V_{ab} until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** of V_{ab} minus 2% of VT.
7. Slowly raise V_{ab} until the Pickup LED first comes on and then goes out. This is the reset voltage, which should be the pickup value plus 2% of VT.
8. Lower V_{ab} until the Pickup LED comes on. This is the pickup voltage of V_{ab}.

c) BUS UNDERVOLTAGE (WYE AND DELTA VTS)

To test Bus Undervoltage for Wye and Delta VTs, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3.

The procedures for testing Indications and Operations are the same as those outlined for Phase TOC 1 on page 8–16.

The following procedure tests Blocking From Logic Inputs:

1. Inject voltage into the required number of phases to cause a pickup.
2. Assert a logic input to provide a "Block Undervolt 1 (2)". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input “Block 1 Trip Relay” as required.

The following procedure tests the Bus Undervoltage element timing:

1. Connect the “Stop Trigger."
2. Set the voltage source to nominal voltage.
3. Reset the timer. Turn the voltage off in the required number of phases, and measure the operating time.
4. Repeat Steps 2 and 3 four more times and obtain an average of the time intervals.
5. Reset the relay and disconnect the “Stop Trigger.”

d) LINE UNDERVOLTAGE

The following procedure tests the Line Undervoltage pickup:

1. Inject nominal voltage into the line voltage input of the relay. The Pickup LED should be off.
2. Slowly lower the voltage until the Pickup LED comes on. This is the pickup voltage.
3. Continue to lower the voltage until the Pickup LED goes out. This is the **MIN OPERATING VOLTAGE** minus 2% of VT.
4. Raise the voltage until the Pickup LED comes on, and continue to increase until the indicator goes out. This is the reset voltage, which should be the pickup value plus 2% of VT.

The procedures for testing Indications and Operations are the same as those outlined for Phase TOC 1 on page 8–16.

The following procedure tests the Blocking From Logic Inputs:

1. Inject voltage to cause a pickup.
2. Assert a logic input to provide a "Block Undervolt 3 (4)". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input “Block 1 Trip Relay” as required.

The following procedure tests the Line Undervoltage element Timing:

1. Connect the “Stop Trigger".
2. Set the voltage source to nominal voltage.
3. Reset the timer. Turn on the voltage, and measure the operating time.
4. Repeat Steps 2 and 3 four more times and obtain an average of the time intervals.
5. Reset the relay and disconnect the “Stop Trigger".

e) OVERVOLTAGE (WYE VTS ONLY)

To test Overvoltage for Wye VTs, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3. The following procedure tests Pickup with One Phase For Operation:

1. Inject V_{an} = V_{bn} = V_{cn} = 0 into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly raise Van until the Pickup LED comes on. This is the pickup voltage.
3. Lower V_{an} until the Pickup LED goes out. This is the reset voltage, which should be the pickup value minus 2% of VT.
4. Repeat Steps 1 through 3 except adjust V_{bn} and V_{cn} in turn.

The following procedure tests Pickup with Two Phases For Operation:

1. Inject V_{an} = V_{bn} = nominal voltage and V_{cn} = a voltage above the pickup into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly raise V_{an} until the Pickup LED goes on. This is the pickup voltage of V_{an}.
3. Reduce V_{an} until the Pickup LED goes off. This reset voltage of V_{an} should be the pickup value minus 2% of VT.
4. Raise V_{an} until the Pickup LED comes on.
5. Repeat Steps 1 through 4, substituting V_{cn} for V_{an}, V_{an} for V_{bn} and V_{bn} for V_{cn}.

6. Repeat Steps 1 through 4, substituting V_{bn} for V_{an}, V_{cn} for V_{bn} and V_{an} for V_{cn}.

The following procedure tests Pickup with Three Phases For Operation:

1. Inject V_{an} = V_{bn} = V_{cn} = a voltage above the pickup voltage into the bus voltage input of the relay. The Pickup LED should be on.
2. Slowly lower V_{an} until the Pickup LED goes out. This reset voltage should be the pickup value minus 2% of VT.
3. Raise V_{an} until the Pickup LED comes on. This is the pickup voltage of V_{an}.
4. Slowly lower V_{bn} until the Pickup LED goes out. This reset voltage should be the pickup value minus 2% of VT.
5. Raise V_{bn} until the Pickup LED comes on. This is the pickup voltage of V_{bn}.
6. Slowly lower V_{cn} until the Pickup LED goes out. This reset voltage should be the pickup value minus 2% of VT.
7. Raise V_{cn} until the Pickup LED comes on. This is the pickup voltage of V_{cn}.

f) OVERVOLTAGE (DELTA VTS ONLY)

To test Overvoltage for Delta VTs, use the test connections specified in Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The following procedure tests Pickup with One Phase For Operation:

1. Inject V_{ab} = V_{cb} = 0 into the bus voltage input of the relay. The Pickup LED should be off.
2. Slowly raise V_{ab} until the Pickup LED comes on. This is the pickup voltage.
3. Lower V_{ab} until the Pickup LED goes out. This is the reset voltage, which should be the pickup value minus 2% of VT.
4. Repeat Steps 1 through 3 except adjust V_{bc}.

The following procedure tests Pickup with Two or Three Phases For Operation:

1. Inject V_{ab} = V_{cb} > pickup into the bus voltage input. The Pickup LED should be on.
2. Lower V_{ab} until the Pickup LED goes out. This is the reset voltage, which should be the pickup value minus 2% of VT.
3. Slowly raise V_{ab} until the Pickup LED comes on. This is the pickup voltage.
4. Repeat Steps 1 through 3 except adjust V_{bc}.

g) OVERVOLTAGE (WYE AND DELTA VTS)

To test Overvoltage for Delta and Wye VTs, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection and Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16.

The following procedure tests Blocking From Logic Inputs:

1. Inject voltage to cause a pickup.
2. Assert a logic input to provide a "Block 1 Trip Relay".

The following procedure tests the element Timing:

1. Connect the “Stop Trigger".
2. Set the voltage source to the required test voltage, then turn off voltage.
3. Reset the timer. Turn the voltage on in the required number of phases, and measure the operating time. Repeat Steps 2 and 3 four more times and obtain an average of the time intervals.
4. Reset the relay and disconnect the “Stop Trigger".

h) NEUTRAL DISPLACEMENT (WYE VTS ONLY)

To test Neutral Displacement (Wye VTs only), use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3.

The following procedure tests the Pickup Level:

1. Apply a three phase balanced nominal voltage to the relay.
2. Reduce one phase voltage slowly until the Neutral Displacement element operates and note this voltage.

3. Calculate the $3V_0$ (neutral voltage, i.e. residual voltage) being supplied to the relay using the formula:

$$3V_0 = V_a + V_b + V_c \quad \text{(EQ 8.2)}$$

4. Repeat Steps 1 through 3 except adjust V_{bn} and V_{cn} in turn.

The following procedure tests Blocking From Logic Inputs:

1. Cause a pickup of the Neutral Displacement element.
2. Assert a logic input to provide a "Blk Ntr Displacement". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input "Block 1 Trip Relay" as required.

The following procedure tests element Timing:

1. Connect the Stop Trigger.
2. Preset the neutral (residual) voltage to be 150% of the pickup setting.
3. Inject the preset neutral (residual) voltage into the relay and note the delay time. Reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals. Disconnect the stop trigger when finished.

8.4.7 FREQUENCY

a) UNDERFREQUENCY

To test Underfrequency, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16.

The following procedure checks Minimum Operating Voltage Supervision:

1. Set the injection source well below the pickup frequency. Inject V_a = 0 V into the bus voltage input of the relay with $I_a = I_b = I_c$ above the Minimum Operating Current level. The Pickup LED should be off.
2. Slowly increase the voltage in Phase A until the Pickup LED comes on. Check that the pickup voltage is the selected Minimum Operating Voltage.
3. Slowly reduce the voltage. Note the voltage at which the Pickup LED goes out. Check that this dropout voltage is the pickup voltage minus 2 x VT nominal. Turn the injection voltage off.

The following procedure checks Minimum Operating Current Supervision:

1. Set the injection source well below the pickup frequency. Inject V_a = 0 V into the bus voltage input and $I_a = I_b = I_c$ = 0 A into the phase current inputs of the relay. The Pickup LED should be off.
2. Slowly increase the voltage in Phase A above the selected Minimum Operating Voltage. The Pickup LED should remain off.
3. Slowly increase the Phase A current until the Pickup LED turns on. This is the Minimum Operating Current level. Now reduce the current until the Pickup LED turns off. Note the dropout level, which should be 2% of CT less than the Minimum Operating Current level when the level is ≤ CT. When the Minimum Operating Current level is > CT, the dropout level should be 97 to 98% of the Minimum Operating Current level.
4. Slowly increase the Phase B current until the Pickup LED turns on. This is the Minimum Operating Current level. Now reduce the current until the Pickup LED turns off. Note the dropout level, which should be 2% of CT less than the Minimum Operating Current level when the level is ≤ CT. When the Minimum Operating Current level is > CT, the dropout level should be 97 to 98% of the Minimum Operating Current level.
5. Slowly increase the Phase C current until the Pickup LED turns on. This is the Minimum Operating Current level. Now reduce the current until the Pickup LED turns off. Note the dropout level, which should be 2% of CT less than the Minimum Operating Current level when the level is ≤ CT. When the Minimum Operating Current level is > CT, the dropout level should be 97 to 98% of the Minimum Operating Current level.

NOTE

For the following Underfrequency test procedures, the injected voltage and currents are always above the minimum operating levels.

The following procedure tests the Underfrequency Pickup:

1. Inject voltage at a frequency above the pickup level into phase V_a. Slowly decrease the frequency until the Pickup LED comes on. Note the pickup value.
2. Slowly increase the frequency until the Pickup LED goes out. Note the dropout level, which should be the pickup plus 0.03 Hz.

The following procedure tests Blocking From Logic Inputs:

1. Inject voltage and current above minimum at a frequency to cause a pickup.
2. Assert a logic input to provide a "Block Underfreq 1 (2)". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input “Block 1 Trip Relay” as required.

The following procedure tests the Underfrequency element Timing:

1. Connect the “Stop Trigger".
2. Set the voltage source prefault mode to nominal voltage, current and frequency.
3. Set the voltage source fault mode to nominal voltage and current, but with a frequency below pickup.
4. Set the source to prefault mode, reset the timer, and apply to the relay.
5. Jump the source to fault mode and measure the operating time.
6. Repeat Steps 4 and 5 four more times and obtain an average of the time intervals.
7. Reset the relay and disconnect the “Stop Trigger".

b) FREQUENCY DECAY

To test Frequency Decay, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16.

The following procedure checks Minimum Operating Voltage Supervision:

1. Inject voltage into the V_a bus voltage input at a level well below the Minimum Operating Voltage level. Also inject $I_a = I_b = I_c$ at a level well above the Minimum Operating Current level. Starting with the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting. The pickup indicator should remain off.
2. Inject voltage into the V_a bus voltage input at a level well above the Minimum Operating Voltage level. Also inject $I_a = I_b = I_c$ at a level well above the Minimum Operating Current level. Starting with the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting. The pickup indicator should come on while the V_a frequency is dropping.

The following procedure checks the Minimum Operating Current Supervision:

1. Inject voltage into the V_a bus voltage input at a level well above the Minimum Operating Voltage level. Also inject $I_a = I_b = I_c$ at a level well below the Minimum Operating Current level. Starting with the V_a frequency at a level well below the Frequency Decay Pickup, drop the frequency of Va at a speed greater than the Frequency Decay Rate setting. The Pickup LED should remain off.
2. With the V_a voltage at a level well above the Minimum Operating Voltage level, increase I_a to a level well above the Minimum Operating Current level. Currents I_b and I_c should be well below the Minimum Operating Current level. Starting with the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting. The Pickup LED should come on while the V_a frequency is dropping.
3. With the V_a voltage at a level well above the Minimum Operating Voltage level, increase I_b to a level well above the Minimum Operating Current level. Currents I_a and I_c should be well below the Minimum Operating Current level. Starting with the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting. The Pickup LED should come on while the V_a frequency is dropping.
4. With the V_a voltage at a level well above the Minimum Operating Voltage level, increase I_c to a level well above the Minimum Operating Current level. Currents I_a and I_b should be well below the Minimum Operating Current level. Starting with the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting. The Pickup LED should come on while the V_a frequency is dropping.

NOTE **For the following Frequency Decay test procedures, the injected voltage and currents are always above the minimum operating levels.**

The following procedure checks the Frequency Decay Pickup:

1. Starting with the V_a frequency at a level well above the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting, to a level still well above the **FREQ DECAY PICKUP**. The Pickup LED should remain off.
2. Continue dropping the V_a frequency at a speed greater than the **FREQ DECAY RATE**. When the frequency drops below the **FREQ DECAY PICKUP**, the Pickup LED will come on.

The following procedure checks the Frequency Decay Rate:

1. With the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed less than the **FREQ DECAY RATE** setting. The pickup indicator should remain off.
2. With the V_a frequency at a level well below the **FREQ DECAY PICKUP**, drop the frequency of V_a at a speed greater than the **FREQ DECAY RATE** setting. The pickup indicator will come on.

The following procedure checks Blocking From Logic Inputs:

1. Decrease the Va frequency at a rate to cause a pickup.
2. Assert a logic input to provide a "Block Frequency Decay". The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input “Block 1 Trip Relay” as required.

The following procedure checks the Frequency Decay Timing:

1. Connect the Stop Trigger.
2. Preset the ramp-rate to a minimum of 110% of the pickup and reset the timer.
3. Inject the preset voltage into the V_a bus voltage input and note the measured delay time. Reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals.
5. Disconnect the Stop Trigger.

8.4.8 BREAKER FAILURE

To test Frequency Decay, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16. This element has no Trip function.

1. Ensure the wiring to the circuit breaker trip and close circuits is complete.
2. Energize the breaker trip and close circuits and close the breaker.
3. Carefully disconnect a wire to open the trip circuit.
4. Set a test current level 3% above the **BRKR FAILURE CURRENT** setpoint and inject current into a phase current input (all overcurrent protection features are “Disabled”).
5. Assert a Trip logic input, which cannot be performed by the breaker. After a delay the element should generate an output (the delay time can be checked in the Event Recorder). Turn the current off and reset the relay.
6. Reduce the current magnitude to 3% below the **BRKR FAILURE CURRENT** setpoint and inject current into a phase current input. Assert a Trip logic input, which cannot be performed by the breaker. The element should not generate an output.

8.4.9 REVERSE POWER

To test the Reverse Power element, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16.

The following procedure tests Pickup for the Reverse Power element:

1. Apply a three phase nominal voltage to the relay.
2. Adjust the phase angle between the voltage and current to be 180°.
3. Inject current into all three phases and increase slowly until Reverse Power operates; note the pickup value.
4. Calculate the power value from the following formula: $P = \sqrt{3} \times VI\cos(\theta)$, where V is the primary line to line voltage, I is the pickup value expressed as a primary value, and cos(θ) is cos 180° (in this case, 1.0).
5. Express the measured power as a percentage of the rated power calculated using rated values in the above equation. The value should be within specifications for this element.
6. Adjust the phase angle to 100°, 120°, 240°, and 260°, checking the current pickup value for each angle. Calculate the relay pickup power for each angle using the formula given in Step 4.

The following procedure tests the Blocking From Logic Inputs for Reverse Power:

1. Cause the reverse power element to pickup.
2. Assert a logic input to provide a “Block Reverse Power”. The Pickup LED should immediately go out.
3. Repeat Steps 1 and 2 for logic input “Block 1 Trip Relay” as required.

The following procedure checks Timing for the Reverse Power Element:

1. Connect the Stop Trigger.
2. Preset the input voltage and current to provide a reverse real power which is 150% of pickup.
3. Inject the preset voltage and current and note the measured delay time. Reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals.
5. Disconnect the Stop Trigger.

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8.5.1 CURRENT MONITORING

a) PHASE CURRENT LEVEL

To test Phase Current monitoring, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Set the Delay time to 0.
2. Inject current at a level below the pickup level into Phase A.
3. Slowly increase the current until pickup is reached and the element generates an output.
4. Slowly reduce the current until the element resets, which should be 2% of CT less than pickup when pickup ≤ CT or 97 to 98% of pickup when pickup > CT.
5. Repeat Steps 2 to 4 for phase B and C current.
6. Set the Delay timer to the required setting.

The following procedure checks the Phase Current Level Timing:

1. Set the test source to a current at least 110% of pickup. Turn off and reset the timer.
2. Inject current into the relay and measure the time to operate.
3. Repeat Step 2 four more times and obtain an average of the time intervals
4. Disconnect the Stop Trigger.

b) NEUTRAL CURRENT LEVEL

To test Neutral Current monitoring, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The testing for this element is the same as outlined above for Phase Current Level, except that current is the residual current injected into the phase current inputs.

8.5.2 FAULT LOCATOR

To test the Fault Locator, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3.

NOTE

Because of the broad range of variables that can be encountered in actual systems a representative configuration with a set of impedances and instrument transformers have been chosen to demonstrate these tests. The model used to calculate the voltage and current phasors for the tests is a radial, 10 km long, three phase, four wire system of 13.8 kV nominal and 600 A feeder capacity. At the relay location there are wye-connected VTs rated 14400/120 V and CTs rated 600/5 A. A prefault load of about 8.5 MVA exists on the feeder. The relay is a 5 A unit.

MODEL IMPEDANCES (Ω)	$Z_{POS} = Z_{NEG}$	Z_{ZERO}
Source	0.028 + j0.662	0.028 + j0.662
Feeder	1.250 + j5.450	5.280 + j15.79

The source voltage (ahead of the source impedance) is 14.0 kV∠1.6°. Any overcurrent feature, all of which can cause a fault location calculation by tripping, set to a pickup current below the programmed test current, can be used for the tests.

1. Program the test set with the following prefault voltages and currents.

   V_{an} = 67.8∠0°; V_{bn} = 67.8∠240°; V_{cn} = 67.8∠120°; I_a = 2.9∠330°; I_b = 2.9∠210°; I_c = 2.9∠90°

2. Program the test set with the following fault voltages and currents. This fault is from Phase A to ground, placed 5.0 km from the relay.

   V_{an} = 59.0∠0°; V_{bn} = 67.4∠241°; V_{cn} = 67.4∠121°; I_a = 13.0∠286°; I_b = 2.9∠210°; I_c = 2.9∠90°

3. Inject the prefault voltages and currents, then apply the fault. The relay should trip and determine the type of fault (A-G), the distance to the fault (5.0 km) and the reactance to the fault (2.73 Ω).

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4. Program the test set with the following fault voltages and currents. This fault is Phase B to ground, 6.0 km from the relay.

   V_{an} = 67.4∠2°; V_{bn} = 60.3∠242°; V_{cn} = 67.4∠122°; I_a = 2.9∠330°; I_b = 12.0∠166°; I_c = 2.9∠90°

5. Inject the prefault voltages and currents, then apply the fault. The relay should trip and determine the type of fault (B-G), the distance to the fault (6.0 km) and the reactance to the fault (3.27 Ω).
6. Program the test set with the following fault voltages and currents. This fault is Phase C to ground, placed 7.0 km from the relay.

   V_{an} = 67.4∠2°; V_{bn} = 67.4∠242°; V_{cn} = 61.3∠120°; I_a = 2.9∠330°; I_b = 2.9∠210°; I_c = 9.9∠47°

7. Inject the prefault voltages and currents, then apply the fault. The relay should trip and determine the type of fault (C-G), the distance to the fault (7.0 km) and the reactance to the fault (3.82 Ω).
8. Program the test set with the following fault voltages and currents. This fault is Phase A to C, 8.0 km from the relay.

   V_{an} = 60.4∠4°; V_{bn} = 67.4∠242°; V_{cn} = 61.7∠117°; I_a = 11.4∠253°; I_b = 2.9∠210°; I_c = 11.4∠73°

9. Inject the prefault voltages and currents, then apply the fault parameters. The relay should trip and determine the type of fault (A-C), the distance to the fault (8.0 km) and the reactance to the fault (4.36 Ω).
10. Program the test with the following fault voltages and currents. This fault is Phase A to B, placed 9.0 km from the relay.

    V_{an} = 62.2∠358°; V_{bn} = 61.0∠244°; V_{cn} = 67.4∠122°; I_a = 10.3∠313°; I_b = 10.3∠133°; I_c = 2.9∠90°

11. Inject the prefault voltages and currents, then apply the fault. The relay should trip and determine the type of fault (A-B), the distance to the fault (9.0 km) and the reactance to the fault (4.91 Ω).
12. Program the test with the following fault voltages and currents. This fault is Phase A to B to C, 10.0 km from the relay.

    V_{an} = 60.3∠0°; V_{bn} = 60.3∠240°; V_{cn} = 60.3∠120°; I_a = 10.8∠283°; I_b = 10.8∠163°; I_c = 10.8∠43°

13. Inject the prefault voltages and currents, then apply the fault. The relay should trip and determine the type of fault (A-B-C), the distance to the fault (10.0 km) and the reactance to the fault (5.45 Ω).

8.5.3 DEMAND MONITORING

a) CURRENT DEMAND

To test Current Demand, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Clear demand data registers before starting this test.
2. Inject a fixed value of current. Monitor the actual value of the measured demand, and note the level at which the feature generates an output. Turn the current off.

b) REAL POWER DEMAND

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To test Real Power Demand, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Clear demand data registers before starting this test.
2. Inject a fixed value of watts. Monitor the actual value of the measured demand, and note the level at which the feature generates an output. Turn the current off.

c) REACTIVE POWER DEMAND

To test Reactive Power Demand, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Clear demand data registers before starting this test.
2. Inject a fixed value of vars. Monitor the actual value of the measured demand, and note the level at which the feature generates an output. Turn the current off.

d) APPARENT POWER DEMAND

To test Apparent Power Demand, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Clear demand data registers before starting this test.
2. Inject a fixed value of VA. Monitor the actual value of the measured demand, and note the level at which the feature generates an output. Turn the current off.

8.5.4 ANALOG INPUTS

a) ANALOG THRESHOLD

1. Inject DC mA current at a level below the pickup level into the analog input.
2. Slowly increase the current until the element generates an output. Slowly reduce the current until the element reset.

The following procedure tests Analog Threshold Timing:

1. Connect the Stop Trigger.
2. Preset the DC mA current source to a minimum of 110% of the pickup current. Turn the current off, and reset the timer.
3. Inject the preset current into the analog input and note the measured delay time. Reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals.
5. Disconnect the Stop Trigger.

b) ANALOG IN RATE

The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Connect the output of a DC ramping-current generator to the analog input.
2. Remove the power supply from the relay to ensure the analog input memory is set to zero, then re-apply power.
3. Set the ramp-rate below the rate-of-change pickup and inject into the analog input. Wait for 90 seconds (fast rate) or 90 minutes (slow rate) to ensure the relay has properly measured the input ramping-rate. The relay should not pickup. Cycle the relay power supply Off then On.
4. Adjust the ramp-rate to a higher rate and again apply and; if the relay doesn't pickup cycle the relay power supply Off then On. Repeat this procedure until the element generates an output.

The following procedure tests Analog Input Rate Timing:

1. Connect the Stop Trigger.
2. Preset the ramp-rate to a minimum of 110% of the pickup. Turn the current off, and reset the timer.
3. Inject the preset current into the analog input and note the measured delay time. Reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals.
5. Disconnect the Stop Trigger.

8.5.5 OVERFREQUENCY MONITORING

To test Overfrequency monitoring, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Inject voltage at a frequency below the pickup level into Phase A.
2. Slowly increase the frequency until the element generates an output.
3. Slowly reduce the frequency until the element resets.

The following procedure checks the Overfrequency monitoring Timing:

1. Connect the Stop Trigger.
2. Preset the voltage source frequency to a minimum of 110% of pickup. Turn voltage off and reset the timer.
3. Inject the preset voltage into phase A and note the measured delay time. Reset the timer.
4. Repeat Step 3 four more times and obtain an average of the time intervals.
5. Disconnect the "Stop Trigger".

8.5.6 POWER FACTOR

To test Power Factor monitoring, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The Indications and Operations are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

The following procedure checks Minimum Operating Voltage/Current Supervision:

1. Inject fixed values of voltage and current at about nominal values, at unity power factor. Slowly increase the lagging current angle, waiting for a time longer than the delay before each adjustment, until the element generates an output.
2. Slowly reduce voltage V_a magnitude until the power factor feature resets. Note the dropout voltage, which should be at about 30% of the selected nominal voltage. Return V_a to nominal.
3. Repeat Step 2 for V_b.
4. Repeat Step 2 for V_c.
5. Slowly reduce I_a and I_b magnitude to 0. The power factor feature should remain operated.
6. Slowly reduce I_c magnitude to 0. The power factor feature should reset.
7. Return I_a to nominal. The power factor feature should operate again. Return I_b and I_c to nominal.
8. Decrease the angle of lagging (balanced) current until the feature drops-out and resets the output relays.

The following procedure checks Power Factor Timing:

1. Connect the Stop Trigger.
2. Preset the 3-phase voltage and current inputs to a power factor more lagging than the pickup level. Turn voltages and currents off, and reset the timer.
3. Inject the preset voltage and current and note the measured delay time. Reset the timer.
4. Repeat step 3 four more times and obtain an average of the time intervals.
5. Disconnect the "Stop Trigger".

8.5.7 VT FAILURE

To test VT Failure monitoring, use the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3.

1. Set V_{an} = V_{bn} = V_{cn} = nominal voltage at 0°, 120°, and 240° respectively, and inject into the relay. With these balanced voltages 120° apart, the positive sequence voltage (V_1) is greater than 0.05 x VT.
2. Set I_a = I_b = I_c = 1 x CT at 0°, 120°, and 240° respectively, and inject into the relay. With these balanced currents 120° apart, the positive sequence current (I_1) is greater than 0.05 x CT.
3. Remove the balanced voltages so the positive sequence voltage (V_1) is less than 0.05 x VT. If this function is set to "Control", any output relays programmed for this condition should operate. If the function is set to "Alarm", check that the Alarm and Message LEDs are flashing, the VT Failure alarm message is displayed, and any output relays programmed for this condition are operated.
4. Apply the balanced voltages and the VT Failure condition should reset.

5. Now reduce V_{an} until the VT Failure condition returns. Verify the ratio of the negative sequence voltage (V_2) to the positive sequence voltage (V_1) is 0.25 at this point. Return V_{an} to nominal and the VT Failure condition should reset. Repeat this step for V_{bn} and V_{cn}.
6. With V_{an} = V_{bn} = V_{cn} returned to nominal voltage at 0°, 120°, and 240° respectively, reduce V_{an} until the VT Failure condition returns. Now reduce Ia until the VT Failure condition resets. Verify the ratio of the negative sequence current (I_2) to the positive sequence current (I_1) > 0.20 at this point. Return I_a to nominal and the VT Failure condition should reset. Repeat this step for I_b and I_c.

8.5.8 TRIP COIL MONITOR

The Indications and Operations for the Trip Coil Monitor are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Ensure the wiring to the circuit breaker trip and close circuits is complete.
2. Energize the breaker trip and close circuits and close the breaker.
3. Carefully disconnect a wire to open the trip circuit. After 5 seconds the element should generate an output.
4. Restore the open circuit and the element should reset.
5. If the Open Breaker permissive is "Enabled", and the trip circuit wiring has been arranged to permit this operation, open the breaker.
6. Repeat Steps 3 and 4.

8.5.9 CLOSE COIL MONITOR

The Indications and Operations for the Close Coil Monitor are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Ensure the wiring to the circuit breaker trip and close circuits is complete.
2. Energize the breaker trip and close circuits and open the breaker.
3. Carefully disconnect a wire to open the close circuit. After 5 seconds the element should generate an output.
4. Restore the open circuit and the element should reset.
5. If the Closed Breaker permissive is "Enabled", and the close circuit wiring has been arranged to permit this operation, close the breaker.
6. Repeat Steps 3 and 4.

8.5.10 BREAKER OPERATION FAILURE

The Indications and Operations for the Breaker Operation Failure are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Ensure the wiring to the circuit breaker trip and close circuits is complete.
2. Energize the breaker trip and close circuits and open the breaker.
3. Carefully disconnect a wire to open the close circuit. Apply a momentary Close command to the relay. After a delay the element should generate an output (the delay time can be checked in the Event Recorder).
4. Restore the open circuit and reset the relay.
5. Close the breaker.
6. Carefully disconnect a wire to open the trip circuit. Apply a momentary Trip command to the relay. After a delay the element should generate an output (the delay time can be checked in the Event Recorder)
7. Restore the open circuit and reset the relay.
8. Open and close the breaker a number of times to confirm the delay time provides sufficient margin to allow for normal operation of the breaker.

8.5.11 ARCING CURRENT

This test requires equipment which is seldom readily available in the field. It is suggested that as this feature does not require extreme levels of reliability and security it is not necessary to be field-tested. A procedure is available upon request from GE Multilin for those users wishing to perform this test. We suggest the following procedure to confirm this element is operational.

The Indications and Operations for the Arcing Current are as outlined for Phase TOC 1 on page 8–16, except that this element has no Trip function.

1. Check the value displayed under **A3 MAINTENANCE ⇨⇩ ARCING CURRENT ⇨⇩ TOTAL ARCING CURRENT** for each phase. Set the Total Arcing Current Limit to a level just above this value. Now perform a number of overcurrent element tests, with current maintained after the Trip command, until this element generates an output.
2. Be sure to reset the Total Arcing Current memory and setpoint at the end of this test.

8.5.12 ANALOG OUTPUT CHANNELS

1. Connect a milli-ammeter to channel output terminals as required.
2. Follow the test procedures previously outlined for the channel parameter observing the output on the milli-ammeter.

8.5.13 IRIG-B

1. Disconnect the IRIG-B input to the relay from the signal source.
2. Under **S1 RELAY SETUP ⇨⇩ CLOCK** manually set the relay date and time to incorrect values.
3. Under **A1 STATUS ⇨⇩ CLOCK** check that the relay has accepted the programmed date and time.
4. Set the **IRIG-B TIME SYNC** setpoint to the required signal type - the relay should display the **IRIG-B FAILURE** self-test warning.
5. Connect the IRIG-B input from the signal source to the relay and check the signal is available at the relay terminals.
6. The **IRIG-B FAILURE** self-test warning should be removed from the display.
7. Under **A1 STATUS ⇨⇩ CLOCK** check that the relay clock now displays the correct date and time.

8.5.14 PULSE OUTPUT

1. Inject quantity to be used to provide a pulse output.
2. Observe that the pulses occur at the proper intervals by using the actual value measurement provided by the relay. A counter or oscilloscope may also be used to confirm pulse timing.

8.6.1 SETPOINT GROUP CONTROL

NOTE

The relay is defaulted to Setpoint Group 1, and will be using this group for setpoints unless specifically changed to another group. This procedure assumes the relay initially uses Group 1 as indicated by the faceplate LED.

Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3.

1. Change the **S7 CONTROL ⇨ SETPOINT GROUPS ⇨ ACTIVE SETPOINT GROUP** setpoint to "Group 2" and the **EDIT SETPOINT GROUP** setpoint in the same menu to "Active Group". The faceplate LEDs should now indicate the relay is using Setpoint Group 2.
2. Change at least one protection element setpoint from the setting in Group 1.
3. Repeat Steps 2 and 3 for active setpoint group selections of Group 3 and Group 4, while monitoring that the LED indicators show the correct group.
4. Check that the operation of the protection feature programmed is controlled by the setting in group 4.
5. Change the **S7 CONTROL ⇨ SETPOINT GROUPS ⇨ ACTIVE SETPOINT GROUP** setpoint to "Group 3". The LED on the faceplate should now indicate the relay is using Setpoint Group 3.
6. Check that the operation of the protection feature programmed is controlled by the setting in group 3.
7. Change the **S7 CONTROL ⇨ SETPOINT GROUPS ⇨ ACTIVE SETPOINT GROUP** setpoint to "Group 2". The LED on the faceplate should now indicate the relay is using Setpoint Group 2.
8. Check that the operation of the protection feature programmed is controlled by the setting in group 2.
9. Change the **S7 CONTROL ⇨ SETPOINT GROUPS ⇨ ACTIVE SETPOINT GROUP** setpoint to Group 1. The LED on the faceplate should now indicate the relay is using Setpoint Group 1.
10. Check that the operation of the protection feature programmed is controlled by the setting in Group 1.
11. Assert logic input Setpoint Group 2, and check that the LED indicator shows Setpoint Group 2.
12. Assert logic input Setpoint Group 3, and check that the LED indicator shows Setpoint Group 3.
13. Assert logic input Setpoint Group 4, and check that the LED indicator shows Setpoint Group 4.
14. De-assert logic input Setpoint Group 4, and check that the LED indicator shows Setpoint Group 3.
15. De-assert logic input Setpoint Group 3, and check that the LED indicator shows Setpoint Group 2.
16. De-assert logic input Setpoint Group 2, and check that the LED indicator shows Setpoint Group 1.
17. Check that the changing of setpoint groups is placed in the event recorder.

If the **BRKR OPEN INHIBIT** setpoint is to be “Enabled”:

1. Assert a breaker state logic input so that the relay determines the breaker is closed.
2. Assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is using Setpoint Group 2.
3. De-assert the breaker state logic input so that the relay determines the breaker is open.
4. De-assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is still using Setpoint Group 2.
5. Assert the breaker state logic input so that the relay determines the breaker is closed.
6. The LED on the faceplate should indicate the relay is now using Setpoint Group 1.

If the **OVERCURRENT P/U INHIBIT** setpoint is to be "Enabled":

1. Assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is using Setpoint Group 2.
2. Inject current above the pickup setting of an overcurrent element that is not Disabled.
3. De-assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is still using Setpoint Group 2.
4. Reduce the injected current until the overcurrent element resets.
5. The LED on the faceplate should indicate the relay is now using Setpoint Group 1. Turn current off.

If the **OVERVOLT P/U INHIBIT** setpoint is to be "Enabled":

1. Assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is using Setpoint Group 2.
2. Inject voltage above the pickup setting of an overvoltage element that is not Disabled.
3. De-assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is still using Setpoint Group 2.
4. Reduce the injected voltage until the overvoltage element resets.
5. The LED on the faceplate should indicate the relay is now using Setpoint Group 1. Turn voltage off.

If the **UNDERVOLT P/U INHIBIT** setpoint is to be "Enabled":

1. Inject voltage above the pickup setting of an undervoltage element that is not Disabled.
2. Assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is using Setpoint Group 2.
3. Reduce voltage below the pickup setting of an undervoltage element that is not Disabled.
4. De-assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is still using Setpoint Group 2.
5. Increase the injected voltage until the undervoltage element resets.
6. The LED on the faceplate should indicate the relay is now using Setpoint Group 1. Turn voltage off.

If the **UNDERFREQ P/U INHIBIT** setpoint is to be "Enabled":

1. Inject voltage with frequency above the pickup setting of an underfrequency element that is not Disabled.
2. Assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is using Setpoint Group 2.
3. Reduce frequency below the pickup setting of an underfrequency element that is not Disabled.
4. De-assert logic input Setpoint Group 2. The faceplate LED should indicate the relay is still using Setpoint Group 2.
5. Increase the injected frequency until the underfrequency element resets.
6. The LED on the faceplate should indicate the relay is now using Setpoint Group 1. Turn voltage off.

8.6.2 SYNCHROCHECK

1. Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3 and also connect a variable voltage source to the line voltage input.
2. Initially set the function setpoint to Control, the Dead Source Permissive setpoint to Off and the Maximum Voltage Difference setpoint to 100 kV.
3. As there are no input voltages, any selected output relays should now be operated along with the Out Of Sync control message.
4. Change the function setting to Alarm. The alarm message and LED should be displayed, and any selected output relays should remain operated.
5. Inject a balanced three-phase voltage at nominal voltage and frequency into the bus voltage input.
6. Turn off the voltage and make parallel connections (observing polarity) from the bus voltage input that corresponds with the selection made under subheading **S2 SYSTEM SETUP ⇨⇩ LINE VT SENSING ⇨ VT CONNECTION** to the line voltage input. Turn the voltage on and check that these voltages show difference measurements of 0 under **A2 METERING ⇨⇩ VOLTAGE ⇨⇩ SYNCHRO DELTA** (the ∆V will not be 0 unless the bus and line VTs have identical ratings. If the difference is not shown as 0, calculate the two equivalent primary voltage values for the injected voltage; they should be the same.) This checks that the relay has selected the correct bus voltage input for the synchrocheck measurements. Turn the voltage off and remove the parallel connections.
7. Inject a single-phase voltage at nominal voltage and frequency into the bus voltage input that corresponds with the selection made under subheading **S2 SYSTEM SETUP ⇨⇩ LINE VT SENSING ⇨ VT CONNECTION**.
8. Inject voltage and frequency into the line voltage input and adjust this voltage until ∆V, ∆F and ∆F as shown under subheading **A2 METERING ⇨⇩ VOLTAGE ⇨⇩ SYNCHRO DELTA** are all 0. Reduce the line voltage magnitude to 0.
9. The “Out of Sync” alarm will be displayed as the line voltage is below the minimum voltage requirement. Slowly raise this voltage until the “Out of Sync” alarm is no longer displayed. This magnitude should be the setpoint value.

10. Raise the line voltage input to the nominal value, and lower the bus voltage magnitude to 0. The “Out of Sync” alarm will be displayed as the bus voltage is below the minimum voltage requirement. Slowly raise this voltage until the “Out of Sync” alarm is no longer displayed. This magnitude should be the setpoint value.
11. Enter the required setting of **MAX VOLTAGE DIFFERENCE**. The “Out of Sync” alarm will be displayed as the voltage difference is above the maximum difference requirement.
12. While monitoring ∆V on the display, slowly raise the bus voltage until the “Out of Sync” alarm is no longer displayed. Check that the voltage difference is the selected value.
13. Set the bus voltage magnitude to nominal, and the line voltage to a level above the minimum required voltage.
14. The “Out of Sync” alarm will be displayed as the voltage difference is above the maximum difference requirement.
15. While monitoring ∆V on the display, slowly raise the line voltage until the “Out of Sync” alarm is no longer displayed. Check that the voltage difference is the selected value.
16. Set both line and bus voltage magnitude and frequency to nominal. Adjust the line voltage phase position to lag the bus voltage by 180°.
17. The “Out of Sync” alarm will be displayed as the angle difference is above the maximum difference requirement.
18. While monitoring ∆F on the display, slowly increase the line voltage lagging phase position until the “Out of Sync” alarm is no longer displayed. Check that the angle difference is the selected value. Return the line voltage angle to 0°.
19. Set the line voltage frequency to a value lower than allowed by the maximum frequency difference.
20. While monitoring ∆F on the display, slowly increase the line voltage frequency until the “Out of Sync” alarm is no longer displayed. Check that the frequency difference is the selected value.
21. Set the line voltage to a frequency higher than permitted by the maximum frequency difference.
22. The “Out of Sync” alarm will be displayed as the frequency difference is above the maximum difference requirement. While monitoring ∆F on the display, slowly decrease the line voltage frequency until the “Out of Sync” alarm is no longer displayed. Check that the frequency difference is the selected value. Turn voltages off.

If the Dead Source Permissive feature is to be used, set the **MAX VOLTAGE DIFFERENCE**, **MAX ANGLE DIFFERENCE**, and **MAX FREQ DIFFERENCE** setpoints to the minimum values; and the **DEAD SOURCE PERMISSIVE**, **DEAD BUS MAX VOLTAGE**, **DEAD LINE MAX VOLTAGE**, **LIVE BUS MIN VOLTAGE**, and **LIVE LINE MIN VOLTAGE** setpoints to the required settings.

For a **DEAD SOURCE PERMISSIVE** setpoint of "DB & DL", perform the following steps:

1. Set the bus voltage to a magnitude above the dead-bus level, and nominal frequency and inject into the relay.
2. Set the line voltage to a magnitude above the dead-line level, 180° out-of-phase with the bus voltage, at the same frequency, and inject into the relay. This ensures synchronism cannot be achieved. The “Out of Sync” alarm will be displayed as both the bus and line voltages are above their dead-setting limits.
3. Turn the bus voltage off. The “Out of Sync” alarm will be displayed as line voltage is above the dead limit.
4. Slowly reduce the line voltage, until the “Out of Sync” alarm is no longer displayed. This should be at the dead line max volt limit. Return the voltages to the level prior to the reduction.
5. The “Out of Sync” alarm will be displayed as both the bus and line voltages are above their dead-setting limits.
6. Turn the line voltage off. The “Out of Sync” alarm will be displayed.
7. Slowly reduce the bus voltage, until the “Out of Sync” alarm is no longer displayed. This should be at the dead bus max volt limit. Turn the voltages off.

For a **DEAD SOURCE PERMISSIVE** setpoint of "LL & DB", perform the following steps:

1. Set the line voltage to nominal magnitude and frequency and inject into the relay. Set the bus voltage to a magnitude above the dead-bus level, 180° out-of-phase with the line voltage, at the same frequency, and inject into the relay. This ensures synchronism cannot be achieved.
2. The “Out of Sync” alarm will be displayed as the bus voltage is above its dead-setting limit.
3. Slowly reduce the bus voltage magnitude until the “Out of Sync” alarm is no longer displayed. This should be at the dead bus max volt limit. Turn both voltages off. The “Out of Sync” alarm will be displayed as the line voltage is below its minimum voltage setting limit.

4. Slowly increase the line voltage magnitude until the “Out of Sync” alarm is no longer be displayed. This should be at the minimum live line voltage limit. Turn both voltages off.

For a **DEAD SOURCE PERMISSIVE** setpoint of "DL & LB", perform the following steps:

1. Set the bus voltage to nominal magnitude and frequency and inject into the relay. Set the line voltage to a magnitude above the dead-line level, 180° out-of-phase with the bus voltage, at the same frequency, and inject into the relay. This ensures synchronism cannot be achieved.
2. The “Out of Sync” alarm will be displayed as the line voltage is above its dead-setting limit.
3. Slowly reduce the line voltage magnitude until the “Out of Sync” alarm is no longer displayed. This should be at the **DEAD LINE MAX VOLTAGE** limit. Turn both voltages off.
4. The “Out of Sync” alarm will be displayed as the bus voltage is below its minimum voltage setting limit.
5. Slowly increase the bus voltage magnitude until the “Out of Sync” alarm is no longer displayed. This should be at the minimum live bus voltage limit. Turn both voltages off.

For a **DEAD SOURCE PERMISSIVE** setpoint of "DL | DB", perform the following steps:

1. Set the bus voltage to nominal magnitude and frequency and inject into the relay. Set the line voltage to nominal magnitude, 180° out-of-phase with the bus voltage, at the same frequency, and inject into the relay. This ensures synchronism cannot be achieved.
2. The “Out of Sync” alarm will be displayed as both voltages are above the dead-setting limits.
3. Slowly reduce the line voltage magnitude until the “Out of Sync” alarm is no longer displayed. This should be at the **DEAD LINE MAX VOLTAGE** limit. Increase the line voltage to nominal magnitude.
4. Slowly reduce the bus voltage magnitude until the “Out of Sync” alarm is no longer displayed. This should be at the dead bus max volt limit. Turn both voltages off.

For a **DEAD SOURCE PERMISSIVE** setpoint of "DL X DB", perform the following steps:

1. Set the bus voltage to a magnitude above the **DEAD BUS MAX VOLTAGE** limit and below the **LIVE BUS MIN VOLTAGE** limit at nominal frequency and inject into the relay. Set the line voltage to a magnitude above the minimum live-line limit, 180° out-of-phase with the bus voltage, at the same frequency, and inject into the relay. This ensures synchronism cannot be achieved. The “Out of Sync” alarm will be displayed.
2. Slowly decrease the bus voltage magnitude until the “Out of Sync” alarm is no longer displayed. This should be just below the **DEAD BUS MAX VOLTAGE** limit.
3. Slowly decrease the line voltage magnitude until the “Out of Sync” alarm is again displayed. This should be just below the **LIVE BUS MIN VOLTAGE** limit.
4. Decrease the line voltage magnitude to below the **DEAD LINE MAX VOLTAGE** limit. The “Out of Sync” alarm should remain displayed.
5. Increase the bus voltage magnitude to above the **LIVE LINE MIN VOLTAGE** limit at which point the “Out of Sync” alarm is no longer displayed.
6. Slowly increase the line voltage magnitude. At just above the max dead-line limit the “Out of Sync” alarm should be displayed. Turn both voltages off.

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8.6.3 MANUAL CLOSE FEATURE BLOCKING

Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The following procedure checks the Manual Close Function and Timer Control:

1. Assert the 52a (or 52b) Contact logic input to simulate an open breaker.
2. If in Local mode, press the front panel CLOSE key momentarily to generate a close command; if in Remote mode assert a momentary Remote Close logic input to cause the relay to go into manual close blocking, and generate an output from this feature. Check that any selected output relays have operated. If the function is selected as Alarm, the alarm message should be displayed with the Alarm LED turned on.
3. After a time interval equal to the Manual Close Block Time, the above indications should reset. This interval can be checked in the Event Recorder.

The procedures below check the control of overcurrent protection features. Use the following procedure to check Phase IOC 1 Blocking:

1. Set a test current, in the number of phases required to generate an output, to a level above the pickup of this element then turn the current off.
2. Apply a Close command, as described above, and immediately inject the test current to the relay. The element will not pickup as it is blocked by manual close blocking. Wait until the element operates, as shown by the Pickup LED coming on, at the end of the programmed Manual Close Block Time.
3. Turn the current off. The time interval can be checked in the Event Recorder.

For Neutral IOC 1 Blocking, Ground IOC Blocking, Sensitive Ground IOC Blocking, and Neg Seq IOC Blocking, follow the procedure described for Phase IOC 1 Blocking above, injecting current as appropriate.

The following procedure checks Phase TOC 1 Raised Pickup:

1. Ensure all other overcurrent features are "Disabled".
2. Manual Close Blocking will raise the pickup setting of the curve normally used by this feature the programmed percentage. Set a test current to a level between the normal pickup setting and the raised setting, then turn the current off.
3. Apply a Close command, as described above, and immediately inject the test current into the relay. Phase TOC will not pickup as the pickup current is raised. Increase the injection current until the Pickup LED comes on, before the manual close feature times-out and returns the pickup to normal. Check that the raised pickup level is correct. Turn current off, and wait until the alarm is removed from the display.
4. Set a test current to a level between the normal pickup setting and the raised setting, then turn the current off.
5. Apply a Close command, as described above, and immediately inject the test current into the relay. Phase TOC will not pickup as the pickup current is raised.
6. At the end of the programmed **MANUAL CLOSE BLOCK TIME**, the Pickup LED should come on, as the pickup setting has returned to normal. When this happens, reduce the injection current until the Pickup LED goes out. The **MANUAL CLOSE BLOCK TIME** can be checked in the Event Recorder.

For Neutral TOC 1 Raised Pickup, Ground TOC Raised Pickup, Sensitive Ground TOC Raised Pickup, and Neg Seq TOC Raised Pickup, follow the procedure outlined for Phase TOC 1 Raised Pickup above, injecting current as appropriate.

To check the Select Setpoint Group function, apply a manual close and verify that the selected setpoint group becomes active when the breaker closes. Verify that settings return to the previous setpoint group after the **MANUAL CLOSE BLOCK TIME** expires.

8.6.4 COLD LOAD PICKUP BLOCKING

Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The following procedure checks the Cold Load Pickup Function and Timer Control:

1. Enable the **COLD LOAD PICKUP** setpoint to cause the relay to go into cold load pickup operation after the **OUTAGE TIME BEFORE COLD LOAD** setpoint expires. Check that any selected output relays have operated. If the function is selected as Alarm, the alarm message and LED should also be turned on.
2. Inject a current in any phase below 10% of nominal, and slowly increase. The relay should go into cold load operation when the current is above 10% of nominal. The alarm message and LED should reset and any output relays programmed to operate should dropout after a time interval equal to the cold load pickup block time. This interval can be checked in the Event Recorder.
3. Reduce this current to 3% of nominal and simultaneously start a timer. This feature should generate an output at the end of the **OUTAGE TIME BEFORE COLD LOAD** setting.

The procedures below check the control of overcurrent protection features. The following checks Phase IOC 1 Blocking:

1. Set a test current, in the number of phases required to generate an output, to a level above the pickup of this element then turn the current off.
2. Assert a Cold Load Pickup logic input, and immediately apply the test current to the relay. The element will not pickup as it is blocked by cold load pickup blocking. Wait until the element operates, as shown by the Pickup LED coming on at the end of the programmed **COLD LOAD PICKUP BLOCK** time.

3. Turn the current off. The time interval can be checked in the Event Recorder.

For Neutral IOC 1 Blocking, Ground IOC Blocking, Sensitive Ground IOC Blocking, and Neg Seq IOC Blocking, follow the procedure described above for Phase IOC 1 Blocking, injecting current as appropriate.

The following procedure checks Phase TOC 1 Raised Pickup for Cold Load Blocking:

1. Ensure all other overcurrent features are "Disabled".
2. Cold Load Pickup Blocking will raise the pickup setting of the curve normally used by the programmed percentage. Set a test current to a level between the normal pickup setting and the raised setting, (at least 5% of nominal current) then turn the current off.
3. Assert a Cold Load Pickup logic input and immediately inject the test current into the relay. Phase TOC 1 will not pickup as the pickup current is raised. Increase the injection current until the Pickup LED comes on, before the cold load pickup blocking feature times-out and returns the pickup to normal. Check that the raised pickup level is correct. Turn current off, and wait until the alarm is removed from the display.
4. Set a test current to a level between the normal pickup setting and the raised setting, then turn the current off.
5. Assert a Cold Load Pickup logic input and immediately inject the test current into the relay. Phase TOC 1 will not pickup as the pickup current is raised.
6. At the end of the programmed **COLD LOAD PICKUP BLOCK TIME** the Pickup LED should come on, as the pickup setting has returned to normal. When this happens, reduce the injection current until the Pickup LED goes out. The **COLD LOAD PICKUP BLOCK TIME** interval can be checked in the Event Recorder.

For Neutral TOC 1 Raised Pickup, Ground TOC Raised Pickup, Sensitive Ground TOC Raised Pickup, and Neg Seq TOC Raised Pickup, follow the procedure outlined for Phase TOC 1 Raised Pickup, injecting current as appropriate.

To check the Select Setpoint Group for Cold Load Blocking, apply a Cold Load Pickup logic input and verify that the selected setpoint group becomes active. Verify that settings return to the previous setpoint group after the Cold **LOAD PICKUP BLOCK TIME** interval expires.

8.6.5 UNDERVOLTAGE RESTORATION

Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The following procedure checks Logic and Timers for Undervoltage Restoration:

1. Program the Undervoltage 1 function as "Trip" and the Undervoltage 2 function as "Disabled".
2. Assert or De-assert a logic input to simulate a closed breaker.
3. Inject a balanced three-phase voltage at nominal voltage and frequency into the bus voltage input.
4. Initially set the undervoltage restoration function setpoint to Alarm, and other setpoints as required.
5. Turn the voltage off. After the programmed delay Undervoltage 1 should cause a trip, which should not initiate undervoltage restoration as the breaker is closed. Diagnostic message "Uvolt Restore Init" should not be displayed.
6. Assert or De-assert a logic input to simulate an open breaker, initiating undervoltage restoration. The diagnostic alarm message and LED should be displayed, and output relays programmed to operate for this condition should operate.
7. Change the Undervoltage Restoration function setpoint to Control, and the diagnostic message should change to control and the Alarm LED should turn off. Return this setpoint to Alarm.
8. Assert logic input Block Restoration. The diagnostic alarm message and LED should be removed from the display, and any output relays that operated should reset.
9. De-assert the logic input. The alarm message and LED should again be displayed and output relays operated. After the delay programmed in Incomplete Sequence Time the alarm message and LED should be removed from the display and output relays reset.
10. Return the reduced voltage to nominal, resetting both the undervoltage trip condition and undervoltage restoration.
11. Reduce voltage until Undervoltage 1 trips, then immediately return the voltage to nominal. The diagnostic alarm message and LED should be displayed, and output relays operated.
12. Provide a Reset to the relay, and the alarm message and LED should be removed from the display and output relays reset. Remove the Reset.

13. Arrange the interval timer to start on appearance of voltage and stop when the Close Relay operates.
14. Turn the voltage off to cause an Undervoltage 1 trip, then reset the timer.
15. Turn the voltage on. The Close Relay should operate after the delay programmed in setpoint Undervolt Restore Delay.
16. If the Undervoltage 2 initiation is to be checked change the Undervoltage Restoration function setpoint to "Disabled", Undervoltage 1 function to "Disabled", Undervoltage 2 function to "Trip" and repeat Steps 2 through 7.

a) FOR WYE VTS

Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection on page 8–3. The following procedure checks Minimum Voltage with One Phase For Operation:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERVOLT RESTORE DELAY** to "0".
3. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
4. Reduce the injected voltages to cause an undervoltage trip, then set V_{bn} and V_{cn} to "0".
5. Slowly raise V_{an} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{an}.
6. Repeat Steps 3 through 5 except adjust V_{bn} and V_{cn} in turn.

The following procedure checks Minimum Voltage with Two Phases For Operation:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERVOLT RESTORE DELAY** to "0".
3. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
4. Reduce the injected voltages to cause an undervoltage trip, then set V_{bn} to 0 and Vcn to nominal.
5. Slowly raise V_{an} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{an} with V_{cn}.
6. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
7. Reduce the injected voltages to cause an undervoltage trip, then set V_{cn} to 0 and V_{bn} to nominal.
8. Slowly raise V_{an} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{an} with V_{bn}.
9. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
10. Reduce the injected voltages to cause an undervoltage trip, then set V_{cn} to 0 and V_{an} to nominal.
11. Slowly raise V_{bn} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{bn} with Van.
12. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
13. Reduce the injected voltages to cause an undervoltage trip, then set V_{an} to 0 and V_{cn} to nominal.
14. Slowly raise V_{bn} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{bn} with V_{cn}.
15. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
16. Reduce the injected voltages to cause an undervoltage trip, then set V_{an} to 0 and V_{bn} to nominal.
17. Slowly raise V_{cn} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{cn} with V_{bn}.
18. Inject V_{an} = V_{bn} = V_{cn} = nominal voltage into the bus voltage input of the relay.
19. Reduce the injected voltages to cause an undervoltage trip, then set V_{bn} to 0 and V_{an} to nominal.
20. Slowly raise V_{cn} until the Close Relay operates. This is the operating level of the **UNDERVOLT RESTORE MIN VOLTS** setpoint for V_{cn} with V_{an}.

The following procedure checks Minimum Voltage with Three Phases For Operation:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERVOLT RESTORE DELAY** to "0".
3. Inject $V_{an} = V_{bn} = V_{cn}$ = nominal voltage into the bus voltage input of the relay.
4. Reduce the injected voltages to cause an undervoltage trip, then set V_{an} and V_{cn} to nominal.
5. Slowly raise V_{an} until the Close Relay operates. This is the operating level of **UNDERVOLT RESTORE MIN VOLTS** for V_{an}.
6. Inject $V_{an} = V_{bn} = V_{cn}$ = nominal voltage into the bus voltage input of the relay.
7. Reduce the injected voltages to cause an undervoltage trip, then set V_{an} and V_{cn} to nominal.
8. Slowly raise V_{bn} until the Close Relay operates. This is the operating level of **UNDERVOLT RESTORE MIN VOLTS** for V_{bn}.
9. Inject $V_{an} = V_{bn} = V_{cn}$ = nominal voltage into the bus voltage input of the relay.
10. Reduce the injected voltages to cause an undervoltage trip, then set V_{an} and V_{bn} to nominal.
11. Slowly raise V_{cn} until the Close Relay operates. This is the operating level of **UNDERVOLT RESTORE MIN VOLTS** for V_{cn}.

b) FOR DELTA VTS

Make the test connections specified in Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The following procedure checks Minimum Voltage with One Phase For Operation:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERVOLT RESTORE DELAY** to 0.
3. Inject $V_{ab} = V_{cb}$ = nominal voltage into the bus voltage input of the relay.
4. Reduce the injected voltages to cause an undervoltage trip, then set V_{cb} to 0 V.
5. Slowly raise V_{ab} until the Close Relay operates. This is the operating level of **UNDERVOLT RESTORE MIN VOLTS** for V_{ab}.
6. Repeat Steps 3 through 5 except adjust V_{cb}.

The following procedure checks Pickup with Two or Three Phases For Operation:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERVOLT RESTORE DELAY** to 0.
3. Inject $V_{ab} = V_{cb}$ = nominal voltage into the bus voltage input of the relay.
4. Reduce the injected voltages to cause an undervoltage trip, then set V_{cb} to nominal.
5. Slowly raise V_{ab} until the Close Relay operates. This is the operating level of **UNDERVOLT RESTORE MIN VOLTS** for V_{ab}.
6. Inject $V_{ab} = V_{cb}$ = nominal voltage into the bus voltage input of the relay.
7. Reduce the injected voltages to cause an undervoltage trip, then set V_{ab} to nominal.
8. Slowly raise V_{cb} until the Close Relay operates. This is the operating level of **UNDERVOLT RESTORE MIN VOLTS** for V_{cb}.

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8.6.6 UNDERFREQUENCY RESTORATION

Make the test connections specified in Figure 8–1: Relay Test Wiring – Wye Connection or Figure 8–2: Relay Test Wiring – Delta Connection on page 8–3. The following procedure checks Logic and Timers for Underfrequency Restoration:

1. Program the **UNDERFREQ 1 FUNCTION** as “Trip”, **MIN VOLTAGE** as “0”, and **UNDERFREQ 2 FUNCTION** as “Disabled”.
2. Assert or De-assert a logic input to simulate a closed breaker.
3. Inject a voltage at nominal voltage and frequency into the bus voltage Phase A input.
4. Initially set **UNDERFREQ RESTORATION** setpoint to Alarm, and other setpoints as required.
5. Reduce the frequency to below the underfrequency pickup level. After the programmed delay Underfrequency 1 should cause a trip, which should not initiate underfrequency restoration as the breaker is closed. Diagnostic message "Ufreq Restore Init" should not be displayed.

6. Assert or De-assert a logic input to simulate an open breaker, which should initiate underfrequency restoration. The diagnostic alarm message and LED should be displayed, and any output relays programmed to operate for this condition should operate.
7. Change the **UNDERFREQ RESTORE FUNCTION** setpoint to "Control", and the diagnostic message should change to control and the Alarm LED should turn off. Return this setpoint to "Alarm".
8. Assert logic input Block Restoration. The diagnostic alarm message and LED should be removed from the display, and any output relays that operated should reset.
9. De-assert the logic input. The alarm message and LED should again be displayed and output relays operated. After the delay programmed in Incomplete Sequence Time, the alarm message and LED should be removed from the display and output relays reset.
10. Return the reduced frequency to nominal, resetting both the underfrequency trip condition and underfrequency restoration.
11. Reduce frequency until Underfrequency 1 trips, then immediately return the frequency to nominal. The diagnostic alarm message and LED should be displayed, and output relays operated.
12. Provide a Reset to the relay, and the alarm message and LED should be removed from the display and output relays reset. Remove the Reset.
13. Arrange the interval timer to start on appearance of voltage and stop when the Close Relay operates.
14. Turn the voltage, of a frequency to cause an Underfrequency 1 trip, off. Reset the timer.
15. Turn the voltage on. The Close Relay should operate after the delay programmed in **UNDERFREQ RESTORE DELAY**.
16. If Underfrequency 2 initiation is to be checked, change Underfrequency Restoration to Disabled, Underfrequency 1 to Disabled, Underfrequency 2 to Trip and repeat Steps 2 through 8.

The following procedure checks the minimum voltage for underfrequency restoration:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERFREQ RESTORE DELAY** to 0.
3. Inject a voltage below the **UNDERFREQ RESTORE MIN VOLTS** level into the bus voltage input of the relay.
4. Reduce the injected frequency to cause an underfrequency trip, then increase the frequency to nominal.
5. Slowly raise V_a until the Close relay operates. This is the operating level of setpoint Underfreq Restore Min Volts.

The following procedure checks the minimum frequency for underfrequency restoration:

1. Assert or De-assert a logic input to simulate an open breaker.
2. Set **UNDERFREQ RESTORE DELAY** to 0.
3. Inject nominal voltage into the bus voltage input of the relay.
4. Reduce the injected frequency to cause an underfrequency trip.
5. Slowly increase the frequency until the Close Relay operates. This is the operating level of the **UNDERFREQ RESTORE MIN FREQ** setpoint.

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8.6.7 TRANSFER SCHEME

a) COMMON LOGIC

1. Ensure that the Phase Inst O/C 1, Neutral Inst O/C 1, Line Undervoltage 3, Line Undervoltage 4, Synchrocheck and Logic Input features in the relays programmed as Incomer 1 and Incomer 2 have been tested and are Enabled.
2. Ensure that the Synchrocheck and Logic Input features in the relay programmed as Bus Tie has been tested and is "Enabled".
3. Ensure all circuit breakers are disconnected from their normal positions in the primary circuit, are open and operating properly, and the close and trip circuits have been tested and are energized.
4. De-assert Logic Inputs 1, 2, 3, 4, 5, 6, 11, 12, and 13 at both Incomer relays. De-assert Logic Inputs 1, 2, 3, 4, 5, 6, and 11 at the Bus Tie relay.

5. At this time both of the Incomer relays should have Output Relays 1 and 4 operated, Output Relays 5 through 7 reset, and be displaying the message Transfer Not Ready. At the Bus Tie breaker relay, Output Relays 4 through 7 should be reset (de-energized).
6. Parallel the Line to Bus voltage inputs of the Incomer 1 relay to the Bus voltage input of the Bus Tie relay and connect this circuit to a voltage source (Source 1 for these tests). Do not energize the source.
7. Parallel the Line to Bus voltage inputs of the Incomer 2 relay to the Line voltage input of the Bus Tie relay and connect this circuit to a voltage source (Source 2 for these tests). Do not energize the source.
8. Assert Logic Input 5 (Breaker Connected) at the Bus Tie relay; Output Relays 4 and 6 on the Bus Tie relay should operate.
9. Assert Logic Input 5 (Breaker Connected) at the Incomer 1 relay - nothing should happen.
10. Assert Logic Input 2 (Remote Close) at the Incomer 1 relay - nothing should happen. Energize Source 1 at nominal voltage - the Incomer 1 breaker should close, Output Relay 4 should reset and Output Relays 5 and 7 on the Incomer 1 relay should operate.
11. Assert Logic Input 5 (Breaker Connected) at the Incomer 2 relay - nothing should happen.
12. Assert Logic Input 2 (Remote Close) at the Incomer 2 relay - nothing should happen. Energize Source 2 at nominal voltage - the Incomer 2 breaker should close, Output Relay 4 should reset and Output Relays 5 and 7 on the Incomer 2 relay should operate.
13. De-assert Logic Input 5 (Breaker Connected) at the Bus Tie relay - Output Relays 4 and 6 on the Bus Tie relay should reset, and at both Incomer relays the message Transfer Not Ready should be displayed.
14. Assert Logic Input 5 (Breaker Connected) at the Bus Tie relay - Output Relays 4 and 6 on the Bus Tie relay should operate, and at both Incomer relays the message Transfer Not Ready should be removed from the display.
15. De-assert Logic Input 5 (Breaker Connected) at the Incomer 1 relay; at the Incomer 1 relay Output Relays 5 and 7 should reset; at both Incomer relays the message Transfer Not Ready should be displayed.
16. Assert Logic Input 5 (Breaker Connected) at the Incomer 1 relay; at the Incomer 1 relay Output Relays 5 and 7 should operate; at both Incomer relays the message Transfer Not Ready should be removed from the display.
17. Momentarily assert Logic Input 3 (Remote Open) at the Incomer 1 relay; the Incomer 1 breaker should trip and Output Relays 5 and 7 should reset; at both Incomer relays the message Transfer Not Ready should be displayed.
18. Momentarily assert Logic Input 2 (Remote Close) at the Incomer 1 relay; the Incomer 1 breaker should close and Output Relays 5 and 7 should operate; at both Incomer relays the message Transfer Not Ready should be removed.
19. De-assert Logic Input 5 (Breaker Connected) at the Incomer 2 relay; at the Incomer 2 relay Output Relays 5 and 7 should reset; at both Incomer relays the message Transfer Not Ready should be displayed.
20. Assert Logic Input 5 (Breaker Connected) at the Incomer 2 relay; at the Incomer 2 relay Output Relays 5 and 7 should operate; at both Incomer relays the message Transfer Not Ready should be removed from the display.
21. Momentarily assert Logic Input 3 (Remote Open) at the Incomer 2 relay; the Incomer 2 breaker should trip and Output Relays 5 and 7 should reset; at both Incomer relays the message Transfer Not Ready should be displayed.
22. Momentarily assert Logic Input 2 (Remote Close) at the Incomer 2 relay; the Incomer 2 breaker should close and Output Relays 5 and 7 should operate; at both Incomer relays, the Transfer Not Ready message should disappear.
23. Momentarily assert Logic Input 2 (Remote Close) at the Bus Tie relay; the Bus Tie breaker should close and Output Relays 5 and 7 should operate; at both Incomer relays the Transfer Not Ready message should be displayed.
24. Momentarily assert Logic Input 3 (Remote Open) at the Bus Tie relay; the Bus Tie breaker should trip and Output Relays 5 and 7 should reset, and at both Incomer relays the Transfer Not Ready message should disappear.
25. Assert Logic Input 11 (Block Transfer) at the Incomer 1 relay; Output Relays 5 and 7 should reset; at both Incomer relays the Transfer Not Ready message should be displayed.
26. De-assert Logic Input 11 (Block Transfer) at the Incomer 1 relay; Output Relays 5 and 7 should operate; at both Incomer relays the Transfer Not Ready message should be removed from the display.
27. Assert Logic Input 11 (Block Transfer) at the Incomer 2 relay; Output Relays 5 and 7 should reset; at both Incomer relays the Transfer Not Ready message should be displayed.

28. De-assert Logic Input 11 (Block Transfer) at the Incomer 2 relay; Output Relays 5 and 7 should operate; at both Incomer relays the Transfer Not Ready message should be removed from the display.
29. Check the Event Recorders in the Incomer 1 and 2 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

b) LOW VOLTAGE LOGIC

1. Slowly reduce test voltage Source 1 supplying Incomer relay 1. At the pickup voltage of the Line Undervoltage 3 feature Output Relay 4 should operate. At this time the Incomer 2 relay should display the Transfer Not Ready message.
2. Slowly increase test voltage Source 1. At the reset voltage of the Line Undervoltage 3 feature Output Relay 4 should reset. At the Incomer 2 relay after the time delay of setpoint Transfer Delay Other Source the message Transfer Not Ready should be removed from the display.
3. Slowly reduce test voltage Source 2 supplying Incomer relay 2. At the pickup voltage of the Line Undervoltage 3 feature Output Relay 4 should operate. At this time the Incomer 1 relay should display the Transfer Not Ready message.
4. Slowly increase test voltage Source 2. At the reset voltage of the Line Undervoltage 3 feature Output Relay 4 should reset. At the Incomer 1 relay after the time delay of setpoint Transfer Delay Other Source the message Transfer Not Ready should be removed from the display. Turn voltages off - Incomer breakers 1 and 2 should trip when Undervoltage 4 times out.
5. Check the Event Recorders in both Incomers and the Bus Tie relay for the correct messages and sequences, then clear the recorders.

c) TRANSFER INITIATED BY LOCKOUT 86-1

1. Energize both test sources at nominal voltage, close Incomer breakers 1 and 2, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. At the Incomer 1 relay assert Logic Input 12 (Transformer Lockout.) The Incomer 1 relay should trip the Incomer 1 breaker and operate Output Relay 6 to send a Close From Incomer 1 signal to the Bus Tie relay. Output Relay 6 at the Incomer 1 relay should reset when the Incomer 1 breaker trips, removing the signal to the Bus Tie relay. The Bus Tie breaker should not close as the voltage on its Bus and Line inputs is too high.
3. Slowly reduce the test Source 1 voltage. The Bus Tie breaker should close when the voltage is below the Dead Bus Max Volts setpoint of its Synchrocheck feature. Increase the voltage to nominal.
4. At the Incomer 1 relay de-assert Logic Input No. 12 (Transformer Lockout.)
5. Momentarily assert Logic Input 3 (Remote Open) at the Bus Tie relay. The Bus Tie breaker should open.
6. Momentarily assert Logic Input 2 (Remote Close) at the Incomer 1 relay. The Incomer 1 breaker should close.
7. Check the Event Recorders in the Incomer 1 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

d) TRANSFER INITIATED BY LOCKOUT 86-2

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. At the Incomer 2 relay assert Logic Input 12 (Transformer Lockout.) The Incomer 2 relay should trip the Incomer 2 breaker and operate Output Relay 6 to send a Close From Incomer 2 signal to the Bus Tie relay. Output Relay 6 at the Incomer 2 relay should reset when the Incomer 2 breaker trips, removing the signal to the Bus Tie relay. The Bus Tie breaker should not close as the voltage on its Bus and Line inputs is too high.
3. Slowly reduce the test Source 2 voltage. The Bus Tie breaker should close when the voltage is below the Dead Line Max Volts setpoint of its Synchrocheck feature. Increase the voltage to nominal.
4. At the Incomer 2 relay de-assert Logic Input No. 12 (Transformer Lockout.)
5. Momentarily assert Logic Input 3 (Remote Open) at the Bus Tie relay. The Bus Tie breaker should open.
6. Momentarily assert Logic Input 2 (Remote Close) at the Incomer 2 relay. The Incomer 2 breaker should close. Check the Event Recorders in the Incomer 2 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

e) TRANSFER INITIATED BY SOURCE TRIP NO. 1

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. At the Incomer 1 relay assert Logic Input 13 (Source Trip). The Incomer 1 relay should trip the Incomer 1 breaker and operate Output Relay 6 to send a Close From Incomer 1 signal to the Bus Tie relay. Output Relay 6 at the Incomer 1 relay should reset when the Incomer 1 breaker trips, removing the signal to the Bus Tie relay. The Bus Tie breaker should not close as the voltage on its Bus and Line inputs is too high.
3. Slowly reduce the test Source 1 voltage. The Bus Tie breaker should close when the voltage is below the Dead Bus Max Volts setpoint of its Synchrocheck feature. Increase the voltage to nominal.
4. At the Incomer 1 relay de-assert Logic Input No. 13 (Source Trip).
5. Momentarily assert Logic Input 3 (Remote Open) at the Bus Tie relay. The Bus Tie breaker should open.
6. Momentarily assert Logic Input 2 (Remote Close) at the Incomer 1 relay. The Incomer 1 breaker should close.
7. Check the Event Recorders in the Incomer 1 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

f) TRANSFER INITIATED BY SOURCE TRIP NO. 2

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. At the Incomer 2 relay assert Logic Input 13 (Source Trip). The Incomer 2 relay should trip the Incomer 2 breaker and operate Output Relay 6 to send a Close From Incomer 2 signal to the Bus Tie relay. Output Relay 6 at the Incomer 2 relay should reset when the Incomer 2 breaker trips, removing the signal to the Bus Tie relay. The Bus Tie breaker should not close as the voltage on its Bus and Line inputs is too high.
3. Slowly reduce the test Source 2 voltage. The Bus Tie breaker should close when the voltage is below the Dead Line Max Volts setpoint of its Synchrocheck feature. Increase the voltage to nominal.
4. At the Incomer 2 relay de-assert Logic Input No. 13 (Source Trip).
5. Momentarily assert Logic Input 3 (Remote Open) at the Bus Tie relay. The Bus Tie breaker should open.
6. Momentarily assert Logic Input 2 (Remote Close) at the Incomer 2 relay. The Incomer 2 breaker should close.
7. Check the Event Recorders in the Incomer 2 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

g) TRANSFER INITIATED BY UNDERVOLTAGE ON SOURCE 1

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. Turn test Source 1 off. The Undervoltage 3 feature of the Incomer 1 relay should operate Output Relay 4 immediately. At Incomer 2, Output Relay 3 operates and the Transfer Not Ready message is displayed. When the Undervoltage 4 feature times out, the Incomer 1 relay should trip Breaker 1 and operate Output Relay 6 to send a Close From Incomer 1 signal to the Bus Tie relay. Output Relay 6 should reset when Breaker 1 trips, removing the signal to the Bus Tie relay. Upon receiving the signal from the Incomer 1, the Bus Tie relay should close the Bus Tie Breaker.
3. Check the Event Recorders in the Incomer 1 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

h) MANUAL RESTORATION OF INCOMER 1

1. Turn test Source 1 on and adjust Source 1 to be out-of-synchronism with Source 2.
2. At the Bus Tie relay assert Logic Input 6 (Selected To Trip).
3. At the Incomer 1 relay assert Logic Input 2 (Remote Close). The Incomer 1 breaker should not close as it cannot pass synchrocheck. Adjust Source 1 until in-synchronism with Source 2. At this time the Incomer 1 breaker should close and the Bus Tie breaker should trip. Turn off both voltages.
4. At the Bus Tie relay de-assert Logic Input 6 (Selected To Trip). Check the Event Recorders in the Incomer 1 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

i) TRANSFER INITIATED BY UNDERVOLTAGE ON SOURCE 2

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. Turn test Source 2 off. The Undervoltage 3 feature of Incomer 2 relay should operate immediately and operate output relay 4; at the Incomer 1 relay, Output Relay 3 will operate and the Transfer Not Ready message will be displayed. When the Undervoltage 4 feature times-out the Incomer 2 relay should trip Incomer Breaker 2 and operate Output Relay 6 to send a Close From Incomer 2 signal to the Bus Tie relay. Output Relay 6 should reset when Breaker 2 trips, removing the signal to the Bus Tie relay. Upon receiving the signal from the Incomer 2 relay the Bus Tie relay should close the Bus Tie Breaker.
3. Check the Event Recorders in the Incomer 2 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

j) MANUAL RESTORATION OF INCOMER 2

1. Turn test Source 2 on and adjust Source 2 to be out-of-synchronism with Source 1.
2. At the Bus Tie relay assert Logic Input 6 (Selected To Trip).
3. At the Incomer 2 relay assert Logic Input 2 (Remote Close). The Incomer 2 Breaker 2 should not close as it cannot pass synchrocheck. Adjust Source 2 until in-synchronism with Source 1. At this time the Incomer 2 breaker should close and the Bus Tie breaker should trip. Turn off both voltages.
4. At the Bus Tie relay de-assert Logic Input 6 (Selected To Trip).
5. Check the Event Recorders in the Incomer 2 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

k) SIMULTANEOUS LOSS OF BOTH SOURCES

1. Energize the line voltage input of both incomer relays from a single source at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both relays.
2. Turn the test source off. The Undervoltage 3 element of both incomer relays should operate immediately and operate Output Relay 4; at both incomers the Transfer Not Ready message will be displayed.
3. If the **BLOCK TRIP ON DOUBLE LOSS** setpoint is set to "Disabled":
   3.1. When the Undervoltage 4 element times out, the incomer relays should trip the incomer breakers. The bus tie breaker should not close.
   3.2. Check the event recorders in both incomer relays for the correct sequences, then clear the recorders.
4. If the **BLOCK TRIP ON DOUBLE LOSS** setpoint is set to "Enabled":
   4.1. When the Undervoltage 4 element times out, the incomer relays should not trip the incomer breakers. The bus tie breaker should not close.
   4.2. Check the event recorders in both incomer relays for the correct sequences, then clear the recorders.

l) AFTER-PARALLEL TRIPPING OF SELECTED INCOMER

1. Energize both test sources at nominal voltage, still in-synchronism, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. At the Incomer 1 relay assert Logic Input 6 (Selected To Trip.)
3. At the Bus Tie relay assert Logic Input 2 (Remote Close.) The Bus Tie breaker should close as the voltages are in-synchronism. After this the Incomer 1 breaker should trip.
4. At the Incomer 1 relay de-assert Logic Input 6 (Selected To Trip.)
5. At the Incomer 2 relay assert Logic Input 6 (Selected To Trip.)
6. At the Incomer 1 relay assert Logic Input 2 (Remote Close.) The Incomer 1 breaker should close as the voltages are in-synchronism. After this the Incomer 2 breaker should trip. Turn the voltages off.
7. Check the Event Recorders in the Incomer 1 and 2 and Bus Tie relays for the correct messages and sequences, then clear the recorders.

m) TRANSFER BLOCKED BY OVERCURRENT ON INCOMER 1

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. Disable the Neutral IOC 1 feature. Inject a current into the phase current input of the Incomer 1 relay. Slowly increase this current until the Phase IOC 1 element operates. At the Incomer 1 relay and the Transfer Not Ready message should be displayed.
3. Slowly decrease the injected current until the Phase IOC 1 element resets. At the Incomer 1 relay after the delay time of setpoint Transfer Delay This Source and the Transfer Not Ready message should be removed from the display.
4. Enable the Neutral IOC 1 feature and Disable the Phase IOC 1 feature. Inject a current into the phase current input of the Incomer 1 relay. Slowly increase this current until the Neutral IOC 1 element operates. At the Incomer 1 relay the Transfer Not Ready message should be displayed.
5. Slowly decrease the injected current until the Neutral IOC 1 element resets. At the Incomer 1 relay after the delay time of the **TRANSFER DELAY THIS SOURCE** setpoint and the Transfer Not Ready message should disappear from the display.

n) TRANSFER BLOCKED BY OVERCURRENT ON INCOMER 2

1. Energize both test sources at nominal voltage, and wait until the Transfer Not Ready message is removed from the display of both Incomer relays.
2. Disable the Neutral IOC 1 feature. Inject a current into the phase current input of the Incomer 2 relay. Slowly increase this current until the Phase IOC 1 element operates. At the Incomer 2 relay the Transfer Not Ready message should be displayed.
3. Slowly decrease the injected current until the Phase IOC 1 element resets. At the Incomer 2 relay after the delay time of setpoint Transfer Delay This Source and the Transfer Not Ready message should be removed from the display.
4. Enable the Neutral IOC 1 feature and Disable the Phase IOC 1 feature. Inject a current into the phase current input of the Incomer 2 relay. Slowly increase this current until the Neutral IOC 1 element operates. At the Incomer 2 relay the Transfer Not Ready message should be displayed.
5. Slowly decrease the injected current until the Neutral IOC 1 element resets. At the Incomer 2 relay after the delay time of setpoint **TRANSFER DELAY THIS SOURCE** and the Transfer Not Ready message should be removed from the display.

8.6.8 AUTORECLOSE (760 ONLY)

For autoreclose testing, make the test connections specified in Figure 8–6: Autoreclose Test Connections below.

NOTE

For these tests Output Relay 7 (Auxiliary) is programmed to operate when the relay trips, to stop the timer. If this is inconvenient, use any other output auxiliary relay.

The following procedure tests overall operation of the Autoreclose feature:

1. Check that the relay is in the local control mode, and the Local LED is on. Open and close the breaker by pressing the OPEN and CLOSE keys. Check that the Breaker Open and Breaker Closed LEDs are correctly displaying the state of the breaker. Leave the breaker open.
2. Check that Reclosure Enabled LED is lit and the Reclosure Disabled LED is off.
3. Close the breaker by pressing the CLOSE key. The Reclosure Enabled LED should go out, and the Reclosure Disabled LED should come on during the **AR BLOCK TIME UPON MANUAL CLOSE** value. Immediately after this interval, check that Reclosure Enabled LED is on, and the Reclosure in Progress and Reclosure Disabled LEDs are off. Any output relays programmed to operate for "Reclose Enabled" should now be operated.
4. Check the interval of the ‘AR block time upon manual close’ by observing the Reclosure Enabled LED.

   NOTE

   For all further testing, ensure that a reclose is not initiated until after the **AR BLOCK TIME UPON MANUAL CLOSE** value has elapsed, after a manual close.

5. Assert a Block Reclosure logic input. The Reclosure Enabled LED should go out and the Reclosure Disabled LED come on. De-assert the Block Reclosure logic input. The Reclosure Enabled LED should come on and the Reclosure Disabled LED should go out.

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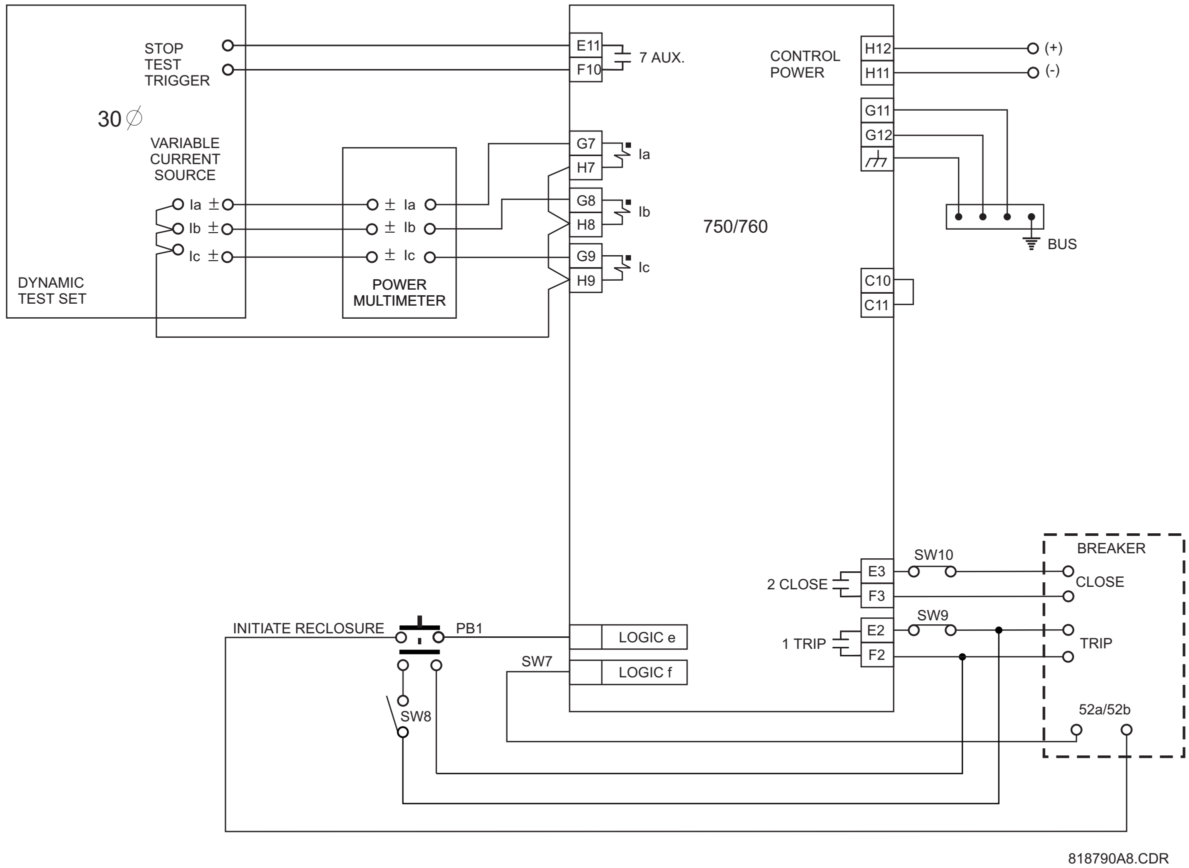

Figure 8–6: AUTORECLOSE TEST CONNECTIONS

6. Assert a Cancel Reclosure logic input. The Reclosure Enabled LED should go out and the Reclosure Disabled LED come on. De-assert the Cancel Reclosure logic input. The Reclosure Enabled LED should come on and the Reclosure Disabled LED should go out.
7. Verify that the **A1 STATUS ⇨⇩ AR ⇨ AR SHOT NUMBER IN EFFECT** value is “0”.
8. Momentarily assert the Initiate Reclosure logic input. The Reclosure In Progress LED should come on immediately, and any output relays programmed to operate for Reclose In Progress should now be operated. After the delay programmed for **INCOMPLETED SEQUENCE TIME**, the Reclosure In Progress LED will go out, as the breaker has not tripped, and the incomplete sequence timer has canceled the reclose in progress. Any output relays operated above should now be reset. Check the interval of the incomplete sequence timer by observing the Reclosure In Progress LED.
9. Momentarily assert the Initiate Reclosure logic input causing a reclose in progress indication. Immediately assert the Block Reclosure logic input and the scheme should become disabled, canceling the reclose in progress. Assert the Initiate Reclosure logic input and check that the scheme does not become in progress. De-assert the Block Reclosure logic input and the scheme should become in progress.
10. Assert a Cancel Reclosure logic input and the scheme should become disabled, canceling the reclose in progress. De-assert the Cancel Reclosure logic input and the scheme should become enabled.
11. Assert the Initiate Reclosure logic input then immediately after assert the Remote Open logic input, initiating a reclose and tripping the breaker (the Reclosure In Progress LED is now on). Verify that the **AR SHOT NUMBER IN EFFECT** value is “0”. Before the programmed dead-time interval for Reclosure 1 has elapsed, press the CLOSE key. The breaker should not close, as reclose is in progress. The breaker should reclose at the end of the dead-time interval, incrementing the shot counter to 1. Before the scheme resets, verify that the **A1 STATUS ⇨⇩ AR ⇨⇩ AR SHOTS REMAINING** value is the number of shots programmed less one. This reading should change to the number of shots programmed when the scheme is automatically reset at the end of the reset interval. The event recorder should have recorded logic input Initiate Reclosure, Remote Open, the Reclose, and Reclosure Reset. Check the interval of the autoreclose reset timer in the event recorder.

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12. Assert the Initiate Reclosure logic input then immediately after assert the Remote Open logic input, initiating a reclose and tripping the breaker. Check that the breaker trips and later recloses, and the displayed number of shots remaining is reduced by one. Immediately assert the Initiate Reclosure and Remote Open logic inputs again, to initiate another trip and reclose and the displayed number of shots remaining is reduced by one again. Repeat this procedure until the programmed number of shots have been performed. Initiate Reclosure once more and the scheme should go to lockout; the Reclosure Lockout and Reclosure Disabled LEDs should now be on, and the Reclosure Enabled LED should be off. Any output relays programmed to operate for Lockout should now be operated.
13. The event recorder should have recorded each logic input for Initiate Reclosure, each Reclose, and Reclosure Lockout. Check the interval of dead time for each shot in the event recorder.
14. Press the RESET key. Lockout should be canceled and the displayed number of shots should return to the programmed value (the event recorder should record this reset.) Check that the Reclosure Lockout and Reclosure Disabled LEDs are off, and the Reclosure Enabled LED is now on. Any output relays operated above should now be de-energized. Close the breaker.
15. Repeat Step 12. Assert a Close command, either locally or remotely, and observe that lockout is reset at the end of the **AR BLOCK TIME UPON MANUAL CLOSE** setpoint, with indications as above.
16. Set a current level above the pickup threshold of any time overcurrent element and turn the current off.
17. Repeat Step 12. Assert a Close command, either locally or remotely, and turn the current on. Check that lockout is not reset at the end of the manual close blocking time interval, and the breaker eventually trips. Turn the current off.

If Breaker Operation Failure, and/or Breaker Failure features are Operational, use the following procedure:

1. Open test switch SW9 to prevent a trip command from the relay from operating the breaker.
2. Enable one of the overcurrent elements by setting its function to "Trip + AR".
3. Inject a current above the pickup level of both the operational overcurrent feature and the Breaker Failure Current into the relay, until the feature sends a trip, which will also initiate reclosure. After the failure delay time, a breaker failure condition will be determined, which should immediately set the reclose scheme to the Lockout state, turning the Reclosure Lockout LED on.
4. Turn the injected current off and Reset the relay. Disable the overcurrent element and close both the breaker and SW9.

Use the following procedure to test Autoreclose Current Supervision. Note that the number of reclosure shots setting controls the messages in this group. If four (4) shots are programmed, all messages are available. If three (3) shots are programmed, the **3 SHOTS FOR CURRENT ABOVE** setpoint is not available on the relay. If two (2) shots are programmed, the **3 SHOTS FOR CURRENT ABOVE** and **2 SHOTS FOR CURRENT ABOVE** setpoints are not available. This procedure assumes four (4) shots are programmed.

1. Close the breaker and wait until reclosure is enabled.
2. Verify that the **A1 STATUS ⇨⇩ AR ⇨⇩ AR SHOTS REMAINING** value is “0”.
3. Open SW9 so the breaker cannot trip. Inject current and slowly ramp higher until an instantaneous feature sends a trip, which also initiates reclosure. The value displayed should be 4 (it has not yet decremented).
4. Continue to very slowly increase the current until the value displayed becomes 3. Continue to very slowly increase the current, until the value displayed sequentially becomes 2 and then 1, at the currents programmed. Very slowly increase the current, at the current programmed, until the relay goes to Lockout.

Use the following procedure to test Autoreclose Zone Coordination:

1. Set the **MAX NUMBER OF RECLOSURE SHOTS** to “4”. Set the test set to a current level above the **PHASE CURRENT INCREASE** setpoint, and ensure that the neutral current is below the **NEUTRAL CURRENT INCREASE** setpoint by making this value larger. Turn on the current. Then, before the **MAX FAULT CLEARING TIME** has elapsed, turn off the current. The **AR SHOT NUMBER IN EFFECT** should have been incremented. Reset the relay. Turn on the current. Then, after the **MAX FAULT CLEARING TIME** has elapsed, turn off the current. The **AR SHOT NUMBER IN EFFECT** should not have been incremented. Reset the relay.
2. Set the current level below the **PHASE CURRENT INCREASE** setpoint value. Turn the current on and then off. The **AR SHOT NUMBER IN EFFECT** value should not change.
3. Set the current level above the **PHASE CURRENT INCREASE** setpoint value, but below the **NEUTRAL CURRENT INCREASE** setpoint value. Turn the current on and then off. The **AR SHOT NUMBER IN EFFECT** value should increment by one.

Repeatedly turning the current on and then off should continue to increment the **AR SHOT NUMBER IN EFFECT** to the **MAX NUMBER OF RECLOSURE SHOTS**, and the Autoreclose scheme will go into lockout.

4. Set the current level so the neutral current is below the **NEUTRAL CURRENT INCREASE** setpoint and the phase current below the **PHASE CURRENT INCREASE** setpoint. Turn the current on and then off. The **AR SHOT NUMBER IN EFFECT** value should not change.
5. Set the current level such that the neutral current is above the **NEUTRAL CURRENT INCREASE** setpoint and the phase current is below the **PHASE CURRENT INCREASE** setpoint. Turn the current on and then off. The **AR SHOT NUMBER IN EFFECT** value should increment as in Step 3.

Use the following procedure to test Instantaneous Overcurrent Blocking for Autoreclose:

1. Select the **MAX NUMBER OF RECLOSURE SHOTS** to be 4. With **PHASE INST OC 1 FUNCTION** selected as "Trip + AR", set the test set to a current level above the pickup of this element, and inject into a phase input. The relay should trip and reclose 4 times. Turn off the current, reset the relay and close the breaker.
2. Enable Phase Inst OC 1 Blocking for Reclosure Shot 1. Turn on the current. The relay should trip and reclose once. The Shot in Effect display should show 1 and the Pickup LED off. Once the **AR RESET TIME** has expired, the relay will then pickup, trip and reclose until lockout as the fault current is still present. Turn off the current, reset the relay and close the breaker.
3. Disable Phase Inst OC 1 Blocking for Reclosure Shot 1, and Enable for Reclosure Shot 2. Turn on the current. Reclosure Shot 2 should not operate, and the Pickup LED will be off. Turn off the current and reset the relay.
4. Repeat Step 3 using Phase Inst OC 1 Blocking for each of the 4 Reclosure Shot settings.
5. Repeat Steps 1 through 4 for each Instantaneous OC Blocking setpoint, disabling each instantaneous overcurrent element before moving on to the next.

Use the following procedure to test Raised Pickup of TOC Elements for Autoreclose:

1. Keep the **MAX NUMBER OF RECLOSURE SHOTS** at 4. With the **PHASE TIME OC 1 FUNCTION** selected as “Trip + AR”, set the test set to a current level above the pickup of this element. Turn off the current, reset the relay and close the breaker.
2. In Reclosure Shot 1 settings, select the **PHASE TIME OC 1 RAISED PICKUP** such that it brings the pickup level just below the actual current that is being injected. Turn on the current. The relay should trip and reclose 4 times.
3. In Reclosure Shot 1 settings, select the **PHASE TIME OC 1 RAISED PICKUP** such that it brings the pickup level just above the actual current that is being injected. Turn on the current. The relay should trip and reclose once. The Shot in Effect display should show 1 and the Pickup LED off. Once the **AR RESET TIME** has expired, the relay will then pickup, trip, and reclose until lockout as the fault current is still present. Turn off the current, reset the relay and close the breaker.
4. Return **PHASE TIME OC 1 RAISED PICKUP** to "0" for Reclosure Shot 1, and set it to a level that is above the actual current for Reclosure Shot 2. Turn on the current. Reclosure Shot 2 should not operate, and the Pickup LED will be off. Turn off the current and reset the relay.
5. Repeat Step 4 using Phase Time OC 1 Blocking for each of the 4 Reclosure Shot settings.
6. Repeat Steps 1 through 5 for each **TIME OC RAISED PICKUP** setpoint, disabling each time overcurrent element before moving on to the next.

The following procedure tests the Select Setpoint Group function for Autoreclose:

1. Keep the **MAX NUMBER OF RECLOSURE SHOTS** at 4. In Setpoint Group 1, set **PHASE TIME OC 1 FUNCTION** to “Trip + AR”. In Setpoint Group 2, set **PHASE TIME OC 2 FUNCTION** to “Trip + AR”. In Setpoint Group 3, set **PHASE INST OC 1 FUNCTION** to “Trip + AR”. In Setpoint Group 4, set **PHASE INST OC 2 FUNCTION** to “Trip + AR”. Select the same pickup level for each element.
2. For Reclosure Shot 1 settings, set the **SELECT SETPOINT GROUP** setpoint to "Group 2". Similarly, set it to "Group 3" for Reclosure Shot 2, "Group 4" for Reclosure Shot 3, and "Group 1" for Reclosure Shot 4.
3. Set the test set to a current level above the pickup of these elements. With the current source off, Reset the relay, and clear the event recorder.
4. Turn on the current. The relay will Trip and Autoreclose four times due to the following elements, in order: Phase TOC 1, Phase TOC 2, Phase IOC 1, Phase IOC 2, Phase TOC 1. The event recorder will show this sequence of events. Turn off the current, and reset the relay.

8.7.1 DESCRIPTION

NOTE

The procedure outlined in this section is explicitly confined to the operation of the relay, and does not include the operation of any equipment external to the relay.

1. Cycle through the relay setpoints and set each setpoint in each group to the required value.
2. Save all the relay setpoints to a file (or print them) for a final inspection to confirm that all setpoints are correct.
3. Set the relay clock (date and time) if IRIG-B is not used or unavailable.
4. Clear all historical values stored in the relay. Under subheading **S1 RELAY SETUP ⇨⇩ CLEAR DATA**, set **CLEAR ENERGY USE DATA**, **CLEAR MAX DMND DATA**, and **CLEAR EVENT RECORDER DATA** to “Yes”. Under subheading **S1 RELAY SETUP ⇨⇩ INSTALLATION**, also set **RESET TRIP COUNTER DATA** and **RESET ARCING CURRENT DATA** to “Yes”.
5. Turn off all test voltages, and the power supply to the relay. Remove all test wiring connections, and restore to normal any panel wiring disturbed for testing.
6. Perform a complete visual inspection to confirm that the relay is ready to be placed in service. Energize the relay power supply circuit and check that the Relay In Service LED is on, and that the Self-Test Warning LED is off, establishing that the relay is operating normally.
7. For complete on-load checking of the relay, it is required to supply load current to the relay in a known direction of power flow, with a known approximate value of power factor. The load current should be high enough to be certain that the main CTs are connected correctly. The power system should be arranged to fulfill these conditions before the feeder to which the relay is connected is energized. Advise operators of the possibility of a trip on initial energization.

8.7.2 ON-LOAD TESTING

1. If possible, before closing the feeder breaker to supply load, energize the VT circuit to which the relay is connected. Check that all relay measurements are as expected. Under **A2 METERING ⇨⇩ VOLTAGE**, verify the following:

   AB: BC: CA: <Magnitude>, **AVERAGE LINE VOLTAGE:** <Magnitude>, **AN: BN: CN:** <Magnitude>, **AVERAGE PHASE VOLTAGE:** <Magnitude in kV>, **LINE A-B VOLTAGE:** <Phasor>, **LINE B-C VOLTAGE:** <Phasor>, **LINE C-A VOLTAGE:** <Phasor>, **PHASE A-N VOLTAGE:** <Phasor>, **PHASE B-N VOLTAGE:** <Phasor>, **PHASE C-N VOLTAGE:** <Phasor>, **POS SEQ VOLTAGE:** <Phasor>, **NEG SEQ VOLTAGE:** <Phasor>, and **ZERO SEQ VOLTAGE:** <Phasor>
2. To have an immediate indication upon closing of the load level and whether some overcurrent protection is operating, before closing the feeder breaker display the **A2 METERING ⇨ CURRENT ⇨⇩ % OF LOAD-TO-TRIP** actual value.
3. After the feeder circuit breaker is closed and the feeder is carrying load current, check that all relay measurements are as expected. Under subheading **A2 METERING ⇨ CURRENT**, verify the following actual values:

   A: B: C: <Magnitude>, **AVERAGE CURRENT:** <Magnitude>, **PHASE A(C) CURRENT:** <Phasor>, **NEUTRAL CURRENT:** <Phasor>, **GND CURRENT:** <Phasor>, **SENSTV GND CURRENT:** <Phasor>, **POS SEQ CURRENT:** <Phasor>, **NEG SEQ CURRENT:** <Phasor>, and **ZERO SEQ CURRENT:** <Phasor>
4. Under subheading **A2 METERING ⇨⇩ PWR**, verify that **REAL PWR**, **REACTIVE PWR**, **APPARENT PWR**, and **PWR FACTOR** values (for single and three-phase values) are as expected.
5. Verify the **A2 METERING ⇨⇩ FREQ ⇨ SYSTEM FREQ** actual value is as expected.
6. It is very important to confirm that the input CTs are connected properly to provide correct directional control and metering calculations. A first check of this connection is to note that the values of watts and vars as calculated by the relay have the correct sign. This is done by comparing the relay measurements, which are signed by the conventions shown in Figure 6–3: Power Quantity Relationships on page 6–8, to the known feeder load characteristics.
7. After some time has passed, dependent on feeder load and demand time interval settings, check the following measured values: Under **A2 METERING ⇨⇩ ENERGY**, verify the **POSITIVE WATTHOURS**, **POSITIVE WATTHOUR COST**, **NEGATIVE WATTHOURS**, **NEGATIVE WATTHOUR COST**, **POSITIVE VARHOURS**, and **NEGATIVE VARHOURS** values.
8. Under subheading **A2 METERING ⇨⇩ DMND ⇨ PHASE A(C) CURRENT**, verify the **LAST PHASE A(C) CURRENT DMND** and **MAX PHASE A CURRENT DMND** values.
9. Under subheading **A2 METERING ⇨⇩ DMND ⇨⇩ REAL PWR**, verify the **LAST REAL PWR DMND** and **MAX REAL PWR DMND** values.

10. Under subheading **A2 METERING ⇨⇩ DMND ⇨⇩ REACTIVE PWR**, verify the **LAST REACTIVE PWR DMND** and **MAX REACTIVE PWR DMND** values.
11. Under subheading **A2 METERING ⇨⇩ DMND ⇨⇩ APPARENT PWR**, verify the **LAST APPARENT PWR DMND** and **MAX APPARENT PWR DMND** values.

8.7.3 DIELECTRIC STRENGTH TESTING

A fully assembled production version of the relay is tested in its metal case. The dielectric strength of all the input/output terminals are tested with respect to its grounded chassis and Terminal G12 (safety ground). The test voltage of the tester, from the initial value of 0 V AC, is raised to 2 kV AC in such a manner (slowly) that no appreciable transients occur. The voltage is maintained for 1 minute and is then reduced smoothly to zero as rapidly as possible. According to IEC255-5, the Hi-Pot test is repeated with a voltage not less than 500 V AC.

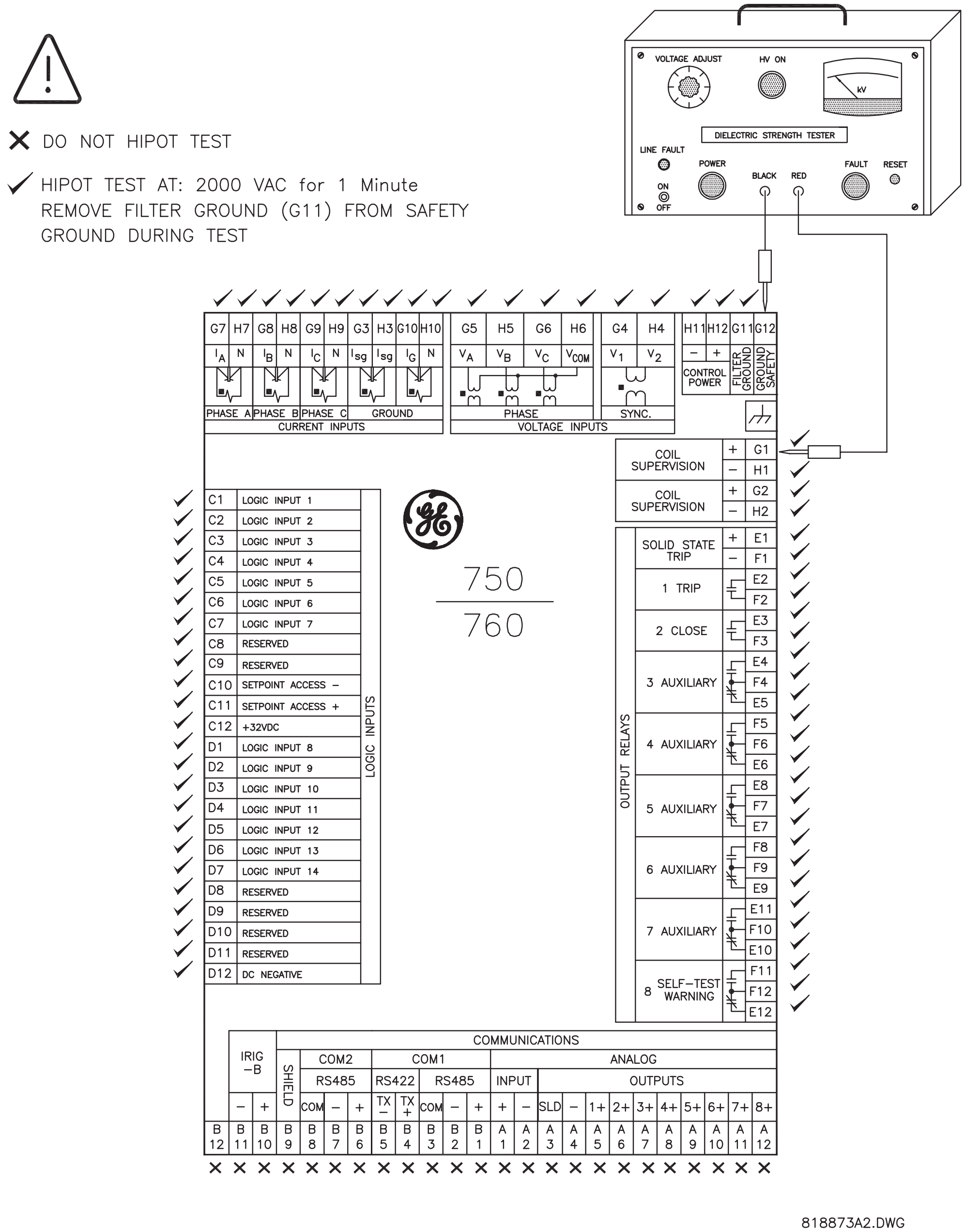

Figure 8–7: DIELECTRIC STRENGTH WIRING

A.1.1 REVERSE POWER

To upgrade the 750/760 to include Mod 008 (Reverse Power), a special 16-digit passcode must be purchased from the GE Multilin Sales Department. As well, the firmware version must be 5.00 or higher. The latest firmware for the 750/760 can be obtained from the GE Multilin website at http://www.GEindustrial.com/multilin. Refer to Upgrading the 750/760 Firmware on page 4–11 for details on the firmware upgrade procedure.

To enable Mod 008:

1. Press the SETPOINT key to display enter the relay setup menu:

```
■■ SETPOINTS
■■ S1 RELAY SETUP
```

2. Press the MESSAGE ▼ key until the following message appears:

```
■ MOD 008 UPGRADE
■ [ENTER] for more
```

3. Press the ENTER key to display the following message:

```
ENABLE MOD 008?
Disabled
```

4. Press the VALUE ▼ key once to change the setpoint value to "Enabled":

```
ENABLE MOD 008?
Enabled
```

5. Press the ENTER key to save the setpoint value. The following message will be displayed:

```
■ NEW SETPOINT
■ STORED
```

6. Press the MESSAGE ▼ key once. The following message appears:

```
ENTER PASSCODE:
0000000000000000
```

7. Press the ENTER key to edit this passcode. Use the VALUE ▲ and VALUE ▼ keys to change each digit to match the 16-digit passcode supplied by GE Multilin. Press ENTER to move to the next digit. After entering the last digit, the cursor will return to the first digit of the code.
8. Press the MESSAGE ▼ key once. The following message will be displayed:

```
UPGRADE OPTIONS?
No
```

9. Press the VALUE ▼ key once to change the message to:

```
UPGRADE OPTIONS?
Yes
```

10. Press the ENTER key to save the new passcode. The following message will be displayed:

```
■ NEW SETPOINT
■ STORED
```

11. Wait at least 30 seconds and then cycle power to the relay by turning it off then back on. After power-up, verify that the following message is displayed:

```
GE Multilin
760 REV 5.00 MOD 008
```

The Reverse Power element is now Enabled. For details on using this element, refer to Section 5.6.10: Reverse Power (if Enabled) on page 5–71.

Should assistance be required at any time during this procedure, please contact GE Multilin technical support at 1-800-547-8629 (within the U.S. and Canada) or +1(905) 294-6222 (outside U.S. or Canada). You can also send an e-mail to our technical support department at gemultilin@indsys.ge.com.

A.2.1 EU DECLARATION OF CONFORMITY

EU DECLARATION OF CONFORMITY

Applicable Council Directives: 73/23/EEC The Low Voltage Directive
89/336/EEC The EMC Directive

Standard(s) to Which Conformity is Declared:

IEC 947-1	Low Voltage Switchgear and Controlgear
IEC1010-1:1990+ A 1:1992+ A 2:1995	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
CISPR 11 / EN 55011:1997	Class A – Industrial, Scientific, and Medical Equipment
EN 50082-2:1997	Electromagnetic Compatibility Requirements, Part 2: Industrial Environment
IEC100-4-3 / EN 61000-4-3	Immunity to Radiated RF
EN 61000-4-6	Immunity to Conducted RF

Manufacturer's Name: General Electric Multilin Inc.

Manufacturer's Address: 215 Anderson Ave.
Markham, Ontario, Canada
L6E 1B3

Manufacturer's Representative in the EU: Christina Bataller Mauleon
GE Multilin
Avenida Pinoa 10
48710 Zamudio, Spain
Tel.: 34-94-4858835 Fax: 34-94-4858838

Type of Equipment: Feeder Management Relay

Model Number: 750/760

First Year of Manufacture: 1994

I the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards

Full Name: John Saunders

Position: Manufacturing Manager

Signature:

Place: GE Multilin

Date: 08/24/1998

A.3.1 GE MULTILIN WARRANTY

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.

Numerics

A

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M

N

O

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