MLS 2000

DISTANCE PROTECTION SYSTEM

Instruction Manual

Manual P/N: GEK-98502

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INTRODUCTION

The MLS2000 is a complete distance protection system for transmission lines. The microprocessor based system controls the selected protection scheme, the trip logic and the distance measuring unit as well. A second microprocessor, installed on a separate module provides self-monitoring, and for remote comunication in the event of an equipment failure via an optically isolated comunications channel.

The MLS is a modular system made up of a series of plug-in boards including a plug-in magnetics module, containing the input/output elements (transformers, telephone relays, etc.). The boards and the magnetics module are contained in a 4 rack unit high 19 " case for rack mounting.

Basic Characteristics

MLS2000 relays are provided with the following basic characteristics:

- Selection of five different protection schemes:

  1) Stepped distance - four zones.
  2) Extension of Zone I.
  3) Acceleration of Zone II.
  4) Permissive overreach transfered trip (POTT).
  5) Permissive underreach transfered trip (PUTT).

- Single/three phase trip.
- Voltage transformer fuse failure detection.
- Power swing trip block.
- Converter type D.C. power supply.
- Test module.

Optional Characteristics

The system may be augmented with the following optional characteristics:

- Additional protection schemes:

  6) Directional comparison blocking scheme.
  - Includes reverse zone five timer (for back up protection)

  7) Hybrid scheme.

- Single/three phase recloser.

- Syncronism check for reclose supervision.

  Line and bus voltage check.
  Angle measurement.
  Slip measuring circuit.

- Continuous monitoring of the MLS system with alarm and data via an RS232 channel.

Of all the above described options, only three may, simultaneously, be provided in a 19" case together with the basic protection. Should the syncronism check and the reclosing options be selected, no other option can be included. In cases where all the options are desired, a second 19" case is provided in order to complete the system.

The recloser is provided with a series of auxiliary inputs and outputs which allow for control of a second independent protection system.

Protection schemes 3, 4, 5, 6 and 7 require a communication channel.

When a pilot scheme is used the stepped distance remains active as a back up scheme.

In the basic model, the reclose is operational for zone 1 trips. Reclosing for additional zones is an optional feature.

The single phase trip mode, when selected, will only operate for zone 1 trips.Three phase tripping is employed for delayed zone trips.

It should be noted that MLS systems have been designed with separate zone 4 analog hardware independent of the microprocessor based zone 1-3 and pilot zone to provide redundant distance backup for phase and ground faults.

Fault detector

The MLS system is provided with a fault detector for supervision of trips produced by the logic unit. This supervision is carried out by means of hardware on the trip circuits, so that in the case where the Fault Detector has not been activated the trips will not be allowed. The function carried out by the Fault Detector is an OR of the three phase selectors (A, B, and C) with the negative sequence directional unit.

The Fault Detector provides a high degree of security by preventing false operation for hardware failures.

Trips produced in zone four (phase selectors) or in zone five are not supervised by the Fault Detector.

Directional Overcurrent Back Up

MLS systems may operate together with TCC5000 Directional Overcurrent Relays in order to provide with ground directional overcurrent back up. The TCC5000 relay is housed in a one third rack separate case.

List of Models

Table I shows how to select the model according to the characteristics desired.

TABLE I

MLS	*	*	*	*	*	*	*	0	*	*	A	
	2											SINGLE PHASE TRIP
	7											THREE PHASE TRIP
		1										1 AMP
		5										5 AMPS
			5									50 HZ
			6									60 HZ
				1								WITHOUT RECLOSE
				2								WITH RECLOSE WITHOUT SYNC
				3								WITH RECLOSE WITH SYNC
					A							WITHOUT CONTINUOUS MONITORING
					B							WITH CONTINUOUS MONITORING
						1						NO CHANNEL SCHEMES NOR ZONE 5
						2						ZONE 5 WITHOUT CHANNEL SCHEMES
						3						CHANNEL SCHEMES WITHOUT ZONE 5
						4						CHANNEL SCHEMES WITH ZONE 5
							0					48 Vc
							1					110/125 Vdc
							2					220/250 Vdc
								0				NOT ASSIGNED
									X	X		SPECIAL OPTIONS
											A	REVISION LEVEL

As an example, assume that an MLS system is desired with the following characteristics:

Three phase trip, 5 Amps, 60 Hz, with reclose, without synchronism, with continuous monitoring, with channel schemes and fifth zone, 110/125 Vdc; the model, according to TABLE I would be:

MLS7562B41000A

OPERATING PRINCIPLES

DISTANCE

-Stepped Distance Basic Protection

Figure 1 shows a simplified block diagram of the MLS system stepped distance scheme. Even though the control of the logic and the measurement is carried out by a microprocessor, the use of a conventional block diagram has been preferred for an easier and more understandable explanation of the operating principles. For this reason, the blocks shown represent logical operations which do not correspond to any specific area of the circuit used.

Inputs coming from voltage transformers (inductive or capacitive) are sent to circuits which produce a series of voltage signals. In the same way, inputs coming from current transformers are sent to circuits which produce a series of current signals (actually, the product of a current by an impedance or IZ). These signals are always present, ready to be switched over to the measure unit.

Phase selectors (or fault detectors) use certain voltage and current signals for a continuous supervision of the conditions in the protected line. The specific signals used will be described subsiquently. The phase selectors are variable mho characteristic distance measure units which must be adjusted to a greater reach than the adjustment carried out for a third zone protection. There are three phase selectors, one for every phase, with a common reach for all three; their function is that of determining which phase or phases are faulted.

Whenever a single phase fault occurs within the reach of the phase selectors, the selector corresponding to the faulted phase will operate. For a two phase fault, the two selectors associated to the faulted phases will operate. For a three phase fault, the three phase selectors will operate. The operation of one or more selectors starts the zone timer through gate OR3.

The logic determines the type of fault by determining which selector or combination of selectors has or have operated. For example, should only selector A have operated, this would mean a phase A to ground fault and the logic would provide an AG signal (figure 1). Should selectors A and B have operated, we would be dealing with a two phase fault between phases A and B or between A and B to ground and the logic would provide an AB signal. In the MLS system, the same magnitudes are used to measure a phase to phase fault or a phase to phase to ground fault. In order to measure three phase faults, the same magnitudes as those used for a fault between phases B and C are used.

The signals provided by the logic of the fault type supervise the switching of the appropriate voltage and current signals and their application on the measure unit. A different set of signals is used for every type of fault. The switching circuit provides the following signals: 1) operation , 2) restraint , and 3) polarizing quantities.

The preliminary operating quantity is adjusted for the desired zone one value as shown in figure 1. The preliminary restraint quantity is sent simultaneously through three different paths, to the zone switching circuit; 1) without adjustment, 2) adjusted for zone two reach, and 3) adjusted for zone 3 reach. The circuit selects one of the signals, depending on the zone timer, and sends it as restraint magnitude. The timer operates as long as one or more phase selectors keep producing an output (fault still present). Starting in zone one, it moves on to the successive zones passing from one to the next according to the established time adjustments. The phase selectors make up the fourth protection zone and therefore signal Z4 is not used to supervise the zone switching circuit. Also, as explained above, the fourth zone trip is completely independent from the trips provided by the logic of the system.

The sum of the operation and restraint quantities constitutes the net operating quantity which, together with the polarizing magnitude, is fed to the coincidence blocks generating circuit and to the main measuring unit in order to determine whether the fault is within the reach of the activated zone at that moment. The method used for the distance measure will be described in detail in the following section.

The activation of the measuring unit produces the trip signals through the trip logic. The trip mode, single or three phase, is determined according to the fault type and the zone. The single phase trip is only allowed in the first zone and if the fault is single phase. The logic selects the appropriate pole to be tripped. Two and three phase faults always produce three phase trips, as well as the single phase faults which may arise in zone two, three or four.

The logic diagram (Figure 2) and its description ("Distance Relay Logic") provide a detailed explanation of the distance relay operation, including the fuse blown and power swing detection, as well as all six alternative protection schemes.

Principles of Distance Measurement

There are five distance measuring units in the MLS; three phase selectors, the main measuring unit, and a permissive zone measuring unit used in the pilot schemes and in the detection of power swing. When a single line to ground fault is detected, a negative sequence directional unit is used to supervise enabling the main measuring unit's characteristic timers and consequently provides the required directional supervisision when the reactance characteristic is selected for single line to ground fault protection. All of these units employ the same principle of measurement. That is, they compare the phase angle between their polarizing and net operating quantities against a reference angle to determine if the fault is within their characteristic. In the directional comparison blocking scheme, three additional measuring units, similar in design to the phase selectors, are included for the blocking function. The blocking units are also used in the hybrid scheme to provide the echo function from the remote terminal.

The phase angle comparison is accomplished by:

1) generating rectangular pulses of voltage for those periods when the polarizing and net operating sine waves are coincidentally positive and coincidentally negative

and,

2) using the pulses to activate a characteristic timer which produces an output when the pulse width exceeds the timer setting. This is known as the "block-block" principle of measurement.

Fig. 3A gives a logical representation of the measurement circuitry, Fig. 3B shows typical waveforms for a fault internal to the characteristic. Note that the width of the coincidence pulses equals 180 degrees minus the phase angle between the polarizing and net operating quantities. Note also that the relative magnitudes of the two quantities are unimportant. The phase angle alone establishes the width of the pulses.

The pickup time of the characteristic timer is converted to electrical degrees as follows:

$$\text{Alfa}\ (\alpha) = A \times \frac{\text{Alfa}}{1000} \times 360$$

Where:

Alfa (α) = pickup pulse width (in degrees)

A = pickup time of timer (in milliseconds)
f = system frequency (in hertz)

The angle (timer setting) establishes the shape of the characteristic for the mho-type measuring units. Alfa = 90 degrees forms a circular characteristic, > 90 degrees forms a lens-shaped characteristic, and < 90 degrees forms a tomato shaped characteristic.

To illustrate how the phase angle comparison is converted to an impedance measurement, consider the case of the basic (non-variable, non-offset) mho characteristic shown in Fig. 4. The principal quantities are as follows:

Operating Quantity: IZR
Restraining Quantity: V
Net Operating Quantity: IZR-V
Polarizing Quantity: V

Where:

I = fault current (in amperes)
ZR = relay reach (in ohms)
V = voltage at relay (in volts)

Fig. 4 is drawn as a voltage diagram because the measuring units employ voltage signals to make the phase angle comparison. The voltage diagram will contract or expand for different fault currents. The voltage phasors, however, will maintain the same relative magnitudes and phase angle as the impedance vectors on an R-X diagram.

As mentioned earlier, a characteristic timer setting of Alfa= 90 degrees forms a circular characteristic. This is so because the apexes of all the right triangles constructed with a common hypotenuse constitute a circle with the hypotenuse as its diameter, as shown in Fig. 5. In this case, the operating quantity phasor (IZR) is the hypotenuse and the polarizing quantity (V) and net operating quantity (IZR-V) phasors are the remaining two legs of the right triangle.

Fig. 4A depicts a fault external to the characteristic, in which case the phase angle B between the polarizing and net operating quantity, exceeds 90 degrees. The coincidence blocks are therefore less than 90 degrees wide (180-B) and the characteristic timer will not pick up. Fig. 4B depicts a fault internal to the characteristic and Fig. 4C depicts a fault on the edge of the characteristic both of which result in an output from the characteristic timer. In this manner, the unit effectively translates the phase angle between its polarizng and net operating quantities into a measurement of impedance to the fault.

Measuring Quantities for MLS Distance Units

The MLS distance units employ modified characteristics which offer improved performance over the basic mho-type characteristic described in the previous subsection. These are dicussed in detail in publication GET-6749.

The measuring quantities for the MLS distance units are given in Table I (phase selectors) and Table II (main measuring unit). The permissive zone measuring unit has the same polarizing and net operating quantities as the main measuring unit, except that its reach is fixed at the thirdzone setting.

TABLE I - Phase Selector Measuring Quantities

Phase	Net Operating Quantity	Polarizing Quantity
A	$(I'_A Z_P - V_{AN}) + KV_{A1M}$	V_{A1M}
B	$(I'_B Z_P - V_{BN}) + KV_{B1M}$	V_{B1M}
C	$(I'_C Z_P - V_{CN}) + KV_{C1M}$	V_{C1M}

where: $I'_{\phi} Z_P = (I_{\phi} - I_0)\, Z_P \angle\theta_1 + K_0 I_0 Z_P \angle\theta_0$

and Z_P = phase selector reach (in ohms)
$V_{\phi N}$ = phase to neutral voltage (in volts)
$V_{\phi 1M}$ = positive sequence voltage with memory referenced to phase ϕ (in volts).
I_{ϕ} = phase ϕ current (in amperes)
I_0 = zero sequence current (in amperes)

θ_1 = positive sequence characteristic angle of relay (in degrees)
θ_0 = zero sequence characteristic angle of relay (in degrees)
ϕ = phase A, B or C
K = design constant equal to 0.25
K_0 = zero sequence current compensation factor (Z_0/Z_1)

TABLE II - Main Measuring Unit Measuring Quantities

Fault Type	Reactance Characteristic		Variable Mho Characteristic	
	Net Operating Quantity	Polarizing Quantity	Net Operating Quantity	Polarizing Quantity
A-G	$I'_A Z_R - V_{AN}$	$I_{A2} X_R$	$I'_A Z_R - V_{AN}$	V_{A1M}
B-G	$I'_B Z_R - V_{BN}$	$I_{B2} X_R$	$I'_B Z_R - V_{BN}$	V_{B1M}
C-G	$I'_C Z_R - V_{CN}$	$I_{C2} X_R$	$I'_C Z_R - V_{CN}$	V_{C1M}
A-B & A-B-G	--	--	$(I_A - I_B) Z_R - V_{AB}$	V_{AB1M}
B-C & B-C-G	--	--	$(I_B - I_C) Z_R - V_{BC}$	V_{BC1M}
C-A & C-A-G	--	--	$(I_C - I_A) Z_R - V_{CA}$	V_{CA1M}
3ϕ	--	--	$(I_B - I_C) Z_R - V_{BC}$	V_{BC1M}

where: $I'_{\phi} Z_R = (I_{\phi} - I_0) Z_R \angle\theta_1 + K_0 I_0 Z_R \angle\theta_0$

and Z_R = relay (main measuring unit) reach (in ohms)
X_R = reactive relay impedance (in ohms)
$I_{\phi 2}$ = negative sequence current referenced to phase ϕ (in amperes)
$V_{\phi\phi}$ = phase to phase voltage (in volts)
$V_{\phi\phi 1}$ = positive sequence voltage referenced to the given phase pair (in volts)
M denotes memory action
Other terms as defined under Table I.

TABLE III - BLOCKING UNIT MEASURING QUANTITIES

PHASE	NET OPERATING QUANTITY	POLARIZING QUANTITY
A	$(-I'_A Z_P - V_{AN}) + KV_{A1M}$	V_{A1M}
B	$(-I'_B Z_P - V_{BN}) + KV_{B1M}$	V_{B1M}
C	$(-I'_C Z_P - V_{CN}) + KV_{C1M}$	V_{C1M}

TABLE IV - DIRECTIONAL UNIT MEASURING QUANTITIES

OPERATING QUANTITY	POLARIZING QUANTITY
$V_{A2} - I_{A2}X'_R$	$I_{A2}X_R$

where: X'_R = 2.4 ohms
All other terms are as defined following tables I and II.

RECLOSER

-Automatic Reclose-Basic Function

The automatic reclose starts when the distance relay produces a trip output and a block signal is not simultaneously produced since the fault is in a protection zone where reclose is allowed.

The recloser is provided with two initiating signals: single phase reclose and three phase reclose.

The recloser output is always three phase, that is, the reclose contacts corresponding to the three terminals of the breaker are activated. The difference between a single phase reclose and a three phase recloseis the adjusted time. The selection of the terminal to be closed is carried out with the breaker's auxiliary contacts in the case of a single phase reclose.

Consider a single phase to ground fault. The distance relay provides a trip output to the faulted phase terminal and sends a single phase initiating signal to the recloser. After counting the time corresponding to the single phase reclose, the recloser gives a closing command to the breaker.

Should the fault persist, the distance relay will trip again, three phase, since the recloser will automatically adjust to the protection for a three phase trip following a first reclosing attempt. The distance relay will send a three phase trip signal to the recloser, and the latter, after counting the time corresponding to the timed reclose will again give the breaker a closing command.

Should the fault still persist, the distance relay will trip again (three phase). The recloser will pass on to the blocking state, thus inhibitting any further reclosing attempts.

The distance relay and the recloser will initially operate in three phase mode for multiphase faults. For this purpose, the recloser is provided with a first three phase timer, adjustable independently from the first single phase reclose timer. The second attempt, however, is always three phase and, therefore, there is only one time adjustment for the second reclose.

The recloser logic diagram is shown in Figure 6 and its associated description (section: Recloser Logic) provides a detailed explanation of the recloser operation. A syncronism check module may, optionally, be included.

Manual Closing

When a manual closing command is given, the recloser operation is inhibitted during the time corresponding to the reset timer adjustment.

DISTANCE RELAY LOGIC

Figure 2 shows a logic diagram describing the MLS distance relay operation. Again, it should be pointed out that it does not correspond phisically with the microprocessor's logic used in the design of the relay.

The complete diagram shown in Figure 2 includes the following functions:

- Phase selectors (Phase A, Phase B, and Phase C)
- Current supervision (Phase A CS, Phase B CS, and Phase C CS) Main measuring unit (switched zones and phases).
- Permissive measuring unit with zone three reach (Switched phases).
- Selection of input magnitudes to the measuring unit.
- Selection of reach of the measuring unit.
- Negative sequence directional unit (DU).
- Zone timers logic.
- Protection against voltage transformers fuse failure.
- Power swing blocking function.
- Trip units (ØA, ØB, ØC).
- Output units for initiating the breaker failure function.
- Optical signaling units.
- Carrier keying functions (MB-ØA, MB-ØB, MB-ØC), only in the blocking diagram.

OUTPUT CIRCUITS

Trip outputs

The distance relay is provided with three totally separate trip circuits, identified as ØA, ØB and ØC, with three electrically separate contacts each.

(BFI) Breaker Failure Back up Initiation

Four breaker failure initiation units are provided, with a normally open contact each. One of the units, labeled BFI is activated through OR20 when done by any of the tripping units. The other three are controlled separately by ØA, ØB or ØC trip outputs. Three selection bridges are provided in module DOM which allow the units to operate individually (position IND) or simultaneously (position COM).

(RI) Reclose Initiation

Two reclose initiation outputs are available: RI-1Ø for single phase reclose and RI-3Ø for three phase reclose.

Channel keying - Permissive trip schemes

An output relay is available with a normally open contact for frequency slip channel pick up to its trip frequency. The scheme selection logic determines the function that the pick up unit operates. For example, should the permissive overreach scheme (POTT) be selected, the channel pick up will be provided by a permissive measuring unit output with a zone three reach, through AND33 and OR11. Should the permissive underreach scheme (PUTT) be selected, the channel pick up will be provided by an output from the main measuring unit itself, supervised in AND34 by a NOT2 output wich will be present until TL5b operates.

Channel keying - Directional comparison blocking scheme

Two output relays are available, each with a normally open contact, for channel supervision. The carrier starting contact is energized by one or more outputs of MB functions through TL7, AND67 and OR11. The carrier stop contact is energized by an output from a zone three reach permissive measuring unit, through AND69.

Optical signals

The following memorized red optical signals are provided:

LED	MODULE	FUNCTION
(CH)	DLM	Trip per channel.
(WI)	"	Week Infeed Trip. (hybrid scheme)
(A)	"	Phase A trip.
(B)	"	B trip.
(C)	"	C trip.
(I)	"	Trip in Zone I.
(II)	"	Trip in Zone II.
(III)	"	Trip in Zone III.
(IV)	DOM	Trip in Zone IV.

One option is available in module DLM which allows A, B and C optical signals to light up in the following conditions:

a) Type of trip signaling - In this mode, every target lights up when the trip path, associated to one of them is energized whether or not the corresponding phase is faulted. For example, with an ØAB fault, the relay will produce a three phase shot and target C will light up at the same time as A and B.

b) Type of fault signaling - In this mode, only targets associated to the faulted phases light up. Thus, for a ØAB fault, the relay will trip three phase, but only A and B targets, corresponding to the faulted phases will light up.

In the standard relay, indication targets are lost when a DC power off occurs. There is an option where the targets listed above are provided with a memory. This means that the relay memorizes the functions signaled at the time of disconnecting the infeed; while the relay remains disconnected, the targets remain out, but they light up as soon as infeed is restored. Reset must be carried out by means of a push button located in module DOM or by means of a Remote Reset external signal. When pressing the reset button, or when the reset external signal is activated, targets light up momentarily, thus providing a means of checking their operation. Target IV remains lit for as long as the reset button is pressed or the external signal is activated.

Due to the independence between the fourth zone function (phase selectors) and the rest of the zones, the trip in zone four does not activate trip signals A, B and C, but rather target IV alone.

Targets listed below are yellow and non-memorized targets:

LED	MODULE	FUNCTION
(ØA)	DSM	Phase selector A.
(ØB)	"	Phase selector B.
(ØC)	"	Phase selector C.
(OSB)	DLM	Power swing.
(FF)	DLM	Fuse failure.

Zones I, II, III and IV trip outputs, Power swing and Fuse failure functions are provided with an alarm unit with a normally open contact.

SCHEME OPERATION

The MLS logic operates according to the scheme in Figure 2. As mentioned earlier, all the MLS logic functions not related to the phase selectors have been carried out by means of a system based on a microprocessor. Nevertheless, in order to provide the operational description of the system, the use of a classical logic scheme has been preferred for an easier comprehension of the system's operation. Therefore, the scheme shown in Figure 2 does not relate directly to the actual circuitry used in the relay.

The scheme in Figure 2 may be applied in different ways, according to the selected protection logic. Logics involving channel are: Permissive overreach transferred trip, permissive underreach transferred trip, zone 2 acceleration, directional comparison block and hybrid scheme. The protection scheme known as zone one extension does not use channel for its operation. The stepped distance scheme is also provided as back up and it is independent from the communications channel.

Phase selectors operation

All three phase selectors (ØA,ØB and ØC) are mho characteristic distance units supervised in AND1, AND2 and AND3 by CS-ØA, CS-ØB and CS-ØC current supervision functions. Phase selectors supervise the output logic of the type of fault and that of the faulted phases, so that the logic may apply the current and voltage magnitudes suitable to the main measuring unit and to the permissive measuring unit.

For example, during an AG fault, AND4 output indicates that phase selector A has operated, unlike B or C. This involves the application of input AG, through AND11, to the measuring units inputs selection circuit. Gates AND5 and AND6 provide, the BG and CG signals through AND12 and AND13 respectively. AND11, 12 and 13 are supervised by timer TL4, energized by OR3 when any of the phase selectors are activated. The delay introduced by this timer prevents an incorrect output from the selection circuit during multiphase faults, should one of the phase selectors operate before the rest.

During AB or ABG faults, AND7's output indicates that ØA and ØB selectors have operated, but not ØC. This involves the application of input AB/ABG through AND15 to the selection circuit, which switches the appropriate magnitudes for a two phase fault to the measuring units. The above mentioned is valid for CA or CAG faults; the signal CA/CAG is applied through gates AND8 and AND16. The input to the selection circuit through AND9 and AND17 indicates a BC/BCG fault or a three phase fault since AND9's output is activated both for BC faults and three phase faults (ABC).

The AND gates associated with faults which involve several phases (AND15, 16, 17 and 18) are also supervised by TL4 timer. An AND18 output indicates that a multiphase fault has been produced and it applies an input to OR21 in order to produce a three phase trip, as soon as the measuring unit responds.

Measuring unit operation

The measuring unit operation is determined by the input magnitudes, selection logic, supervised by the phase selectors, and the reach selection logic, supervised by the zone timers.

The main measuring unit (MU) is provided with a directional mho characteristic for multiphase faults, and a mho or reactance characteristic for single phase to ground faults. The selection of the type of characteristic for single phase faults is carried out through a selector located inside the module DRM. The response from the measuring unit is determined by the characteristic timers and by the MU output logic. The operation of the timers, in the whole of the system, will be described in a later subsection.

The operation of the permissive measuring unit is determined by the same input selection logic which supervises the main measuring unit. Nevertheless, its reach is fixed and equal to the main measuring unit third zone reach.

Operation in the stepped distance mode

The operation of the scheme in the stepped distance mode depends on the adjustment of TL5a-TL5d zone timers, and on the measuring unit reach adjustment. TL5a to TL5c timers are initiated, through OR3, when one or more phase selectors operate. In normal in-service conditions of the protected line, none of the phase selectors are operated and, therefore, none of the zone timers will be energized. In these conditions, NOT1 and NOT2 will be providing an output. The function of TL5a and NOT1 will be discussed in detail further on; for now, it should just be noted that this timer must be adjusted to a shorter time than zone two TL5b timer. Let's imagine, for the moment, that the zone selector (L2, at the front of the module DLM) is in position 3. AND21 and AND75 will be activated through their NOT inputs. NOT2 output will be applied, through AND32, to zone 1 input (Z1) of the measuring unit reach selection logic. That is, in normal conditions, the reach is located in its zone one adjustment and will remain there until zone TL5b timer operates. AND21 output provides a supervision signal to the reclosing module and keeps one contact deenergized for the supervision of an external recloser. The purpose is that of allowing reclose only for trips within the first interval of the zone timer. When TL5b timer operates, AND21 output is activated, disconnecting NOT2, and therefore, Z1. The Z2 input to the reach selection circuit will be activated through AND21, AND22 and OR8. This condition will remain until zone three TL5c timer operates, disconnecting AND22 through AND75 and energizing Z3 input to the reach selection circuit through AND23.

Zone four reach is determined by the reach setting for the phase selectors. Trips in zone four do not involve the same logic as the one used for the rest of the zones since, the phase selectors trip independently from the DLM module. The activation of any phase selector starts the operation of zone four TL5d timer. As soon as this timer ends its count, it produces, directly, a three phase trip signal, through OR42, OR43 and AND81. This signal combines with the signals coming from the logic in gates OR45, OR46 and OR47, which operate directly on the trip outputs.

It should be noted that TL5a, TL5b and TL5c timers must have progressively longer adjustments than the preceding timer value. TL5a will have the shortest adjustment and TL5c the longest one. Should the adjustment not be carried out in the way indicated, the actual time of a particular timer may result longer than the adjusted one. TL5d timer is a special case due to its independence; it may be adjusted to any value without taking into account the rest of the zone timers, as regards the final response time. However, application reasons lead to a criteria equal to that described for the other three timers. Should the time adjusted for TL5d be shorter than those adjusted for the three preceding timers, a trip would be produced in zone four before the logic has gone through the prior zones.

Assume an A phase to ground fault within the measuring unit zone one reach. The A phase selector and the negative sequence directional unit (DU) will operate. Activation of phase selector A starts the operation of the zone timers through OR3, of zone four timer through OR40, it provides AND20's lower input through OR1 and AND14, it applies AG input to the selection logic through AND11 and it activates AND51 upper input in pole A logic selection. Since the directional unit has operated, there will be an output in AND20 which will disconnect NOT3, thus eliminating TL9a, TL9b, and TL9c characteristic timers reset input from MU measuring unit, thus allowing its operation. AND14 output, indicating that only one phase selector has operated, energizes NOT input of AND42 which gives input to TL9a, avoiding its operation and, therefore, eliminating mho characteristic for phase to phase faults. AND14 also activates AND43 and AND44 inputs which activate timers TL9b and TL9c respectively, providing the characteristic for single phase to ground faults, mho or reactance depending on its selection.

The function of TL5a timer is that of giving time for an adjustment of the reactance characteristic which provides additional security during an external fault in the remote bus. The adjustment for TL5a timer is selected so that it may give the remote bus relay time to clear, in zone one, (an external fault in the bus mentioned). Prior to the fault , the timer will not have produced an output and therefore, NOT1 will produce an output which will block AND43 and will activate the lower input to AND44.

Thus, when a single phase fault is produced, it is TL9c timer that determines the MU characteristic during the time adjusted for TL5a timer. Supposing the reactance characteristic has been selected, and that the coincidence angle has been adjusted to 120°, the characteristic will be as shown in Figure 7A. Until TL5a times out, the characteristic in diagram R-X will be between the line of points labeled 135° and the line labeled 120°. Should the initial coincidence block at AND44 output be greater or equal to 135°, TL9c timer would provide an output in this first block. Should the initial pulse be greater or equal to 120° but less than 135°, TL9c would begin to integrate and would provide an output if the successive pulses are wide enough. Should the initial pulse be less than 120°, TL9c will not begin integration until a block wider than 120° is available. As soon as TL5a times out, TL9c will be blocked and the characteristic will be determined by TL9b timer. The characteristic, in diagram R-X will evolve from the "Tent shaped" characteristic (120° in Figure 7A) to 90°.

Should mho characteristic have been selected for ground faults, the operation would have been similar except that, initially, the characteristic would be lens shaped and would evolve to the circular MHO characteristic when TL5a timer times out.

The sequence time feature provided by TL5a timer may be eliminated by adjusting it to ten miliseconds. This way, TL5a will time out before TL4 times out and enables AND11. The shape of the characteristic will be determined by TL9b from the moment when AND11 activates the selection logic AG input.

The zone one time operation for an AG fault leads to a trip through OR12, AND47 and OR14. OR14 output is applied to gates AND51, AND52 and AND53, in the trip circuits. Provided that only the phase A selector has operated and that the L3 trip mode selector is in the single phase position, only the trip circuit corresponding to phase A will be energized.

Should AG fault be beyond the reach adjusted for zone one, but within the protected line, TL5b zone two timer, when operating, will activate the measuring unit Z2 input through AND21, AND22 and OR8. TL5b timer, also deactivates Z1 input through NOT2. The zone two timed trip will be provided through the measuring unit TL9b characteristic timer. The zone two timer output energizes OR21 and AND50 upper input so that the trip from OR14 may trip all three poles through AND50 and OR16. A trip in zone three, started by TL5c timer will also be three phase. Should the trip not be produced in any of the above zones, TL5d would determine its count and would produce a three phase trip through OR42, OR43 and AND81.

Assume that a two phase fault is produced (AB or ABG, for example) within the reach determined by the adjustment of zone one. A and B phase selectors will operate and will start the zone timers through OR3 and they will provide the AB input to the measuring unit inputs selection logic through AND7 and AND15. AND7 output energizes AND18 through OR2 indicating that the fault has been two or three phase. AND18 output disactivates through OR4, NOT inverter, enabling TL9a, TL9b and TL9c characteristic timers. Also, AND18 output activates through OR21, AND50 upper input so that the trip may be three phase. Provided that there is no output from OR1 and AND14, the measuring unit operation will be determined by TL9a integrator timer. TL9b and TL9c timers, as well as TL5a timer are not activated during two or three phase faults. The trip output from OR14 will start a three phase trip through AND50 and OR16 both for zone one and for any other trip zone.

The L2 zone limitation selector may be used to limit the trip to a specific zone. In position 1, it unables AND21 by means of its inverting input and therefore zone two TL5b timer output. This leads to the continuous unabling of AND22 and AND23. NOT2 provides a permanent output by keeping the reach blocked in zone one (or extended zone one).

In position 2, L2 unables AND75 keeping TL5c timer from producing an output and therefore unabling AND23 and AND24 so that the reach may remain blocked in zone two.

Zone 1 extension (Z1X) -

The extended zone one operating mode is enabled by means of the zone one extension output of the scheme selection logic and with the absence of AND29 lower input through OR29. OR29 output is activated by a signal coming from the reclosing module or by the activation of the CC5 contact converter. AND29 output activates the reach selection logic Z1X input and disactivates the one corresponding to Z1. This causes the enlargement of the reach to the whole length of the line plus one margin. A fault anywhere in the protected line will be cleared in zone one time. The trip will be three phase for single phase to ground faults and three phase for two and three phase faults, as long as L3 selector is in position 1P.

Before the reclose is carried out, a signal coming from the recloser will appear and will activate AND29 lower input, eliminating the extended zone one mode and resetting Z1 input to the reach selection logic. Should the fault be present after reclose, and should it be within the zone one reach (normally 90% of the protected line), the breaker would be tripped again in zone one time, but the trip will now be three phase for all type of faults. This results from the OR21 input, coming from the recloser which appears prior to the first reclose.

Channel schemes

The protection scheme selection logic may be adjusted for one of the following schemes involving channel:

1. Permissive overreach transfered trip (POTT).
2. Permissive underreach transfered trip (PUTT).
3. Zone two acceleration (Z2ACC).
4. Directional comparison blocking (DCB).
5. Hybrid scheme (HS).

1. Permissive overreach

The permissive overreach transfered trip scheme operation can be described using Figure 8.

The selection logic will be set to POTT mode, which activates AND28 lower input and AND33 upper input.

Let's consider in the first place an external fault in point X in Figure 8. The C terminal permissive overreach measuring unit will operate and its output in AND48 will activate the transmitter through AND33, OR11 and L-12 (NORMAL position if the transmitter is activated through a contact closing), sending a trip signal to terminal D. The receiver in D will activate AND28 upper input through CC1, L-10 (NORMAL position if the closing of a contact indicates the receiving of a channel signal) and AND25, but there will be no trip in AND28 since the permissive unit in D will not have operated provided that the fault is behind this terminal.

During an internal fault, at Y for example, the permissive overreach unit will operate in both terminals, keying the channel and sending a trip signal from each of the ends to the other. Also, it will activate AND28 middle input through TL6 timer whose purpose will be described later on. Provided that AND upper and lower inputs are already present, the transfered trip scheme establishes the fault as internal and a trip per channel is produced in both ends of the line through OR5, TL7b and OR14 timer. The trip will be single or three phase according to the position of L3 selector and according to the type of fault, as will be described later on. In the following discussion, it is provided that L3 selector is in the position of single phase trip.

Assume that initially, the fault is phase A to ground. As described in the section corresponding to the stepped distance scheme, the phase A selector will operate and AND11 gate output will be activated. This output will also activate AND51 gate upper input, in the selection logic of the pole to be tripped. Eventhough the channel trip output, coming from OR14 is applied on AND51, AND52 and AND53, only the trip unit corresponding to phase A will be energized since only that phase selector has been activated.

Should the internal fault involve more than one phase, AND50 upper input will be activated through OR21, AND28 and OR2. This way, when the channel trip signal is produced coming from OR14, it will result in a three phase trip.

The purpose of TL6 coordination timer can be explained as follows. Refering to Figure 8, assume an external fault in a parallel line detected by the permissive overreach unit in terminal C. AND48 output will activate the channel through AND33, OR11 and L-12, sending a trip signal to end D. The receiver in D will activate AND28 upper input through CC1, L-10 and AND25, but no output from AND28 will be produced since this terminal permissive unit has not operated. Let's suppose now that the parallel line fault sequential clearing produces an reversal in the CD line fault current. This reversal would cause the permissive measuring unit activation in end C. The purpose of TL6 timer is to delay the application of the permissive unit output on AND28 middle input in terminal D until the channel signal disappears. That is, TL6 timer operation time must be slightly longer than the channel reset time in order to prevent an incorrect trip during the current reversal.

2. <u>Permissive underreach (PUTT)</u>

For this operation mode, the scheme selection logic must be set to the PUTT mode which activates AND27 lower input and AND35 upper input through OR10. In this scheme, the channel is activated through AND34, AND35, OR11 and L-12 (NORMAL position if the channel needs a closed contact for its activation), by the operation of the main measuring unit within zone one reach. For a fault in point X of the line in Figure 8 the channel will not be keyed at any line terminal since the fault is out of zone one reach in both of them. Provided that, during an external fault the channel is not keyed in any of the ends, no coordination timer is necessary.

Assume an internal phase AG fault in point Y, near end D but out of the zone one reach in end C. The phase A selector in end D will operate applying signal AG on the input magnitudes selection logic. Provided that signal Z1 is present at the reach selector circuit input, the measuring unit will provide an output in AND47 gate which will start a single phase trip in D through OR14 and AND51 and will activate AND34 lower input. Since AND34 upper input has already been activated by NOT2 output, the channel will be activated in D, sending a trip signal to C. The receiver output will activate AND27 upper input in C; its middle input will have been activated by its permissive measuring unit (with zone three reach), and its lower input is activated by the logic selector output (PUTT). Therefore, a single phase trip per channel will be produced in C through OR5, TL7b and OR14.

For a fault in the center of the line, in point Z in Figure 8, for example, there will be a zone one output in the main measuring units in both ends, a transfered trip signal will be sent in both directions and a trip per channel will be started in both terminals. In the practice, the trip will be carried out before by the zone one activation of the main measuring unit.

In the case of an external fault in X, should the zone 2 timer times out and the measuring unit out put corresponding to that of zone two is produced, the measuring unit output in AND47 will activate AND34 lower input. However the channel activation will not be produced this way. For this reason, the zone two timer operation deactivates NOT2 output and , therefore, AND34 upper input. Should the relay trip in zone two or three, the channel will be activated through the trip signal, OR20 output, through TL15 and AND36, but this does not affect the PUTT operation mode for the external fault we are considering. The purpose of TL15 is to provide a trip signal of a duration adequate for ensuring the remote terminal trip in those cases in which it could be slower when operating for an internal fault.

3. Zone 2 Acceleration (Z2ACC)

For this operation mode the scheme selection circuit must be set to the zone two acceleration position which activates AND26 lower input and AND35 upper input, through OR10.

Refering again to Figure 8, a fault at the end of the line, in Y, will be seen in zone one by end D, but not by C. The AND47 zone one trip output, in D will activate the channel through AND34, AND35, OR11 and link L12 (NORMAL position if the transmitter is activated by the closing of a contact). The reception of a channel signal in C is applied to AND26 upper input. Provided that the permissive unit, with a zone three reach will have operated in C, and the logic selection circuit provides the Z2ACC output, the AND26 middle and lower inputs will be activated.

AND26 output activates the reach selection circuit Z2 input through TL7a and OR8 without waiting for the zone two timer to finish. This way, the main measuring unit in C will operate inmediately for a fault at the end of the protected line and will start a single phase trip if the circuit is adjusted to provide single phase trips.

4. <u>Directional Comparison Block (DCB)</u>

For this operation mode, the logic selector circuit must be adjusted to the directional comparison block position which activates AND68 second input and AND70 lower input. In this scheme, the transmitter is activated by the operation of one or more of the carrier start functions (MB-ØA, MB-ØB or MB-ØC) through OR24, TL17, AND67, AND70, OR11 and L-12 (in NORMAL position if the transmitter is activated by the closing of a contact).

Assume the incidence of a fault in point X of the line in Figure 8. One or more MB functions will operate at D, starting the transmission of a signal over the channel. The operation of the permissive unit in C will activate AND68 lower input through TL6 coordination timer. The MB functions in C will not have operated and, therefore, there will be an input to AND68 coming from its inverting input. However, the reception of a channel signal coming from D blocks the AND68 upper input (L-10 selector must be in position INV if the closing of a contact indicates the channel activation). Therefore, the trip through AND68 will be blocked for an external fault in X. When the fault is cleared in X and when the MB units are reset at D, the channel signal transmission from AND70 will remain for a time equal to the sum of the TL17 and TL16 reset times.

For an internal fault at Z, the permissive unit will be activated in both terminals and will activate AND68 lower input in both ends. The MB functions will not be activated in any of the ends and the permissive measuring unit will activate AND69 lower input in both ends (the upper input of AND69 is activated because none of MB units have operated), inhibitting the channel transmission in both ends. (L-11 in NORMAL position if the closing of a contact is required in order to stop the channel transmission). All inputs to gate AND68 are activated in both ends of the line and a trip per channel will be started through OR5, TL7b, OR14 and AND51, -52 and -53, depending on whether the trip is single or three phase. CH optical indicator will operate through OR9.

The purpose of both TL17 and TL16 timers can be explained as follows: Assume that a three phase fault with a zero voltage is produced just beyond breaker E in Figure 8. MB units will be activated due to their voltage memory, but will be deactivated once the memory has reset. The TL17 reset time must be adjusted long enough so that the combination of TL17 and TL16 reset times may maintain the channel signal sent from D to C for a longer time than the setting in E for the breaker failure function.

On the other hand, should the phase to ground external fault beyond D evolve towards an internal fault in Y, the permissive unit in D will deactivate AND67 output through OR26 and the AND67 inverting input, and the channel signal will remain only during the TL16 50 millisecond reset time.

MB units, oriented towards the outside of the protected line, may be used to start a back up timed trip for external faults. The operation of one or more MB units and their current supervision units produces an output in OR24 which starts TL18 timer (fifth zone). TL18 output leads to a three phase trip through OR43, AND81 and OR45, -46 and -47.

Should the total of the channel time plus the transmission time be under eight milliseconds, the TL6 coordination timer must be set to zero. The channel total time is defined as the time from the starting contact operation at the sending terminal and the moment in which the receiver provides an output with the equipment connected back to back. Should that time be above eight milliseconds, refer to section CALCULATION OF SETTINGS

5. Hybrid Scheme

For this operation mode, the logic selector circuit must be set to the position determined as hybrid scheme, which activates AND86 upper input.

This protection scheme is used in those cases in which one of the protected line terminals has a weak contribution and its measuring units may not operate in the presence of an internal fault. In the cases where both terminals detect the fault as internal, the scheme behaves as a permissive overreach transfered trip scheme (POTT). The difference in the behavior arises when a terminal is not able to detect an internal fault. This terminal would not be able to produce a trip even if it received a channel signal from the other side because none of its measuring units has been activated. The trip would be delayed until the moment in which the terminal detecting the fault opened its associated breaker. When opening the strong contribution terminal breaker, the weak contribution terminal will be able to detect the fault and will trip.

The hybrid scheme allows for a fast clearing of the fault on both sides. Let's imagine a fault in point Y in Figure 8 and that C is the weak contribution terminal. Also assume that, due to its small contribution capacity to the fault, the permissive measuring unit is not activated in terminal C and therefore, no channel sending signal is activated, but rather AND87 lower input.
MB signals will neither be activated since the fault is in front of the relay and thus, AND86 third input will be activated through NOT4.

The permissive measuring unit will have operated in end D, causing the sending of the channel, as described in the section corresponding to POTT scheme. In end C, the channel sending from D activates AND86 lower input through CC1, L-10 (in NORMAL position if a closed contact indicates the channel activation) and AND25 so that an output from gate AND86 will be produced. The activation of AND86 output will cause the sending of a channel signal through TL20, AND90, OR11, NOT6 and L12 (NORMAL position if the channel is activated by the closing of a contact). A trip will also be started through OR14 and it will be single or three phase according to the number of activated selectors and to L3 position. The channel sending signal produced in C will start a trip per channel in D through CC1, L-10 (in NORMAL position if the activation of the channel produces the closing of a contact), TL6, AND28, OR5, TL7b and OR14. In this terminal the trip will be single or three phase depending on the type of fault and on the position of link L3.

Finally, the non operation of MB blocking units in D allows for repetition, as an echo, of the channel signal produced in C.

Power Swing Block

The power swing block scheme, provided in this equipment may be activated by setting the L4 selector to the position IN. The diagram in Figure 9 represents the characteristics involved in this scheme.

The scheme operates as indicated: Swing, represented by AB straight line, exhibits the characteristics of a three phase fault. When the point representing oscillation in the R-X diagram is within the characteristic of the phase selectors, all three selectors will operate. This causes an output from AND10 which starts timer TL11 through OR22. It also switches the permissive measuring unit to the lens shape shown in Figure 9. This is achieved by blocking the 90° characteristec timer in AND45 NOT input and by activating the 120° characteristic timer, through AND46 lower input. Should TL11 timer end its count before the impedance point enters the permissive unit characteristic, both measuring units will remain blocked, the main unit in AND47 inverting input and the permissive unit in AND48 inverting unit. However, if the point representing the impedance enters the characteristic prior to the operation of TL11 timer, as would occur in the case of a three phase fault, the permissive unit output in AND48 will reset TL11 timer.

There is a possibility for swing may occur during the period of time in which one of the breaker poles is open. For this reason, AND19 gate receives an input from CC6, when one pole is open; the other receives it from AND18 indicating that two or more phase selectors have operated. AND19 output starts TL11 timer through OR22 and switches the permissive unit characteristic to its 120° lens shape.

Fuse Failure Detector

The fuse failure detector has been designed to operate in the case of loss of one or two alternating voltage phases. Figure 10 shows a block diagram of the fuse failure detection function.

In a fault absence fuse failure condition, of one or two voltage transformers, a negative sequence voltage will appear which will cause the operation of the D2 level detector. Provided that no fault exists, there will be no negative sequence current and after 11 milliseconds, a time determined by T3 timer, the FF output will be activated. Once the FF signal appears at AND2 through NOT2, the currents negative sequence detection is blocked, so that FF will not drop should a fault appear. That is, the fuses fusing prior to the fault leads to the activation of FF signal. The state of FF is not reset by the appearance of a fault but only by replacing the fuses and the consequent removing of the negative sequence voltage.

If, with the fuses intact, a fault is produced, a negative sequence current will appear and also, as a result from the fault, the simultaneous appearing of a negative sequence voltage. The T3 timer lags the negative sequence voltage operation on FF so that AND2 gate will remain blocked in its upper input, before its lower input is activated. Thus, the FF output will not be activated.

The clearing of the fault leads to the resetting of both negative sequence, current and voltage signals. However, the resetting of the negative sequence current detector is slower than that of the negative sequence voltage detector in order to prevent its operation on the FF signal during the resetting of the fault.

Refering to Figure 2 again, the activation of the fuse failure detector operates on a led indicator and on an alarm unit with a normally opened conctact. By means of selector L9, it is possible for the fuse failure condition detection to block the trips from the relay while that condition persists.

Close into fault

The MLS relay will provide a three phase trip in the case where the breaker associated to it closes into a close in zero voltage fault. AND49 upper input is activated by a signal coming from the recloser or from an external contact (CC3), through OR15 and will remain activated during 128 milliseconds after the reclosing attempt, automatic or manual. AND49 lower input is activated through AND63 and TL19 if the overcurrent and undervoltage have operated and if this condition persists during, at least 22 miliseconds. The overcurrent detector operates with a current of 2.5 times the rated current and the undervoltage detector operates if the voltage drops below 1.5% of the rated voltage. The activation of AND63 starts a three phase trip through OR16.

GENERAL INFORMATION

1. Breaker Failure Functions

There are four breaker failure starting units. Three of them, BFI-ØA, -ØB and -ØC, are associated to each pole's individual trips. The fourth, identified as BFI, operates through OR20 and OR51 when any pole's trip circuit is activated. When the scheme operates in the single phase mode, L6, L7 and L8 selectors will be set to individual mode (IND position). If the scheme is operating in the three phase mode, these selectors will be set to the common mode (COM position), so that any trip output may activate all the breaker failure starting units.

2. Current Seal in

For trips produced by the DLM logic module (zones one, two, three and trips per channel), the current seal in characteristic operates pole by pole through AND54, -55 and -56. For example, for an AG fault, with the scheme in the single phase mode, the phase A trip unit is energized through AND51, OR17 and AND57. AND output activates AND54 upper input whereas the lower input is activated by the phase A current supervision unit. Thus, there will be an output from AND57 as long as the current is above the supervision unit detection, even if the distance units have reset. Likewise, the phase A BFI unit will remain energized. If the scheme is operating in the three phase mode, BFI selectors will be in the COM mode; the seal in of any phase will maintain all the BFI units energized while the overcurrent supervision unit remains operated.

3. Target Operation

The MLS relay is provided with fifteen optical indicators of the operation of its various trip or pick up units. Nine of them have memory. There is an option where they keep memory even if the relay is deenergized. Reset is only possible by pressing the reset button located at the front of module DOM, or through the activation of an external contact (CC8). This is indicated in the logic diagram by an L contained inside the indicator symbol.

Trips produced by the stepped distance scheme for zones one to three, are indicated by the operation of indicators I, II and III, located at the front of module DLM. Any trip per channel activates the CH indicator. These signals are activated through gates AND37, AND38, AND39 and AND41 whose lower input is activated by means of the trip signal coming from OR20.

The zone one indicator (I) will light up when the measuring unit (AND47) and the trip signal (OR20) operate with no output from the zone two timer which blocks AND37 in its inverting input.

A trip in zone two, started by TL5b timer, will activate indicator II through AND38 and will block AND37.

A trip in zone III is started when TL5c timer times out and causes the operation of indicator III through AND39.

A channel trip, either in the permissive overreach mode or the permissive underreach mode, will activate the CH indicator through OR9 and AND41. It should be noted that indicator I may light up at the same time as the CH indicator because the local measuring unit may operate in zone one.

When the zone two acceleration scheme is selected, a trip will be indicated by the lighting up of CH through OR9 and of II through OR8. Indicator I will be blocked.

Trips in zone four cause the operation of indicator IV, located at the front of module DOM, through OR42 when TL5d timer times out.

A trip in extended zone one activates indicator I.

In the hybrid scheme, a trip produced by the channel reception without neither the operation of the measuring units nor the operation of the blocking units, causes the activation of indicator WI, through AND88 and AND87.

The operation of A, B and C indicators at the trip output is determined by the adjustment of L5a, L5b and L5c selectors.

For example, with the system set to the single phase trip mode and L5 selector in position TRIP, the detection of a single phase to ground fault will cause the tripping of the pole corresponding to the faulted phase and also the activation of the indicator corresponding to that phase. Any multiphase fault or delayed trip will trip all three poles and will activate all three indicators.

With the L5 selector in position FAULT the faulted phase or phases indicators are activated even if all three poles are tripped. For example, let's take an AG fault with the relay in the three phase mode. All three poles will be tripped, but only indicator A will be activated, determined by AND60 input activation by phase A selector. Likewise, for an AB fault, all three poles will be tripped but only A and B indicators will light up.

When the trip is caused by a closing into fault, all three poles will be tripped, LP(Line Pickup)indicator will be activated through AND89 and those corresponding to all three phases.

Indicators described up to now are red and are provided with the feature of not resetting themselves when the condition that caused their operation disappears. Five other yellow colored indicators are available, and they are reset when their operating signal disappears. Three of them correspond to the phase selectors (A, B and C) and they are located at the front of module DSM. They are supervised by OR4 through AND71, AND72 and AND73, respectively. That is, during a phase to ground fault, the directional unit must operate so that phase selector indicators may operate.

The fourth yellow indicator is activated by an output from the TL11 timer which, in the power swing blocking scheme is identified by OSB, located at the front of the DLM module.

The FF yellow indicator located on the front of the DLM module DLM, is activated when a fuse failure condition is produced.

RECLOSER LOGIC

The MLS recloser operates according to the block diagram shown in figure 6 . It is a functional representation not related directly with the actual circuitry.

The recloser may operate in one of the following modes:

1. One reclosing attempt, single or three phase, depending on the trip.
2. One reclosing attempt, single phase only.
3. One reclosing attempt, three phase only.
4. Two reclosing attempts, single or three phase the first, and three phase the second.
5. Two reclosing attempts, both three phase.

We shall begin our discussion with mode 4 since it involves the whole recloser circuitry. The rest of the modes will be described afterwards.

The reclosing cycle begins automatically when the distance relay produces a trip and generates the reclosing initiating signals: IR1 if the trip has been single phase and IR3 if it was a three phase trip. Trips in fourth or fifth zone do not generate reclose initiate signals.

First reclosing attempt after a single phase fault

Consider the case of an A phase to ground fault resulting in a single phase trip. The recloser receives an IR1 signal which provides the third AND1 input. The first will be activated since the MONO selector is closed (selected single phase shot). The third input will also be activated through NOT1 since the BR signal (reclose blocking) will be deactivated. The BR signal is activated when the protection second zone timer times out, thus avoiding reclosing for delayd trips. Finally, AND1 lower input will be activated through NOT5 since the L6 latch will be set to zero (non blocked recloser).

Output AND1 is transformed into a P1 pulse (edge detector) and it activates the L1 latch, providing the upper input to AND8 so that its output will be activated, given that it is the first trip and the sequencer is in state "1".

The activation of L1 produces, through OR3, the lighting of OPN LED, indicating that the breaker is open and the starting of TL5 timer (20 milliseconds). When TL5 times out, its output activates L4 latch which, through OR22 activates signal 3PT (three phase trip activation). This signal is sent to the protection logic module (DLM) so that from now on the following trips may be three phase. The TL5 timer function is that of delaying signal 3PT long enough for the breaker to open and for the distance unit to be reset; otherwise, signal 3PT would be applied before clearing the fault and the present trip would become three phase.

AND8 output starts the TL1a single phase reclosing timer, which, at the end of the adjusted time, provides a pulse in its output which, through OR6, activates AND5 lower input. If selector HOLD(whose function will be described later on), is OUT and therefore, with AND5 upper input activated, AND5 output will be applied through OR8 to AND11 upper input.

AND9 output will be deactivated, since the trip has not been three phase, and therefore, AND3 output will also be deactivated, thus activating NOT9 and AND11 lower input. AND11's output activates TL4 timer, and, through it, RCL reclosing output. This output will remain activated during the time adjusted for TL4 maintenance timer. Likewise, AND11 output, trough OR21, starts TL3 reset timer and timer TL6, which produces a 128 millisecond pulse at COFD output. The purpose of COFD is to let the distance protection know that an output has been produced.

The reclosing time end pulse, originated in OR6 output, sets to "one" the L9 latch which, through OR13, activates PBZ1X. This output, sent to the distance relay, has the purpose of, following the first reclosing attempt, pulling extended zone one back to its normal reach for further trips. Should the distance relay be adjusted in a logic scheme different to that of extended zone one, PBZ1X signal would have no effect whatsoever on it.

RCL reclosing output, resets L1 latch, through its R input, leaving the system prepared to receive a new starting input. Also, through the sequencer's CL input, it makes it advance one stage ahead.

Second reclosing attempt after a single phase fault

Should TL3 timer time out before a new trip is produced, the sequencer will be reset through OR4, as well as signal 3PT through OR9 and OR10, and signal PBZ1X through OR9, so that the recloser remains in state of reset.

If after the first reclosing attempt, the fault persists and the distance relay trips again, before TL3 reset timer times out. The new trip will be three phase because the recloser has sent signal 3PT to the distance relay logic module as a result from the first reclose starting.

It is assumed that the three phase reclosing selector (TRI selector) is activated and so is AND2's upper input. If the trip reccurs in the first zone, BR signal will be deactivated and, through NOT1, the AND2 second input is activated. Since the recloser is not blocked by the activating of L6, AND2 third input will be present. Activating the three phase IR3 starting signal produces an output from AND2, which, transformed into a pulse in P2, activates L2 latch; the OPN LED will light up again through OR3. The sequencer will be in stage 2 and, therefore, AND10's output will be activated, thus starting up TL1c reclose timer. The following sequence of events is the same as in the case of the first operation. When RCL output is activated, the sequencer will pass on to stage 3, thus activating AND4 upper input.

Should the fault persist, the protection will again trip in three phase. This time, since the sequencer is in stage 3, OR3 output will activate AND4's output which, through OR5 and OR17, will activate L6 latch, lighting up the LOCKOUT L/O LED. L6 output activates the LOCKOUT output to the outside in order to close an alarm contact and, through OR22 and OR13, it maintains 3PT and PBZ1X outputs, respectively.

The blocked recloser output resets the following latches and timers:

L9 through OR9.
L5 through OR7.
L4 through OR9 and OR10.
L1 and L2 through OR15.
TL2 and TL3 through OR16.
TL1a, TL1b and TL1c through OR16.
SEQ through OR4.

Also, through NOT5, it enables gates AND1 and AND2, keeping the recloser from operating on new starting inputs.

First reclosing attempt after a multiphase fault

Consider the case of a two phase or multiphase fault. The distance relay will produce a three phase trip and will send signal IR3 to the recloser, which, through AND2, P2 and L2 will activate AND9's upper input. Since this is the first trip, the sequencer will be in stage 1, and AND9 will produce an output which will start the three phase TL1b reclosing timer. The following series of events will be the same as for the first single phase reclosing attempt described earlier. As in that case, 3PT and PBZ1X outputs will be activated.

Second reclosing attempt after a multiphase fault

The second reclosing attempt following a two or three phase fault is identical to the second reclosing attempt after a single phase fault. Again, the recloser will reach the lockout state after the third trip.

One only reclosing attempt

The second reclosing attempt may be avoided by closing the selector called NO-TEMP. In this case, when the first reclosing attempt is carried out, the sequencer passes on to stage 2. The activating of this stage will, through selector NO-TEMP and OR19, produce a new clock pulse on the sequencer taking it to stage 3, so that the following trip will lead the sequencer to the lockout state.

Single phase reclose only

In order to set the recloser to this mode, selector TRI must be opened and selector MONO must be closed. With the selectors in these positions, only IR1 (single phase trip) inputs will be started, since gate AND2 will be blocked since selector TRI is open.

It should be noted that in this mode, only one reclosing attempt will be produced since the second trip, will always be three phase and the corresponding reclosing attempt will be blocked in AND2.

Three phase reclose only

In order for the recloser to operate in this mode, selector TRI must be closed and selector MONO must be opened. With selectors in these positions, 3PT output will be activated through NOT2 and OR22, so that all the operations will be three phase; therefore, only IR3 three phase reclose starting signal will be activated.

In this case, the recloser will perform both reclosing attempts, if the selector NO-TEMP is opened.

Manual close

The activating of the CC5 contact converter activates L10 latch through AND13, and starts the reset timer through AND13 and OR21. It also resets the following latches:

L6 and L8 through AND13 and OR12.
L4 through AND13, L10 and OR10.

The output of L10 latch activates AND14 lower input. Should a trip be produced before the reset timer times out, output OR3 will be activated and the recloser blocking will be produced through AND2, OR5 and OR17. Should the reset timer time out before a trip is produced, its output will reset L10 latch and the recloser will remain in the reset state.

Syncronism check supervision

The synchronism check is an option available in MLS systems. When currents on both sides of the breaker are out of syncronism, the supervision circuit provides an output which is applied to the recloser's SYNC input. If the synchronism check equipment is external, the CC3 contact converter will be activated. In both cases, AND3 lower input is activated. AND3 upper input is only activated when the reclose starting has been three phase (AND9 output activated). Supposing that the trip has been three phase, AND3 output will be activated, thus blocking AND11 through NOT9 and avoiding the operation.

The HOLD Link (L3) is used when reclose is desired should the blocking disappear within the adjusted time for TL2 (the same time as that adjusted for the reset timer). TL2 timer is started when OR6 is activated at the end of the reset time. OR6's output activates L5 latch which keeps AND7 upper input active. Should selector HOLD be in position OUT, AND7 middle input will be active. In the case where no syncronism exists AND7 lower input will be activated and, as soon as OR6's output activates L5 latch, AND7 output and L8 latch will be activated through OR11. L5 latch lights up N/S LED indicating that a reclosing attempt has ocurred, blocked by a lack of syncronism, and it activates the recloser blocking L6 latch.

Should L3 be in the IN position, AND7 middle input would be absent and L8 and L6 latches would not be activated. However, should TL2 timer time out before the lack of syncronism condition disappears, it would produce an output which would activate L8 through OR11. If, before TL2 times out, SYNC input is disconnected, thus indicating that there is syncronism, a reclosing command would be generated through AND6 (L5 is activated an selector HOLD is in position IN), OR8 and AND11 (its lower input would be unblocked when SYNC input is disconnected). The reclosing output resets TL2 timer through OR21.

Recloser external blocking

The recloser may be blocked externally through CC4 contact converter. When this contact is activated, both AND1 and AND2 gates are blocked through NOT1 and no starting signal is allowed to enter.

CC4 contact also blocks, through OR23, NOT1 and AND15, the arrival of manual close commands.

The purpose of the blocking input is that of coordinating the recloser with an external protection, so that only reclosing for faults in zone one will be allowed.

In the case where the use of this input is desired as an external blocking of the recloser, the distance relay inputs corresponding to "THREE PHASE TRIP" and "EXTENDED ZONE ONE PULL BACK" will have to be simultaneously energized, as corresponds to a blocked recloser.

Recloser in OFF position

The recloser can be set to the OFF position by opening the MONO and TRI selectors. When this occurs, AND1, AND2, as well as AND13 gates are blocked, as it happens with an external blocking. The difference is that in the OFF position, a series of signals, which would not be activated by external blocking, are now activated:

R-OFF through OR2 and NOT10.
3PT through NOT2 and OR22.
PBZ1X through OR2, OR1, NOT7 and OR13.

External inputs to the recloser

All the signals reaching the recloser, apart from that of remote reset (RR) can be activated from the outside and from its own protection system. The (RR) system can be activated only from the outside. However, a button at the front of the reclosing module (RLM) performs the same function.

Reclosing module outputs

The reclosing module outputs are:

-3PT.- Three phase trip supervision. It is sent through a contact to the logic board (DLM) and to the outside. Its purpose is that of making the associated protection trip in three phase, regardless of the nature of the fault. This signal is activated due to one of the following reasons:

- Recloser in three phase mode only.
- Recloser in the OFF position.
- Started reclosing cycle.
- LOCKOUT.

-R-OFF.- Recloser in the OFF position. It is sent to the outside through a contact.

-RCL.- Reclosing command; it activates a telephone relay located inside the magnetic module.

-LOCKOUT.- Recloser blocked due to a permanent fault. It is sent to the outside through a contact.

-PBZ1X.- Extended zone one pull back. It is sent through a contact to the logic board (DLM) of the protection and to the outside for supervision of any external protection associated to the recloser. Its purpose is that further trips may be carried out with the zone one reach in its normal value, after the cycle is started.

-NO-SYNC.- It is activated when the synchronism check module sends a signal indicating the lack of syncronism. This signal activates a telephone relay located in the magnetic module.

-COFD.- Close. It is sent to the logic module (DLM) to indicate that a close has been produced. It is used within the line energizing logic.

SYNCHRONISM CHECK FUNTION
(Optional)

Overall

Figure 11 is a combination block/logic diagram of the overall sync check circuit. The bus and line voltages are stepped down by external PTs and again by PTs within the relay, this time to a level compatible with the internal electronics. The relay PTs are located in the magnetics module . The remainder of the circuitry depicted in Figure 11 is located in the SVM module.

The line voltage is supplied to both a live and a dead detector, each of which compare the magnitude of the voltage to a preset (adjustable) threshold. The live detector produces an output when the voltage exceeds the live threshold and the dead detector produces an output when the voltage is less than the dead threshold. In other words, outputs are produced when conditions are as desired for reclosing. The bus voltage is similarly sent into separate live and dead detectors.

In addition to the magnitude detectors, the bus and line voltages are together sent into:

1) a combined angle detector and high set slip detector.

2) a low set slip detector. Unlike the magnitude detectors.

These circuits produce outputs when conditions are undesirable for reclosing, i.e.,

1) the angle is out of limits or the slip exceeds the high set cut-off, or

or

2) the slip exceeds the low set cut-off.

The mode of supervision is selected by closing the appropriate switch. More than one switch may be closed at a time to obtain a combination of functions.

Consider the case of reclosing under dead line, dead bus conditions. Closing the DLDB switch enables AND1 while AND2, 3 and 4 remain disabled. For AND1 to produce an output, both the dead line and dead bus detectors must de issuing outputs, indicating that the line and bus voltages both register as being dead. In the dead line, dead bus mode, an output from AND1 constitutes the ..Permit Reclosing.. signal through OR2. Its absence results in reclosing being blocked. The dead line, live bus and live line, dead bus modes operate in similar fashion through AND2 and AND3, respectively.

In the sync check mode (SYNC CK switch closed), an output is required from AND4 to permit reclosing. This will occur only when:

1) the line and bus are both live

and

2) there is no output from either the angle and high set slip detector or the low set slip detector. An output from either of these detectors blocks reclosing by disabling AND4 at its NOT input (via OR1).

Angle and High Set Slip Detectors

The angle and high set slip detectors are depicted in Figure 12. The bus and line voltages are brought into an anti-coincidence circuit which produces a positive output only when the instantaneous voltages are of opposite polarity, either the bus positive and line negative, or vice versa. When the instantaneous voltages are both positive or both negative, there is no output from the anti-coincidence circuit. Thus, the output of the anti-coincidence circuit (waveform A) can be considered as a pulse train in which the width of the positive pulses (or blocks) is equal to the angular separation 0 (phase shift) between the bus and line voltages.

The output of the anti-coincidence circuit is fed into the angle timer. This timer produces an output only when the width of an input block exceeds the angle setting 0 (adjustable). The timer output consists of a narrow pulse (waveform B) which is issued every time the angle setting delay elapses.

$$\text{Angle Setting Delay} = \frac{0}{360^\circ} \times \frac{1}{f} \text{ seconds}$$

Where: f is the nominal system frequency (50 or 60 hertz)

A pulse from the angle timer sets the output flip flop (FF1), resulting in a continuous ..Block Reclosing.. signal (waveform D). The pulse also initiates the high set slip timer. This timer will produce an output only if the time delay THS elapses before the next pulse comes along because each successive pulse resets and re-initiates the timer.

$$THS = \frac{1}{FHS} \times \frac{20}{360^\circ}$$

Where: FHS is the high set slip cut-off (in hertz)

By coupling the angle setting into the high set slip timer, the angle setting may be changed without having to readjust the slip timer setting, FHS.

An output from the high speed slip timer (waveform C) resets FF1 and thereby permits reclosing.

Consider the example of the bus and line voltages being at exactly the same frequency (no slip) and having an angular separation of Ø between them which exceeds the setting θ. The waveforms will be as illustrated in Figure 12, item 1. The dots at the left of each waveform indicate the reference point.

The output from the high set slip timer (waveform C) is continously low because the steady stream of pulses from the angle timer (waveform B) continually reset and re-initiate the slip timer, preventing it from timing out. Therefore, FF1 gets set and never gets reset, resulting in the ..Block Reclosing.. output shown in waveform D.

If Ø is less than θ, waveforms B, C and D will all be continously low.

Now consider the example of a frequency difference between the voltages which is less than the high set slip cut-off, FHS. The waveforms will be as illustrated in Fig. 12, item 2. Eleven cycles of VL are shown in the same interval as 12 cycles of VB (90° to 90°). This is one complete slip cycle and the angular labels above the VB wave and around the circle are slip degrees. If the VB sine wave is taken to represent 60 hertz, the VL sine wave has a frequency of 11/12 x 60 = 55 hertz and the slip rate is 60 - 55 = 5 hertz. Although this exceeds the maximum acceptable setting of the circuit (2.5 hertz), it is shown for the sake of discussion to be less than the high set slip setting. A slip of 5 hertz was used only so that the diagram might be clear and not be unreasonably long.

The voltages are shown to be 90 degrees out of phase initially (VL lagging VB). This is an arbitrary point as far as the high set slip detector is concerned. The anti-coincidence circuit output blocks vary in width as the angular separation between the two voltages changes throughout the slip cycle (waveform A).

The angle timer measures the varying anti-coincidence blocks and responds accordingly. When the block width exceeds the angle setting, a pulse is produced. As the angular separation increases, the block width may be two or more multiples of the angle setting, in which case the angle timer will output two or more pulses. For example if the angle is set to 35°, the maximum anti-coincidence block in the slip cycle (at 180°) has a width of 180/35 = 5.14 multiples of the angle setting and the angle timer will output 5 consecutive pulses (integer part only).

The angle timer produces no output during the portion of the slip cycle in which the angular separation between the voltages is less than the angle setting 0. This dead band is labeled the slip measurement interval on waveform B. It represents a reclosing ..window.. so to speak, having a dimension of 20 slip degrees. The slip measurement interval will always have a dimension of 20 slip degrees, but its duration (tSMI) will decrease as the slip rate increases and vice versa. It therefore provides a convenient means of measuring the slip.

$$tSMI = \frac{1}{fs} \times \frac{2x0}{360^{\circ}}$$

Where: fs is the actual slip frequency.

The absence of pulses from the angle timer during the slip measurement interval gives the slip timer an opportunity to time out because it is not being reset and re-initiated. After a delay of THS following the last pulse before the slip measurement interval, the high set slip timer produces an output (waveform C) which resets FF1 and thereby removes the ..Block Reclosing.. signal. This signal reappears on the first pulse from the angle timer. Its momentary absence, however, provides an opportunity to reclose (waveform D).

If the slip is greater than the high set cut-off (fs > FHS), tSMI will be less than THS, the slip timer will not time out, and reclosing will be continously blocked.

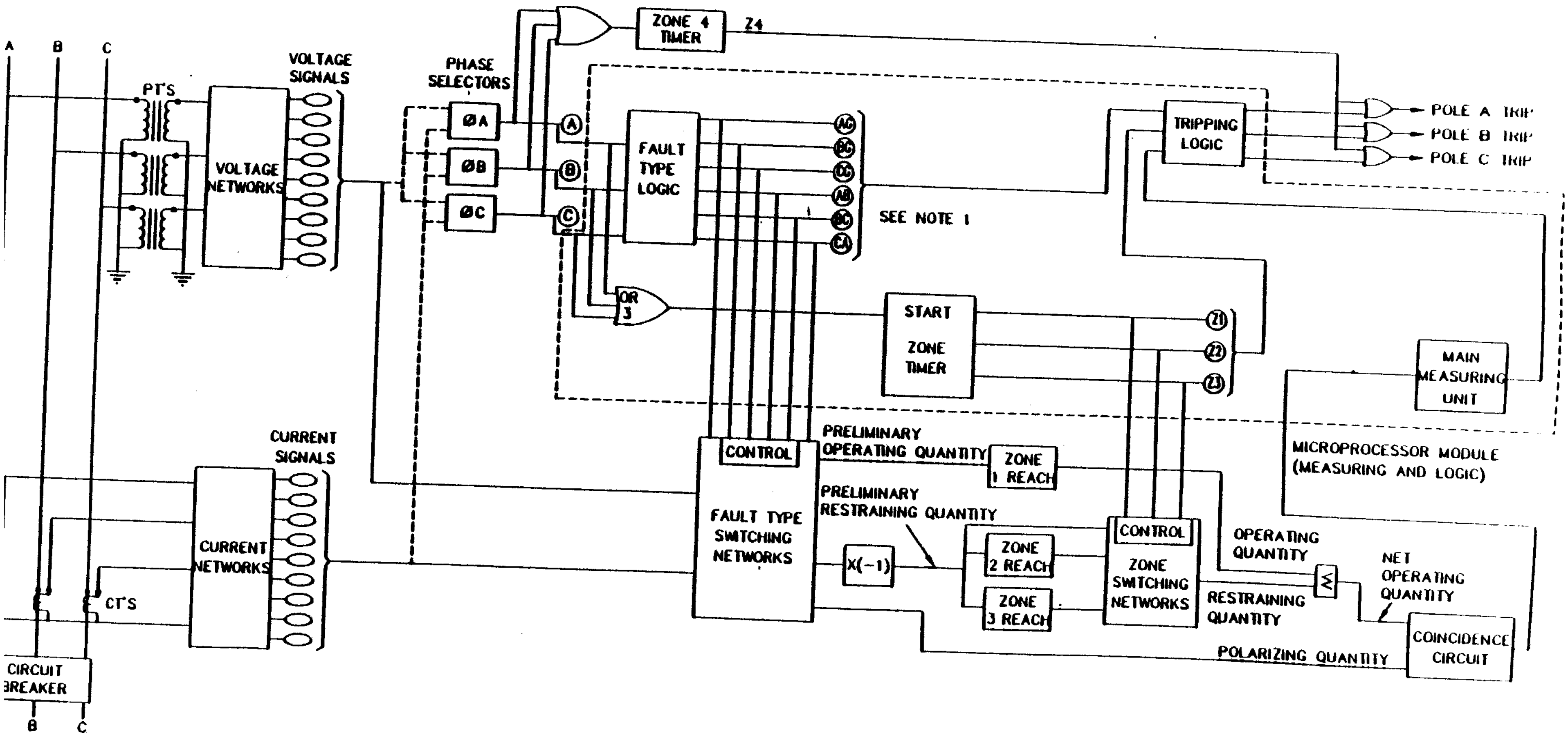
Low Set Slip Detector

This detector determines the rate of slip by measuring the time it takes for the line voltage to traverse 90 degrees in the slip cycle (one quadrant). This time, T90°, is then compared against the time limit established by the low set slip cut-off, TLS.

$$TLS = \frac{1}{4} \times \frac{1}{FLS}$$

Where: FLS is the low set slip cut-off (in hertz) and the factor of 1/4 pertains to one quadrant.

If T90° is less than TLS, the rate of slip exceeds the cut-off (FLS) and reclosing is blocked. If T90° is greater than TLS, the rate of slip is less than the cut-off, and reclosing is permitted.



NOTE 1: (BC) IS USED FOR ØB-ØC FAULTS AND 3Ø FAULTS

Figure 1 (226B7445 Sh 13): Simplified Block Diagram of MLS Stepped Distance Scheme.

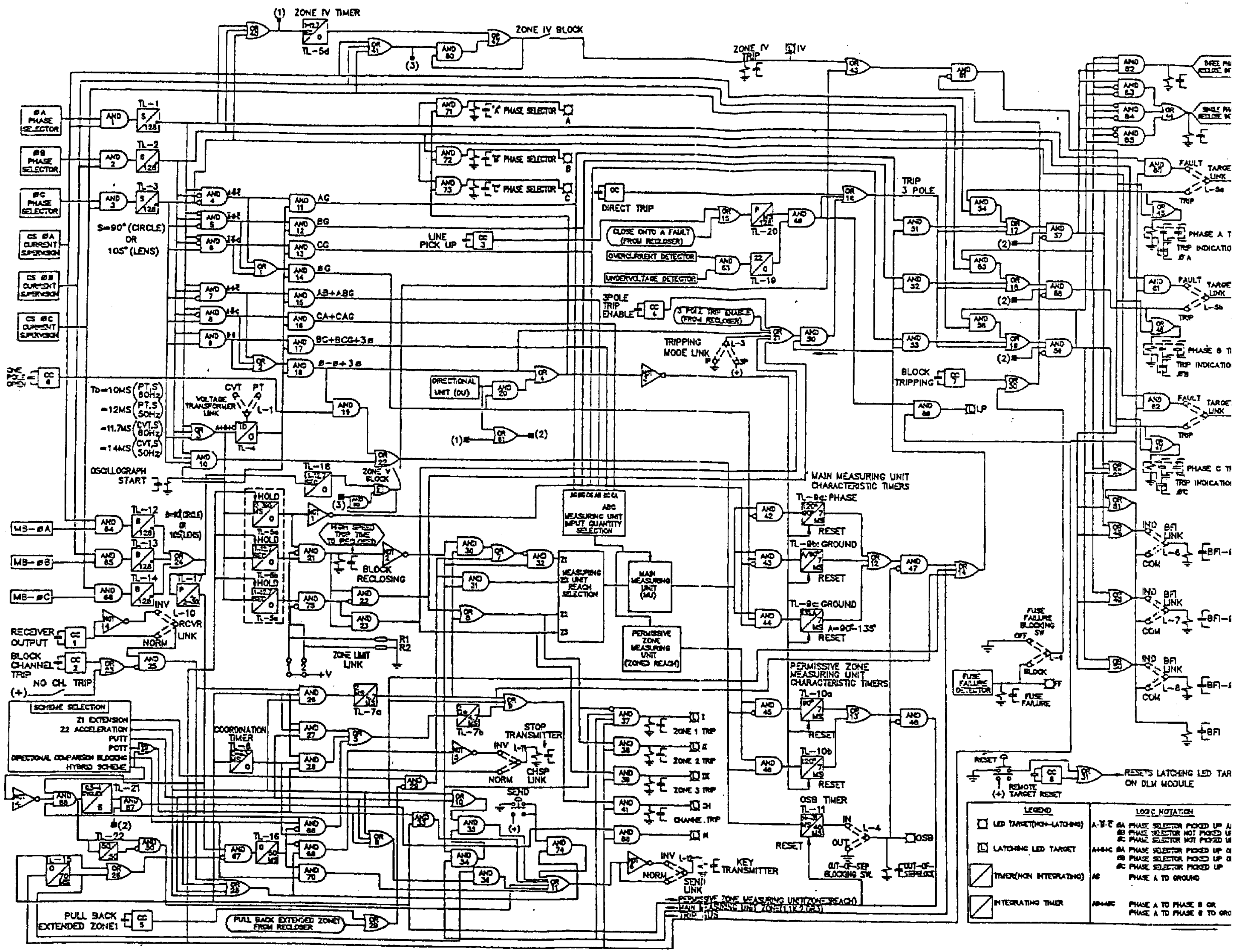


Figure 2 (189C5240 Fig 1): Logic Diagram.

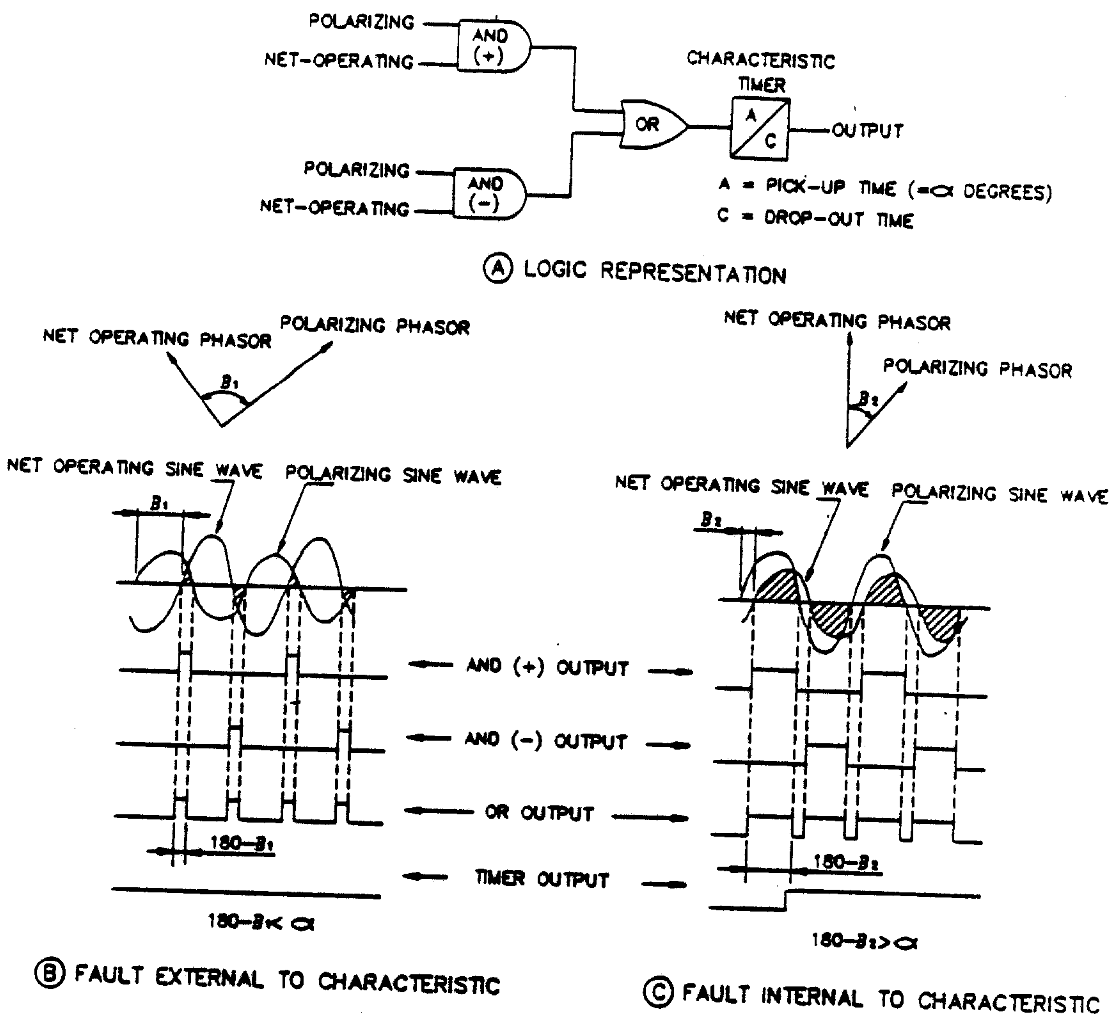
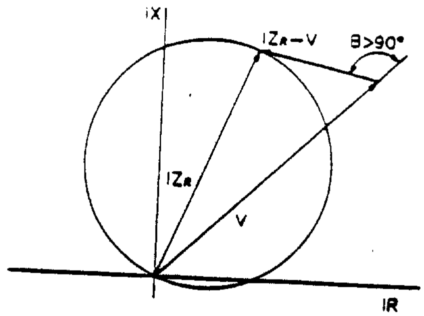
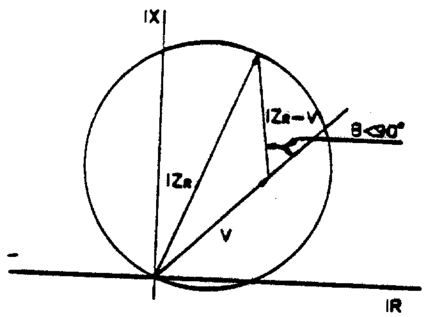


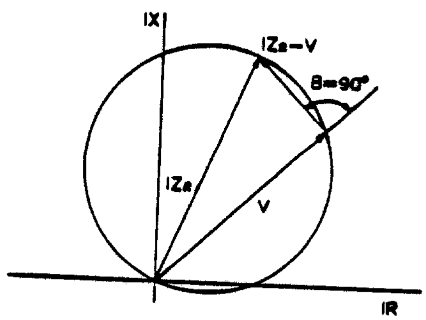
Figure 3 (226B7445 Sh 14): "Block-Block" Principle of Distance Measurement.



Ⓐ FAULT EXTERNAL TO CHARACTERISTIC



Ⓑ FAULT INTERNAL TO CHARACTERISTIC



Ⓒ FAULT AT EDGE OF CHARACTERISTIC

Figure 4 (226B7445 Sh 15): Voltage Diagrams of Circular Mho Type Characteristic.

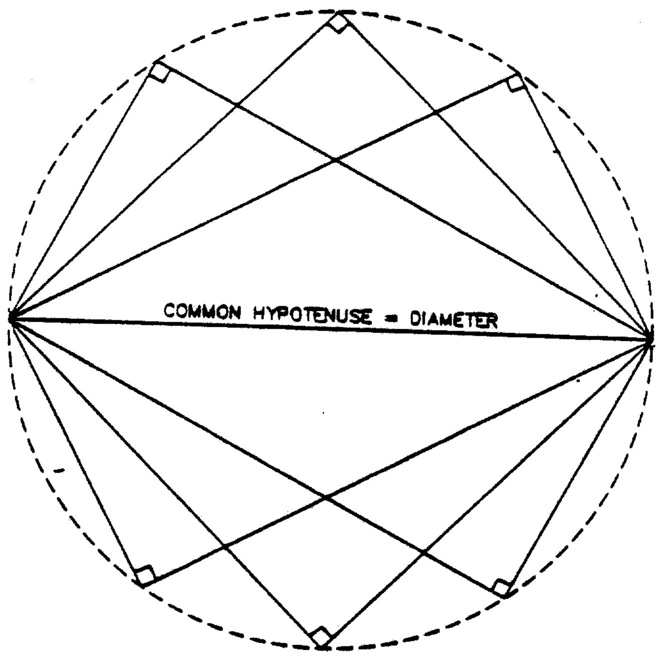


Figure 5 (226B7745 Sh 16): Formation of a Circle by Constructing Right Triangles About a Common Hypotenuse.

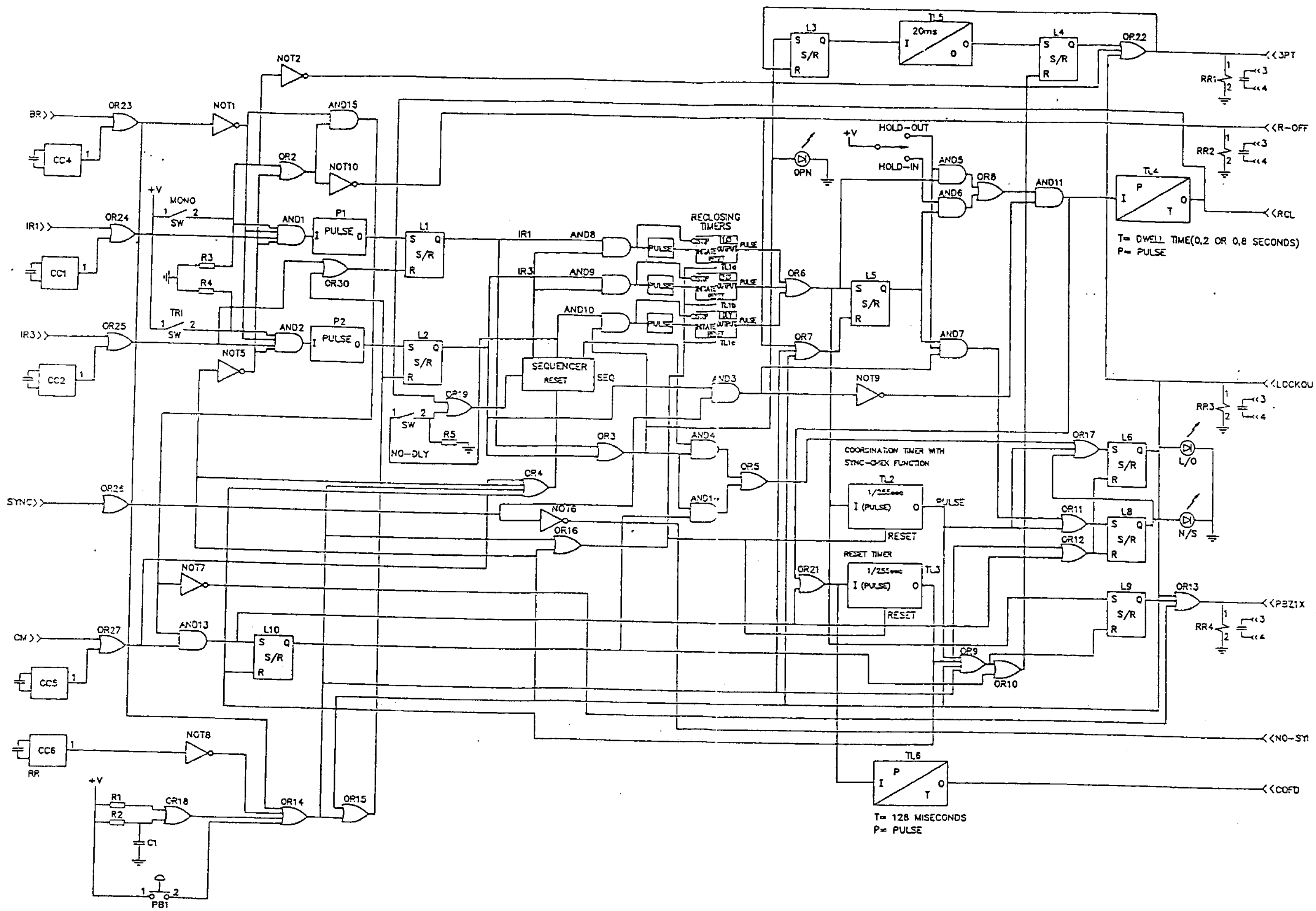


Figure 6 (189C5241 Fig 2): Logic Diagram of the Recloser.

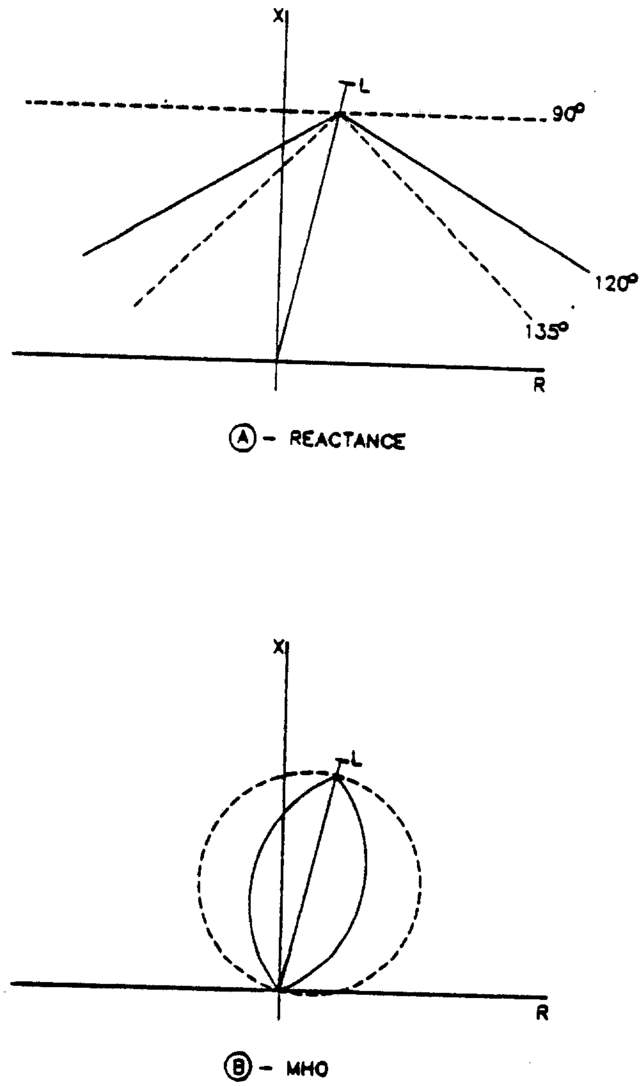


Figure 7 (226B7445 Sh 17): Reactance and Mho Ground Characteristics.

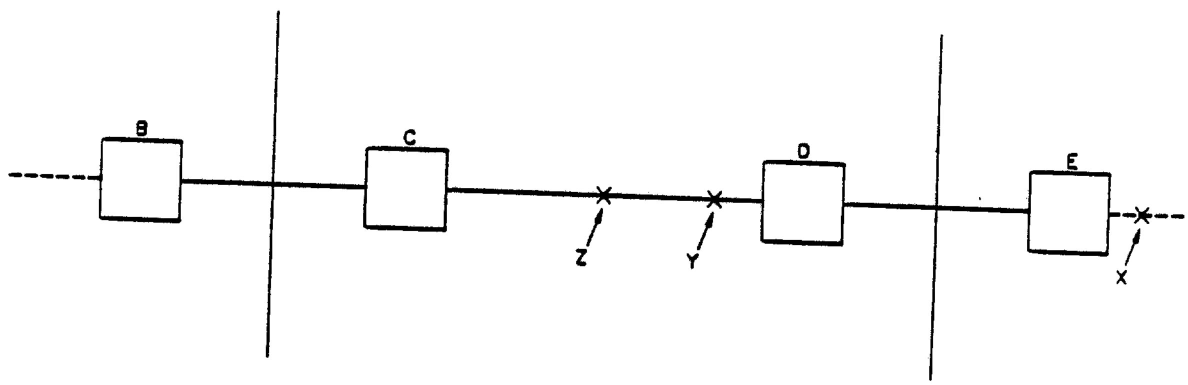


Figure 8 (226B7440 Sh 19): One Line Diagram of Typical Line Section.

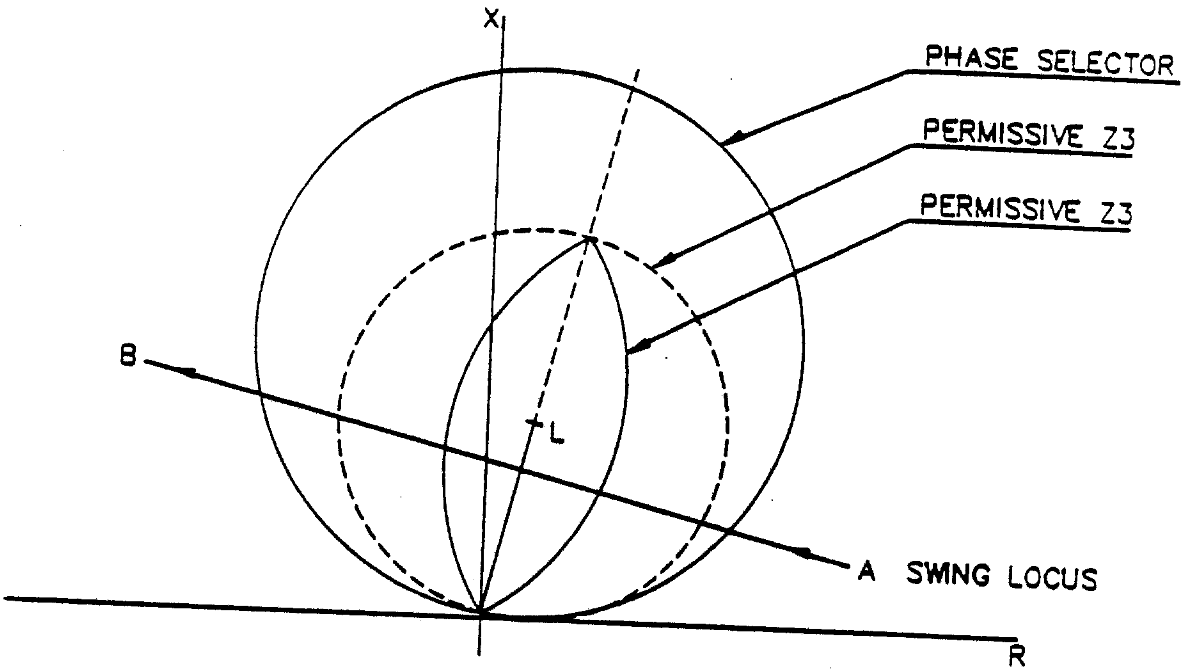


Figure 9 (226B7445 Sh 19): Characteristics for Out-of-Step Detector Scheme.

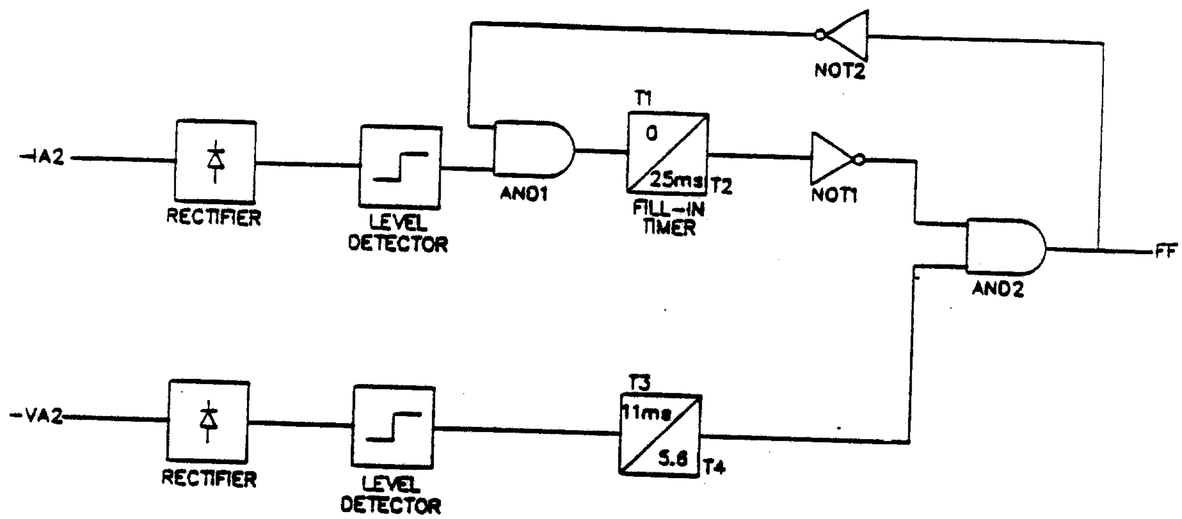


Figure 10 (226B7745 Sh 36): Block Diagram of the Fuse Failure Detector.

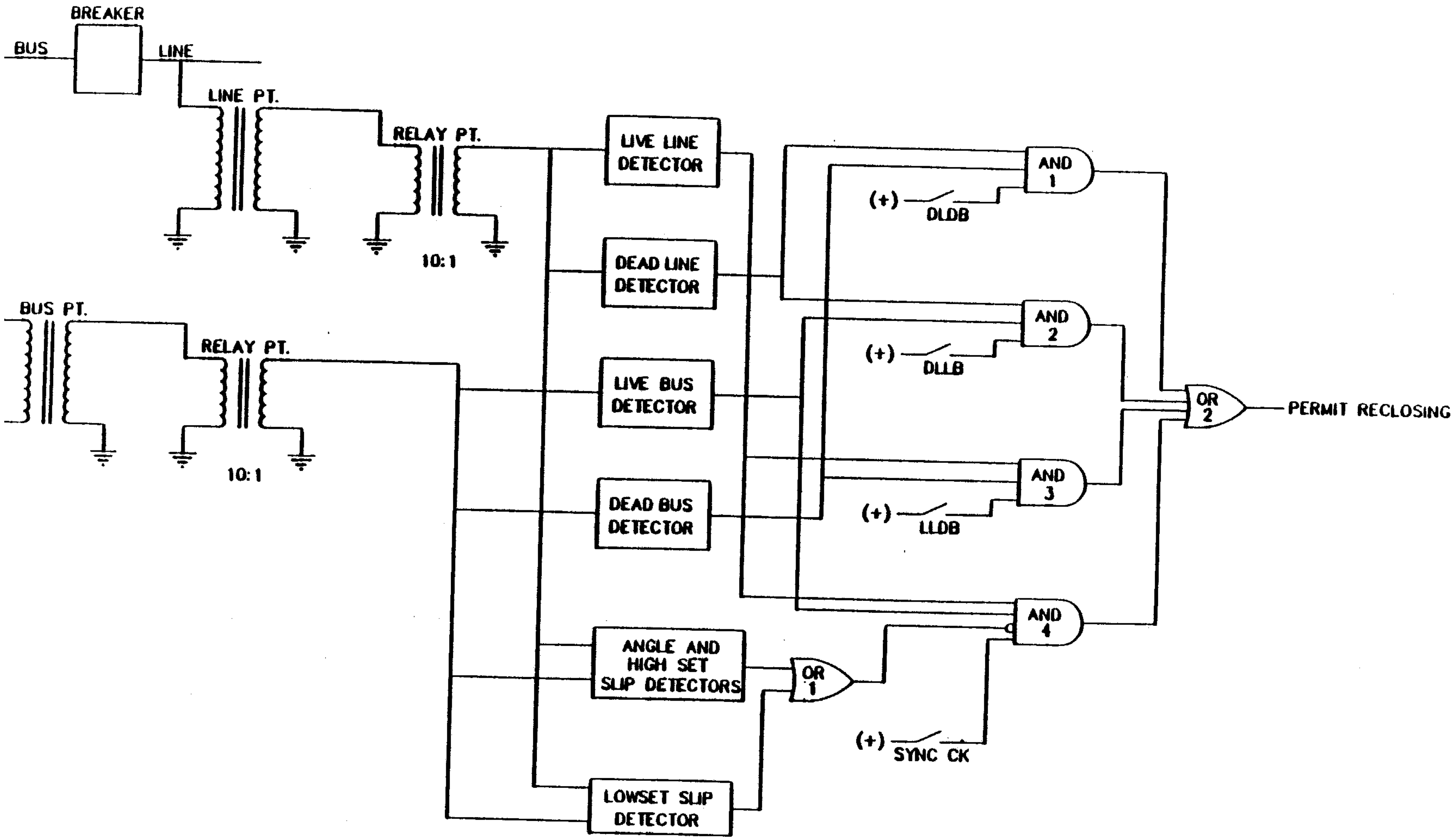


Figure 11 (226B7445 Sh 20): Logic/Block Diagram of MLS Syncronism Check Circuit.

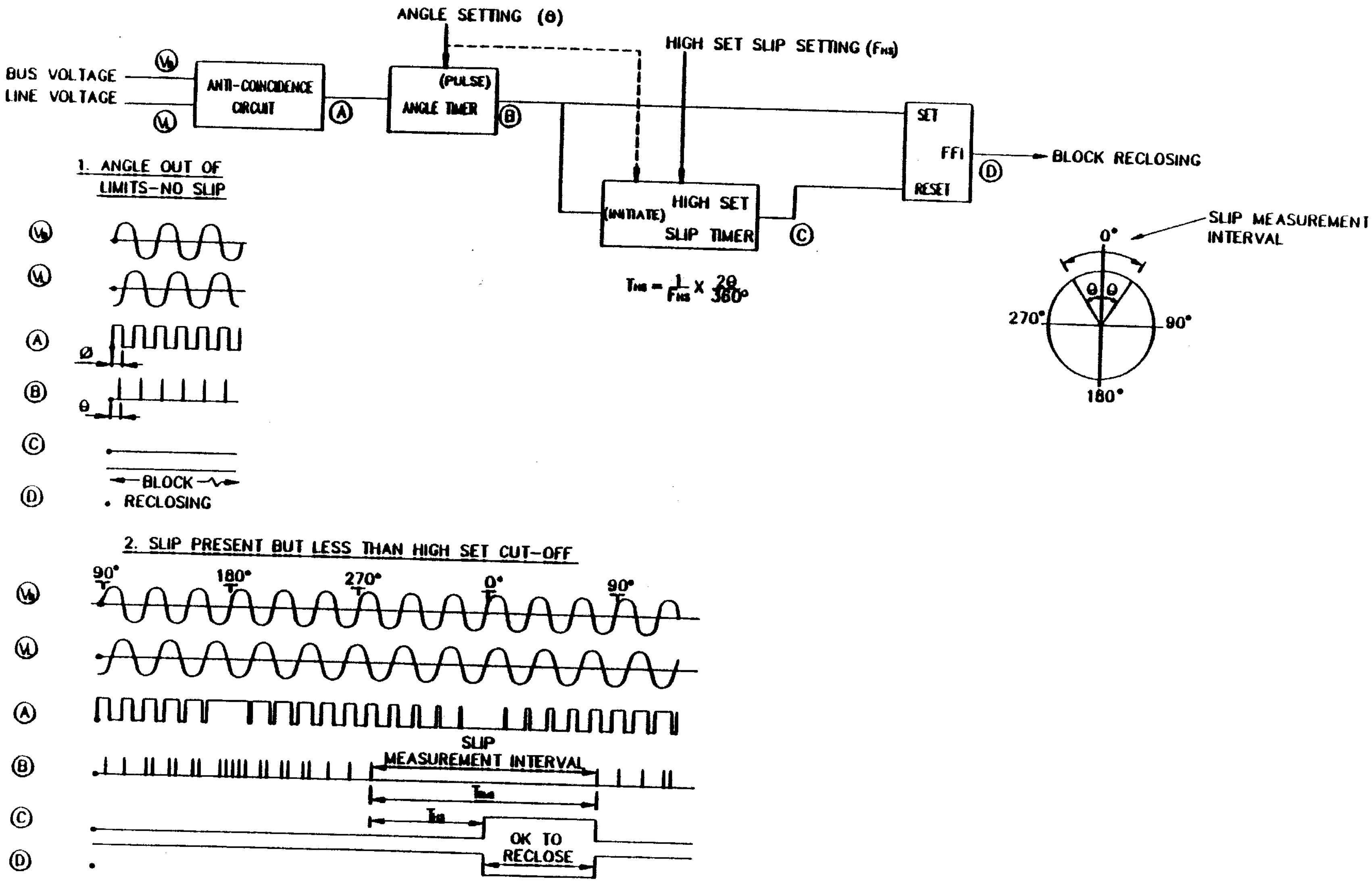


Figure 12 (226B7445 Sh 21): MLS Angle and High Set Slip Detector.

APPLICATION AND CALCULATION OF SETTINGS

The MODULES SECTION describes the required settings and the location of the links or switches used to affect these settings. This section will discuss the application requirements and restrictions of the various settings as influenced by line and system conditions. Quantitative examples will be given for many of the settings discussed, and exact link or switch positions will be stated.

Characteristic Impedance Angles

The positive and zero sequence characteristic angles should be set by means of the ØZ1 and ØZ0 switches. They should be set at the next lower switch setting that is closest to the actual line positive and zero sequence impedance angles. For the sample system of Fig. 14, set 0Z1 at 70° and 0Z0 at 65°. The angle settings thus determined apply to the main measuring unit, the permissive zone measuring unit, the phase selectors and to the MB carrier start functions, if present.

Zero Sequence Compensation

The zero sequence compensation setting, K0, is determined by the ratio of the line zero sequence impedance to the line positive sequence impedance, i.e., Z0/Z1. In the example of Fig. 28:

$$Z0/Z1 = \frac{4.92}{1.44} = 3.42$$

Therefore, the K0 setting on the DRM module should be at 2 + (.75 + .4 + .2 + .05) = 3.4, where the number in (-) indicate the K0 switches which should be closed (right-hand position).

Phase Selector Settings

Characteristic Timer Setting

The characteristic timer can be set for either a 90° coincidence angle, which results in a circular mho characteristic, or a 105° coincidence angle which results in a lens shaped characteristic. The circular characteristic would normally be used unless one of the following conditions exists:

1. The expected load impedance is so low that a circular mho characteristic cannot be set with sufficient margin beyond the zone-3 reach without reducing the margin against operation on load.
2. The ratio of total impedances, Z0/Z1, for a fault at the remote end of the line is less than 0.75, and the ratio of the positive sequence source impedance (ZS) to the zone-3 reach is unity or less.

In the example of Fig. 13 the ratio of Z0/Z1 is less than 0.75, but the ratio of the positive sequence source impedance to the zone--3 reach is greater than unity.

Reach Setting

The reach setting of the phase selectors must be considered from two points of view.

1. The maximum allowable setting based on maximum load flow.

2. The desired setting to insure that the phase selectors will outreach the zone-3 measuring unit by a practical margin.

In determining the phase selector reach setting, it must be noted that, due to the KVIM term in the operate circuit, the steady state reach for three phase faults is 1.33 times the ohmic reach as set on the front plate of the DSM module, and may be greater than 1.33 times the set reach for phase-to-ground faults. This accounts for the 0.75 multiplier in the following section on maximum allowable reach to prevent operation on load.

The maximum allowable reach setting of the phase selectors is based on the minimum load impedance (i.e., maximum load flow) that the relay will see during their normal service for a particular application.

The maximum allowable phase selector reach setting is determined from:

$$PSR = \frac{ZL \sin \emptyset}{\sin (180^\circ + \theta L - \emptyset Z1 - \emptyset)}$$

Where:
- PSR = maximum allowable reach
- θL = angle of minimum load impedance
- ØZ1 = positive sequence impedance angle (characteristic impedance angle as set on relay)
- Ø = 60° for the 90° mho characteristic; 75° for the 105° lens characterist.
- ZL = magnitude of minimum load impedance

Fig.14 is an R-X diagram plot showing the above quatities for the example of Fig. 13. In the example:

$$PSR = \frac{(20) \sin 60^\circ}{(\sin 180^\circ + 15^\circ + - 70^\circ - 60^\circ)}$$

PSR = 19.11 ohms

The actual reach setting is 75 percent of this value (0.75) (19.11) or 14.3 ohms. The required setting to obtain this is 4 + 10 = 14, where the number in (__) indicates the switch which should be closed (right-hand position).

For the minimum or ..desired.. setting, the phase selectors should outreach the zone-3 setting of the measuring unit by a reasonable margin. Conversely, the zone-3 functions can be set only so large, relative to the phase selector setting. The following limits apply:

1. 90° phase selector characteristic timer:

ZIII <(0.7)(phase selector reach setting on DSM module)

2. 105° phase selector characteristic timer:

ZIII <(0.65) (phase selector reach setting on DSM module)

Zone I Reach Adjustment

The zone I reach establishes the reach of the ground and phase functions of the first zone. It is not advisable to adjust this reach higher than 85% the line positive sequence impedance.

In the example shown in Figure 13, zone I reach is:

ZI = (0.85) x (1.44) = 1.2 ohms

The adjustment required to obtain this value is:

ZI = 25 x (0.048) x 5/5 = 1.3 ohms

In the formula: 25 is the multiplying factor A included on the formula shown on the module DRM front plate.

0.048 = 0.02 + (0.028), the value in brakets is the addition of the values of those switches set to the right.

Zone-1 Extension Reach

It is necessary to set the zone-1 extension reach only if the Zone One Extension Protective Scheme has been selected via the toggle switches on the DTM module. When the Zone One Extension Scheme is used, the zone-1 extension reach (Z1X) provides high-speed distance relay coverage for the entire line on the initial occurrence of a fault, and then reverts back to the zone-1 reach following the initial high-speed reclosure initiated by the associated reclosing package.

It is essential that Z1X be set to assure operation during a remote fault on the line. However, Z1X should be limited to prevent nuisance tripping for remote external faults. For a simple system without infeed, a setting of 110 percent of the line positive sequence impedance is suggested.

In the example of Fig. 13, this reach is:

Z1X = 1.1 (1.44) = 1.58 ohms

Since the zone-1 reach is 1.22 ohms, the required multiple for IX is:

$$\frac{1.58}{1.22} = 1.3$$

The required setting to obtain this is 1 + (0.25 + 0.05) = 1.3, where the numbers in (-) indicate the switches which should be closed (right-hand position).

Zone-2 Reach Setting

The main purpose of zone-2 in a stepped distance scheme is to provide protection against end-zone faults; that is faults that are internal to the protected line, but beyond the reach of zone-1. Taking arcing faults and any underreaching tendency due to intermediate current sources into account results in a setting that must reach beyond the end of the protected line. Under conditions of maximum overreach, the zone-2 setting should be short enough to be selective with zone-2 units of distance relays on the shortest adjoining line sections. A typical setting would be 125 percent of the positive sequence line impedance.

In the example of Fig. 13, this reach is:

$$ZII = (1.25)(1.44) = 1.8 \text{ ohms}$$

Since zone-2 reach is set as a multiple of the zone-1 reach, the II multiple is:

$$II = \frac{1.8}{1.22} = 1.48$$

The required setting to obtain this is 1 + (0.25 + 0.1 + 0.1) or 1 + (0.5), where the numbers in (-) indicate the switches which should be closed (right-hand position).

Zone-3 Reach Setting

Ideally, the zone-3 reach should be set to meet the following requirements:

1. It should reach to the end of all lines out of the remote station, even with high infeed at the remote bus.

2. It should not out-reach the zone-2 on any line out of the remote station when there is lower infeed at the remote bus.

3. It should coordinate with the phase selector reach as previously discussed.

It is important to remember that the zone-3 reach setting determines the reaches of both the main measuring unit, which is used in the step distance scheme, and the independent permissive zone-3 unit, which is used in the pilot and out-of-step detection schemes.

In the example of Fig. 13, the maximum zone-3 reach that will allow coordination with the phase selectors is:

$$ZIII = (0.7)(14) = 9.8 \text{ ohms}$$

The above calculation is based on the recommendations in the section, assuming a 90° phase selector characteristic timer. Since the zone-3 rach is set as a multiple of zone-1 reach, the maximum III multiple is:

$$III = \frac{9.8}{1.22} = 8.03$$

The required setting to obtain this is 1.0 + (5.0 + 1.5 + 0.4 + 0.1). where the number in (-) indicate the switches that should be closed (right-hand position).

Measuring Unit Characteristics - Ground Faults

The characteristic of the measuring units, both the main unit and the permissive unit, for single-phase-to-ground faults, is selectable as either a reactance characteristic or a variable mho characteristic. The following discussion applies to the zone-1 function of the main measuring unit as used in a stepped distance scheme.

Reactance Characteristic

The reactance characteristic, which is shown as the dotted line parallel to the R axis in Fig. 7A, finds wide application on shorter lines where fault resistance can be a significant portion of the impedance seen by the relay during a single-phase-to-ground fault. A relay employing the reactance characteristic provides excellent line protection on a homogenous system, where the fault current at the relay location is essentially in phase with the total fault current in a phase-to-ground fault at the remote end of the line; or if the fault current at the relay location is more lagging than the total fault current in the remote end single-phase-to-ground fault.

On a non-homogenous system where the fault current at the relay location is more leading than the total fault current in the remote end single-phase-to-ground fault, the conventional reactance characteristic may tend to overreach, especially when fault resistance is present. In this situation, the so-called tent characteristic, shown as the solid line plot in Fig. 7A, should be used. This characteristic is obtained by setting the GND CHAR ANGLE (A setting of timers TL9b determine of the tilt angle in Fig. 6A, and the setting of the SEQ TRIP TIME in the DLM module (timer TL5a in Fig. 5) which keeps the characteristic from immediately reverting to a conventional reactance characteristic.

In Fig. 13, the impedance angle (Z1A + Z1L) is 79°. (Z1A + Z1L) is the impedance which determines the angle of the current at the relay location A for a fault at B. Z1B in parallel with (Z1A + Z1L) is used in the calculation of the total fault current for a single-phase-to-ground fault at B. The angle of this net impedance is 83°. The difference of 4° between these two impedance angles defines the tilt angle in Fig. 7A. For this example, the GND CHAR ANGLE is set for 95° to yield 5?

The SEQ TRIP TIME setting determines how long the tent characteristic will persist after the occurrence of a fault. The setting be long enough to allow the fault just beyond the remote bus to be cleared by the primary relaying on the faulted line off of the remote bus, including relay time and breaker time. If system conditions are such that the tent characteristic is not needed, it can be effectively eliminated by setting the SEQ TRIP TIME to its minimum value of ten milliseconds. With this setting the timer will have timed-out and shifted the ground function to the integrating reactance characteristic before the phase selectors have switched the main measuring unit to the faulted phase. In this situation, it is recommended that the GND CHAR ANGLE in the DLM module be set for 125 degrees.

Variable Mho Characteristic

For longer lines, the variable mho characteristic may be preferred by some users to provide protection for single-phase-to-ground faults. As with the reactance characteristic, timers TL9b and TL9c in Fig. 2 determine the mho characteristic.

As in the previous section, the SEQ TRIP TIME setting determines if timer TL9c determines an initial characteristic, and if so, for how long. More secure performance during faults just beyond the remote bus can be carried out by setting the SEQ TRIP TIME to coordinate with the primary or first zone relaying on lines out of the remote station, and with the GND CHAR ANGLE set to produce a lens characteristic. With this arrangement, the characteristic will persist as a directional lens determined by the GND CHAR ANGLE until the SEQ TRIP TIME elapses, at which point the characteristic will integrate to a mho circle. It is recommended that the GND CHAR ANGLE be set for 125 degrees.

If the possible increase in trip time for high resistance faults near the balance point resulting from the above settings is objectionable, despite the increased security, the initial lens characteristic can be effectively eliminated by setting the SEQ TRIP TIME to its minimum setting of ten milliseconds. Again it is

Zone Timers adjustment

These adjustments may vary according to each user's operations. Nevertheless, some general observations may be considered. All the timers of the direct zones are started by the operation of one or more selectors. The zone sequencing may be limited on the front of the module DLM, so that the relay should trip only for faults within the zone defined by the adjustment or within inferior zones. This means that when the adjustment is set to ZI, the relay will only trip for faults in zone I; when the adjustment is set to ZII, the relay will only trip for faults within zones one or two, but it will not trip for faults in zone three;

when the adjustment is set to ZIII, the relay will only trip for zones inferior to zone three. The zone IV, corresponding to the phase selectors reach is out of the sequence of the timers of the rest of the zones, due to its functional independance.It is only effective when the ZIV microbreaker on the front of the module DSM, is set to the right. The zone five is present only when MB blocking optional units are provided and, it is effective only when the Microswitch ZV on the front of the module, is set to the right.

The typical time adjustment for zone two is within the range from 0.2 to 0.5 seconds. Should selectivity with zone two of the adjacent lines relays be possible by means of the reach adjustments, the time of the particular line zone two needs only to be long enough to provide selectivity with the slowest of:

a) The zone I relays of the adjacent line sections.
b) The bus differential relays on the remote bus.
c) The transformer differential relays on the remote bus.

II times of the lines adjacent to the remote bus. This may happen when or more lines adjacent to the remote bus are short in relation to the protected line.

The typical adjustment of zone three is within the range from 0.4 to 1 seconds. Should the selectivity with the zone three units of the adjacent lines have been obtained by means of the reach, the time of the zone three of the particular line needs only to be long enough to be selective with the slowest zone two time in the adjacent lines.Should it not be possible to obtain selectivity by means of the zone III reaches, the zone III time must be long enough to be selective with the zone III times of the adjacent lines.

Zone IV time, when used, must be long enough to be selective with all the zone timers of the lines resulting from the remote bus.

The fifth zone may be considered a third zone protection of the remote terminal. Frequently, it is named as "reverse third zone" and it is useful for the following circumstances:

When the contribution on the local bus, combined to a reach practical adjustment of zone three in the remote bus, results in a zone three unit, in the remote bus which underreaches for a fault at the end of the local bus longest line. The considerations to make are the same as for the third zone timer.

MB Function Settings

The optional MB functions, one per phase, are included when the equipment is to be operated in the directional comparison blocking mode. These carrier start functions are similar in design to the phase selectors, but are connected to look away from the protected line. The MB positive and zero sequence characteristic angles will be the same as set by the ØZ1 and ØZ0 switches. The MB characteristic timer (coincidence

Since the MB functions initiate the transmission of blocking carrier from the line terminal closest to the external fault, a basic requirement in the selection of a reach setting is that they outreach the carrier stop function (permissive zone measuring unit) at the other end of the line - with margin. Referring to Fig. 8, if the permissive measuring unit at C is set for a reach of twice the impedance of line CD, then a reasonable setting for MB at D would be 1.5 times the impedance of line CD.

In the example of Fig. 13, a reasonable MB reach setting is:

$$(1.5)(9.8) = 14.7 \text{ ohms}$$

Coordination Timer (TL6) Settings

Permissive Overreaching Scheme

The operating time of TL6 must be set slightly longer than the reset time of the channel to prevent an incorrect trip during the power reversal that may occur when clearing an external fault on a parallel line. If a power reversal is not possible, then TL6 may be set to zero.

Blocking Scheme

If the total channel time plus propagation time is less than eight milliseconds, TL6 should be set for zero operate time. Total channel time is defined as the time from operation of the keying contact at the sending end, to the instant of receive output at the receiving end - with equipment connected back-to-back.

If the eight millisecond channel time is exceeded, set the operate time (t) of TL6 as follows:

$$t = C + P - 8$$

Where: C = total channel time (milliseconds)
P = propagation time (milliseconds)
t = operate time of TL6 (milliseconds)

These suggested settings will provide a minimum margin of two milliseconds in coordination time between the local trip and receipt of the remote end block signals.

Out-of Step Blocking Timer (TL11) Setting

As previously discussed, the OSB timer, TL11, is used to detect a power swing condition by measuring the time from when the swing impedance enters the phase selector characteristic until it enters the permissive zone-3 lens characteristic.

Referring to Fig. 15, let:

- OC = The protected line impedance
- CA = The equivalent positive sequence system impedance from the remote line terminal C, to the infinite bus
- OB = The equivalent positive sequence system impedance from the relay location at zero to the infinite bus
- ZØ = The reach of the phase selectors units (1.33 times the nameplate setting)
- Z3 = The reach of the permissive zone-3

The out-of-step blocking unit is not a completely separate function. The OSB function is dependent upon the reach of the permissive zone-3, the reach of the phase selectors, and the phase selector characteristic timer setting (90° or 105°). To establish the proper OSB timer (TL11) setting, one must know the rate of the swing between point E where the apparent impedance intersects the phase selector characteristic, and point F where it intersects the permissive zone-3 characteristic; that is, $(\theta 2 - \theta 1)/t$. The pickup setting of TL11 should be adjusted such that the fastest swing moving from point E to point F will permit the timer to produce an output before point F is reached. A method for determining the proper setting for the OSB is indicated below.

First, plot the permissive zone-3 and the phase selector characteristics on the R-X diagram. Note that the reach of the phase selector is 1.33 times the nameplate reach for the power swing condition, and that the permissive zone-3 assumes a lenticular characteristic for three phase disturbances (see Fig. 15). Next, add the time-impedance plot of the swing to the diagram using the fastest swing rate that may exist on the system. The pickup delay of the OSB timer, TL11, should be equal to the time required for the swing impedance to move between the two characteristics, plus one half cycle.

In many applications, it will be difficult, if not impossible, to establish the equivalent system impedances represented in Fig. 15 by AC and OB. In these cases, the swing time-impedance data should be developed from a system stability study. If no data is available, and it is still desired to use the out-of-step blocking feature, the OSB timer pickup should be set for one cycle.

Synchronism Check Function

An optional synchronism check function may be included to supervise the closing of the breaker. Typically, a synchronism check function checks the angle between the voltages on the bus and line sides of the breaker and will produce an output if the angle is within set limits for a set period of time. The combination of angle and time settings establishes the slip cut-off frequency; that is, the slip frequency above which the synchronism check function will not permit reclosing. For any given closing angle, a lower slip cut-off will result in a longer time delay. Because this time delay is introduced for all measurements, a requi-

-rement for high speed reclosing and low slip cut-off settings may result in conflict.

The synchronism check function used in the MLS system (SVM module) has been designed to permit fast reclosing while setting a reasonably low slip cut-off frequency. To accomplish this, the relay is provided with both a high set and low set slip cut-off circuit. The low slip cutoff setting is based on the maximum slip that can be tolerated and still allow reclosing. The high slip cut-off setting is a function of the set closing angle, and the time that the line is de-energized.
To explain the operation of this sync check function, assume the following:

1. The line shown in Fig. 16 has a fault cleared by opening breakers 1 and 2. Breaker 2 is then allowed to close without synchronism check, thereby re-establishing the line voltage, VL, at breaker 1.

2. The bus voltage, VB, is assumed to be fixed in phase and is the reference voltage.

3. The line voltage, VL, can appear anywhere relative to VB and may be rotating in either direction, relative to VB, if the systems on each side of the breaker are out of sysnchronism.

CASE 1:

The systems are in synchronism, but separated by an angle Ø.

A. If the angle between VL and VB is greater than the set closing angle O, then the synchronism check function will not operate and reclosing will not be permitted.

A. If the angle between VL and VB is greater than the set closing angle Θ, then the synchronism check function will not operate and reclosing will not be permitted.

B. If the angle between VL and VB is less than the set closing angle Θ, then the synchronism check function will operate and permit reclosing, but only after a time delay that is related to the high slip cut-off setting, FHS, and the set closing angle Θ. This time delay is expressed as follows:

Where: THS is the time delay in milliseconds
FHS is the high slip cut-off setting in hertz
Θ is the set closing angle in degrees

Typically, the high set slip cut-off frequency would be equal to the slip frequency required to traverse (270 - O)° during the time that the line is dead; that is:

$$FHS = \frac{(270 - \theta)}{(360)\ (TLD)}$$

Where: TLD is the time that the line is dead in seconds. This is equal to the time setting on the recloser at Breaker 2.

The high slip cut-off frequency setting, FHS, is based on (270-θ) to insure that, if the slip rate is less than FHS, VL will have traversed less than three quadrants during the interval when both breakers are open (dead time). If the slip rate is just slightly less than FHS, VL will return in quadrant III for clockwise rotation, or quadrant II or III, the low slip cut-off frequency measurement will be set up and the actual slip will have to be less than the low slip cut-off setting to permit reclosing.

There are three possible conditions that might cause VL to appear in quadrant I or IV when the line is re-energized. One condition is a slip frequency that is higher than FHS. In this case the high slip cut-off circuit will prevent reclosing. A second condition is an extremely low slip frequency. For this condition, reclosing will be permitted provided that VL remains within the closing angle for the time associated with the high set slip measurement (THS). If VL has not moved outside the closing angle during the time that the line was de-energized, there is little risk in permitting reclosing without making a low slip cut-off measurement.

The third condition that might cause VL to appear in quadrant I or IV is a reclosing attempt at the remote end (breaker 2) that has been delayed longer than the normal reclosing time. An example of a delayed reclosure would be a manual closing of the breaker. The SVM module includes a timer whose output enables the low slip cut-off circuit, thus preventing the high slip cut-off and angle check circuits from permitting a reclose attempt until the low set slip cut-off circuit has produced a permissive output. The input to this timer is energized when the line voltage, VL is less than the dead line voltage setting. the pickup delay of the timer is set for the time that the line is de-energized, plus a suitable margin.

The setting is:

TD =[(time that the line is de-energized) + (channel time) x 1.1]

The channel time is included to account for possible differences in clearing time of the two line terminals due to a channel trip at one terminal and a direct trip at the other.

CASE 2:

The systems are out of synchronism, and VL is rotating relative to VB

A. If the voltage VL plots in quadrants I or IV when the voltage is re-established, and if it enters the set closing angle without entering either quadrant II or III, and if it remains within the closing angle longer than the time associated with the high set slip measurement, then a sync check output will be provided after a time delay established by the high slip cut-off setting (THS).

B. If the line voltage VL returns in quadrants II or III, or rotates into quadrants II or III from I or IV, the low slip cut-off circuit is enabled and used to supervise the closing angle and high slip cut-off circuits. Thus, a sync check output cannot be produced unless the slip is less than the low slip cut-off setting and the voltage VL remains within the closing angle for the time established by the high slip cut-off setting (THS).

The low set slip frequency cut-off circuit establishes the slip rate by comparing the time that VL remains in any quadrant against a reference time established by the low set slip cut-off setting. This reference time is the time it takes the voltage phasor, VL, to traverse 90° (one quadrant) at a frequency equal to the low slip cut-off setting. This is expressed by:

$$TLS_{-} = \frac{1}{4} \times \frac{1}{FLS}$$

Where: TLS is the low slip cut-off setting
TLS is the time required to traverse 90°

If VL remains in a quadrant longer than the reference time, then the slip rate is less than the low slip cut-off setting and the circuit will produce a permissive output signal to enable the angle and high slip cut-off circuits. The low slip cut-off measurement is started whenever VL enters a new quadrant; however, if a permissive signal was generated in the previous quadrant, it will remain unless the slip is determined to be greater than the low slip cut-off, at which time the permissive signal will be removed.

If VL returns in quadrant II (Fig. 16) and is rotating in a counterclockwise direction, the low set slip cut-off circuit will produce a permissive output to the angle and high set slip cut-off circuits only if VL remains in quadrant II longer than the time established by the low slip cut-off setting (TLS). After VL enters quadrant I, reclosing will be permitted after VL has entered the set closing angle and remained there for a time established by the high set slip cut-off frequency (THS). If on the other hand, VL returns in quadrant II, but does not remain in that quadrant for the time established by the low slip cut-off setting, then the low set slip cut-off circuit will block reclosing. However, after VL enters quadrant I, a new measurement will be started and if VL remains in quadrant I longer than the time established by the low slip cut-off setting, (TLS), the low slip cut-off circuit will produce a permissive output which will enable the high set slip cut-off and angle check circuits. Reclosing will then be permitted if the voltage VL is within the closing angle (or enters the closing angle) and remains there for a time established by the high set slip cut-off setting (THS).

Similar operation will occur if VL returns in quadrant III and is rotating in a clockwise direction.

Note that if VL returns in quadrant III and is rotating counterclockwise, the low set slip cut-off measurement made in that quadrant is inconsequential because reclosing cannot occur until VL enters the closing angle in quadrant I. Therefore, the evaluation of the slip rate made in quadrant II will determine the operation.

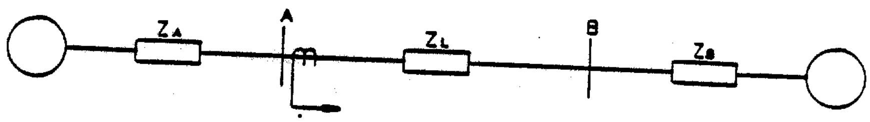
An option exists in the SVM module to prevent a sync check output unless a low slip cut-off mesaurement is made and satisfied. In this mode of operation, after the frequency is determined to be less than the low slip cut-off setting, the voltage VL must still remain within the closing angle for a time established by the high set slip cut-off circuit (THS). This is so even though the high set slip cut-off feature is not in service. A minimum delay will be obtained by setting the high slip cut-off frequency to its maximum setting.

Voltage Supervision

Because the synchronism check function requires that a voltage be present (live) on both the bus and line sides of an open breaker, this function alone will not allow a dead line to be energized. For those applications that require dead line and/or dead bus operation, the undervoltage detecting functions can be used. Selection switches are provided on the front panel of the SVM module to permit reclosing for one or more of the following conditions:

1. Live line and dead bus.
2. Dead line and live bus.
3. Dead line and dead bus

The live and dead voltage levels are adjustable, and may be set with switches located within the SVM module.



SYSTEM VOLTAGE = 115KV

CTR = 120

PTR = 1000

SOURCE A (SECONDARY OHMS)

$Z_{1A} = Z_{2A} = 12\angle 80°$
$Z_{0A} = 3.96\angle 85°$

LINE (SECONDARY OHMS)

$Z_{1L} = Z_{2L} = 1.44\angle 72°$
$Z_{0L} = 4.92\angle 67°$

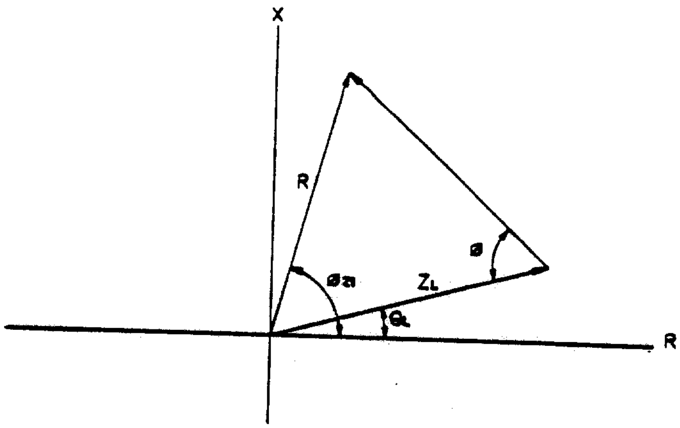
SOURCE B (SECONDARY OHMS)

$Z_{1B} = Z_{2B} = 6.0\angle 85°$
$Z_{0B} = 2.4\angle 85°$

MINIMUM LOAD IMPEDANCE (SECONDARY OHMS)

$Z_L = 20\angle 15°$

Figure 13 (226B7445 Sh 26): One Line System Diagram Showing Source and Line Impedances.



$$R = \frac{Z_L \sin \emptyset}{\sin(180 + \Theta_L - \emptyset_{ZI} - \emptyset)}$$

WHERE:

- R = MAX. ALLOWABLE PHASE SELECTOR REACH
- Θ_L = ANGLE OF ASSUMED MIN. LOAD IMPEDANCE
- $\emptyset_{ZI}$ = CHARACTERISTIC ANGLE OF PHASE SELECTOR
- Z_L = MINIMUM LOAD IMPEDANCE
- Ø = 60° FOR 90° MHO CHARACTERISTIC; 75° FOR 105° LENS CHARACTERISTIC.

Figure 14 (226B7445 Sh 27): Analytical Reach Determination for Phase Selector Setting.

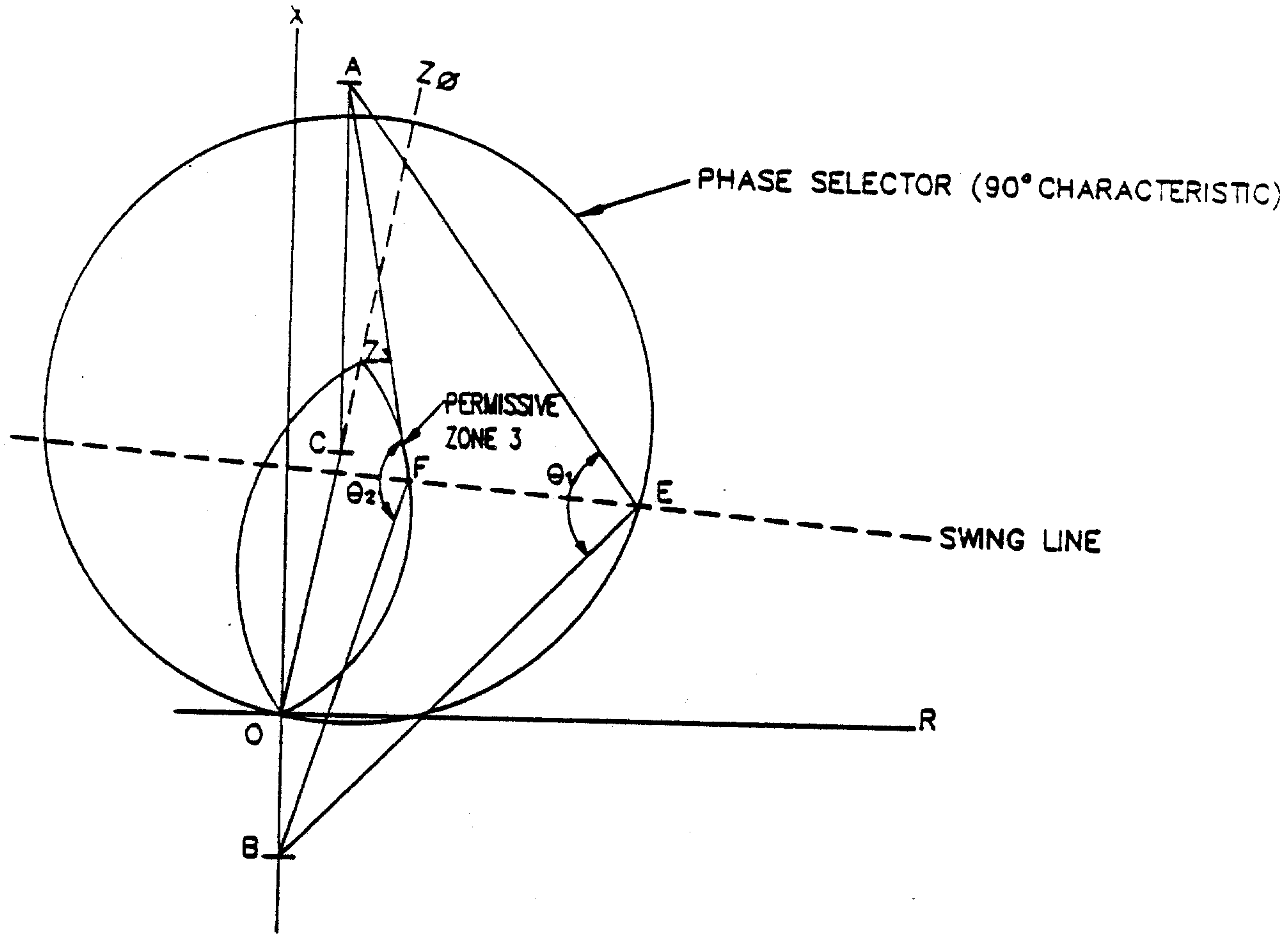
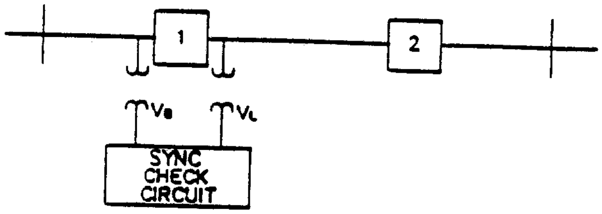


Figure 15 (226B7445 Sh 28): Typical Out-of-Step Blocking Characteristic.



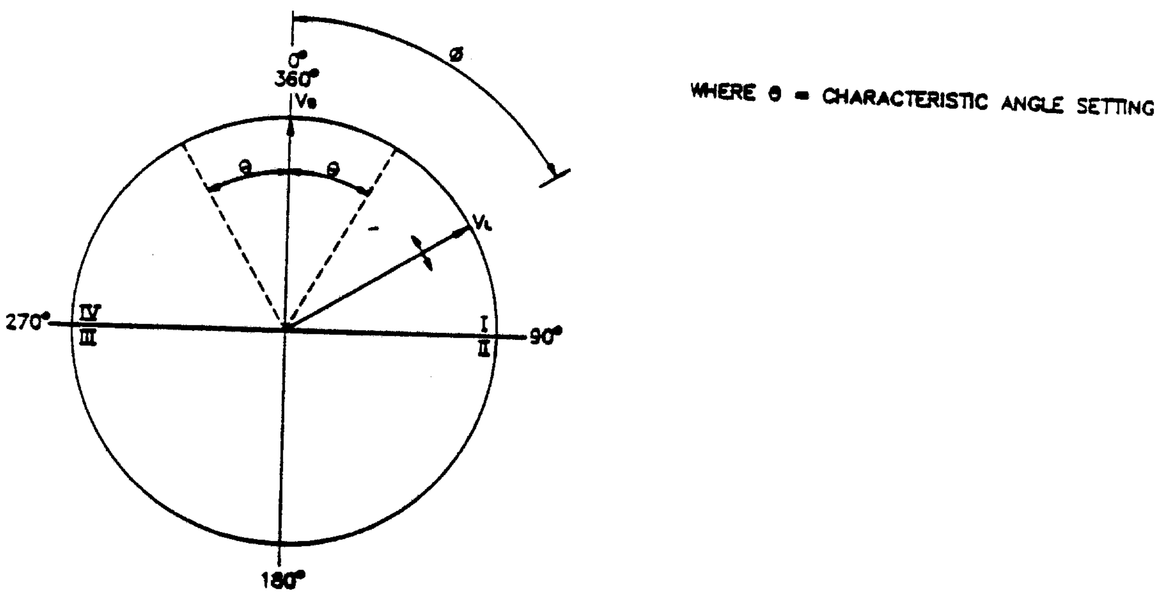


Figure 16 (226B7445 Sh 22): System and Phasor Diagram for Syncronism Check Discussion.

DESCRIPTION OF THE HARDWARE

The MLS system is made up of plug-in modules housed in a metal case.

CASE UNIT

Construction

It is a steel plated case. Its external dimensions are shown in the specifications section.

The front cover is made of transparent plastic and housed within an aluminum frame, and is held by four anchor bolts on the cover. The target reset of the relay as well as the reclosing function can be operated by means of push buttons through the cover.

The edges of the back plate and the inner frame which houses the cover are provided with gaskets to protect the MLS system from dust.

The modules are assembled vertically and their sockets act both as mechanical support and as means for electric interconnection. The modules are aligned by means of upper and lower plastic guides. The MGM magnetics module, the DOM input and output modules and the RLM reclosing module are supported by double upper and lower guides.

Electric connections and internal wiring

External connections are achieved by means of ten connection boards assembled on the rear side of the case. Each board is provided with fourteen screw in connectors. The typical external connections are shown in Figure 19-23.

Those systems including Monitoring option (TAM module) are provided with a D type 25 pin connector to allow the system to connect to an external terminal.

Printed circuit boards are connected by means of 60 pin board edge connectors. The magnetic module is connected by means of two connectors; one provided with eight contacts for connection with the current circuits, and the other provided with 104 pins to connect the module to the rest of the circuits. The current connector has been designed for the operation on line current transformer secondaries. The connector base is provided with a system which maintains the current transformers shortcircuited when the magnetic module is pulled out.

The sockets of the board and magnetic module connectors are mounted on the same surface 23 cm. from the front, whereas the bases for test and connection receptacle are mounted only 4 cm. from the front.

With the exception of current circuit bonding, wire wrap connections are used for internal wiring between modules and for the wires connecting to the test block and the terminal boards. Wiring of sensitive signals are organized in braids with right angled crossings in order to minimize the effects of the electromagnetic coupling. Controlled wire routing is also employed for the test receptacle and terminal block wiring.

All the current inputs are positioned together on the same connection board which is able to carry the line CT currents. In these circuits, the internal wiring cross-section is substantially wider than in other wires. The length has been reduced to minimize the resistance and therefore, the CT burden.

Identification

Two identification strips situated at the upper and lower segments the front frame, show the location of the modules in the system. These address strips specify the name and position of each module.

Each terminal board is identified by a two letter code printed on a label situated at its bottom left side.

Each terminal board is marked with numbers from 1 to 14.

RECEIVING, HANDLING AND STORAGE

CAUTION

This relay is provided with electric components which may be harmed by electrostatic discharge currents flowing through certain components terminals. The main discharge current is the human body. Low humidity conditions, carpetted floors and isolated footwear worsen the problem of generation of this type of discharge currents. With these conditions, special care must be taken when pulling out and handling the modules in order to have access to internal adjustments. Any person handling the equipment must make sure that his or her body has been discharged by touching any grounded surface before touching any component of the modules.

The systems are provided to the customer in a special packing unit that properly protects it during transportation, provided it is done under normal conditions.

Inmediately after receiving the equipment, the customer should check if there is any evidence of the system having suffered damage during transportation. If injury or damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the factory.

Reasonable care should be exercised in unpacking the relay in order not to lose the accessories provided in the box.

If the equipment is not going to be installed inmediately, it is convenient to store it in its original packing, in a place free from moisture and dust.

It is important to check that the inscription on the nameplate matches the data handed over with the order.

INSTALLATION

ENVIRONMENT

The place where the relay is to be installed must be clean, dry, free from dust and vibrations and should be well lit in order to ease inspection and testing.

CONSTRUCTION

MLS systems are designed to be housed in standard racks. Each rack is four rack units high. The relay must be installed on a vertical surface. Figure 17 shows the panel drilling and the mounting dimensions.

The relay's external connections are shown in Figure 13-22 which show all the options available. There is no need to connect to those terminals associated with options not used or provided in the equipment.

GROUND CONNECTION FOR SURGE SUPRESSION

The relay's BD14 terminal must be connected to ground so that the surge supression circuits provided in the relay may operate correctly. Also, a jumper must be connected between terminals BD14 and BD13. The ground connection should be as short as possible in order to ensure the maximum protection. (preferably 25 cm or less).

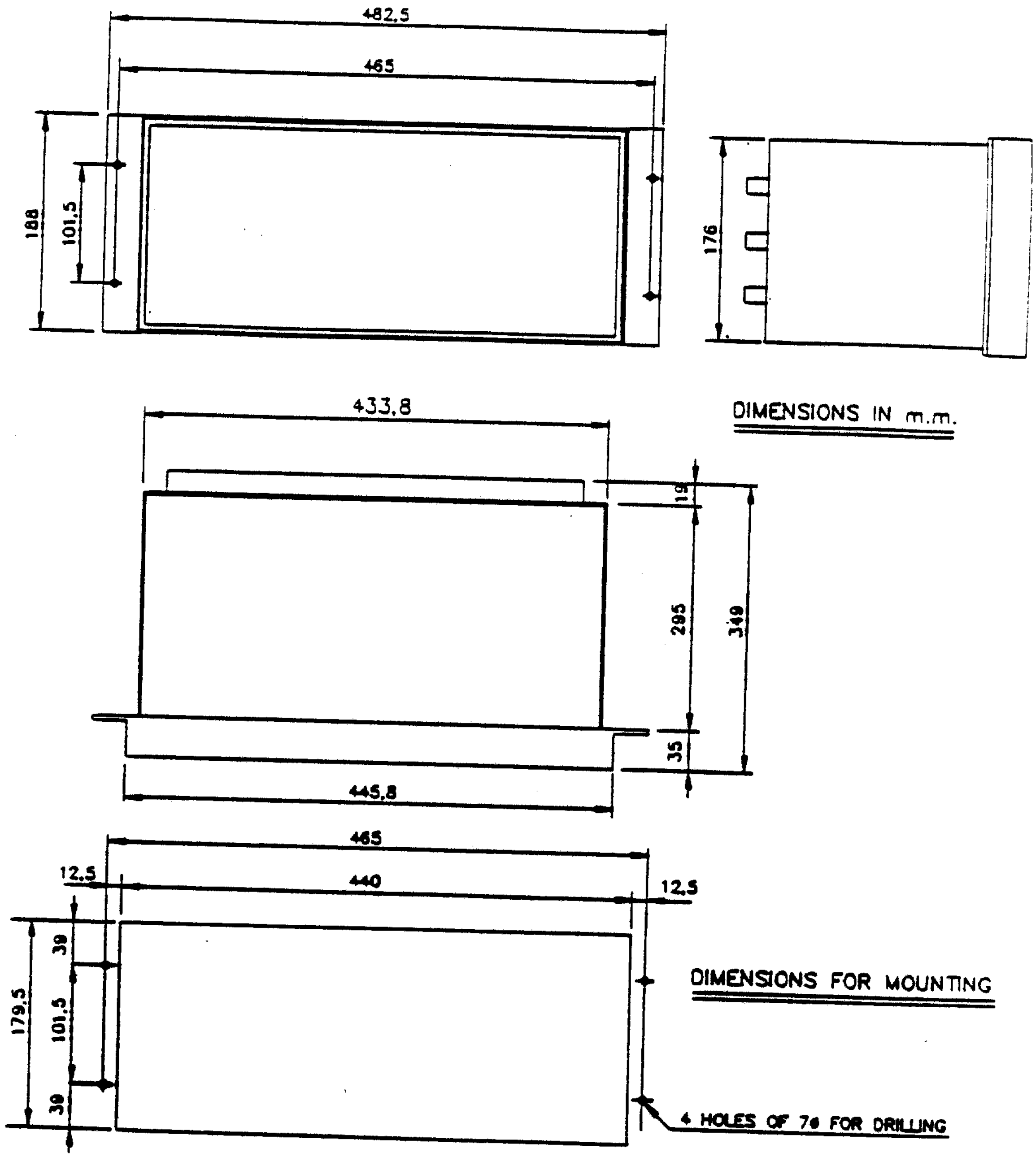


Figure 17 (301A7049 Fig _): MLS Case Mounting Dimensions.

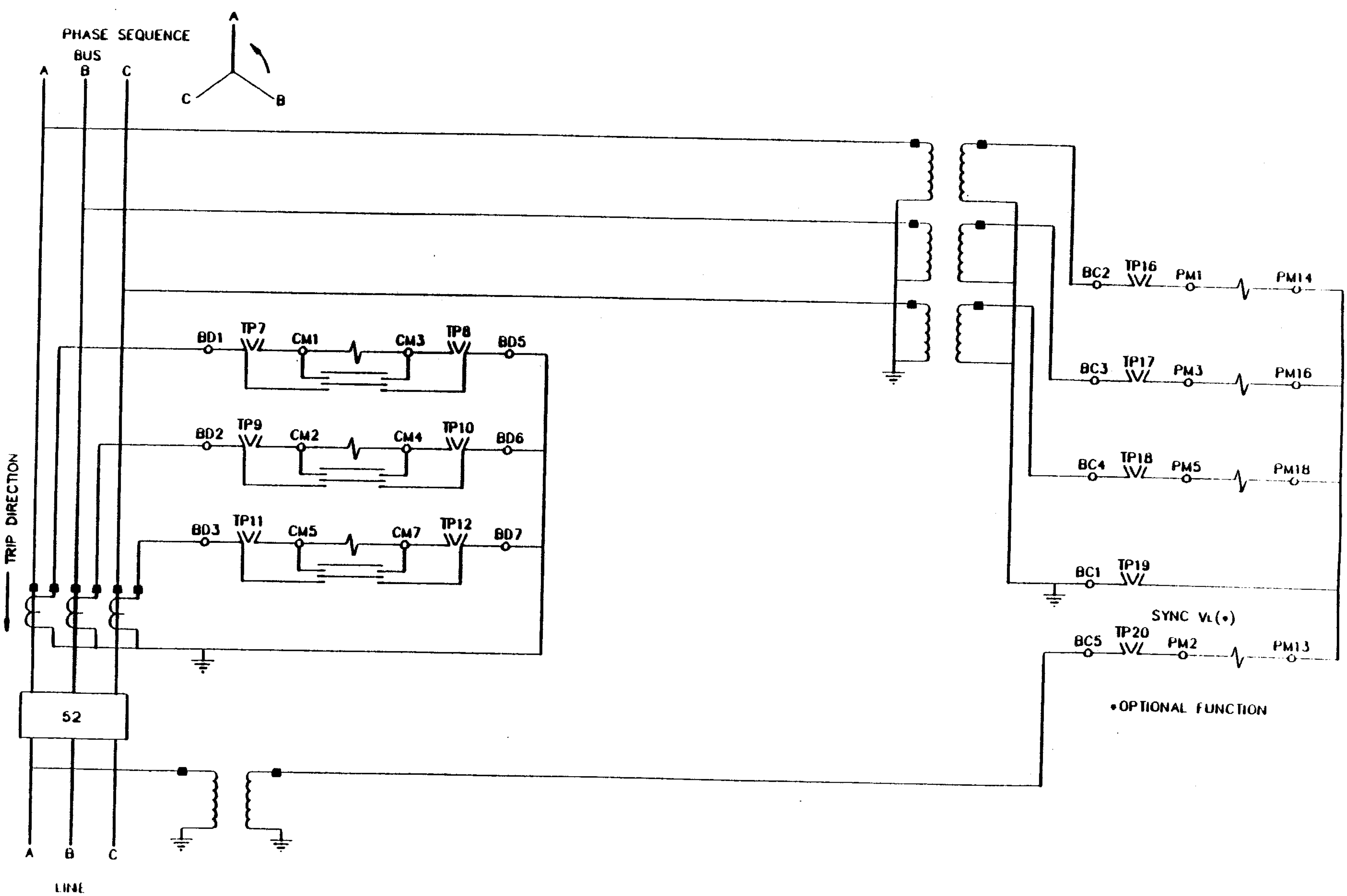


Figure 18 (226B7447 Sh 1): External Connections.

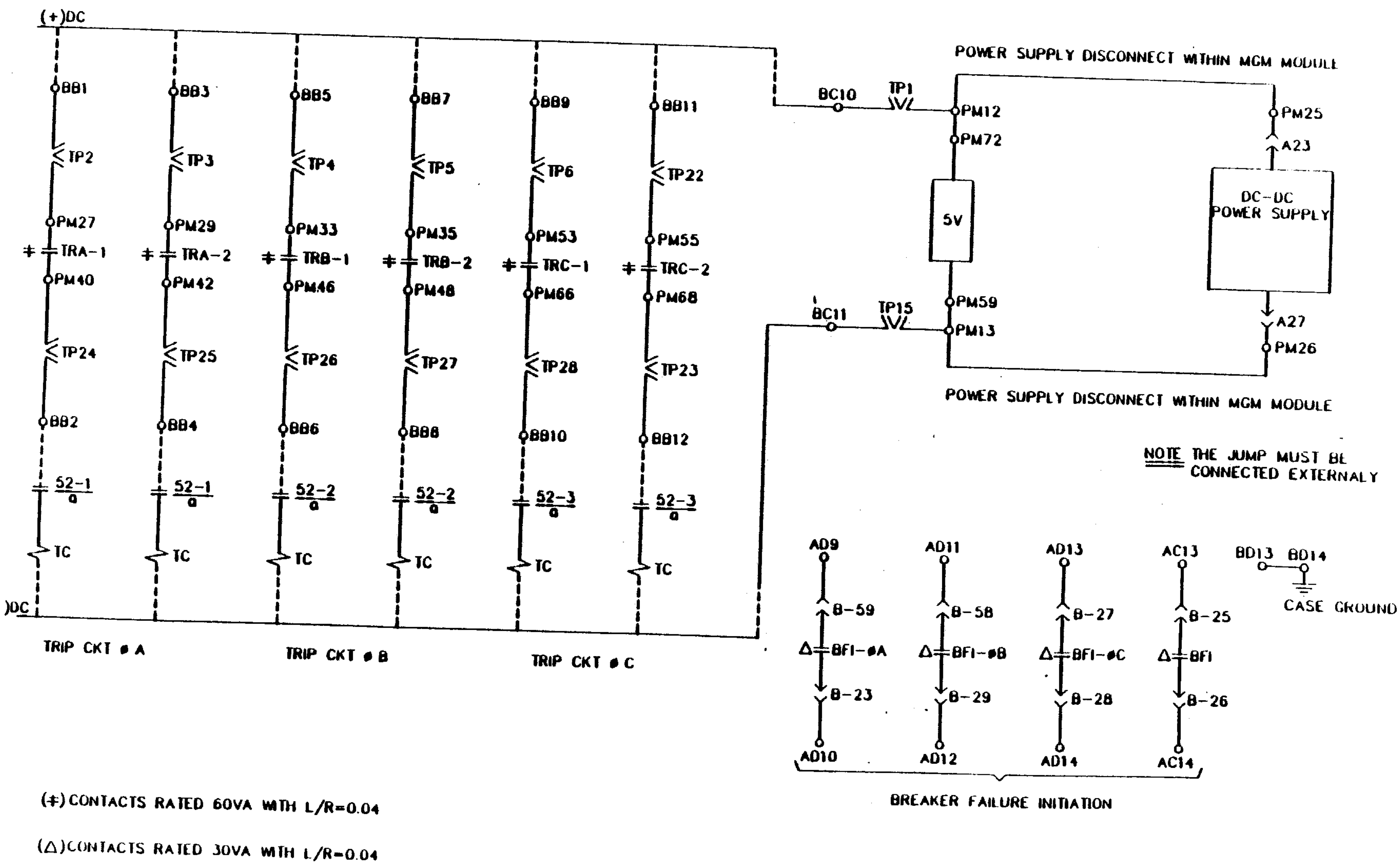


Figure 19 (226B7447 Sh 2): External Connections.

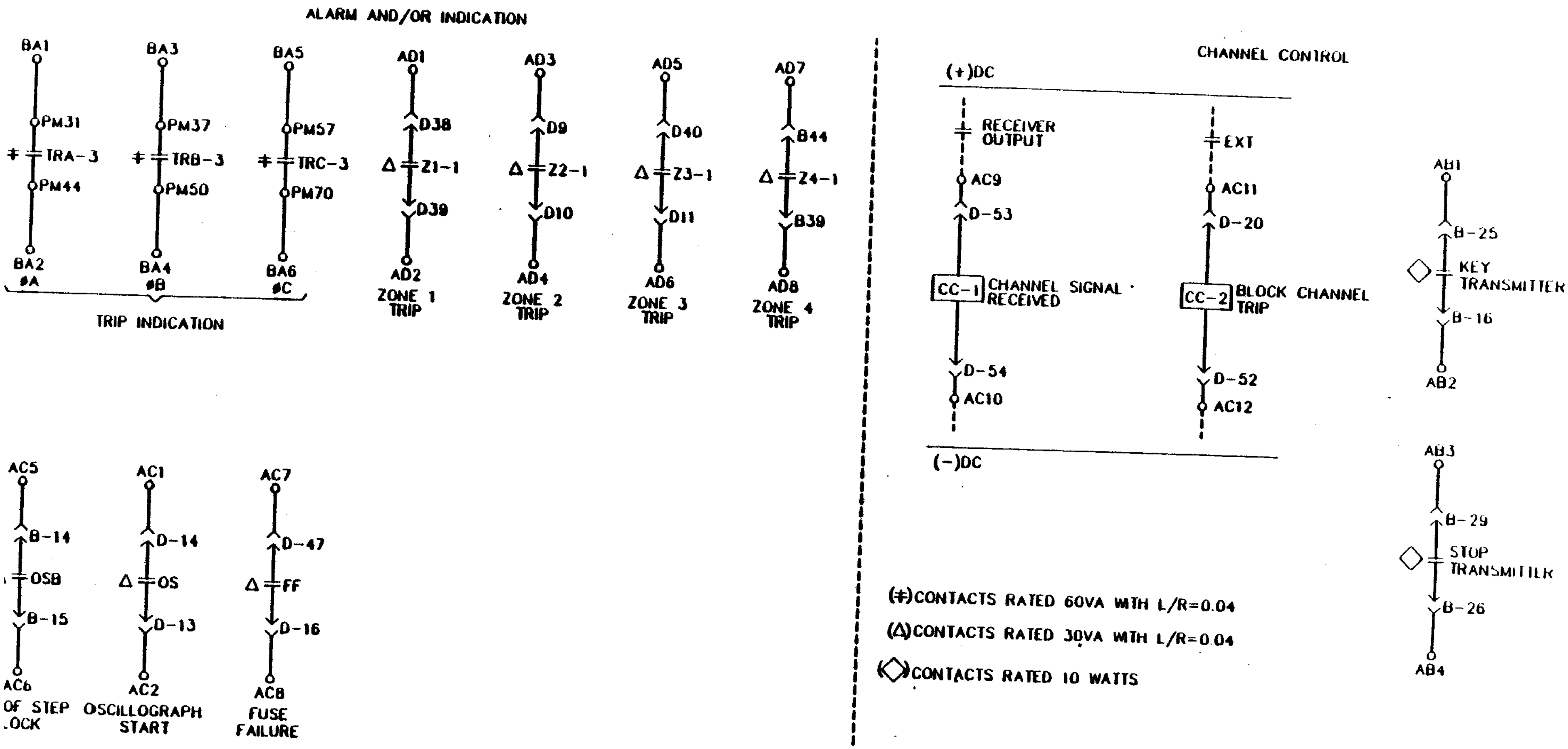


Figure 20 (226B7447 Sh 3): External Connections.

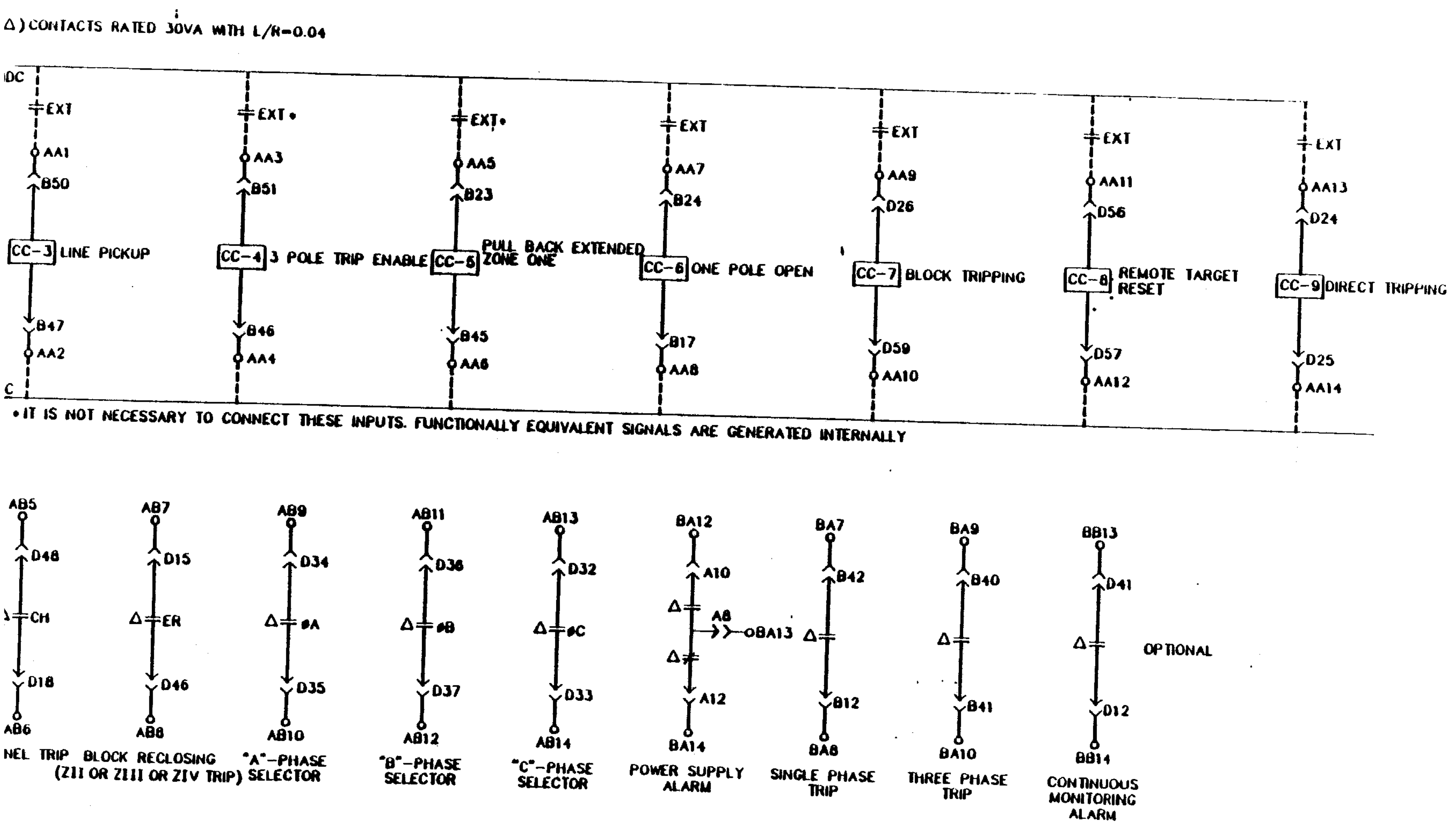


Figure 21 (226B7447 Sh 4): External Connections.

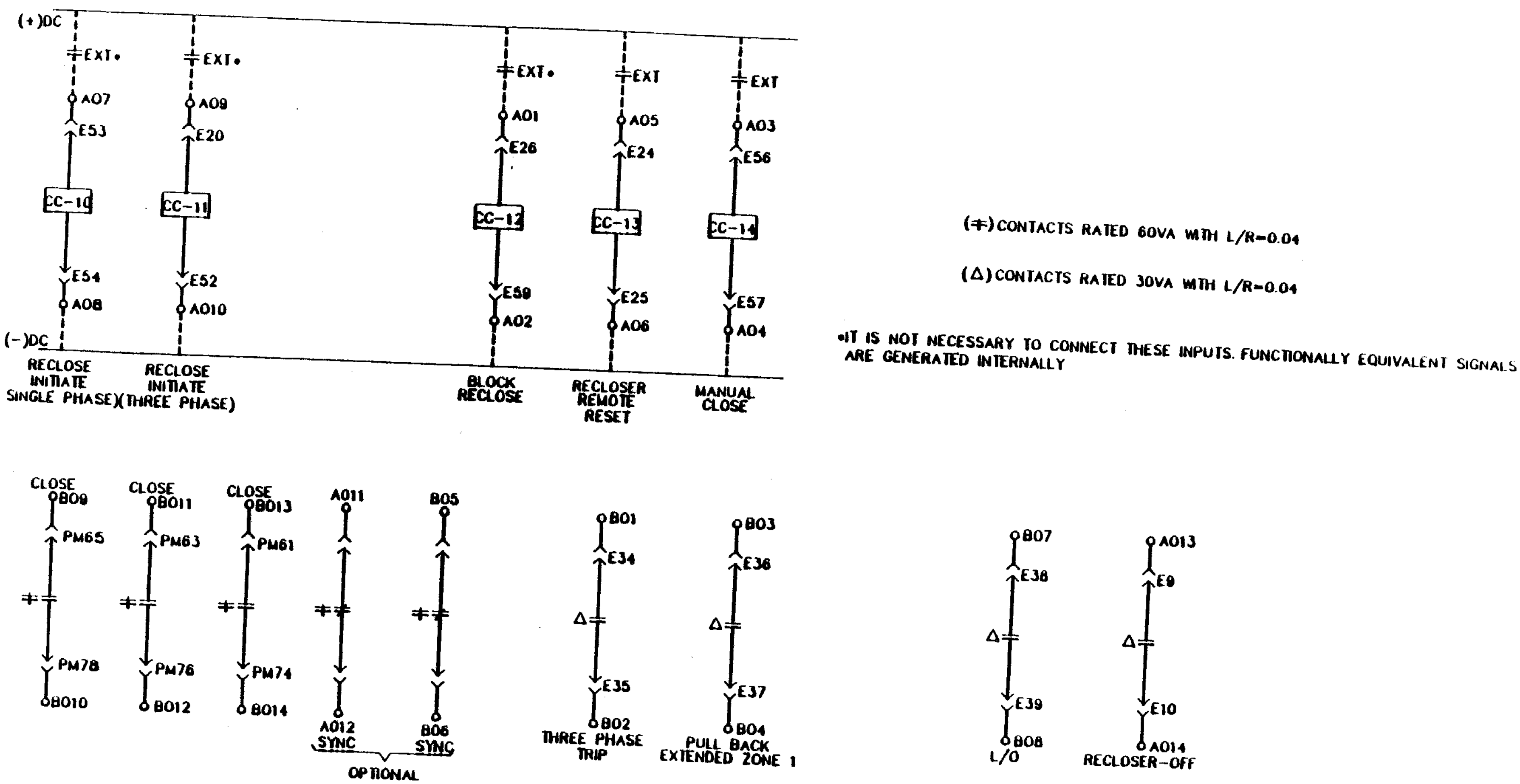


Figure 22 (226B7447 Sh 5): External Connections.

MODULES

Basic Construction

Each module is made up of a printed circuit board and a front plate mounted at right angles to the board. (modules DOM and RLM are exceptional since each of them contains two boards). Each module is provided with two pullers situated on its front panel in order to pull the module in and out. The electric connection is achieved by means of connectors situated on the edge of the board.

In those cases when the number of funtions is insuficient to fill the space available in each case, empty modules are used to fill the remianing spaces.

Identification

Each module has its own model number which consists of three letters and three figures. This number is shown at the bottom of the module's front plate.

Adjustments

MLS system modules have their adjustments distributed between the front pannel and the module's inside. There are several types of adjustments:

(1) Microswitch.
(2) Rotary Switch.
(3) Selector Link.
(4) Pushbutton.
(5) Potentiometer.
(6) Switch.
(7) Double digit rotary switch.

DSM 055 - Phase Selector Module (Figure 23)

The circuitry in this module is provided with selectors for each of the three phases with LED operation indicators, plus a directional unit based on negative sequence magnitudes. The selectors reach isset by means of an adjustment which operates on the restraint magnitudes.

Apart from operating as starting units, the phase selectors constitute
the fourth protection zone. For this purpose, the module is provided with a timer and an interface circuit with output relay drivers to perform a three phase trip.

This module includes as well, a fixed frequency oscillator giving time reference to the characteristic timers giving zone and reset reference for both the phase selectors and the module DBM blocking units.

Front Panel Switches

Identification	Type	Function and Description
Zp	Microswitch	Adjustment in ohms of the phase selectors(fourth zone). All selectors have the same reach. The procedure to position the breakers in order to achieve an optimum reach, is described in the section PROCEDURES FOR ADJUSTMENT included in this book.
ZIV	Microswitch	The adjustment in seconds, for the three phase trip for a fault in the fourth zone after the starting of any of the phase selectors. When the eighth position is adjusted to the left, the trip in fourth zone is deactivated.

Internal Selectors

Identification	Type	Function and description
LENS/CIRCLE	Selector Link	Selection of the selectors mho characteristic shape. The circle requires 90° coincidence between polarization and operation magnitudes; The lens requires 105°. The three phase selectors have the same characteristic.
50/60	microswitch	Selection of the frequency for the operation of the phase selector characteristic timers.

Indicator Diodes (LED) on the Front Panel

Identification	Color	Funtion and Description
A	Yellow	Starting of the phase A phase selector; it lights up when a fault (or any other abnormal condition) is found within the characteristic of the phase A phase selector.

B	Yellow	Starting of phase B phase selector; it lights up when a fault (or any abnormal condition) is found within the characteristic of the the phase B phase selector.
C	Yellow	Starting of phase C phase selector; it lights up when a fault (or any abnormal condition) is found within the characteristic of the phase C phase selector characteristic.

DFM 055-056 - Filter Module (Figure 24)

The two DFM modules only differ in their rated frequency. The 055 model is used in 50 Hz systems while model 056 is used in 60Hz systems.

DFM modules are provided with the following circuitry:

- Interface circuits between the secondaries of the current transactors and voltage transformers and the rest of the electronic circuitry.

- Sequence networks for generation of the different magnitudes of polarization:

    1) Positive sequence voltage networks - one per phase.
    2) Negative sequence current networks - one per phase.
    3) Composite voltage sequence network - one corresponding to each pair of phases.
    4) One voltage negative sequence network corresponding to phase A.

At the outputs of some of the sequence networks, filters are included to provide memory for the polarization quantities:

- The shift circuits which operate on the current signals establish the positive sequence impedance angle and the sequence zero impedance angle

- Fuse Failure detection circuit of the voltage transformers.

- The voltage detector used in Line Pick-up logic.

Switches on the Front Panel

Identification	Type	Function and Description
ØZ1	Rotary Switch	Adjustment of the positive (and negative) impedance angle. This angle is the same for the phase selectors, for the main measuring unit and for the permissive unit.The adjustment is made in degrees.
ØZo	Rotaryswitch	Adjustment of the zero sequence impedance angle. This angle is the same for the phase selectors, the main measuring unit and the permissive unit. The adjustment is made in degrees.

DRM 055-056 - Reach Module (Figure 25)

The two DRM modules only differ in their rated frequency. Model 055 is used 50 Hz systems, while model 056 is used in 60 Hz systems.

The circuitry of this module contains the following funtions:

- Adjustment of reach in zones I,II,III.
- Adjustment of the zero sequence compensation factor.
- Derives the operating quantities for the permissive and main measuring units.
- Analog switching of the desired polarization quantities and restraint voltages to the permissive and main measur-ing units.
- Overcurrent detectors (one per phase) to supervise the operation of trip functions and phase selectors.
- Detection of the three phase overcurrent for Line Pick-up logic.
- Coincidence circuits for the permissive and main meassu-ring units.

Switches on the Front Panel

Identification	Type	Function and Description
ZI	Microswitch	Adjustment in ohms of the reach in Zone I. The procedure for the setting of these switches is described in the section PROCEDURES FOR ADJUSTMENT.
Ix	Microswitch	Adjustment of the reach extension in Zone I to as many times as the value established for the reach in Zone I.
II	Microswitch	Adjustment of the reach in Zone II to as many times as the value established for Zone I.
III	Microswitch	Adjustment of the reach in Zone III to as many times as the value established for Zone I.
Ko	Microswitch	Adjustment of the zero sequence compensation factor.

Internal Selectors

Identification	Type	Function and Description
X/Y	Selector Link	Adjustment of the type of characteristic for measuring the single phase ground faults as reactance (position X) or mho (position Y).

DBM 055 - Blocking Directional Comparison Module (Optional) (Figure 26)

The circuitry in this module is provided with blocking units (MB) used in the Directional Comparison scheme. These units are similar to the phase selectors except the current has been connected to have the reach in the opposite direction. There is one MB per phase. The outputs are connected through an OR in order to produce one blocking signal only.

The blocking units may also be applied as reverse Zone5 time delayed
backup protection.

Switches on the Front Panel

Identification	Type	Function and Description
Zp	Microswitch	Adjustment in ohms of the blocking units (fifth zone). All the units have the same reach.
ZV	Microswitch	Adjustment in seconds of the three phase back-up trip time for a fault in the fifth zone after a starting of the blocking units (MB). When the eighth position is adjusted to the left, the trip in fifth zone is deactivated.

Internal Selectors

Identification	Type	Function and Description
CYCLES DROPOUT	Microswitch	Adjustment in cycles of the time during which the blocking signal is maintained after the blocking units no longer provide an output.
LENS/CIRCLE	Selector Link	Selection of the shape of the characteristic mho. The circle requires 90° of coincidence between the polarization and operation magnitudes; the lens requires 105°.

DLM 055 - Logic and Measuring Module (Figure 27)

The logic and measuring functions included in this module, are performed by a microprocessor. The included functions are:

- Main measuring unit.
- Permissive measuring unit.
- Detection of power swing.
- Type of fault.
- Zone II and III timers.
- Protection logic schemes:
    1) Stepped distance.
    2) Zone I extension.
    3) Zone II acceleration.
    4) PUTT.
    5) POTT.
    6) Directional comparison.
    7) Hybrid scheme.
- Trip outputs.
- LED indicators.

Switches on the Front Panel

Identification	Type	Function and Description
II	Microswitch	Adjustment in seconds of the time period between the starting of one or several phase selectors and the reach switching in Zone II. When the eighth switch is set to the right side, the time adjusted on the other seven is multiplied by ten.
III	Microswitch	Adjustment in seconds of the time period between the starting of one or several phase selectors and the reach switching in Zone III. When the eighth switch is set to the right side, the time adjusted on the other seven, is multiplied by 10.

NCT	Microswitch	When the switch is to the right side, all channel trips are blocked.
SEND	Push button	Manual channel transmission.
ZI	Microswitch	When the switch is set to the right side, tripping is limited to zone I.
ZII	Microswitch	When the switch is set to the right side, tripping is limited to zone II.

If the two zone limitation switches are set to the right side, only the one corresponding to the shorter zone (ZI) will be effective.

The limitation established for these adjustments is only related to the logic module. This means that it has no influence whatsoever on the trips in fourth or fifth zones. The trips corresponding to these zones are controlled on the module which corresponds to each of the zones.

Internal Selectors-DLM MODULE

In the DLM module, the internal switches are not identified by funtions. Therefore, the adjustments will be described in relation to the switch and position numbers.

Microswitch	Positions	Function and Description
SW1	1 to 6	Sequence Trip Time. This adjustment controls the time during which the characteristic of the main measuring unit (tent or lens) remains in its initial angle after the fault has started and before the integration begins. This adjustment is only appliable to single phase to ground faults. The time is given in milliseconds.
SW1	7	Fuse Failure Blocking. When this switch is set to the right side, it blocks the trips when a fuse failure is detected.On the opposite position, the fuse failure detector does not supervise the trips although it lights up an indicator on the front panel and activates an alarm contact.

SW1	8	This selector coordinates the relay with the type of transformer used, either inductive or capacitive. Set to the right, it selects coordination with capacitive transformers; whereas set to the left, it selects coordination with inductive transformers.
SW2	1 to 4	Adjustment of the characteristic angle. It determines the necessary initial angle of coincidence between the operation and polarization net magnitudes in order to have the fault within the single phase characteristic (mho or reactance). Therefore, this adjustment establishes the "tent" or "lens" degree of the characteristic for ground faults. This measure is given in degrees.
SW2	5	Frequency Adjustment. It establishes the time base in all the timers, according to the system frequency. Set to the right, it coordinates with a 50Hz system; while to the left, it coordinates with a 60 Hz system.
SW2	6 to 8	Selection of the protection logic scheme. For the right positioning of these selectors, see section PROCEDURES FOR ADJUSMENT.
SW3	1 to 6	Adjustment of the time of coordination with the channel in the POTT scheme. It establishes in milliseconds, the period of time until the local breaker is allowed to trip after the starting of the permissive measuring unit in the local relay.
SW3	7	SEND signal (channel keying) logic. It establishes whether the transmission starting contact is

		normal conditions. Set to the right, the contact is open in normal conditions and it closes in order to start the transmission. To the left, the contact will remain closed in normal conditions while it will open to start the transmission.
SW3	8	RCVR signal (channel receiver) logic. When set to the right side, the presence of a open contact is interpreted as channel in normal conditions, whereas a closed contact implies the presence of a channel signal. Setting SW3to the rightside give opposite operation.
SW4	1 to 3	Weak Infeed timer. Only used in the Hybrid Scheme. The adjustment must be long enough to guarantee security in the presence of channel receiver spurious outputs.
SW4	4	Not used.
Sw4	5	Signaling mode. When set to the left side, the trip indicators corresponding to the faulted phases are activated; This means that in the case of a two phase fault resulting a three phase trip, only the indicators corresponding to the faulted phases are activated. When positioned to the right, the indicators corresponding to the phases receive trip signals; in this case, all three trip indicators will be activated.
Sw5	6	STOP signal (Channel stop) logic. It establishes whether the channel stop contact is open or closed under normal conditions. Positioned to the left side, the contact is open in normal conditions and it closes in order to start the transmission.To the right side, the contact will be closed in normal conditions and it will open to start the transmission.

SW5	1 to 5	Swing timer. It establishes the minimum time allowed for the system's characteristic apparent impedance to pass between the phase selectors and the permissive characteristic. This allows to descriminate between a power swing and a three phase fault.
SW5	6	Out of Blocking. When positioned to the left, tripping is blocked for out-of-step conditions. On the opposite position, the trip is allowed.
SW6	1	Trip type selection. When positioned to the left, the trip will be single phase for single phase ground faults in zone I, and three pase for other types of faults. On the opposite position all the faults will be cleared with three phase trips.
SW6	2 to 4	Indicators activation time. It is the time during which the indicators activation is allowed after the trip command; Once this time is over, any attempt to activate other indications will be blocked. It must be adjusted at a time shorter than the breaker operation time.

<u>LED Diode Indicators on the DLM Front Panel</u>

Identification	color	Function and Description
A	red	Output of the phase A trip. When the trip mode selector is positioned to the right side, the indicator will light up for any Phase A trip, either a single phase trip or a part of a three phase trip. Positioning the selector to the left, it will be only activated for faults involving phase A. See the description of the DLM module internal adjustments.
B	red	Same as phase A indicator, but, indicating a phase B trip.

C	red	Same as phase A indicator, but indicating a phase C trip.
I	red	Trip in zone I. It is activated as the result of a trip produced by a fault within zone I reach.
II	red	Trip in zone II. It is activated as the result of a trip produced by a fault within zone II reach.
III	red	Trip in zone III. It is activated as the result of a trip produced by a fault within zone III reach.
CH	red	Channel trip. It is activated when the trip is produced as result of the reception a channel signal and one of the channel involved schemes is being used (or when the trip takes place in the absence of channel reception in the directional comparison scheme). In transferred trip schemes (PUTT, POTT), either one or both relays may produce trips by the detection of the fault in zone I, before a channel signal is received. In such cases, in addition to the zone I indicator, the CH indicator will light up, too.
WI	red	Trip by Weak Infeed. This indicator is activated when the trip has been produced by the activation of the Weak Infeed circuit; that is from channel reception from the remote end and by not activating the local blocking units.
OSB	yellow	OBS is activated when a power swing is detected. This is not a trip indicator and it operates together with the power swing alarm contact (module DLM). It is not a sealed in indicator.
FF	yellow	Fuse Failure in the voltage transformers. It is activated when the decribed condition is detected. It is not a trip indicator and it operates together with a fuse failure alarm contact(DLM module).

RLM 055 - Reclosing Module (Figure 28)

This module is made up of two printed circuit boards assembled together.
The component sides are orientated towards the inside of the module. One of the boards (left) contains all the circuitry concerning the reclosing functions. The other one (right) contains the contact converters and the auxiliary relays needed for communication with the recloser and with the outside. The front panel is assembled on the left board. The distance system communicates with the reclosing function through the system's internal wiring. But the system, through the input and output board housed in the module, can communicate with an independent second distance protection.

Breakers on the Front Panel

All the adjustments on the front panel correspond to the functions included on the reclosing module logic board.

Identification	Type	
1Ø	Microswitch	Adjustment in seconds of the time passed until the first reclose after a single phase trip has taken place.
3Ø	Microswitch	Adjustment in seconds of the time passed until the first reclose after a three phase trip has taken place.
DLY	Microswitch	Adjustment in seconds of the time until the second reclose (which is always three phase).
RST	Microswitch	Adjustment in seconds of the reset time. This adjustment establishes the dwell time as well, when the adjustment of HOLD is set to the IN position, while waiting for a validation signal from the synchronism check circuits.
1Ø	Microswitch	No single phase reclosing attempt takes place as long as this switch is set to the left.
3Ø	Microswitch	No three phase reclosing attempt takes place as long as this switch is set to the right.

DLY	Microswitch	No second reclosing attempt takes place as long as this switch is set to the left.
RST	Push button	Reset push-button causes the recloser reset.

Internal Selectors on the Reclosing Board

Identification	Type	Function and Description
HOLD	Selector Link	This adjustment when set to the IN position, establishes the three phase dwell time for a time equal to the reset time while waiting for a reclose validation command from the synchronism check circuits. In the OUT position, the reclosing comand will not be maintained and the recloser will be blocked unless the reclosing command is validated right after being produced.
DWELL TIME	Selector Link	This adjustment establishes the dwell time after the reclosing command. Times between 2 and 8 seconds may be selected.

The output and input boards which are part of the reclosing module, house the four auxiliary relays with "a" type contacts, corresponding to the following functions:

Three phase preparation for the Distance relay.

Extended Zone I pull-back signal of the Distance relay.

Blocked recloser.

Recloser in the OFF position.

Apart from the described relays, the board contains the following five contact converters:

Reclose blocking.

Manual close.

Remote reset.

Single phase reclose initiation.
Three phase reclose initiation.

Internal Selectors on the Output and Input Board

Identification	Type	
	Links	Function and Description
		These selectors adjust the interface circuits to the appropiate control voltage. There is a separate selector for each contact converter.

DOM 055 = Input and Output Module for the Distance Relay (Figure 29)

This module is made up of two printed circuit boards assembled together.
The component side of both boards are orientated towards the inside of the module. The front panel is assembled on the left board.

The left board contains eleven auxiliary relays with type "a" contacts, corresponding to the following functions:

Phase A,B,C selectors.

ZI,ZII,ZIII trips.

Monitoring module alarm.

Oscillograph starting.

Reclosing permission.

Fuse failure.

Channel trip.

This board contains five contact converters, corresponding to the following functions:

Trip blocking.

Remote reset.

Direct trip.

Channel reception.

Channel trip blocking.

The left board includes, Zone IV trip signaling circuit (Phase Selectors) and the reset push-button for all the trip signals corresponding to the distance functions.

Breakers on the Front Panel

Identification	Type	Function and Description
RESET	Push button	Reset push-button. The activation of this button causes the reset of all the target indicators (red color) situated on the front panel of the DLM module, and the indicator IV situated on the front panel of the DOM module.

Internal Selectors on the Left Board

Identification	Type	Function and Description
48/110-125/220-250	Link	These selectors adjust the interface circuits to the appropiate control voltage. There is a separate selector for each contact converter.

LED Diodes Indicators on the Front Panel

Identification	Color	Function and Description
IV	Red	This LED indicates a Zone IV trip (Phase Selector).

The right board contains eight auxiliary relays with "a" type contacts, corresponding to the following functions:

Phase A,B,C & common breaker failure initiation.

Three phase trip.

Single phase trip.

Power swing alarm.

Trip in zone IV.

This board contains two output reed relays for channel keying (SEND and STOP).

This board also contains the four contact converters corresponding to the following external signals:

Line energizing.

Three phase trip.

Extended Zone I pull-back.

An open Pole.

<u>Internal Selectors on the Right Board</u>

Identification	Type	Function and Description
48/110-125/220-250	Link	These selectors adjust the interface circuits to the appropriate control voltage. There is a separate selector for each contact converter.
IND/COM	Link	In the IND position the Breaker Failure Initiation contacts close independently, pole by pole. Set to COM the four contacts always close, no matter which pole has tripped.

<u>PSM - DC Power Supply Module (Figure 31)</u>

This module consists of a DC-DC converter with three different input rated voltages.

PSM 211 - 48 Vdc.

PSM 212 - 110-125 Vdc.

PSM 213 - 220-250 Vdc.

The PSM module has the following dc outputs:

1) ±12 in relation to a common reference with a current capacity of 1 Amp. This output is used to feed the system's analog circuitry.

2) 25 Vdc in relation to the same common reference, and a capacity of 1 Amp. It is used to energize the auxiliary relays assembled on the Reclosing and DOM modules. It provides as well, half of the operation voltage for the telephone relays contained in the magnetics module MGM and also provides the 5 Vdc for the distance and reclosing logic.

3) A second output of 25 Vdc with 0.2 Amp capacity, independent from the above input, which provides the telephone relays with the other half of their operation voltage.

This module contains an alarm relay with a "c" type contact. This relay is normally picked up and resets for a loss of normal ac output or station batters.

<u>LED Diodes Indicators on the Front Panel</u>

Identification	Type	Function and Description
Output Voltage	green	This LED is energized for normal battery input and regulated output voltage.

<u>Switch on the Front Panel</u>

Identification	Type	Function and Description
ON/OFF	Switch	This switch disconnects the positive and negative from the substation battery. It provides an alternate means for disabling the MLS.

SVM - Syncronism Check Module (Optional) (Figure 31)

This module contains the synchronism check circuitry used to supervise reclosing. It includes:

- Voltage detectors to establish whether the line and the bus are live. Reclosing can be allowed or blocked for various combinations of live or dead line and buses.

An angle measuring circuit to establish whether the phase angle between the two voltages is within the set limits. Reclosing is blocked when the angle is out of limits.

A low slip measuring circuit to establish whether the difference of frequency between the voltages is within the setlimits. Should the slip be greater than the setting reclosing is blocked.

A high slip measuring circuit which permits fast synchonic check before the angle between bus and line voltage is greater than the setangle.

A "dead time" timer in order to coordinate the reclosing time with the remote terminal. Should the remote terminal not reclose within the time allowed, the high slip detector might give an erroneous output. This risk can be eliminated by disabling the detector once the "dead time" is over and operating on the slow slip detector the slow slip detector.

Breakers on the Front Panel

Identification	Type	Function and Description
ANGLE	Rotary Switch (2 digit)	Sets the maximum angle limits between bus and line voltages for reclosing.
SYNK CK	Microswitch	Enables Synchronism Check Supervision of reclosing and voltage supervision.
LLDB	Microswitch	Live Line Dead Bus Supervision.

DLLB	Microswitch	Dead Line, Live Bus Supervision.
DLDB	Microswitch	Dead Line, Dead Bus Supervision of Reclosing.

Internal Selectors

Identification	Type	Function and Description
PT VOLTAGE	Microswitch	Rated voltage of the voltage transformers secondary. This switch establishes the phase to neutral rated voltage from which voltage thresholds are established.
BUS LIVE	Microswitch	Threshold of live busses. This selector establishes the voltage level in percentage of the rated voltage. Above this level, it is assumed that busses are live.
BUS DEAD	Micrswitch	Threshold of dead busses. This selector establishes the voltage level in percentage of the rated voltage. Above this level, it is assumed that busses are live.
LINE LIVE	Microswitch	Threshold Setting for Live Line.
LINE DEAD	Microswitch	Threshold setting for Dead Line.
LOW SET SLIP	Microswitch	Low slip detector adjustment. This selector establishes the slip value (FLS) above which reclosing is blocked. (with the exception of instantaneous reclosing).

HIGH SET SLIP	Microswitch	High slip detector adjustment. This selector establishes the threshold (FHS) for the high speed slip detector used for supervision of instantaneous reclosing.
DEAD TIME	Microswitch	This selector establishes the time following a trip for which the high slip detector is disabled.
50 HZ / 60 Hz	Microswitch	This selector sets the synchronism check circuits to the frecuency of the system.
1	Microswitch	Multiplier of the slow slip detector adjustment. When set to the right, (at the lower side of the board) it multiplies the setting by ten.
2	Microswitch	Slow slip detector control for a second breaker. This selector is not used in MLS. It must be set to the left (at the upper side of the board).
LOW SET ONLY	Microswitch	This selector cancels the synchronism check by means of the high slip detector, preventing reclosing until an output obtained from the slow slip detector.

LED Indicators on the SVM Front Panel

Identification	Color	Function an Description
TL1	red	Angle out of limits. This indicator lights up when the angle between line and bus voltages is greater than the angle set at the front of the module.
TL2	red	Slip greater than the slow slip detector adjustment. This indicator lights up when the described condition takes place, but only after the slip measuring has been carried out.
TL3	red	Permission for reclosing. It lights up when the SVM module is giving permission for reclosing. It operates in coordination with the voltage supervision modes, as well as with the syncronism check mode.

MAGNETIC MODULES

Basic Construction

The magnetic modules, also named MGM, consist of a steel structure which houses the relay's electromagnetic components; These components include the voltage transformers, transactors and the output telephone relays with trip contacts. Besides, they contain a printed circuit board with the circuits described below:

- 5Vdc infeed source that provides voltage to all the logic circuitry of the system: DLM, RLM. This source is fed by 25 Vdc voltage and 1 Amp current capacity.
- Trip supervision circuit at the starting and outage of the relay.
- Circuit actuators on the output telephone relays.

The electric connection is achieved by means of two connectors: one 104 pins signal connector and one 8 pins current connector.

The module is provided with two pullers, one at the upper section and the other at the lower section in order to pull the module in and out.

Identification

The MGM model nuber is shown at the bottom of the front plate. The information on the rated values of those magnitude which affect the magnetic module are shown on the central part of the 'plate, as described below:

IN - Rated current in Amps.
VN - Rated voltage in volts.
FREQ - Rated frequency in Hertz.

Internal Selectors

Identification	Type	Function and Description
		Fuse failure blocking of the trip resulting from the phase selectors (Zone IV) or from the blocking units (Zone V). Set to the BLOCK position, the trips are unabled when a voltage transformers fuse failure condition is given. Set to the OFF position, the trip is allowed even when a fuse failure condition has been detected.

PROCEDURES FOR ADJUSTMENT

The settings referred in this section are located at the front of the MLS relay. Access to the internal settings, where indicated, is accomplished by withdrawing the module or modules where they are housed. Figures 23 to 33 are included for reference, showing module adjustment locations.

CONTROL VOLTAGE ADJUSTMENT

The control voltage rating must be selected on the modules indicated in TABLE VI.

TABLE VI

MODULE	NUMBER OF SELECTORS	FUNCTION
DOMO55	4 on the left board	Contact converters
	4 on the right board	Contact convert-
ers		
RLM	4 on the right board	Contact convert-
ers		

These selectors are accessable by unscrewing the four mounting screws and separating the boards in the corresponding module.

RECLOSER ADJUSTMENTS

Operation modes

The recloser is provided with five operation modes:

1) One reclosing attempt, single or three phase, depending on the type of trip.
2) One reclosing attempt, single phase only.
3) One reclosing attempt, three phase only.
4) Two reclosing attempts, single or three phase the first and three phase the second.
5) Two reclosing attempts, both three phase.

The operation mode desired is programmed by positioning the program switches as shown in TABLE VII.

TABLE VII

MODE	1Ø	3Ø	DLY
1	RIGHT	RIGHT	LEFT
2	RIGHT	LEFT	LEFT

TABLE VII

MODE	- 1Ø	- 3Ø	DLY
3	LEFT	RIGHT	LEFT
4	RIGHT	RIGHT	RIGHT
5	LEFT	RIGHT	RIGHT

The recloser can be set to the OFF position by setting all three program switches to the left.

<u>Time Adjustment</u>

First reclosing attempt - Single phase

The time between the trip and the first reclosing attempt is adjusted by means of eight microswitches identified as 1Ø located on the front of the RLM module. The time setting is sum of the values of all the switches set to the right.

First reclosing attempt - Three phase

If the first reclosing attempt is three phase, the reclosing time will be the adjusted by the group of eight switches identified as 3Ø on the front of the RLM module. The time setting is determined as in the case of the first single phase reclose.

Second reclosing attempt - Three phase always

The time between the second reclosing initiation (first failed attempt) and the corresponding reclose (timed reclose) is determined by the group of eight switches known as DLY located on the front of the RLM module. The time setting is determined as in the case of the first single phase reclose. This setting must always be greater than the dwell time.

Reset time

The reset time is determined by the group of eight switches identified as RST, located on the front of the module, and should always be greater than the dwell time.

Dwell time

This time is adjusted by means of an internal selector in the RLM module. There are two possible positions: 0.2 and 0.8 seconds

Auxiliary Functions

Synchronism check reclosing supervision

If the MLS is provided with the Synchronism check option (SVM module), all three phase reclosing attempts will be supervised by means of a signal coming from the SVM module. If the HOLD internal selector is set to the IN position, the reclosing signal will be enabled if a synchronism check appears within the set time. If the OUT position is selected, a synchronism check signal must be present when the reclose signal first appears, or reclosing will be blocked.

SYNCHRONISM CHECK MODULE (SVM - Optional)

Mode of Operation

There are four modes by which to supervise reclosing:

1. SYNC CK - Synchronism check using angle and slip detectors. This requires Live line, Live bus conditions.
2. LLDB - Live line, Dead Bus
3. DLLB - Dead line, Live Bus
4. DLDB - Dead line, Dead Bus

The desired mode is selected by closing (moving to the right) the appropriate switch on the SVM module. The functions may be combined by closing more than one switch at a time. If none of the switches are closed, reclosing will always be blocked.

Synchronism Check Settings

Angle

The maximum phase angle between the bus and line voltage for which reclosing is to be permitted is set by the double digit thumbwheel switch on the SVM module. The digits are advanced by the lower pushbuttons labelled (+) and reduced by the upper pushbuttons labelled (-). The value displayed is in degrees.

Low Set Slip Cut-Off

The low set slip cut-off value is set by positioning four miniature toggle swtiches within the SVM module. The setting is equal to the sum of the values corresponding to those switches which are closed. The switch values (in cycles) are given on the printed circuit board. The setting may be multiplied by ten by moving the miniature switch (below the 50 Hz/60 Hz switch) to the right.

High Set Slip Cut-off

The high set slip cut-off value is also set by positioning four miniature toggle switches within the SVM module. The setting is equal to the sum of the values corresponding to those switches which are closed. The switch values (in cycles) are given on the printed circuit board.

Low Set Slip Only

The capability of the sync check circuit to permit a high speed reclosure based on an output from the high set slip detector may be defeated by positioning the miniature switch labelled LOW SET ONLY in the SVM module to the right (towards bottom of board). This requires that a low slip measurement be made before reclosing is permitted.

Dead Time Timer Setting

This time (DT) is set by positioning six miniature toggle switches within the SVM module. The setting is equal to the sum of the values corresponding to those switches which are closed. The switch values (in seconds) are given on the printed circuit board.

Voltage Threshold Settings

Potential Transformer Voltage

The synchronism check circuit must be set according to the nominal secondary voltage of the potential transformers connected to the MLS. This setting is made using four miniature toggle switches within the SVM module, designated PT VOLTAGE. One of these should be closed, according to the value given on the printed circuit board (phase-to-neutral voltage).

Live Bus

The voltage threshold which determines whether or not the bus is to be considered live is set using four miniature toggle switches within the SVM module designated BUS LIVE. The setting is made in terms of a percentage of the nominal voltage and is equal to 70 percent plus the sum of the values corresponding to the switches that are closed. The values are given on the printed circuit board.

Live Line

Similar to live Bus.

Dead Bus

The voltage threshold which determines whether or not the bus is to be considered dead is set in similar fashion to the live thresholds. The setting is equal to ten percent plus the sum of the values corresponding to the switches in the BUS DEAD group that are closed.

Dead Line

Similar to Dead Bus.

Frequency Setting

The synchronism check circuit is set for the rated system frequency by positioning the 50 Hz/60 Hz miniature switch within the SVM module.

DISTANCE RELAY ADJUSTMENT

Protection scheme selection

The distance relay is provided with five standard protection schemes and two optional ones:

1) Stepped distance
2) Zone I extension
3) Zone II acceleration
4) Permissive overreach transfered trip (POTT)
5) Permissive underreach transfered trip (PUTT)
6) Directional comparison blocking
7) Hybrid scheme

The desired scheme is selected by means of three microbreakers within module DLM as indicated in TABLE VIII. They correspond to all three lower positions in the grouped known as SW2.

TABLE VIII

DESIRED SCHEME	SW2-6	SW2-7	SW2-8
1	Left	Left	Left
2	Right	"	"
3	Left	Right	Left
4	Right	"	"
5	Left	Left	Right
6	Right	"	"
7	Right	Right	"

Reach Settings

Phase Selector Reach

The phase selector reach is set by positioning the eight toggle switches on the DSM module. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$Zp = [4 + ( )] \times 5/IN$$

IN represents the current rating which is given on the distance relay MGM module.

The value in parentheses represents the composite setting of the eight toggle switches. This number is arrived at by summing the values corresponding to all the switches in the closed (right) position. For example, suppose the first, fifth, and seventh switches are positioned to the right (closed) and the remaining switches are positioned to the left (open). The values corresponding to the closed switches are 1, 10 and 20 respectively. The composite setting is 1 + 10 + 20 = 31. If IN = 5 amperes, the phase selection reach is then:

$$Zp = [4 + (31)] \times 5/5 = 35 \text{ ohms}$$

It should be kept in mind that the reach is the same for all three phase selectors and that this reach also constitutes the Zone Four reach.

MB Blocking Unit Reach (Optional)

The MB blocking unit reach is set in similar fashion to the phase selector reach by positioning switches on the DBM module. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$ZB = [4 \times (\quad)] \times 5/IN$$

Again, the value in parentheses represents the composite setting of the toggle switches. Keep in mind that the reach is the same for all three blocking units (phase A, B, C) and that the reach also constitutes the reach for the reverse zone five.

Zone I reach

It is carried out by means of the group of ten upper switches (one group of eight and another of two) of the module DRM and it is given in ohms by the following expression which appears at the front of the module:

$$Z1 = A \times I \times 5/IN$$

Where: IN indicates the system's rated current.

I is the sum of .02 plus the rates of all the switches in the first group of eight, located on the right.

A is a multiplier determined by means of the second group of switches according to the following table:

TABLE VIII

Value of A	Upper	Lower
1	Left	Either
5	Right	Left
25	Right	Right

Assume switches 1, 4 and 6 from the first group of eight are located on the right, the upper switch from the second group of two on the right, and the lower one on the left; also assume that the relay's nominal voltage is 5 amps:

$$I = 0.02 + 0.002 + 0.016 + 0.06 = 0.098$$

$$A = 5$$

$$ZI = 5 \times 0.098 \times 5/5 = 0.49 \text{ ohms}$$

Extended Zone One Reach

This reach, which is to be used in the Zone One extension scheme, is set by positioning the set of five toggle switches on the DRM module, designated IX. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$Z = [1 + (\ )]\ ZI$$

ZI represents the Zone One reach.

The value in parentheses represents the composite setting of the five IX switches.

Zone Two Reach

The procedure for setting the Zone Two reach is similar to that for setting the extended Zone One reach except that it involves the set of seven toggle switches on the DRM module, designated II.

Zone Three Reach

The procedure for setting the Zone three reach is also similar to that for setting the extended Zone One reach except that it involves the set of eight toggle switches on the DRM module, designated III. Note that this establishes the reach for the permissive unit in addition to determining the third zone reach for the main measuring unit.

<u>Zero Sequence Compensation Factor</u>

This factor, designated KO, is adjusted by positioning the lower seven toggle switches on the DRM module. Its value is given by the following expression which appears on the module front panel:

$$KO = 2.0 + (\ )$$

The value in parentheses represents the composite setting of the toggle switches.

Characteristic Impedance Angles

The relay positive (and negative) sequence impedance angle is set by rotating the upper switch on the DFM module (designated ØZ1) to the desired position. The values are given in degrees.

The relay zero sequence impedance angle is set by rotating the lower switch (designated ØZ0) on the same module. Again, the values are given in degrees.

Note that the angles established by these switches are the same for the phase selectors, the main measuring unit, and the permissive zone measuring unit.

Zone Timer Adjustment

Zones two and three

The zone II and zone III times are set by the II and III switches on the DLM module. The value is determined by the sum of the values of those first seven switches from each group which have been set to the right. The eigth switch in each group is a multiplier, so that if it is set to the right, the set value is multiplied by ten.

The zone III timer must be set larger than zone II.

Zone IV time

The value, in seconds, of zone four time is determined by means of the lower eight switches, in the DSM module, identified as ZIV T according to the following expression:

$$ZIV\ T = 0.05 + ()$$

The value in brackets indicates the sum of the switch values set to the right, except for the eighth. This switch, identified as ZIV TRIP blocks zone four trips when set to the left.

The zone IV time is totally independent from the other zones.

Zone V time (Optional)

The zone V time setting, in seconds, is accomplished in the same way as for zone IV time,except with the DBM switches, identified as ZV T and according to the formula:

$$ZV = 0.05 + ()$$

The eighth switch (ZV TRIP), blocks trips in zone five, when set to the left.

The zone V time is independent from the rest of the relay logic.

<u>Tripping zone limitation</u>

The ZONE LIMIT switches on the DLM module can be used to limit the step distance operation as follows: In the ZI position, the relay will only trip for faults within zone one. In the ZII position, the relay remains limited to the fault tripping in zone two or zone one.

In order to limit the trip to lower zones I-III, it is necessary to block the trip in zone four by means of the ZIV TRIP switch described above and located in the DSM module.

<u>Selection of Phase Selector Mho Characteristic</u>

The phase selector mho characteristic may be set to be circular (90 degrees coincidence between polarizing and operating quantities) or lenticular (105 degrees coincidence). The selection is made by means of a link within the DSM module. The one link controls the characteristics of all three phase selectors. Note that this is also the zone four characteristic.

Selection of MB Blocking Unit Characteristic - (Optional)

The mho characteristic for the blocking units may also be set to be either circular or lenticular by positioning the link in the DBM module. As for the phase selectors, this one link controls all three MB units (phase A, B, C) which also constitutue the reverse zone five.

Dropout Time of MB Blocking Units - (Optional)

The dropout time of the MB blocking units may be adjusted by positioning four miniature toggle switches within the DBM module, designated CYCLES DROPOUT. The time is equal to the composite switch setting, determined by summing the values corresponding to all the switches in the closed position. The values are given in

Single Phase Fault Detection

Selection of Measuring Unit Characteristic

The main measuring unit and permissive zone measuring unit may use either a reactance or a mho-type characteristic for single phase-ground faults. The desired characteristic is selected by positioning the X/Y link within the DRM module. X corresponds to reactance, Y corresponds to mho. Whichever is selected, both measuring units will have the same type of characteristic.

Characteristic Angle Timer Adjustment

The coincidence initial angle (prior to integration) of the main measuring unit characteristic for ground faults (mho or reactance type) is adjusted by means of the first four SW2 switch group inside module DLM. The adjustment is determined by means of the formula:

$$GCA = 90^\circ + ()$$

The brackets indicate the sum of the rates of those switches set to the right; the values are:

SW2-1 = 5°
SW2-2 = 10°
SW2-3 = 20°
SW2-3 = 40°

If the adjustment is greater than 135°, the effective value is 135°.

This adjustment determines the reactance characteristic initial slope or the narrowing of the lens if it is an mho characteristic. The later integration expands the characteristic to a straight line or to a circle according to the characteristic selected.

Sequence Trip Time

Sequence trip time is set using the first six switches from the group of eight identified as SW1, in the DLM module. The resulting time, in miliseconds, is the sum of the values of all those switches set to the right; the values are as follows:

SW1-1 = 10 ms
SW1-2 = 20 ms
SW1-3 = 40 ms
SW1-4 = 80 ms
SW1-5 = 160 ms
SW1-6 = 320 ms

This adjustment determines the time in which the characteristic coincidence angle, for ground faults, is determined by the characteristic angle adjustment.

Frequency Adjustment

The relay is set for the rated frequency of the application in two different places. The phase selectors are adjusted to the system frequency by positioning the 50 Hz/60 Hz switch located inside DSM. The main, measuring and permissive units are adjusted to the system frequency by means of the fifth switch in group SW2, inside the DLM. Set to the right, the adjustment corresponds to 50 Hz; to the left, the adjustment is 60 Hz.

If the relay is provided with the synchronism check module as an option, the 50 Hz/60 Hz switch must be adjusted inside module SVM.

Trip Mode

The trip mode is set with the upper microswitch of the SW6 group. Set to the right, (Three phase mode) it causes all the trips to be three phase. Set to the left, (NORMAL mode), it allows for single phase trips for single phase faults in zone one.

Target Indication Mode

It is possible to chose the signaling mode of leds A, B and C at the front of the DLM module so that they indicate the faulted phase or phases, or the tripped phase. This adjustment is made with the fifth switch in group SW4. When this adjustment is set to the right, the LED's indicate the tripped phase or phases whereas if set to the left they indicate the faulted phase or phases.

Voltage Transformer Type

Coordination with the type of MLS Ac potential, capacitor voltage transformer or wound potential transformer, is accomplished with the eighth switch of the SW1 group. Set to the right, the relay is coordinated with a CVT, set to the left. with a PT.

Fuse Failure Trip Blocking

The fuse failure detector in voltage transformers can be used to block the trips. This supervision is obtained, regarding trips by the main measuring unit or channel trips, by means of the seventh switch from group SW1. Set to the right, the trips are blocked when a fuse failure condition is detected; set to the left, tripping is allowed. The adjustment corresponding to fuse failure blocking of the fourth or fifth zone trips is accomplished by means of a selector provided on the printed circuit board inside the Magnetic Module. Set to the upper position, the trips are blocked by a fuse failure condition. Set to the lower position, trips are allowed.

Breaker Failure Initiation Outputs

There are four breaker failure initiation (BFI) output contacts in the distance relay. To operate these contacts on a per pole (individual) basis, the three IND/COM links in the DOM101 module should be placed in the IND position. In this mode, single pole tripping will result in the closure of the BFI contact corresponding to the tripped pole plus the closure of the supervisory BFI contact (any pole tripped).

If the links are placed in the COM position, all four BFI contacts will close simultaneously (common) for any single pole or three pole trip.

Power Swing Detector

This detector can be used to block the trips for an out-of-step condition. This supervision is set bythe sixth switch of the group SW5, inside the DLM module. Set to the left, it blocks the trip whereas to the right, this supervision is disabled. In either position the visual indication and the alarm contact are activated when a power swing is detected.

Power Swing Timer

This setting is determined by the time required for system apparent impedance to pass between the phase selectors characteristic and the permissive measuring unit characteristic. The adjustment is made by means of the five upper switches of the group SW5 in the DLM module. The value of the setting in milliseconds is equal to 16 plus the addition of the values corresponding to those microswitches set to the right. These values are:

SW5-1 = 1 ms
SW5-2 = 2 ms
SW5-3 = 4 ms
SW5-4 = 8 ms
SW5-5 = 16 ms

For 50 Hz, the adjustment should not be lower than 20 ms (one cycle)

Channel Scheme Selection

Channel Trip Blocking

A channel trip can be blocked by setting the NCT switch to the right, on the front of the DLM module. This switch does not block the stepped distance trips scheme which operates with the selected carrier scheme.

Coordination Time in the POTT schemes and Directional Comparison

This time is set by means of the six upper SW3 switches, inside of the DLM module. Its value in milliseconds, is equal to addition of the values of those switches set to the right. The adjustment is zero with all the switches set to the left. The time rates corresponding to each switch are:

SW3-1 = 1 ms
SW3-2 = 2 ms
SW3-3 = 4 ms
SW3-4 = 8 ms
SW3-5 = 16 ms
SW3-6 = 32 ms

Receiver Contact Monitor

This monitor may be set to interpret either an open or a closed receiver output contact to indicate the receipt of a channel signal. The setting is made by positioning the RCVR link in the DLM module. This permits the MLS to be used with different types of channel equipment.

For the zone two acceleration, permissive underreaching transfer tripping, and permissive overreaching transfer tripping schemes, RCVR Link positions have the following significance:

Left Position: (NORM) — An open receiver contact indicates normal conditions on the channel. Channel tripping is inhibited while the contact is open. A closed receiver contact indicates that the remote relay is sending a signal over the channel, be it a trip signal (tripping scheme) or zone 2 reach signal (zone 2 acceleration scheme).

Right Position: (INV) — Operation opposite of the above.

For the optional directional comparison scheme, the RCVR link positions have a different significance.

Left Position: (NORM) — Referring to the distance relay logic diagram (Fig. 2), an open receiver contact into CC1 will block channel tripping by disabling AND25, which in turn disables the comparer (AND68). Thus, an open contact indicates that the remote relay is sending a blocking signal over the channel. A closed contact permits channel tripping.

Right Position: (INV) — In this case, a closed receiver contact indicates that the remote relay is sending a blocking signal over the channel. The CC1 output then disables AND25 (through NOT4), which in turn disables AND68 and blocks channel tripping. An open contact permits channel tripping.

State of Transmitter Keying Contact

Depending on the channel equipment used, a contact closure or a contact opening may be required to key the transmitter. Provision is made for either case. By placing the seventh switch in SW3 set inside the DLM module to the left, the transmitter keying contact is open for normal conditions and closes when it is desired to send a channel signal. With the switch in the opposite position, the contact operation is reversed.

State of Stop Transmitter Contact

Again, depending on the channel equipment used, a contact closure or a contact opening may be required to stop the transmitter in the optional directional comparison blocking mode. Provision is made for either case. By placing the sixth switch in SW4 set (inside DLM module) to the left, the STOP TRANSMITTER contact is open for normal conditions and closes when it is desired to stop the channel signal. With the switch in the opposite position, the contact operation is reversed.

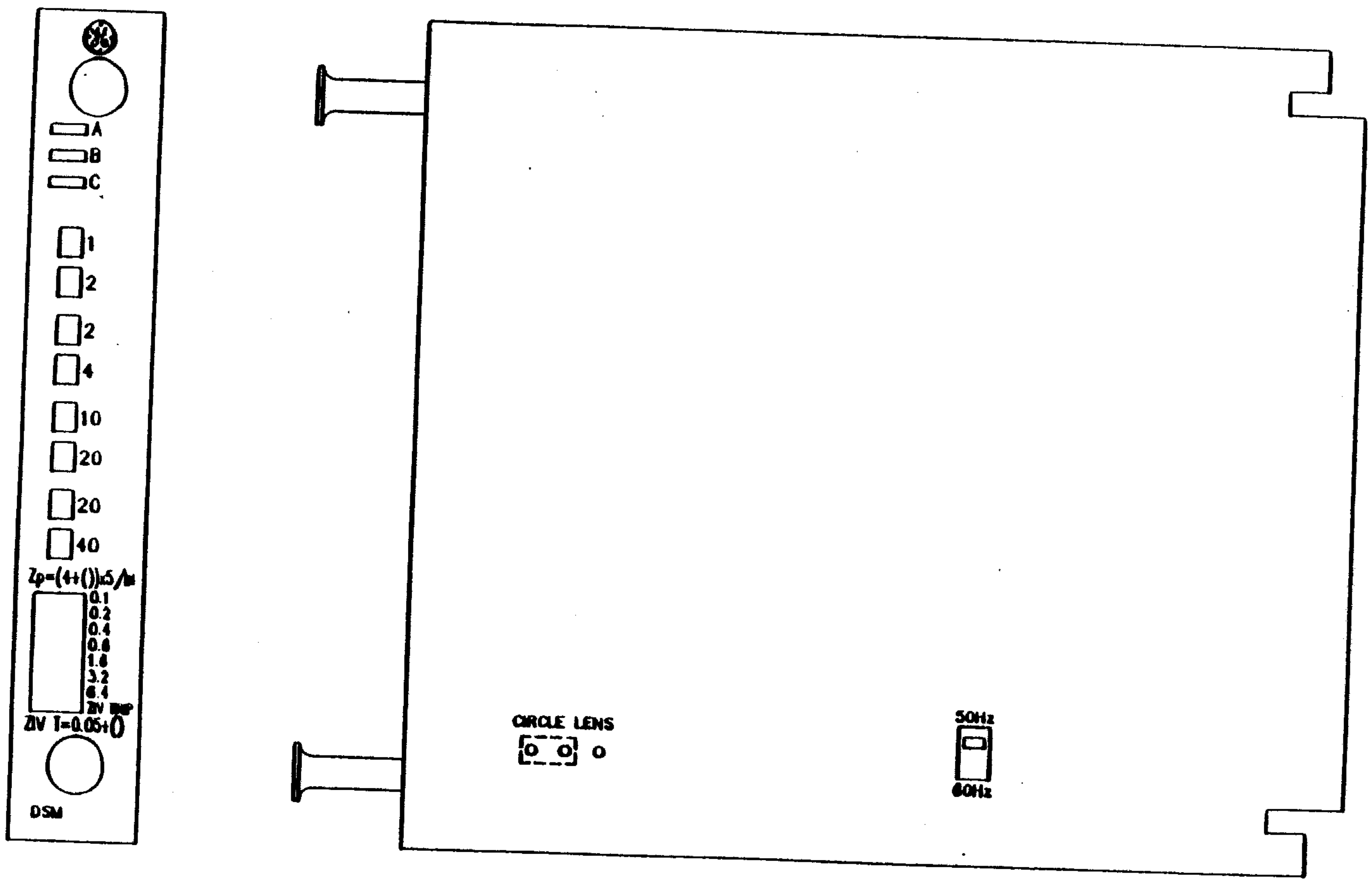


Figure 23 (226B7440 Sh 24): DSM Phase Selectors Module.

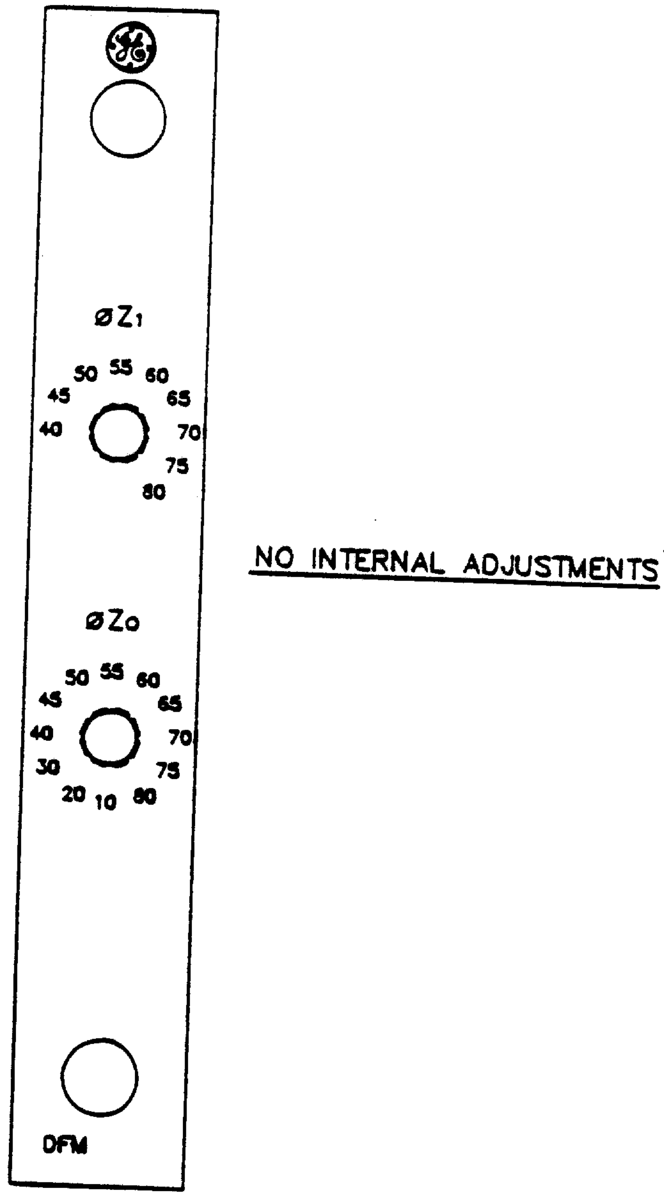


Figure 24 (226B7445 Sh 18): DFM Filter Module.

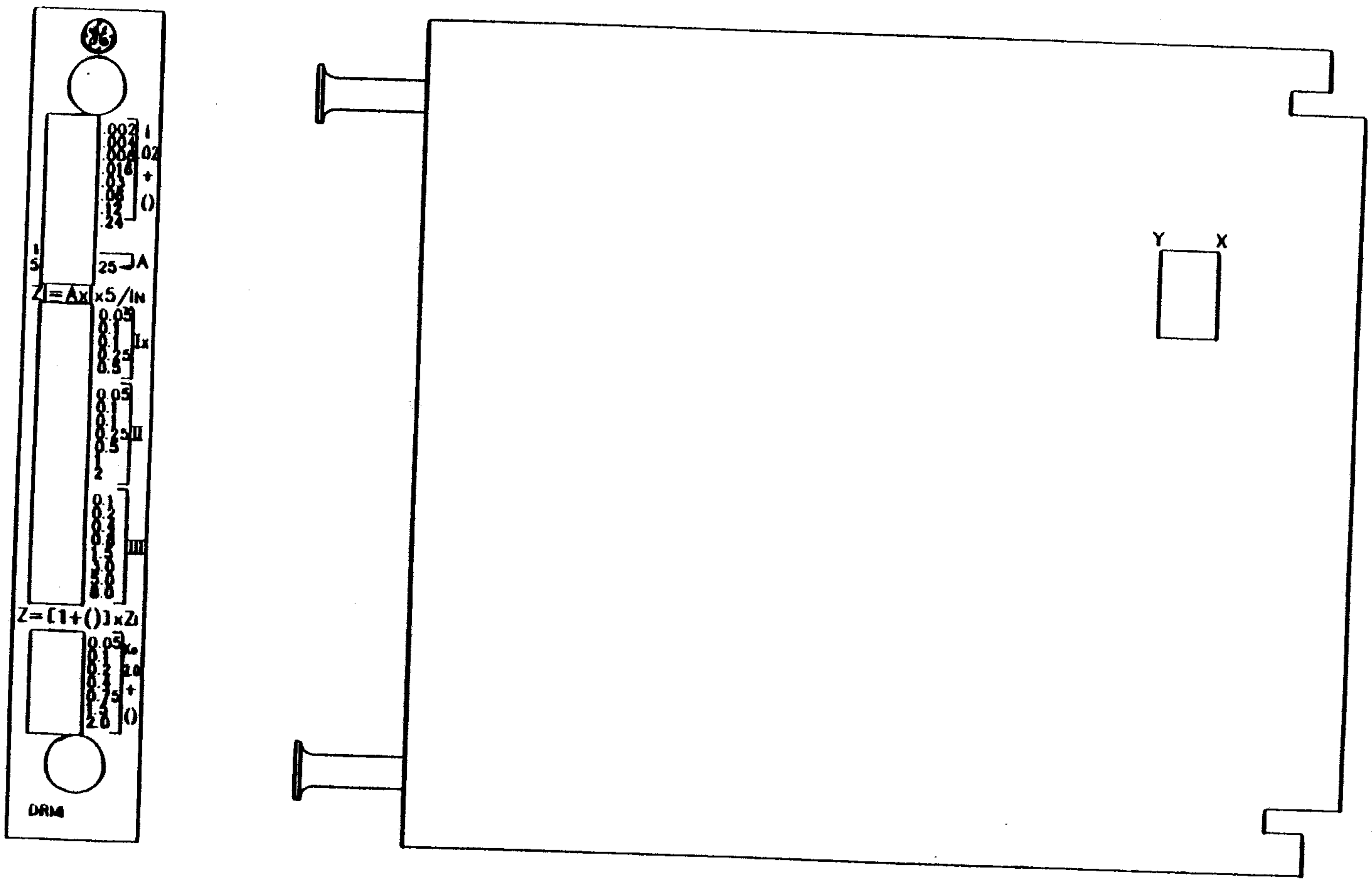


Figure 25 (226B7440 Sh 33): DRM Reach Module.

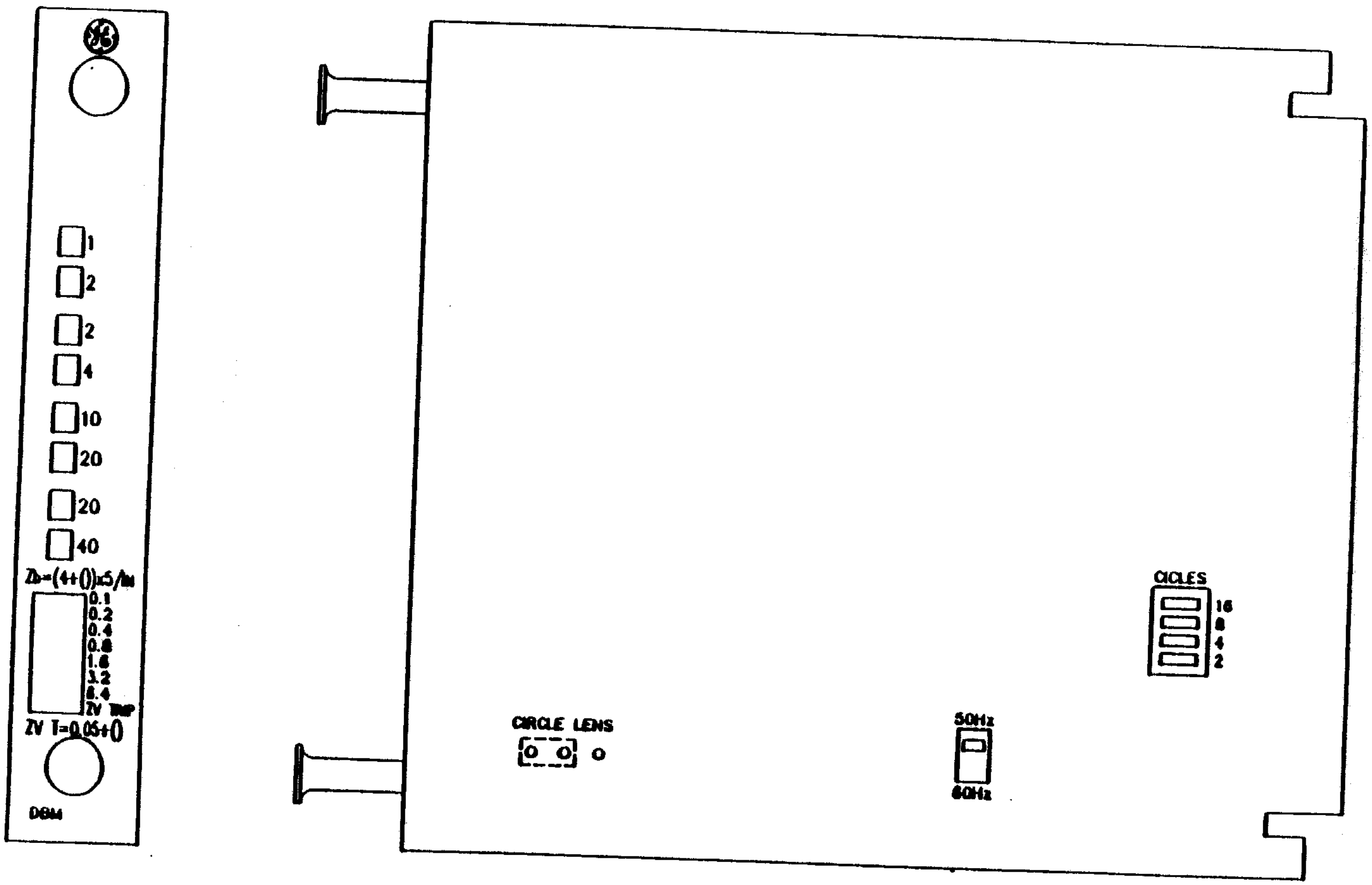


Figure 26 (226B7440 Sh 32): DBM Blocking Module.

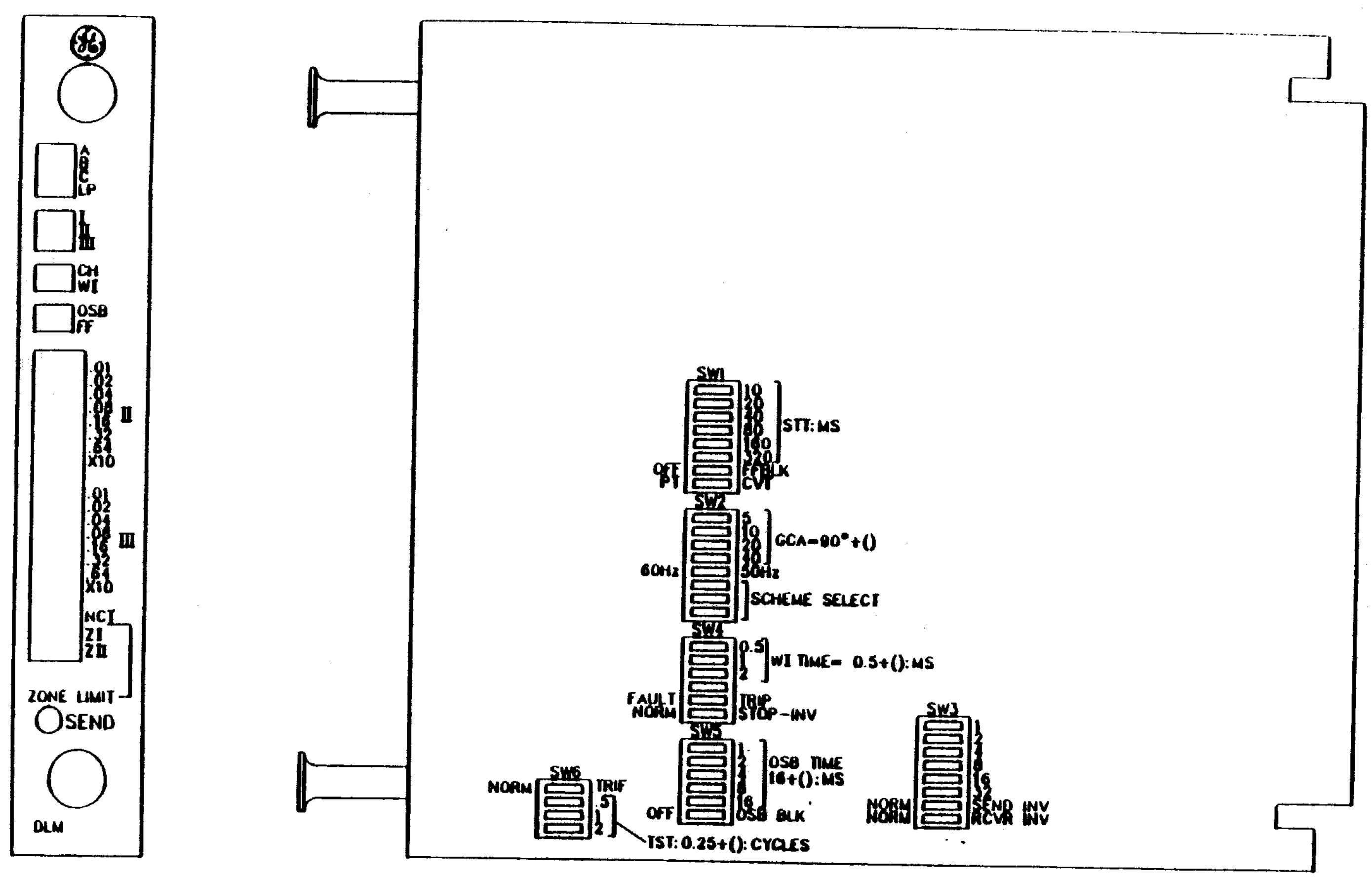


Figure 27 (226B7440 Sh 36): DLM Logic Module.

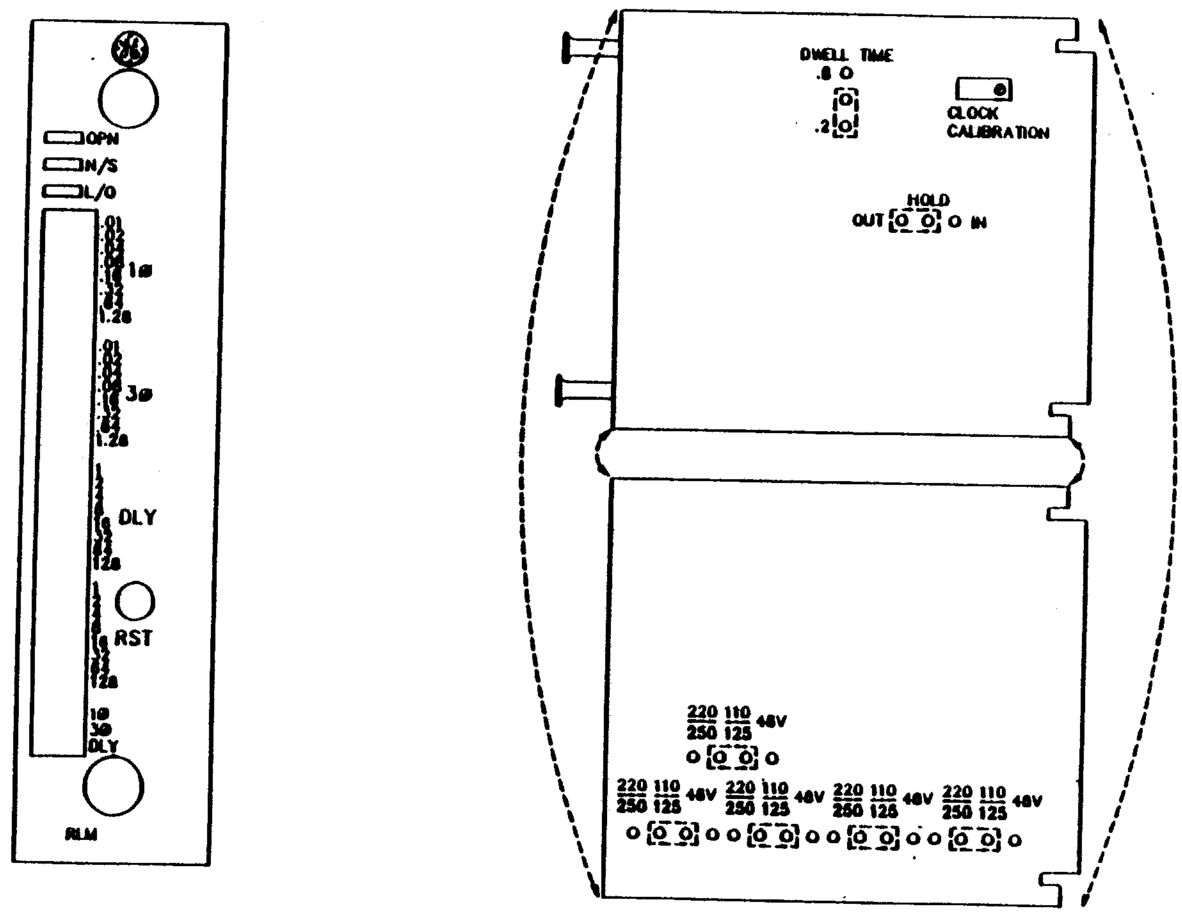


Figure 28 (226B7440 Sh 37): RLM Reclosing Logic Module.

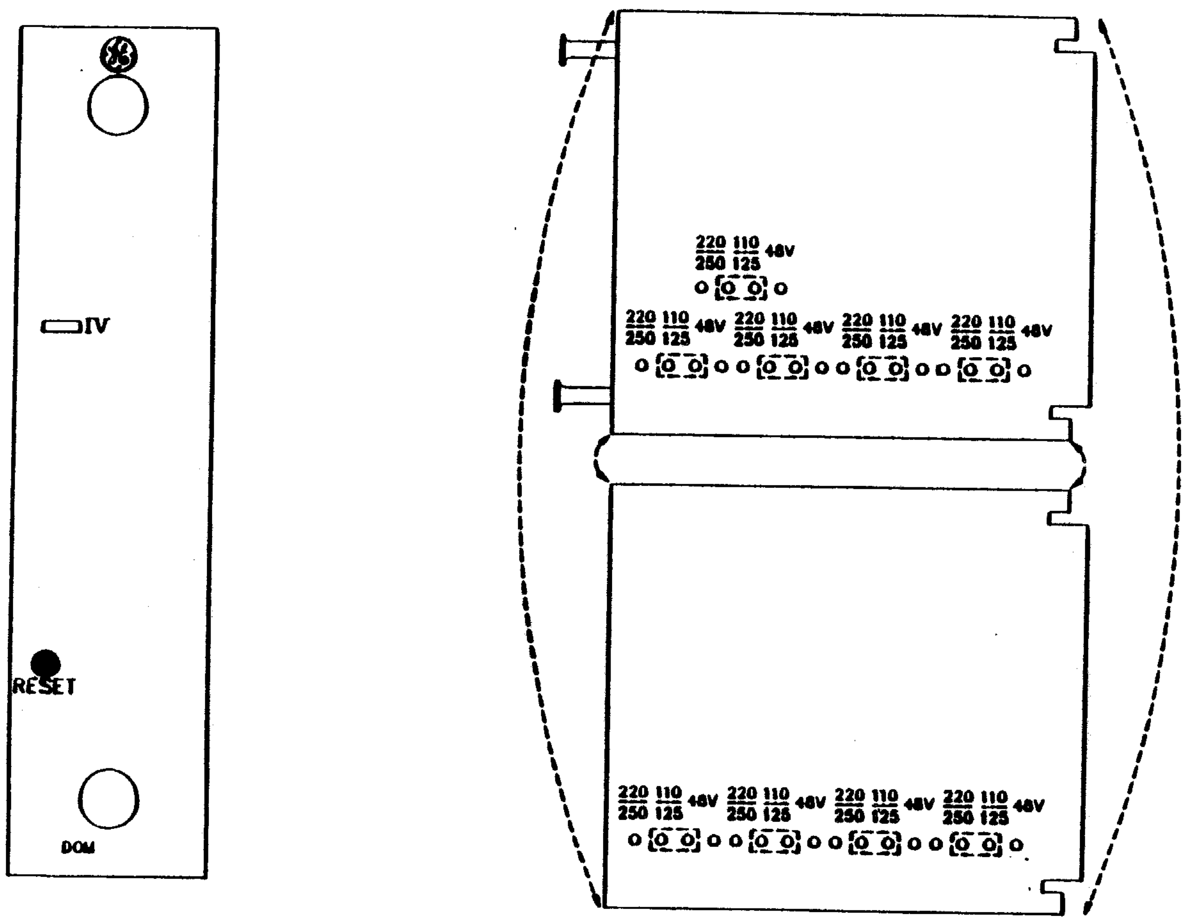


Figure 29 (226B7440 Sh 38): DOM Output Module.

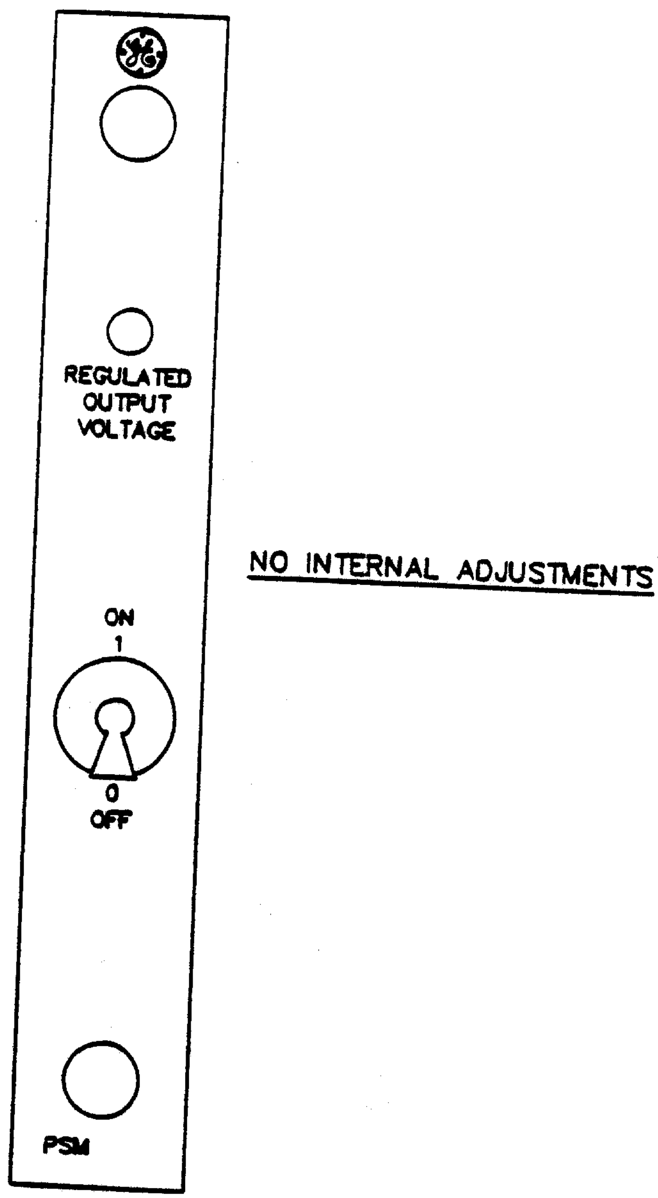


Figure 30 (226B7445 Sh 18): PSM Power Supply Module.

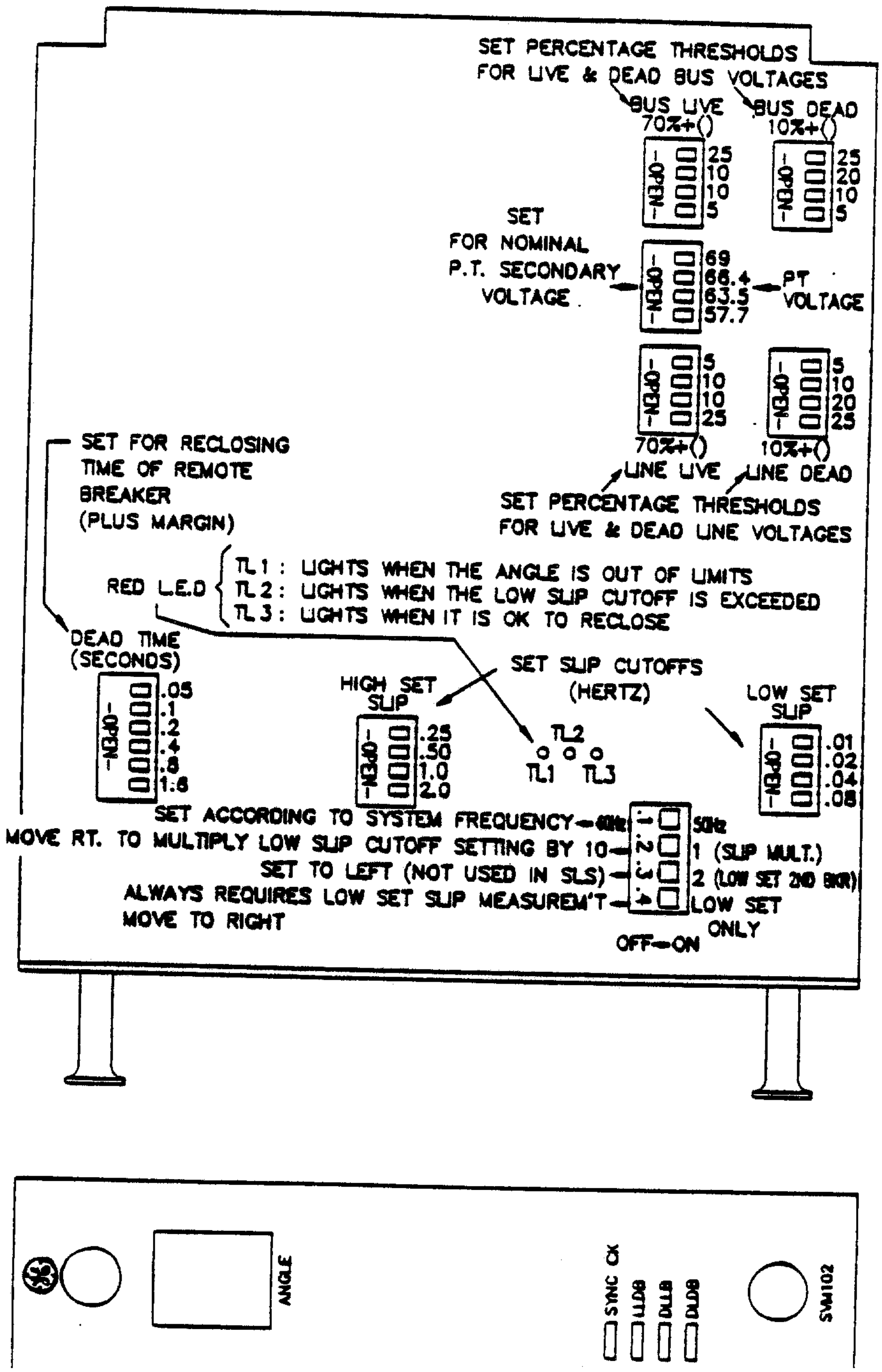


Figure 31 (226B7445 Sh 29): SVM Synchronism Check Module.

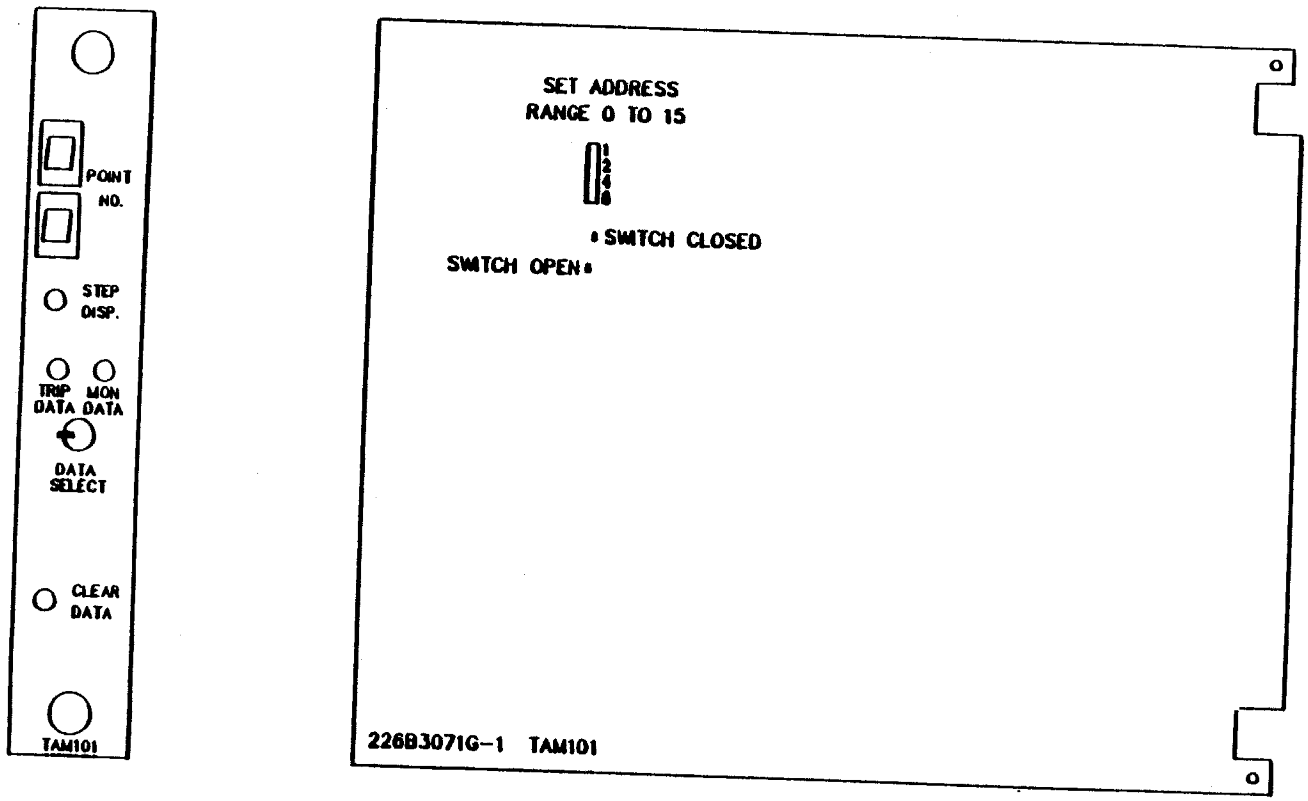
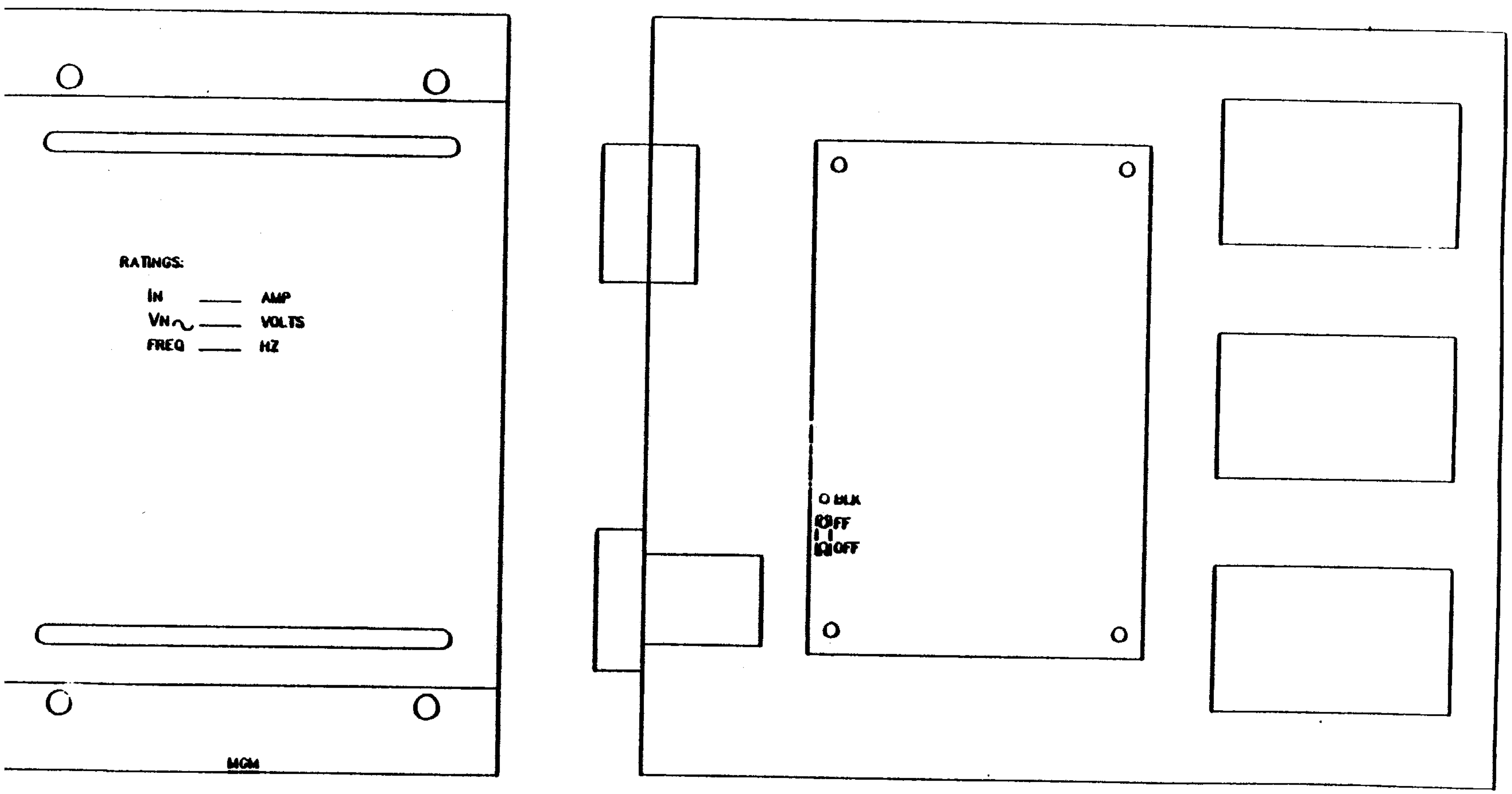


Figure 32 (226B7440 Sh 23): TAM Continuous Monitor Module.


RATINGS:
IN ____ AMP
VN~ ____ VOLTS
FREQ ____ HZ
MGM
O BLK
OFF
OFF

ACCEPTANCE TESTS

It is recommended that the functional tests described below be carried out prior to the installation of the relay.

Initial adjustments

In order to begin with the acceptance tests, the modules should be adjusted as shown in Tables VIII and IX. It is necessary to withdraw the modules for access to the settings described in Table VIII.

Test equipment

The acceptance tests may be performed using the following test equipment:

- One rated frequency three phase voltage source.
- One control voltage source (48, 110-125 or 220-250 Vdc).
- One phase shifter.
- One phase angle meter.
- Two variable autotransformers:
  - One with a current of 1 amp (or greater).
  - One twice the rated current (or greater).
- Three test reactances:
  - With 6/12/24 ohm taps for 5 amp relays.
  - With 30/60/120 ohm taps for 1 amp relays.
- Two a.c voltmeters
- One timer.
- 8 Contact monitors.
- One AC ammeter.
- Test switches and push buttons to control the test signals
- One board extender (GE #0138B7406G1).
- Two XTM Test Receptacles (one GE*XTM28R, one GE*XTM28L)

The specific requirements for this equipment are detailed in this section and in the adjoining diagrams.

It is essential that the AC test power source applied is a balanced three phase system and with non distorted sine-waves.

Alternatively, a voltage and current injection electric system may be used. These systems have the advantage of the accuracy and pureness of the waves generated, as well an easy adjustment. In many cases, its versatility allows to simplify considerably the circuits described in this section.

Test connections

The numbers of the terminals in the MLS back connection boards and their corresponding points in the XTM test receptacle are shown in the test circuit diagrams. In order to carry out the acceptance tests, it is recommended to use the terminal blocks on the back of the MLS case for initial bench test to verify all imput/output circuits. The purpose of the test receptacle is to provideeasy connection for tests after the equipment has been installed. This will be described in a separate section called PERIODIC TESTS.

TABLE VIII - Internal Settings for Acceptance Tests.

Module	Setting	Initial Position
DSM	50/60 HZ	ACCORDING TO THE SYSTEM'S FREQUENCY
DSM	LENS/CIRCLE	CIRCLE
DRM	X/Y	Y
DBM	LENS/CIRCLE	CIRCLE
DBM	TIMER.RESET	0
DLM	SING/3 PH. TRIP	1Ø
"	FF BLOCKING	NO
"	TYPE OF TRANSF.	FOR INDUCTIVE TRANSF.
"	SIGNALLING MODE	FAULT
DLM	TARGET SET TIME	3.0 CYCLES
"	RECEPTION LOGIC	NORMAL
"	SENDING LOGIC	NORMAL
"	OUTAGE LOGIC	NORMAL
"	LOGIC SCHEME	STEPPED DISTANCE
"	COORDINATION TIMER	3.0 MILISECONDS
"	SWING BLOCKING	NO
"	50/60 Hz	ACCORDING TO SYSTEM FREQUENCY
DLM	CHARACT. ANGLE	90°
"	OSCILLATION TIMER	31 MILISECONDS
"	SEQ. TRIP TIMER	10 MILISECONDS
DLM	WEEK INFEED TIMER	3 CYCLES
RLM	HOLD	OUT
"	DWELL TIME	0.2 SECONDS
RLM	48/110-125/220-250V	ACCORDING TO AVAILABLE CONTROL VOLTAGE
DOM	IND/COM	IND
DOM	48/110-125/220-250V	ACCORDING TO AVAILABLE CONTROL VOLTAGE

TABLE IX - Switch Settings on the Mopdule Front Panels for Acceptance Tests.

Module	Selector	Initial Position
DSM	ZP	4 OHMS (5 A RELAYS) 20 OHMS (1 A RELAYS)
"	TZIV	6.0 SECONDS
	ZIV TRIP	NO
DFM	ØZ1	75°
"	ØZo	75°
DRM	I	4 OHMS (5 A RELAYS) 20 OHMS (1 A RELAYS)
"	Ix	1.5
"	II	2.0
"	III	4.0
DRM	Ko	4.0
DBM	ZB	4 OHMS (5 A RELAYS) 20 OHMS (1 A RELAYS)
"	TZV	MINIMUM
DBM	ZV TRIP	NO
DLM	TZII	1 SECOND
"	TZIII	3 SECONDS
"	NCT	RIGHT
DLM	ZONE LIMIT	I TO THE RIGHT
RLM	1Y TIME	0.5 SECONDS
"	3Y TIME	0.9 SECONDS
"	DLY TIME	15 SECONDS
"	RST TIME	60 SECONDS
"	1Ø	NO
"	1Ø	NO
RLM	DLY	NO

Distance Relay Tests

Fuse Failure Indicators

The voltage transformer fuse failure detector operates whenever there is negative sequence voltage in the absence of negative sequence current. This condition occurs periodically in the forthcoming tests under a variety of circumstances, particularly during the adjustment and/or switching of the input currents and voltages. Operation of the detector is therefore virtually unavoidable during testing and the lighting of the amber FF LED indicator on the DLM module should not be cause for concern. The proper operation of the fuse failure detector will be checked in a separate subsection of these tests.

A. Single Phase to Ground Reach Tests

Connect the distance relay according to the test circuit shown in Fig. 3.4.

A1. Phase Selector Test

Apply a voltage of VT = 60 volts to the phase under test and apply normal line-to-neutral voltage (69 volts) to the other two phases. Apply a single phase current of IT = 7 (five amp relay) or 1.4 amperes (one amp relay) to the phase under test.

Vary the phase angle between IT and VA (IT lagging) until the phase selector picks up, indicated by the steady lighting of the yellow LED on the DSM module corresponding to the phase under test (ØA, ØB or ØC). This should occur at an angle between 28 and 44 degrees. The OSCILLOGRAPH START contact between terminals AC1 and AC2 should close at the pickup point, along with one of the three phase selector contacts (terminals AB9 and AB10 for ØA, AB11 and AB12 for ØB, AB13 and AB14 for ØC). Record the angle at which pickup just occurs as A1.

Continue to increase the phase angle until the phase selector drops out (LED indicator goes out) and then back up slightly to the point where the light just comes on. This should occur at an angle between 106 and 122 degrees. Record this angle as A2.

Calculate the characteristic angle of the phase selector as follows:

$$\text{Ø Sel Characteristic Angle} = \frac{A1 + A2}{2}$$

This angle should fall between 72 and 78 degrees. This verifies that the relay angle is within three degrees of its setting.

Now adjust the phase angle between IT ans VA to 75 degrees (IT lagging) and lower the current to the point where the phase selector just picks up. This should occur between 5.2 and 5.8 amperes (five amp relay) or between 1.05 and 1.16 amperes (one amp relay). This checks the reach at the replica impedance angle, including the pull back at this current level (approximately two percent).

Conduct the above tests for all three phases.

If it is desired to check the phase selector characteristic under conditions other than those specified above, the following equation should be used:

$$I\emptyset\text{-SEL} = \frac{2.75\,(VT - 12.55)}{Zp\,(2\,\angle\theta 1 + KO\,\angle\theta O)\,\cos(\alpha - \theta R)} \quad \text{(Eq. 1)}$$

Where:

IØ-SEL	=	pickup current for phase selector (in amperes)
Zp	=	phase selector reach as set on DSM module (in ohms)
VT	=	phase-to-neutral voltage applied to phase under test (in rms volts)
θ1	=	positive sequence impedance characteristic angle of relay as set on DFM, module (ØZ1: in degrees)
θO	=	zero sequence impedance characteristic angle of relay as set on DFM, module (ØZO: in degrees)
KO	=	zero sequence compensation factor as set on DRM module (=ZQ/Z1)
α	=	angle between IT and VT (in degrees lagging)
θR	=	resultant relay characteristic angle (in de grees)

θR is determined as follows:

Let KR /θR = 2 /θ1 + KO /θO

Where: KR = resultant mangitude factor (for calculation purposes only).

θR and KR are calculated by breaking down 2 /θ1 and KO /θO into real and imaginary components (polar to rectangular conversion), summing the respective terms, and reconverting into polar form.

When using equation 1 to calculate current values for reach measurement, the test voltage VT should never exceed 69 volts. Also, the calculated pickup currents must be above 0.15 per unit because, below this level the undercurrent detectors (CS-ØA, ØB,ØC) inhibit the operation of the relay.

Equation 1 yields the nominal theoretical pickup current. The measured value will exhibit a percentage error and this error will probably increase as the test angle is shifted farther from the relay angle due to the compounding of the angle and the reach errors.

As an example of the use of equation 1, consider the following condition:

ZP = 20 ohms
θ1 = 65 degrees
θO = 40 degrees
KO = 7
VT = 60 volts
pi= 20 degrees

Begin by determining KR and θR:

$$KR\ /\theta R = 2\ /\theta 1 + KO\ /\theta O =$$
$$= 2\ /65^\circ + 7\ /40^\circ =$$
$$= (0.85 + j1.81) + (5.36 + j4.50) =$$
$$= 6.21 + j6.31 =$$
$$= 8.85\ /45.5^\circ =$$

KR = 8.85 and θR = 45.5°

Now substitute the conditions stated into equation 1:

$$I\emptyset\text{-SEL} = \frac{2.75 \times (60 - 12.55)}{20 \times 8.85 \times \cos(20^\circ - 45.5^\circ)} = 0.82 \text{ amp}$$

A2. <u>Phase to Ground Measuring Unit Tests - Mho Type Characteristic</u>

Increase the phase selector reach to its maximum value of Zp = 103 ohms (five amp relay) or 515 ohms (one amp relay) by positioning all of the switches to the right on the DSM module. This is done to make the phase selectors pick up at low levels so that attention may then be focused on the measuring unit output.

Again using the test circuit of Fig. 34, apply VT = 20 volts and IT = 6.7 amperes (5 amp relay) or 1.34 amperes (1 amp relay) to the phase under test. Vary the phase angle between IT and VT (IT lagging until the measuring unit produces a trip output, indicated by the lighting of two red target LEDs on DLM; one corresponding to the phase under test (A, B or C) and the other corresponding to a zone one trip (I). This should occur between 26 an 41 degrees. Record the angle as A3. The phase tripping contacts wired in series should close at the tripping point (terminals BB1 to AC14 for A, BB5 to AD12 for B, BB9 to AD14 for C), along with the zone one trip

Continue to increase the phase angle until the tripping unit drops out. This will be indicated by the opening of the zone one trip contact between terminals AD1 and AD2. Back up slightly on the angle adjustment to the point where the trip output just occurs and record this angle as A4. It should be between 109 and 123 degrees. The red LEDs are latching targets. They may be reset by depressing the RESET pushbutton at the bottom of the DOM module. The red A, B and C LEDs are sealed-in on fault current and may not be reset until the test current is lowered below 0.10 per unit.

Calculate the characteristic angle of the phase to ground measuring unit using the following formula:

$$\text{Ø-G MU Characteristic Angle} = \frac{A3 + A4}{2}$$

This angle must be between 72 and 78 degrees.

Now adjust the phase angle between IT and VT to 75 degrees (IT lagging), and lower the current to the point where the measuring unit just produces a trip output. Again, the zone one trip contact between terminals AD1 and AD2 is the most useful point to monitor because it doesn.t seal-in. The current at the pickup point should fall between 4.7 and 5.3 amperes (five amp relay) or between 0.94 and 1.06 amperes (one amp relay).

Conduct the above tests for all three phases.

If it is desired to check the measuring unit mho type characteristic under conditions other than those specified above, the following equation shoul be used:

$$IMU, Y = \frac{3VT}{ZR\ (2\ /)1 + KO\ 7\theta O)\ x\ \cos(\ -\theta R)}$$

Where: IMU,Y = pickup current for measuring unti: mho type characteristic (in amperes)

ZR = zone one reach as set on DRM module (I: in ohms)

and all other terms as previously described

Again, VT should never exceed 69 volts and IMU, Y must be calculated to be above 0.15 per unit. The percentage error will likely increase as the test angle is shifted farther from the relay angle.

A3. <u>Phase to Ground Measuring Unit Tests - Reactance Characteristic</u>

De-energize the test circuit, remove the DRM module, and place the X/Y link in the X position. Reinsert the module and reapply power. With VT = 20 volts and the phase angle between IT and VT set to 90 degrees (IT lagging), increase IT until a trip output is produced. This should occur at between 4.9 and 5.5 amperes (five amp relay) or at between 0.98 and 1.10 amperes (one amp relay).

Lower the phase angle to 30 degrees. The pickup point should now be between 2.5 and 3.3 amperes (five amp relay) or between 0.50 and 0.66 amperes (one amp relay).

If it is desired to check the reactance characteristic at other points, the following equation should be used:

$$I_{MU,X} = \frac{3\ V_T}{Z_R\ (2\ \angle\theta 1 + K_O\ \angle\theta O)} \times \frac{\sin}{\sin\theta R} \quad \text{(Eq. 3)}$$

Where: IMU,X = pickup current for measuring unit: reactance characteristic (in amperes) and all other terms as previously defined.

As for the phase selector and mho type measuring unit tests, VT should not exceed 69 volts. IMU,Y must exceed 0.15 per unit, and the error will likely increase as the test angle is shifted farther from the relay angle.

Return the X/Y link in the DRM module to the Y position for the remainder of these tests.

B. <u>Fuse Failure Detector Test</u>

Leave the relay connected in the test circuit of Fig. 34. The ..phase under test.. selection for this test is arbitrary. Set the relay as follow:

Switch	Location	Setting
Zp (1 amp relay)	DSM	60 ohms
(5 amp relay)	"	12 ohms
I (1 amp relay)	DRM	40 ohms
(5 amp relay)	"	8 ohms
ØZ1	DFM	75 degrees
ØZO	"	75 degrees
KO	DRM	4

Adjust VT to 69 volts so that the relay receives balanced three phase voltage. Apply a single phase test current (IT) of five amperes (five amp relay) or one ampere (one amp relay) at = 75 degrees lagging. Verify a single pole zone one trip, indicated by the lighting of the phase LED (red; A, B, or C, depending on the input terminals used) and the I LED (red). The yellow phase selector LED (A, B or C) should also light.

With the current adjustment still set for five amperes (or one ampere), completely remove the current by opening SW2 in the test circuit. Reset the latching LED targets by depressing the RESET push button on the DOM module.

Switch off one phase of the voltage by opening SW3 in the test circuit. The amber FF LED on the DLM module should not light.

Adjust the current (IT) to 0.6 amps (5 amp relay) or 0.12 amps (1 amp relay). At 75 degrees lagging, and with one phase of the voltage still off, suddenly reapply the current by closing SW2. Verify that the amber FF light on the DLM module does light, and the contact between terminals AC7 and AC8 does close.

Remove the current by opening Sw2. Adjust the current (IT) to five amperes (5 amp relay) or one ampere (1 amp relay). Close SW3, open SW1 and reapply the current by closing SW2. Verify a single pole zone one trip. Remove the current by opening SW2.

De-energize the test circuit, remove the DLM module and set the FUSE FAILURE BLOCK switch to the BLOCK position (SW1 -7 to the right). Reinsert the module and suddenly reapply the current by closing SW2. Verify that the relay does not trip.

De-energize the test circuit, and return the FUSE FAILURE BLOCK switch in the DLM module to the OFF position (SW1-7 to the left).

C. Phase to Phase Reach Tests

Connect the relay according to the test circuit shown in Fig. 35.

Set Zp on DSM to the maximum setting of 515 ohms (1 amp relay) or 103 ohms (5 amp relay): all switches to the right. Table X indicates the pickup currents for the main measuring unit (trip output) based on the relay settings and the magnitude of the test voltage. Apply the voltage VT specified in Table X and increase the current until the relay gives a trip output, indicated by the lighting of three red LEDs on the DLM module; two corresponding to the phase pair under test (A and B, B and C, or C and A) and the other indicating a zone one trip (I). Verify that the trip current is within ten percent of the value given in Table X. As mentioned earlier, these are latching targets which must be reset. The two yellow phase selector LEDs corresponding to the phase pair under test will light prior to the trip output as the current is increased. The current level at which the phase selectors operate is unimportant in this test.

Table X - Phase-to-Phase Reach Tests

Z_R					I_{MU}	
1 Amp Relay	5 Amp Relay	θ1	V_T	α	1 Amp Relay	5 Amp Relay
20	4	75	40	75	1.00	5.00
"	"	"	"	45	1.15	5.77
"	"	"	"	105	1.15	5.77

Note that the pickup level for phase-to-phase faults is independent of the θO and KO setting.

If it is desired to check the phase-to-phase reach for conditions other than those given Table X, the following equation should be used:

$$IMU = \frac{VT}{2\ ZR \cos(\ -\ \theta 1)} \qquad \text{Eq.4)}$$

When using equation 4, the test voltage, VT, should be kept below 120 volts. The calculated pickup current must be above 0.15 per unit, as discussed earlier.

Also, the angle α should be kept between 30 and 120 degrees, since both phase selectors will not operate properly outside these limits in the test circuit used (does not replicate real system conditions).

D. <u>Zone Switching Time Tests</u>

Connect the distance relay according to the test circuit shown in Fig. 36. Note that the set-up is the same as for the previous test except that a timer and switch are added. The terminals shown correspond to the C-A phase pair. Set the relay as follows:

Switch	Location	Setting
Zp (1 Amp Relay)	DSM	150 ohms
(5 Amp Relay)	"	30 ohms
I (1 Amp Relay)	DRM	15 ohms
(5 Amp Relay)	"	3 ohms
II	DRM	2 x ZI
III	"	4 x ZI
ØZ1, ØZO	DLM	75 degrees
ZONE LIMIT	DLM	Both to the left

Remove the DLM module and set the SW4-5 to the right (TRIP indication mode)

Apply a test voltage (VT) of 40 volts. Suddenly apply a test current (IT) of 8 amperes (five amp relay) or 1.6 amperes (one amp relay) at 75 degrees lagging by closing SW1 in the test circuit. Verify a three pole zone one trip, indicated by the lighting of the A, B, C and I red LEDs on the DLM module. The zone one trip contact between terminals AD1 and AD2 should close. The yellow A and C phase selector LEDs on the DSM module should also light. The timer should register 24 to 32 milliseconds for 60 hertz relays or 28 to 38 milliseconds for 50 hertz relays. This is not an accurate measurement of the zone one operating time because the test circuit does not exactly simulate system conditions during a phase-to-phase fault.

Remove the test current and reset the latching targets by depressing the RESET push button on the DOM module. Suddenly reapply a test current of five amperes (five amp relay) or one ampere (one amp relay) and verify a three pole zone two trip, indicated by the lighting of the A, B, C and II red LEDs on the DLM module. The zone two trip contact between terminals AD3 and AD4 should close and the enable reclosing contact between terminals AB7 and AB8 should open. Again, the yellow A and C phase selector LEDs on the DSM module should light. The timer should register one second.

Remove the test current, reset the targets, and repeat with a test current of three amperes (five ampere relay) or 0.6 amperes (one ampere relay). Verify a zone three trip (A, B, C and III LEDs) with a measured trip time of three seconds. The enable reclosing contact between terminals AB7 and AB8 should open one second after the current is applied when the relay switches into zone two. The zone three trip contact between terminals AD5 and AD6 should close at the time of the trip.

Repeat the test one final time with a test current of one ampere (five amp relay) or 0.2 amperes (one amp relay) and verify a zone four trip (A, B, C, and IV LEDs) with a trip time of six seconds (the reading on the IV thumbwheel switch) the zone four trip contact between terminals AD7 and AD8 should close at this time.

Return ZONE LIMIT setting to Zone I (switch I to the right and switch II to the right).

E. Out-of-Step Blocking Test (Three Phase Condition)

Connect the distance relay according to the test circuit shown in Fig. 38. Set the relay as follows:

Switch	Location	Setting
Zp(1 Amp Relay)	DSM	75 ohms
(5 Amp Relay)	,,	15 ohms
I (1 Amp Relay)	DRM	20 ohms
(5 Amp Relay)	,,	4 ohms
III	,,	2.5 x ZI
ØZ1,ØZO	DFM	75 degrees

Remove the DLM module and set the OUT OF STEP BLOCK switch in the BLOCK position (SW5-6 to the left). Reinsert the module and apply a balanced test voltage of VT = 115 volts. Adjust both variable auto-transformers as necessary so that the two voltmeter readings are as close as possible.

Apply a balanced three phase test current of IT = approximately 2.9 amperes (five amp relay) or IT = approximately 0.6 amperes (one amp relay) by closing the three pole switch (SW1). Verify that the phase selectors do not pick up (no yellow LED indication).

Remove the current by opening SW1, and decrease VT to 75 volts. Reapply the current and verify that the out-of-step blocking unit picks up in addition to all three phase selectors, as indicated by the lighting of the A, B, C LEDs on the DSM module and OSB LED on the DLM module. The out-of-step block contact between terminals AC5 and AC6 should close.

Again remove the current. Decrease VT to 30 volts. Reapply the current and verify that all three phase selectors pick up, but the out-of-step blocking unit does not pick up. With the voltage, current and reach setting specified, the closing of SW1 simulates a sudden transition from outside the phase selector characteristic to inside the permissive zone characteristic.

Remove the current one final time and decrease VT to 15 volts. Reapply the current and verify a three pole zone one trip, indicated by the lighting of the A, B, C and I red LEds on the DLM module. All three yellow phase selector LEDs (A, B, and C) should also light.

F. Out-of-Blocking Test (Phase-to-Phase Condition with One Pole Open)

A power swing is a three phase phenomenon. If one breaker pole is open, however, the relay will receive accurate inputs from only two phases. The MLS power swing detector includes additional circuitry to use phase to phase quantities to measure an out-of-step condition when one pole is open.

To test this function, connect the distance relay to the test circuit shown in Fig. 38. This is similar to the test circuit for the phase-to-phase reach test with DC inputs to CC6 to simulate a one pole open signal. The terminals shown correspond the the A-B phase pair. Set the relay as follows:

Switch	Location	Setting
Zp(1 amp relay)	DSM	50 ohms
(5 amp relay)	,,	10 ohms
I (1 amp relay)	DRM	20 ohms
(5 amp relay)	,,	4 ohms
III	,,	1.5 x ZI
ØZ1, ØZO	DFM	75 degrees

The OUT OF STEP BLOCK switch in the DLM module should be left in the IN position (SW5-6 to the left).

Adjust VT to 100 volts and, SW1 closed, IT to equal 3.5 amperes (five amp relay) or 0.7 amperes (one amp relay) at 75 degrees lagging VT. Verify that the phase selectors do not pick up.

Remove the current by opening SW1 and decrease VT to 60 volts. Reapply current and verify that the out-of-step blocking unit picks up in addition to the A and B phase selectors. Again, the contact between terminals AC5 and AC6 should close.

Again remove the current. Decrease VT to 30 volts. Reapply current and verify that the A and B phase selectors pick up, but not the out-ofstep blocking unit.

Remove the current one final time and decrease VT to 20 volts.Reapply current and verify a three pole zone one trip with no OSB indication.

De-energize the test current, remove the DLM module, and return the OUT OF STEP BLOCK switch to the OUT position (SW5-6 to the right).

G. Line Pickup Tests

The MLS contains circuitry to trip the breaker immediately (three pole) if it is closed onto a three phase zero voltage fault, as would be the case if grounding chains where inadvertently left on the line after servicing. The detector requires an overcurrent and undervoltage condition in the time interval immediately following the closing attempt. The circuit is tested as follows:

Connect the distance relay according to the test circuit shown in Fig. 39.
. No particular settings are necessary, since the overcurrent and undervoltage detectors have fixed thresholds. With SW2 open, close SW1 and verify that the unit does not trip. Quickly remove the current by opening SW1, since the input exceeds the continuous rating of the relay.

Close SW2. This simulates the line pickup signal from the recloser. Now close SW1 a second time before the line pickup timer times out (approximately 128 milliseconds), and verify a three pole trip, indicated by the lighting of the A, B, C and red LEDs on the DLM module. No zone targets should light, only the three phase targets.

H. Pilot Scheme Tests

Connect the distance relay according to the test circuit shown in Fig. 40. Note that the set-up is similar to that used for the single phase to ground reach tests except for the addition of a contact monitor and another DC input. The contact monitor verifies that the relay under test (local relay) properly initiates its associated transmitter while the DC input simulates the receipt of a channel signal from the remote relay. The terminals shown correspond to an A-G test. Set the relay as follows:

Switch	Location	Setting
Zp(1 amp relay)	DSM	60 ohms
(5 amp relay)	"	15 ohms
I (1 amp relay)	DRM	20 ohms
(5 amp relay)	"	4 ohms
II	"	1.5 x ZI
III	"	2.0 x ZI
ØZ1	DFM	75 degrees
ØZO	"	75 degrees
KO	DRM	

NOTE: The pickup currents specified in the forthcoming Pilot Scheme Tests may vary by ± 5%. These tests are not intended to check the accuracy of the reaches, but rather the proper operation of the scheme logic.

H1. Zone 2 Acceleration Test

To check the zone 2 acceleration scheme, remove the DLM module and set the LOGIC switches as follows:

SW2-6: Left
SW2-7: Right
SW2-8: Left

Reinsert the module and check that the NCT switch is to the left. Leave SW1 open. Apply power and with VT at 40 volts, increase the current from zero. The A phase selector should pick up when IT reaches 0.84 amperes (five amp relay) or 0.17 amperes (one amp relay). Continue to increase the current and verify a single pole zone two channel trip when IT reaches 3.33 amperes (five amp relay) or 0.66 amperes (one amp relay). This is the pickup point of zone two. The trip is indicated by the lighting of the A, II, and CH red LEDs on the DLM module. The KEY TRANSMITTER contact between terminals AB1 and AB2,, and the CHANNEL TRIP contact between terminals AB5 and AB6 should also close at this point.

Lower the current, reset the targets and move the NO CH TRIP switch on the DTM101 module to the right. Increase the current again. The phase selector should pick up at the same point but there should not be a channel trip when IT reaches 3.33 amperes (five amp relay) or 0.66 amperes (one amp relay). Continue to increase the current and verify a single pole zone one trip when IT reaches 5.00 amperes (five amp relay) or 1.00 amperes (one amp relay). The KEY TRANSMITTER contact should also close at this point, but the CHANNEL TRIP contact should not close.

Repeat this test with the NCT switch to the left, but with SW1 closed in its place (CC2, Block Channel Trip). The results should be the same.

H2. Permissive Underreaching Transfer Tripping Tests

To check the permissive underreaching transfer tripping scheme, remove the DLM module and set the logic switches as follows.

SW2-6: Right
SW2-7: Right
SW2-8: Left

H2.1 Reinsert the module. Leave the NCT switch to the left and open SW1. Apply power and, with VT at 40 volts, increase the current from zero. The A phase selector should pick up when IT reaches 0.84 amperes (five amp relay). Continue to increase the current and verify a single pole channel trip when IT reaches 2.50 amperes (five amp relay) or 0.50 amperes (one amp relay). This is the pickup point of the permissive zone. The trip is indicated by the lighting of the A and CH red LEDs on the DLM module. The KEY TRANSMITTER and

CHANNEL TRIP contact should also close at this point.

H2.2 Lower the current, reset the targets, and move the NCT switch on the DLM module to the right. Increase the current again. The phase selector should pick up at the same point but there should not be a channel trip when IT reaches 2.50 amperes (five amp relay) or 0.50 amperes (one amp relay). Continue to increase the current and verify a single pole zone one trip when IT reaches 5.00 amperes (five amp re- lay) or 1.00 amperes (one amp relay). The KEY TRANSMITTER contact should also close at this point, but the CHANNEL TRIP contact should not close. Repeat this test using SW1 to block channel tripping instead of the NCT switch on DLM. The results should be the same.

H3. <u>Permissive Overreaching Transfer Tripping Tests</u>

To check the permissive overreaching transfer tripping scheme, remove the DLM module and set the logic switches as follows.

SW2-6: Left
SW2-7: Left
SW2-8: Right

Reinsert the module. Leave the NCT switch to the left and open SW1. Apply power and, with VT at 40 volts, increase the current from zero. Because of the nature of the test circuit, the results should be identical to those specified for the permissive underreaching test.

That is, the A phase selector should pick up when IT reaches 0.84 amperes (five amp relay) or 0.17 amperes (one amp relay); there should be a single pole channel trip and the KEY TRANSMITTER and CHANNEL TRIP contact should close when IT reaches 2.50 amperes (five amp relay) or 0.50 amperes (one amp.)

H4. <u>Hybrid scheme check (Optional)</u>

Pull out module DLM and modify the following switch settings:

SW2-6: Right
SW2-7: Right
SW2-8: Right

Pull out module DBM and substitute it with an empty extender. Jumper points 2 and 6 of the extender. This jumper simulates the operation of MB units and inhibits the hybrid scheme specific operation, transforming it into POTT for the first part of the test.

Carry out the tests indicated in the above section corresponding to scheme POTT. The results should be the same.

Open SW2 switch of the test circuit. Remove the jumper from the extender and connect it again between points 1 and 6, in order to simulate the non-operation of the MB units.

Apply a current of 1 Amp (five amp relays) or .2 amps (one Amp relays). With this current phase selectors are activated and, together with the non-operation of the blocking units allows the activation of the hybrid scheme function.

Close SW2 switch and check that a trip per channel is produced, indicated by the lighting up of A, B, C and CH LEDS in module DLM. WI LED will also have lit up, indicating that the trip has been produced by the operation of the hybrid scheme. The transmission starting contact (during 50 milliseconds) between terminals AB1 and AB2 and the trip per channel indication contact between terminals AB5 and AB6 will be closed.

Remove the current, open SW1 switch and reset the signals of module DLM. Disenergize the test circuit, pull out module DLM and arrange the logic selectors as follows:

SW2-6: Left
SW2-7: Left
SW2-8: Left

This adjustment corresponds to the stepped distance scheme.

I. Auxiliary functions check

The MLS is provided with contact converter inputs for the following auxiliary functions:

- Three phase trip
- Trip blocking
- Signal remote reset
- Direct trip

In order to check these functions, connect the relay as indicated in Figure 4t. The circuit is similar to the one used for single phase reach tests, except for the addition of four switches in order to simulate the external contacts operation for auxiliary functions. The terminals correspond to an A-G fault. Adjust the relay as follows:

	Switch	Location	Adjustment
Zp	(1 Amp relay)	DSM	30 ohms
	(5 Amp relay)	"	6 ohms
I	(1 Amp relay)	DRM	20 ohms
	(5 Amp relay)	"	4 ohms
ØZ1		DFM	75°
ØZ2		"	75°

With SW3, 4, 5 and 6 opened, apply VT = 40 Volts and IT = 6 Amps (five Amp relays) or 1.2 Amps (one Amp relays). Check that a single phase trip is produced (phase A) in zone one. Remove the current and close SW3 in order to arrange the relay for a three phase trip. Apply the current again and check that a three phase trip is produced in zone one (SW4-5 breaker, inside module DLM must be set to the left - signaling mode in trip). Remove the current.

Close SW5 momentarily and check that the DLM module red LED's are reset.

Close SW4 in order to block the trip. Apply the current again and check that the relay does not trip. The phase selector must be activated while current is applied. No indicator in DLM module is activated.

Remove the test current. Close switch SW6 momentarily and check that a three phase trip is produced with activation of A, B and C indicators at the front of the DLM module. No zone indicator will be activated.

J. <u>Recloser check</u>

Connect the MLS system as indicated in Figure 42. Once again, the circuit is similar to the one used to check single phase reach, with the necessary wiring for the recloser. Adjust the distance relay as follows:

Switch		Location	Adjustment
Zp	(1 Amp relay)	DSM	75 ohms
	(5 Amp relay)	"	15 ohms
I	(1 Amp relay)	DRM	50 ohms
	(5 Amp relay)	"	10 ohms
ØZ1		DFM	75°
ØZo		"	75°
Ko		DRM	4

Module RLM must be adjusted as shown in tables VIII and IX.

Adjust VT = 20 Volts. With SW1 closed, adjust IT = 1.7 Amps (five Amp relays) or 0.24 Amps (1 Amp relays). This current is enough to provide a trip in zone one. Open SW1 and reset the indicators. Also reset the recloser by pressing RST button at the front of the module RLM. The recommended time adjustment in these tests is long enough that a clock with a second hand is sufficient for this test.

J1. Automatic Reclose: Two attempts

Apply a current pulse by momentarily pressing SW1. The rest of the test circuit switches must be left open. Check that the reclosing cycle is correct, indicated by the lighting of OPN LED at the front of the RLM module and by the closing of the contact between BO3 and BO4 terminals. Also, the distance relay must indicate a phase A trip, in zone one.

Check that the reclosing contacts close between BO9 and BO10, BO11 and BO12, BO13 and BO14 terminals five seconds after the trip. The five seconds correspond to 10 adjustment at the front of the RLM module. Check that the reclosing contacts open 0.8 seconds after closing. The OPN LED will go out when the reclosing contacts open. The contact between BO3 and BO4 will remain closed.

Summing up:

1) Press SW1 momentarily: Phase A trip in zone one; OPN indication and closing of the contact between BO3 andBO4.

↓ 5 seconds

2) Check the closing of contacts between: BO9 and BO10, BO11 and BO12, BO13 and BO14.

↓ 0.8 seconds

3) Check that the contacts closed in point 2) open. The OPN LED will go out. The contact between BO3 and BO4 will remain closed.

Reset the distance relay indicators, but do not reset the recloser. Before the reset time is over (60 seconds - RST adjustment at the front of the RLM module), apply a second current pulse by pressing SW1. The OPN LED will light up again (contact between BO3 and BO4 is still closed) and the distance relay will indicate a three phase trip in zone one. Check that 15 seconds later all three reclosing contacts close. The 15 seconds correspond to DLY adjustment at the front of the RLM module. Check that the reclosing contacts open 0.8 seconds after closing and that at that moment the OPN LED goes out. The contact between BO3 and BO4 is still closed.

Summing up:

1) Press SW1 momentarily: Three phase trip in zone one; OPN indication.

↓ 15 seconds

2) Check the closing of contacts between: BO9 and BO10, BO11 and BO12, BO13 and BO14.

↓ 0.8 seconds

3) Check that the contacts closed in step 2) open.

The OPN LED will go out. The contact between BO3 and BO4 will remain closed.

Reset the distance relay indicators again without resetting the recloser. Before the reset time is over, apply a third current pulse. It should be noted that the reset time is restarted with the second reclose and does not end until 60 seconds later. Check that the recloser is immediately blocked, indicated by the lighting up of L/O LED at the front of the RLM module and by the closing of the contact between BO7 and BO8 terminals. The distance relay will indicate a three phase trip in zone one. The contact between BO3 and BO4 will open.

Summing up:

1) Press SW1 pushbutton momentarily. Three phase trip in zone one, lighting up of L/O LED, closing of contact between BO7 and BO8 and opening of the contact between BO3 and BO4.

Reset the distance relay indicators, and reset the recloser. When resetting the recloser, L/O will go out and the contact between BO7 and BO8 will open.

J2. Automatic Reclose: Single phase only

Move 3Ø and DLY switches, located at the front of the RLM module to the left. Apply a current pulse. Check that a phase A trip is produced in zone one, and a reclose five seconds later. Reset the distance relay indicators.

Apply a second current pulse before the reset time is over. Check that a three phase trip is produced in zone one, but without starting of the recloser. The OPN LED will not light up neither will the reclosing contacts close.

Reset the distance relay signals and reset the recloser. Place 3Ø and DLY breakers back at the front ofthe RLM module to the right.

J3. Automatic Reclose: Three phase only

Move the 1Ø switch, located at the front of the RLM module to the left. Apply a current pulse. Check that a three phase trip is produced, and a reclose nine seconds later. The nine seconds correspond to the adjustment of the set of eight switches called 3Ø at the front of the RLM module. Reset the distance relay indicators.

Apply a second current pulse before the reset time is over. Check that a three phase trip is produced followed by a close fifteen seconds later. These fifteen seconds correspond to the adjustment of the set of eight switches called DLY, located at the front of module (RLM). Reset the distance relay signals.

Apply a third current pulse before the reset time is over. Check that a three phase trip is produced as well as the immediate blocking of the recloser. Reset the distance relay signals and reset the recloser. Place 1Ø switch back at the front of the RLM module, to the right.

J4. Automatic Reclose: One attempt

Move DLY microswitch, located at the front of module RLM, to the left. Apply a current pulse. Check that a single phase trip is produced and followed by areclose five seconds later. Reset the distance relay signals.

Apply a second current pulse; a three phase trip will be produced and the recloser will be immediately blocked. Reset the distance relay and recloser signals. Reset DLY switch to the right.

J5. Manual Reclose

Press SW5 button, which simulates a manual close command, and before the reset time is over, apply a current pulse. A three phase trip will be produced as well as the immediate blocking of the recloser. Reset the distance relay signals.

Press SW5 button again, and the recloser will be reset. Before the reset time is over, apply a current pulse; a three phase trip will be produced as well as the immediate blocking of the recloser. Reset the distance relay and recloser signals.

J6. Zone I Extention

Disconnect the system and select, (inside the DLM module), the zone one extension scheme. Change the zone one reach from ten to seven ohms(5 Amp relays) or from 50 to 35 ohms (one Amp relays), at the front of the DRM module. The adjustment of Ix, also at the front of DRM must be set to 1.5.

Energize the circuit and check that the test current is still 1.2 Amps (five Amp relays) or 0.24 Amps (one Amp relays). The current level is critical in this test. Reset the distance relay signals and reset the recloser.

Apply a current pulse. Check that a single phase trip is produced in zone one followed by a reclose five seconds later. Reset the distance relay signals but do not reset the recloser.

Before the reset time is over, apply a second current pulse; check that the distance relay does not trip. The phase selector yellow LED must remain lit during the time current is applied. The distance relay will not trip since zone one extension has been pulled back after the first reclosing attempt. It must be noted that the recloser does not operate because the distance relay does not trip.

Reset the recloser and close SW7 switch in the test circuit. This provides the distance relay with a pull back external signal of the extended zone. Apply a current pulse and check that the distance relay does not trip. Once again, phase A selector will operate as long as the test current is applied. As before, the recloser will not operate.

Deenergize the test circuit and reset, inside the DLM module, the stepped distance scheme. Readjust the zone one reach, located at the front of module DRM, to ten ohms (five Amp relays) or to 50 ohms (one Amp relays).

J8. Recloser in OFF position

Energize the test circuit again and reset switches 1Ø, 3Ø and DLY, located at the front of the RLM module, to the left. The open contact between terminals A013 and A014 must be closed. Apply a current pulse and check that a three phase trip is produced as a result from setting the recloser to the OFF position. Also check that the reclosing contacts do not close.

K. Directional Comparison Blocking Tests (optional)

Remove the DLM module and set the relay for the directional comparison blocking scheme:

SW2-6: Right;
SW2-7: Left;
SW2-8: Right.

The SEND and CHSP switches should be left in the normal position but the RCVR link should be placed in the INV position.

K1. Reach Test for MB Blocking Units

Connect the distance relay according to the test circuit shown in Fig. 43. This is similar to the test circuit for the single phase to ground reach tests, except the current is applied in the reverse direction. It is not necessary to connect the timer for this portion of the tests. Leave SW2 open.

Apply a voltage of VT = 60 volts to the phase under test and apply normal line-to-neutral voltage (69 volts) to the other two phases. Apply a single phase current of IT = 7 amperes (five amp relay) or 1.4 amperes (one amp relay) to the phase under test.

Vary the phase angle between IT and VT (IT lagging) until the MB unit picks up, indicated by the closure of the KEY TRANSMITTER contact between terminals AB1 and AB2. This should occur at an angle between 28 and 44 degrees. Record this angle as A7.

Continue to increase the phase angle until the MB unit drops out (KEY TRANSMITTER contact opens) and then back up slightly to the point where the unit just picks up. This should occur at an angle between 106 and 122 degrees. Record this angle as A8.

Calculate the characteristic angle of the MB unit as follows:

$$\text{MB Unit Characteristic Angle} = \frac{A7 + A8}{2}$$

This angle should fall between 72 and 78 degrees.

Now adjust the phase angle between IT and VT to 75 degrees (IT lagging), and lower the current to the point where the MB unit just picks up. This should occur between 5.2 and 5.7 amperes (five amp relay) or between 1.04 and 1.14 amperes (one amp relay).

Conduct the above tests for all three phase pairs.
If it is desired to check the reach of the MB units for conditions other than those specified above, use equation 1, substituting IMB for IO-SEL and ZB for Zp.

K2. Zone Five Timer Tests

Set the zone five timer to 6.4 seconds. The ZV TRIP switch must be to the right. Connect the timer into the test circuit.

Adjust the variable auto-transformers so that the test current and voltage are sufficient to pick up the MB unit when SW1 is closed. It is advisable to use a current which exceeds the pickup current by a significant margin to insure operation. Check that the switches 1Ø, 3Ø and DLY on RLM module are to left to disable reclosing.

Close SW1 and measure a trip time of 6.4 seconds (within three percent).

Repeat for each of the three phases.

If it is desired to check the zone five timer at settings other than 6.4 seconds, readjust the setting switches on DBM module and repeat the timing test. Open the ZV TRIP switch on DBM101 when the tests are completed.

K3. Scheme Tests (Tripping and Blocking Action)

To test the ability of the relay to trip and block in the directional comparison blocking mode, it is necessary to reverse the current inputs shown in Fig. 43 so that the fault now appears in the forward direction. Using phase A as a reference, this is accomplished by connecting the lead labelled T to TP8A or BD5, and by connecting the lead labelled Z to TP7A or BD1. The voltage inputs should be as indicated in the table for phase A. It is not necessary to connect the timer for this portion of the tests. Set the distance relay as follows:

Switch	Location	Setting
Zp(1 amp relay)	DSM	60 ohms
(5 amp relay)	''	15 ohms
I (1 amp relay)	DRM	20 ohms
(5 amp relay)	''	4 ohms
III	''	2.0 x ZI
ØZ1,ØZO	DFM	75 degrees
KO	DRM	4

Adjust the variable auto-transformers so that VT = 40 volts and IT will be 3 amperes (five amp relay) or 0.6 amperes (one amp relay) when SW1 is closed.

With SW2 open, apply current by closing SW1. Verify a three pole channel trip (with the recloser out-of-service, all trips will be three pole), indicated by the lighting of the A, B, C and CH LEDs on DLM, and the closure of the CHANNEL TRIP contacts between terminals AB5 and AB6. The STOP TRANSMITTER contacts between terminals AB4 should also close while current is applied.

Remove current and close SW2. This simulates the receipt of a blocking signal from the remote terminal. Reset the targets and reapply current. Verify that the relay does not trip. The STOP TRANSMITTER contact between terminals AB3 and AB4, however, should still close while current is applied.

Remove current, open SW2, and move the NCT switch on the DLM module to the right. Reapply current and again verify no trip. As before, the STOP TRANSMITTER contact shoul close. Remove current and return the NCT switch to the left.

De-energize the test circuit, remove the DLM module, and return the relay to the stepped distance mode. Also return the RCVR link to the normal position.

M. <u>Synchronism check (Optional)</u>

Recloser Supervision Check

Connect the system as shown in figure 42. Adjust the distance relay as shown below:

Switch		Location	Adjustment
Zp	(1 Amp relay)	DSM	60 ohms
	(5 Amp relay)	"	15 ohms
I	(1 Amp relay)	DRM	50 ohms
	(5 Amp relay)	"	10 ohms
ØZ1		DFM	75°
ØZo		"	75°
Ko		DRM	4

Adjust VT = 40 Volts. With SW1 closed, adjust IT = 1.7 Amps (five Amp relays) or 2.4 Amps (1 Amp relays). This current is enough to provide a trip in zone one. Open SW1 and reset the indicators. Also reset the recloser.

Move 1Ø and DLY breakers, located at the front of module RLM to the left and 3Ø to the right. Apply a current pulse. Check that a three phase trip is produced and, nine seconds later, a reclose. Reset the distance relay signals. Since line and bus voltages have not been connected and are registered as absent and module SVM has been adjusted to allow reclosing in line and bus voltage absence conditions, the recloser operates as described.

Reset the recloser. On the front of the SMV module, set the DLDB switch to the right, and SYNC CK to the right.

Apply a current pulse again and check that a three phase trip without further reclose is produced (reclosing contacts do not close at any time). After nine seconds, the N/S red LED will light up indicating that the reclosing attempt has been blocked by the synchronism check module. In the SYNC CK mode, the presence of line and bus voltage is required in order to allow for reclose. Since they have not been connected, they are registered as absent and the reclose is blocked.

TEST NOTE:

The preceding tests verify the ability of the synchronism check module to work in conjunction with the recloser. With that established, it is recommended that the remaining tests monitor only the outpup of the SVM module so as to avoid repeated runs through the reclosing sequence. The test circuits and procedures described subsequently follow this approach.

Voltage Level Tests

Connect the MLS according to the test circuit given in Figure 44. The MVM module should be removed, a card extender inserted, and the module reinserted into the card extender. This is done for the purpose of viewing the three red LEDs within the SVM module. Remove the RLM module altogether in order to preclude operation of the recloser.

Apply the line and bus voltages and adjust Vline while watching red LED TL3 (closest LED to bottom edge of board). When this LED is lit, reclosing is permitted; when it is out, reclosing is blocked. Check the thresholds for each mode of operation. To check the thresholds at other than 20 and 80 percent (dead and live, respectively), the setting switches within the module need to be adjusted.

TL3 should be energized only when:

1. LLDB a) Vline is above 55 volts and
   b) Vbus is below 14 volts

2. DLLB a) Vline is below 14 volts and
   b) Vbus is above 55 volts

3. DLDB a) Vline is below 14 volts and
   b) Vbus is below 14 volts

Angle Tests

Connect the MLS according to the test circuit of Fig. 45. SVM module should remain on a card extender and RLM should still be out.

"Dead Time" Timer Tests

With the angle on the SVM module set to 30 degrees, adjust the applied test angle to 20 degrees and then allow 20 seconds for the circuit to stabilize. Open SW1 and close it in less than three seconds (dead time setting). Verify that TL1 lights and TL3 goes out when SW1 is open, and that the pattern reverses almost immediately when SW1 is closed (actually 167 milliseconds after; the delay of the high set slip detector). TL2 should not light during this test sequence.

Repeat the above test, but this time wait longer than three seconds before closing SW1. When SW1 is closed, verify that TL1 goes out and TL2 lights immediately, but TL3 remains out. Approximately 13 seconds later, TL2 should go out and TL3 should light concurrently, corresponding to the time delay of the low set slip detector. This verifies that the dead time timer has switched the synchronism check circuit out of the high speed mode.

Low Set Only Operation

Move the LOW SET ONLY miniature switch in the SVM module towards the bottom of the board. Leave the angle setting at 30 degrees and the applied test angle at 20 degrees. Again open SW1 and close it in less than three seconds. Verify that TL1 and TL2 light when SW1 is open (TL3 goes out), and that only TL1 goes out initially when SW1 is closed (TL3 remains out). Approximately 13 seconds later, TL2 should go out and TL3 should light concurrently. This time the circuit has been taken out of the high speed mode by the LOW SET ONLY switch. Return this switch to its normal position (towards top of board).

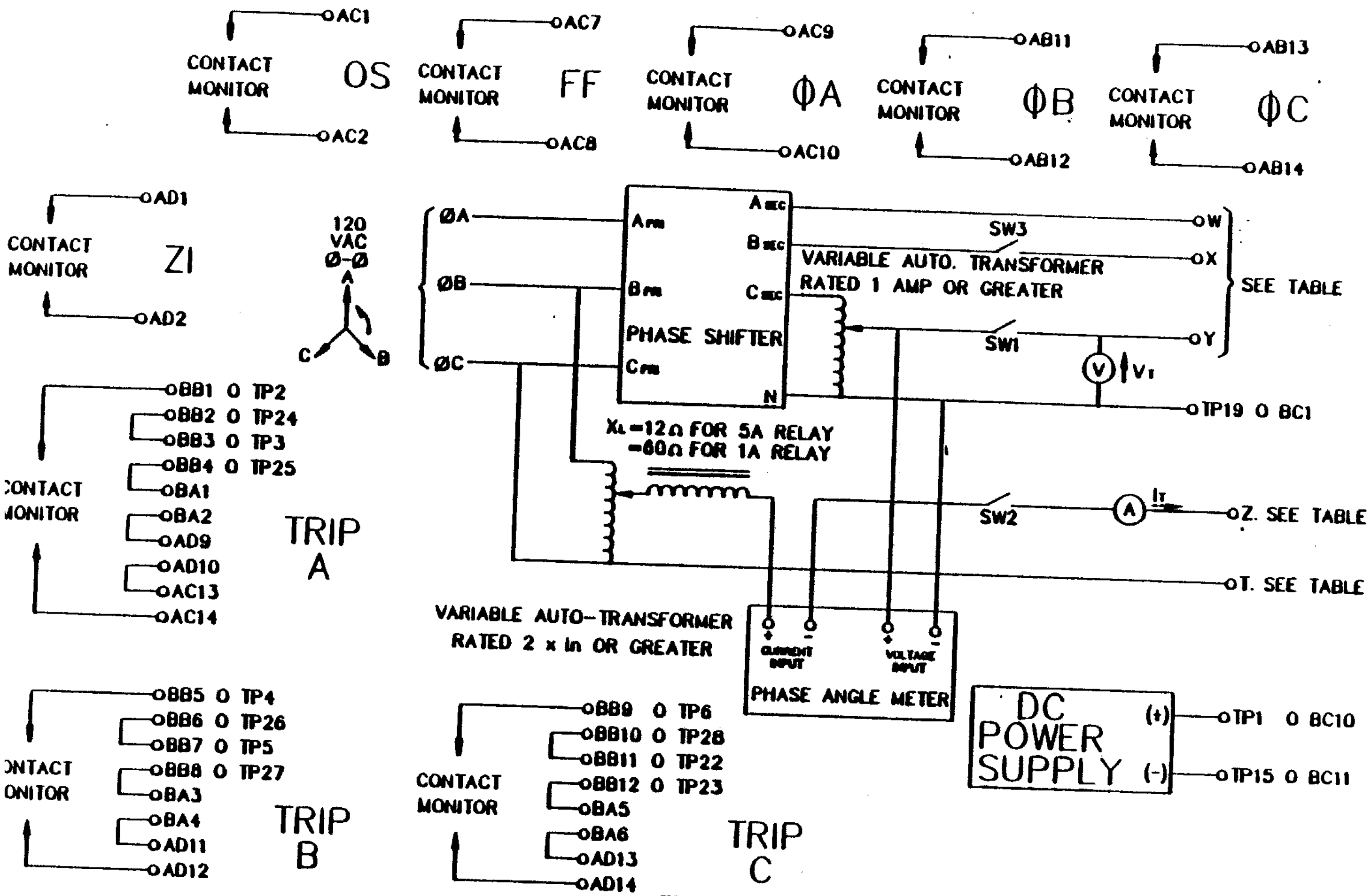
SLip Test

With the angle setting still at 30 degrees, the applied test angle still
at 20 degrees, and SW1 closed, allow another 20 seconds for stabilization. TL3 should be the only LED lit. Now swing the test angle from 20 to 200 degrees in ten seconds or less to simulate a slip condition. When the angle exceeds 30 degrees, TL1 should light and TL3 should go out. When the angle reaches 180 degrees, TL2 should light because the test angle has swung through one full quadrant (90° to 180°) in less time than allotted by the low set slip detector, TLS, where:

$$TLS = \frac{1}{4} \times \frac{1}{FLS} = \frac{1}{4} \times \frac{1}{.02} = 12.5 \text{ seconds}$$

Thus, the synchronism check circuit interprets this test as a slip condition in which the slip frequency is exceeding the low slip cut-off (.02 hertz) and gives an output accordingly (TL2 lights). If the angle is left at 200 degrees, TL2 should go out 12.5 seconds after crossing through 180°, but TL1 will remain lit up and TL3 will be remain off.

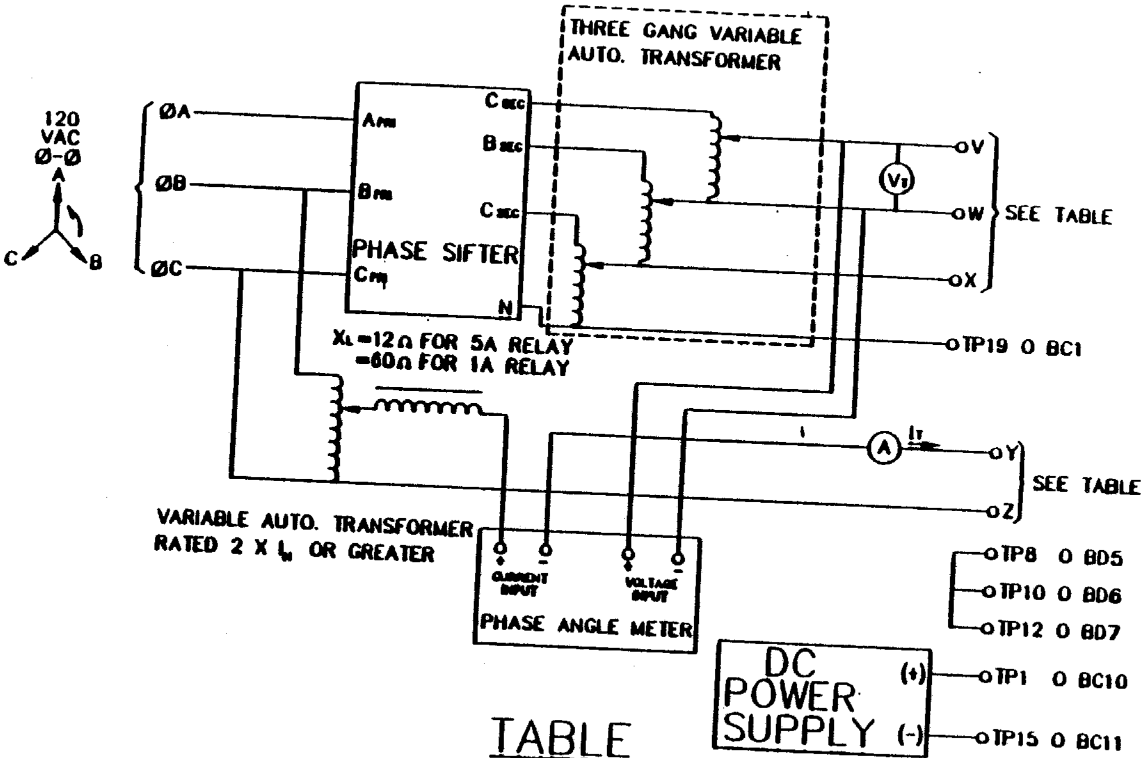
Return the test angle to 20 degrees, and again allow 20 seconds for stabilization. TL3 should be the only LED lit. Now slowly swing the test angle from 20 to 200 degrees so that it traverses the 90 to 180 degrees span in greater than 12.5 seconds. However, since the simulated slip is slower than the cut-off, TL2 should not light at any point.



TABLE

PHASE UNDER TEST→	A	B	C
CONNECT "W" TO TERMINAL	TP17 OR BC3	TP18 OR BC4	TP16 OR BC2
"X"	TP18 BC4	TP16 BC2	TP17 BC3
"Y"	TP16 BC2	TP17 BC3	TP18 BC4
"Z"	TP7 BD1	TP9 BD2	TP11 BD3
CONNECT "T" TO TERMINAL	TP8 OR BD5	TP10 OR BD6	TP12 OR BD7

Figure 34 (226B7445 Sh 1): Phase to Ground Reach Tests.



TABLE

PHASE UNDER TEST→	A-B	B-C	C-A
CONNECT "V" TO TERMINAL	TP16 OR BC2	TP17 OR BC3	TP18 OR BC4
"W"	TP17 BC3	TP18 BC4	TP16 BC2
"X"	TP18 BC4	TP16 BC2	TP17 BC3
"Y"	TP7 BD1	TP9 BD2	TP11 BD3
CONNECT "Z" TO TERMINAL	TP9 OR BD2	TP11 OR BD3	TP7 OR BD1

NOTE 1: REMOVE DOM AND RLM MODULES FOR PERIODIC TESTS

Figure 35 (226B7445 Sh 2): Phase to Phase Reach Tests.

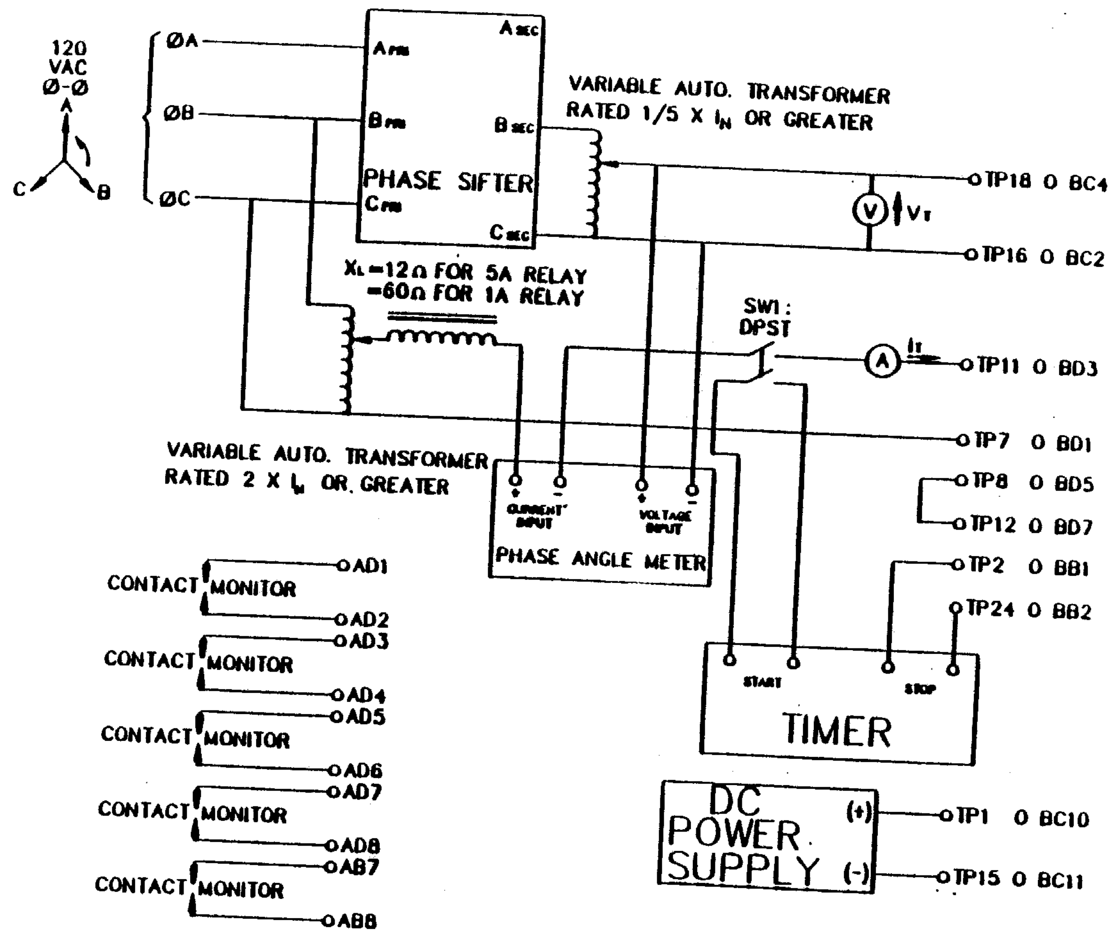


Figure 36 (226B7445 Sh 3): Zone Timer Tests.

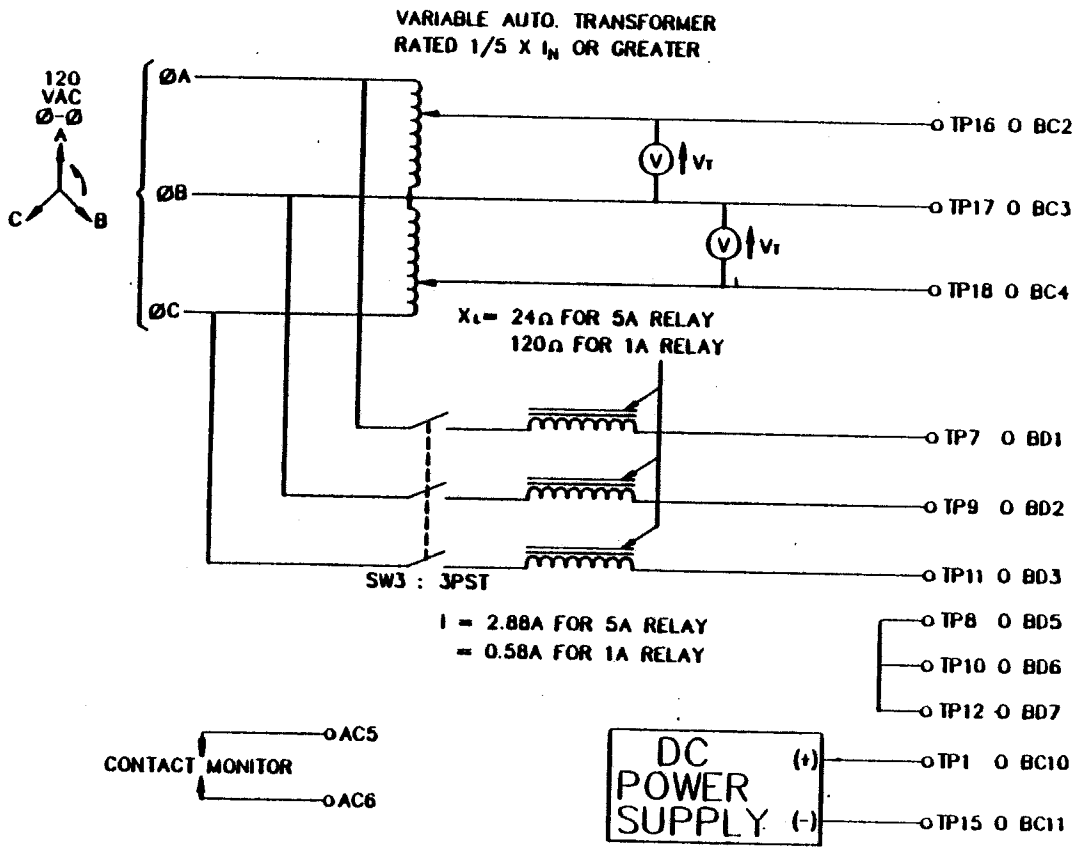


Figure 37 (226B7445 Sh 4): Out-of-Step - 3 Phase Test.

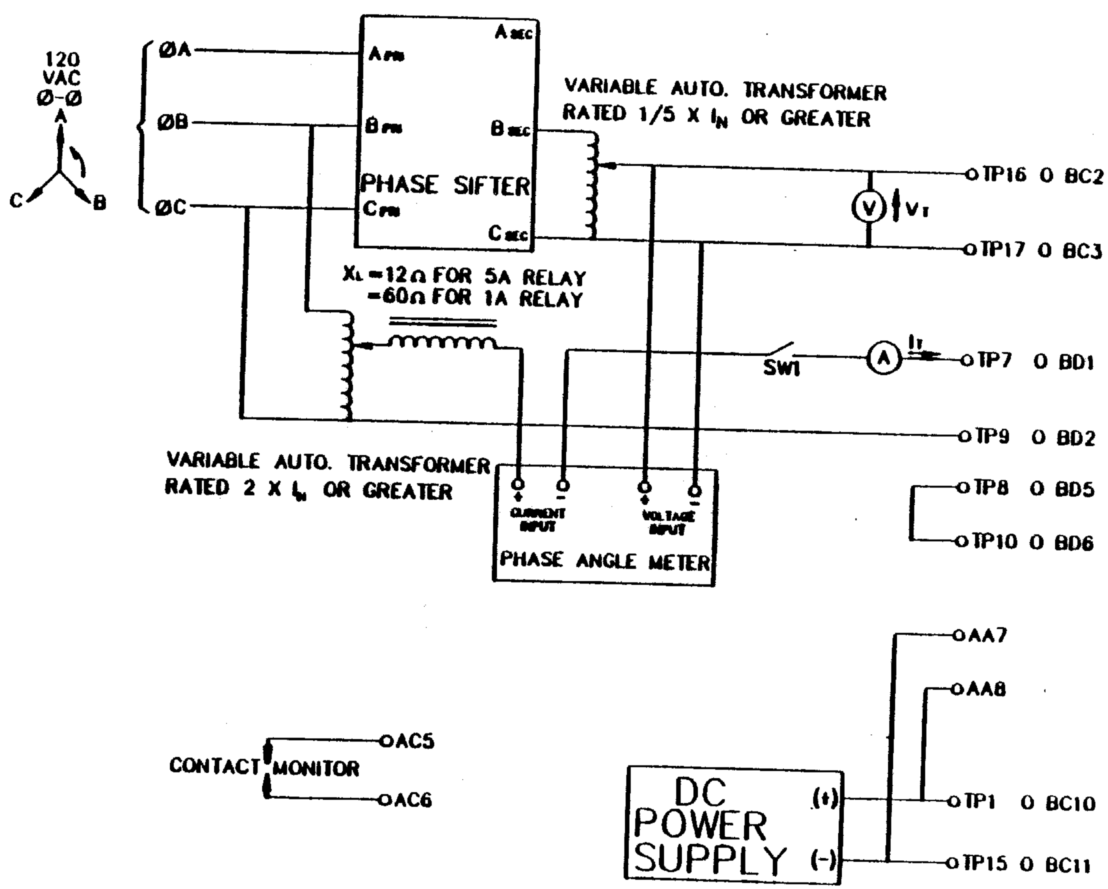


Figure 38 (226B7445 Sh 5): Out-of-Step Test (ϕ-ϕ).

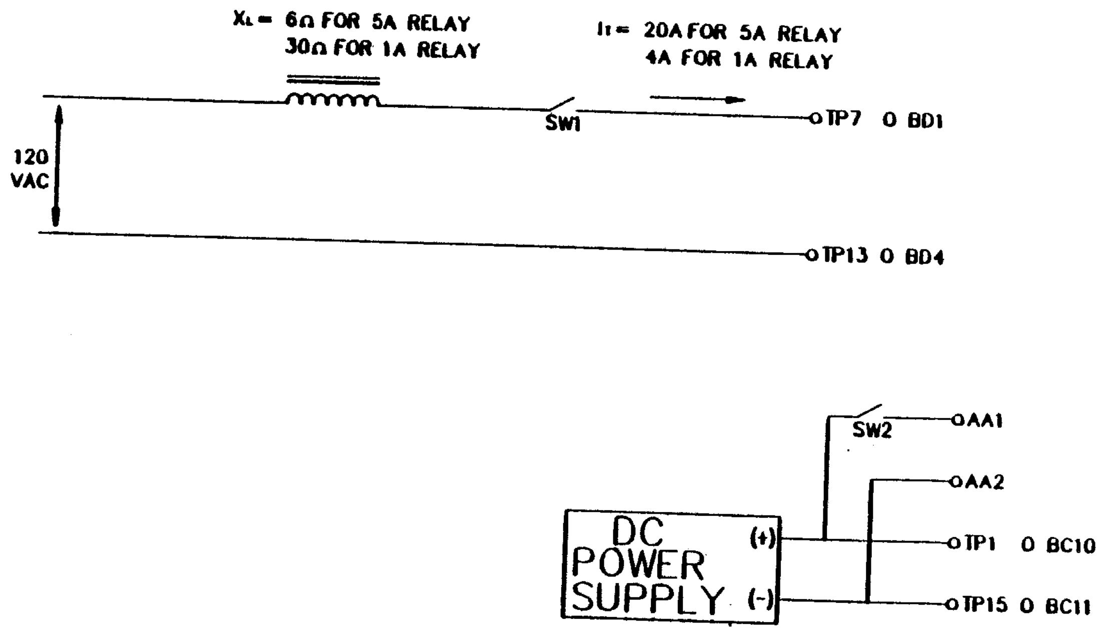


Figure 39 (226B7445 Sh 6): Line Pick-Up Tests.

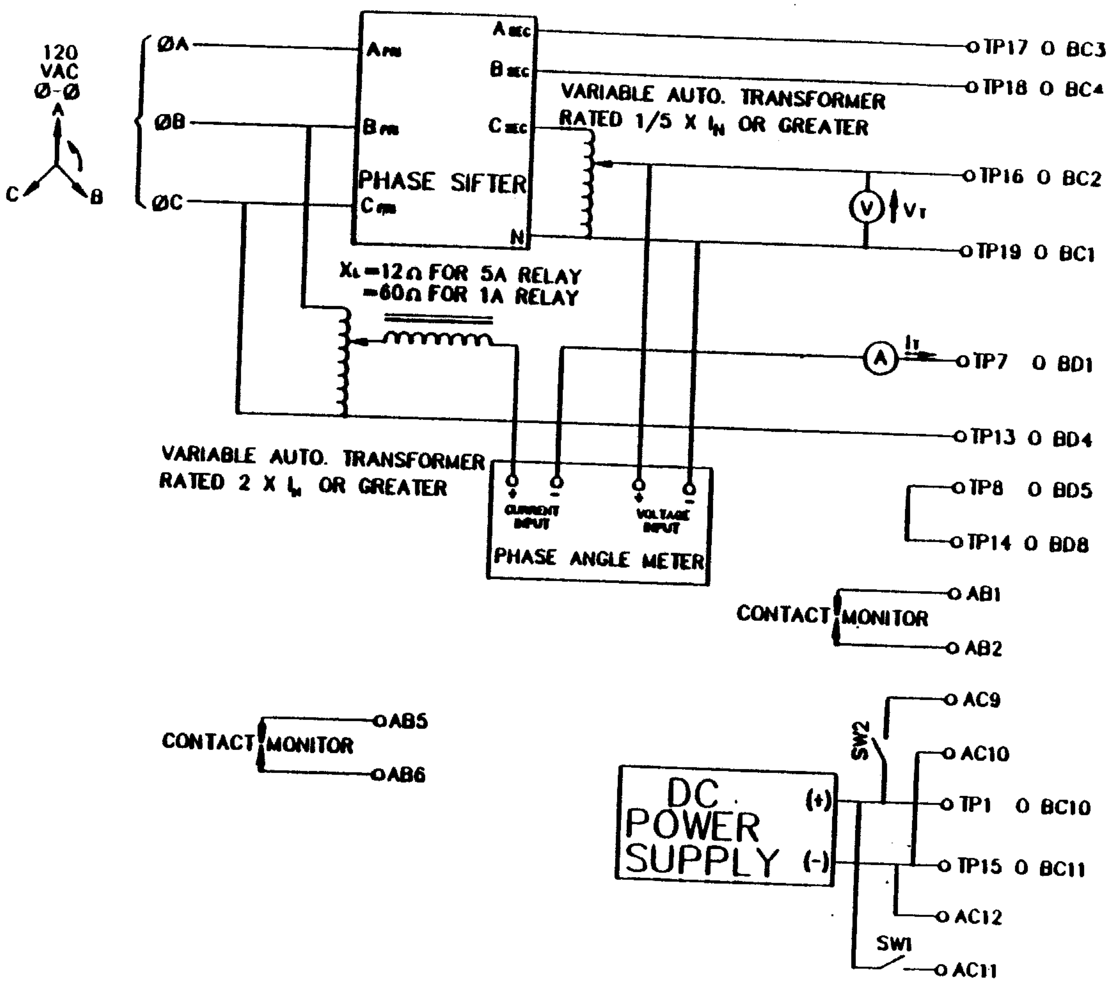


Figure 40 (226B7445 Sh 7): Pilot Scheme Tests.

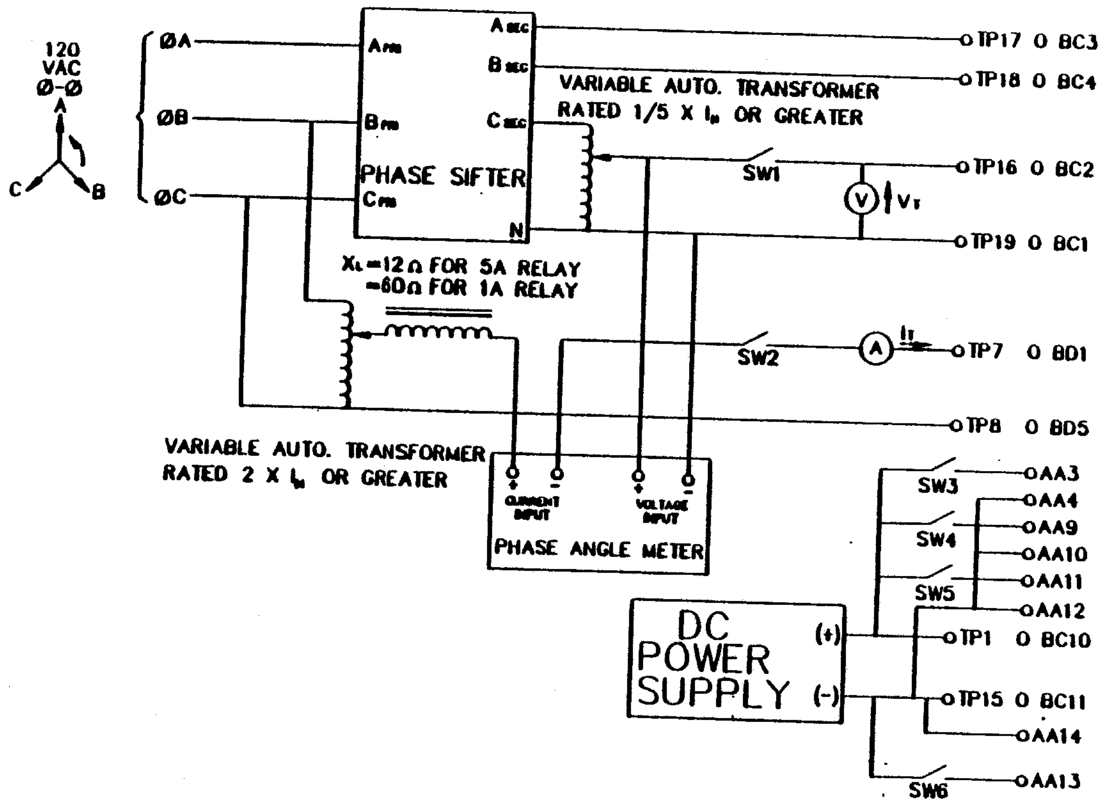


Figure 41 (226B7445 Sh 8): Test Circuit for Auxiliary Functions Requiring Contact Inputs.

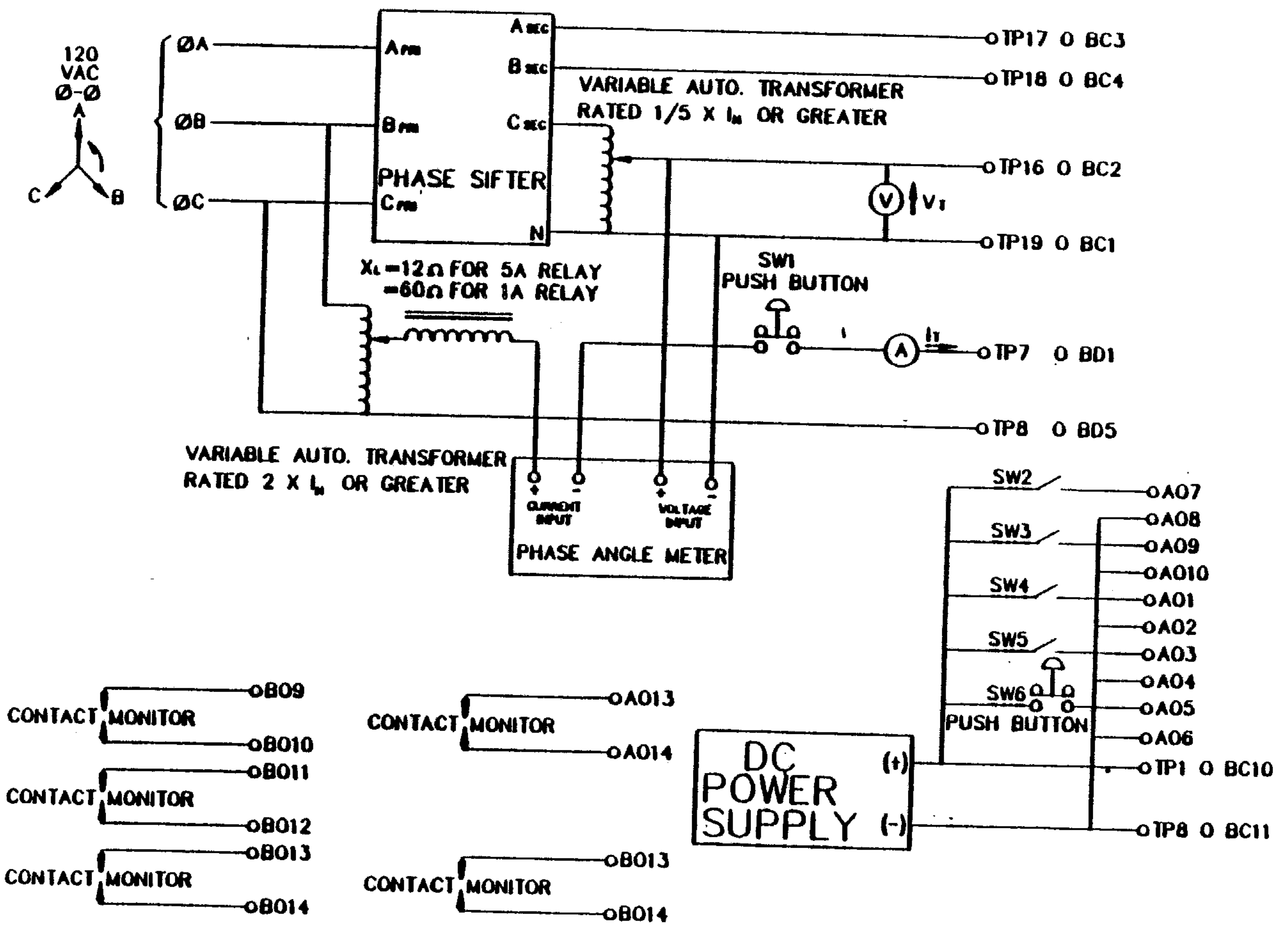
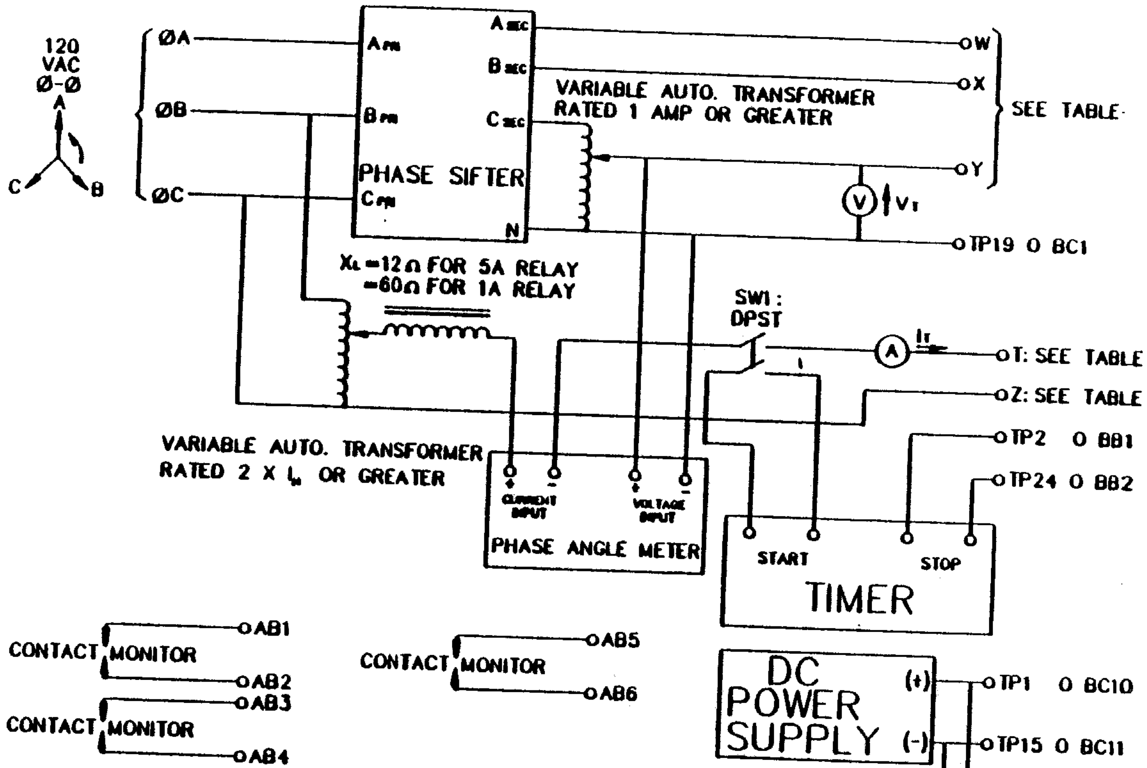


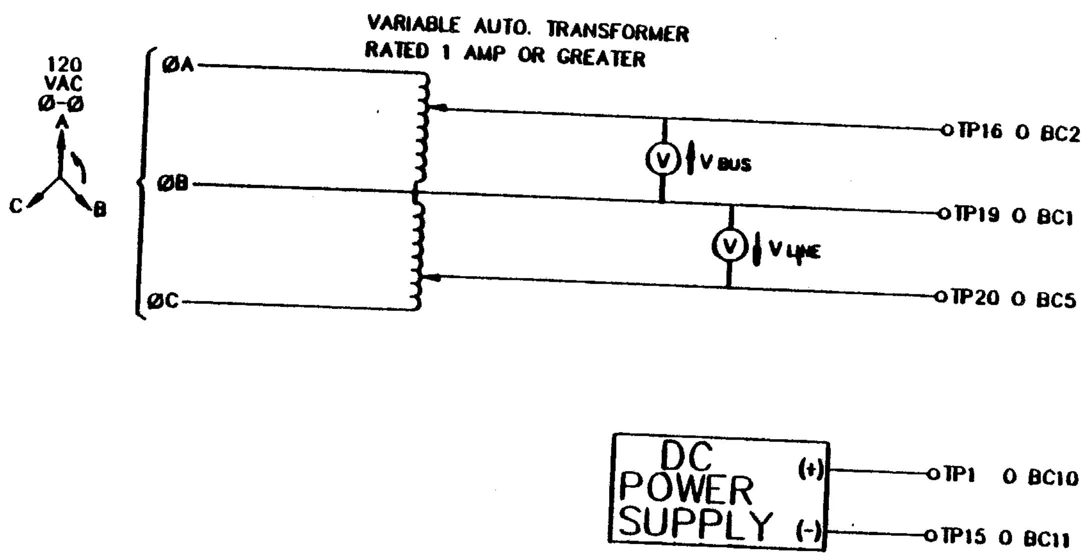
Figure 42 (226B7445 Sh 9): Reclosing Test Circuit.



TABLE

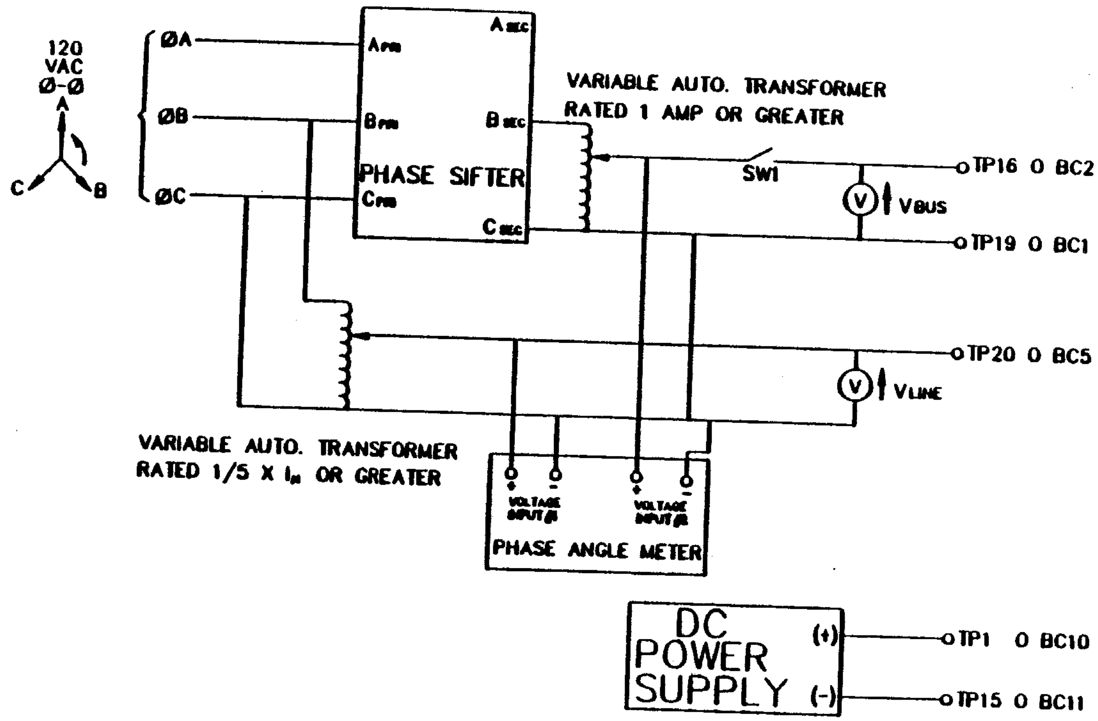
PHASE UNDER TEST→	A	B	C
CONNECT "W" TO TERMINAL	TP17 OR BC3	TP18 OR BC4	TP16 OR BC2
"X"	TP18 BC4	TP16 BC2	TP17 BC3
"Y"	TP16 BC2	TP17 BC3	TP18 BC4
"Z"	TP7 BD1	TP9 BD2	TP11 BD3
CONNECT "T" TO TERMINAL	TP8 OR BD5	TP10 OR BD6	TP12 OR BD7

Figure 43 (226B7445 Sh 10): Test Circuit for Directional Comparison Blocking and Zone 5 Tests.



NOTE 1: PLACE SVM MODULE ON ACARD EXTENDER

Figure 44 (226B7445 Sh 11): Test Circuit for Synchronism Check Voltage Level Tests.



NOTE 1: PLACE SVM MODULE ON ACARD EXTENDER

Figure 45 (226B7445 Sh 12): Test Circuit for Synchronism Check Angle and Slip Tests.

PERIODIC TESTS (Post Installation)

It is recommended that a periodic test program be developed which checks all of the MLS functions employed in the protective scheme under consideration. It is left to the user.s discretion to choose from among the Acceptance Tests, given in the previous section, those which are applicable as Periodic Tests for a particular installation.

Additional Test Equipment

The post-installation tests described herein require the following test equipment in addition to that listed for the acceptance tests:

One DC voltmeter (30 volts or greater)

Three card extenders (GE #0138B7406G1)

One set of XTM test plugs (XTM28L1 and XTM28R1) - described below

XTM TEST PLUGS

Description

The XTM test plugs are designed specifically for post- installation testing of the MLS system. There are two plugs; XTM28L1 (left-hand plug) and XTM28R1 (right-hand plug), each providing access to fourteen relay and fourteen system points. The system points are located on the outer edge. The plugs are keyed by the contact finger arrangement so that there may be no accidental interchange between the left-hand and right-hand plugs.

The plugs are fitted with a sliding handle which swings out to facilitate wiring to the terminals. The terminals consist of number 8 screws threaded into flat contact plates. The handles each have a tab on the outside edge to guide the wire dress of the test leads.

Not all of the external connections to the MLS are wired through the test receptacle for accessibility via the test plugs. Only those signals which are required for testing have been selected, as listed below:

- AC Current Inputs
- AC Voltage Inputs
- DC Control Power
- Output Tripping Contacts

Terminal Designation

The test receptacle and connection plugs are located to the left of the magnetic module (extreme left-hand position). Their terminals are labelled 1 through 28 with 1 through 14 corresponding to the left-hand side and 15 through 28 corresponding to the right-hand side. These points are designated on the elementary diagram (Figs.18-22) and test circuit diagrams as TP1 through TP28.

The left-hand test plug (XTM28L1) terminals are labelled 1R through 14R and 1S through 14S for the relay side and system side, respectively, with the system side labelled in red. Similarly, the right hand test plug (XTM28R1) terminals are labelled 15R through 28R and 15S through 28S.

XTM Test Circuit Connections

Test circuit connections, designated as TP points in the diagrams, should be made to the relay side of the test plug. Where it is desired to use available system quantities for testing, e.g., DC control power, jumpers may be inserted between the corresponding system side and relay side test plug terminals. Appropriate precautions should be taken when working with station battery DC.

Connections should be made to the test plugs prior to insertion into the MLS. As mentioned earlier, wiring is facilitated by the slide-out, swing-away handles.

Test Plug Insertion

To insert the test plugs, the two connection plugs must first be removed. In so doing, electrical continuity is broken between the power system and the MLS for those signals which are wired through the test receptacle (refer to TP points on elementary diagram). For the terminals connected to the current transformer secondaries, shorting bars are included on the system side of the test receptable. The shorting bars make contact before the connection plug contacts break during removal, so that the CT secondaries are never open-circuited.

Both test plugs may be inserted at the same time. Otherwise, if using only one test plug, the connection plug may remain in the other half of the receptacle.

When the test plugs are inserted into the receptacle, the power system remains isolated from the MLS insofar as the test signals are concerned.

WARNING

IT IS CRITICAL THAT JUMPERS BE INSERTED ON THE SYSTEM SIDE TEST PLUG TERMINALS WHICH ARE CONNECTED TO THE CT SECONDARIES. IF THESE JUMPERS ARE INADVERTENTLY LEFT OUT, THE RESULTING HIGH VOLTAGES DEVELOPED PRESENT A SERIOUS HAZARD TO PERSONNEL AND MAY SEVERELY DAMAGE CONNECTED EQUIPMENT.

Again refer to the elementary diagram for the proper TP points.

DC Disconnect

The primary DC control power feeding the power supply module (PSM) may be disconnected by removing either connection plug in the MLS relay case. It may also be disconnected by removing the magnetics module.

Connection and Procedure for equipment tests after installation

In order to separate the system from the inputs and outputs, the same procedure as for acceptance tests may be used after measures have been taken. XTM plugs are used for this purpose in the case of basic functions, but for certain auxiliary and alarm functions, specific precautions must be taken, as the disconnection of certain modules and the use of extenders.

The following sub-sections, together with the corresponding acceptance tests sub-sections make up the periodic test instructions. Following these instructions makes it unnecessary to modify or eliminate the relay external connections except for the case of the reclosing contacts.

It is recommended that the RLM module be withdrawn for the tests described in sub-sections from A to I in order to prevent the recloser operation. The DOM module can be withdrawn to avoid operation of the breaker failure starting circuits. For the recloser tests, it is necessary to separate the inputs and outputs board (the one containing the auxiliary relays and the contact converters) mounted in the RLM module.

In order to simulate the external contacts closing, jumpers and switches will be used in th extenders. Combinations of resistors and a voltmeter are used for observation of signals which operate on the auxiliary relays as indicated below:

Acceptance Tests | Tests with equipment in-

Relay disenergized | Voltage across the resistance: 0 Vdc

Contact opened

Relay energized
Contact closed | Voltage across the resistance: 5 Vdc or 12Vdc

WARNING

WHEN INSERTING AN EXTENDER IN THE POSITIONS CORRESPONDING TO MODULES DOM, PSM OR THE RLM MODULE OUPUTS AND INPUTS BOARD, GREAT CARE MUST BE TAKEN, SINCE THE BATTERY VOLTAGE MAY BE PRESENT IN CERTAIN POINTS. FAILURE TO OBSERVE THIS WARNING MAY RESULT IN PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT.

In order to test the equiment without pulling out the module, it should be recognizedthat, The XTM plugs only interrupt trip signals. The rest of the contacts remain connected to their associated control circuitsand may operate during test. To avoid undesired control outputs, wires from the corresponding terminals must be isolated. At the end of the test, it should be confirmed that all the wires have been correctly replaced.

A. Single phase reach check and
B. Fuse failure detector check

Acceptance tests: (bench test) — Figure 34
Tests with the equipment installed: — Figure 34

Function	Contact	Terminals on XTM or Voltmeter on: DLM pins
Pole A Trip	BB1-AC14	TP2-TP25
Pole B Trip	BB5-AD12	TP4-TP27
Pole C Trip	BB9-AD14	TP6-TP23
Oscillograph Start	AC1-AC2	Pin 8
Fuse Failure	AC7-AC8	Pin 42
Phase A selector	AB9-AB10	Pin 25
Phase B selector	AB11-AB12	Pin 55
Phase C selector	AB13-AB14	Pin 26
Zone I Trip	AD1-AD2	Pin 35

Notes:

1) Pull out modules DOM and RLM.
2) Place module DLM on an extender.

C. Phase to Phase Reach Tests

Acceptance tests: — Figure 35
Tests with the equipment installed: — Figure 35
(Same as Acceptance Tests)

D. Zone timers check

Acceptance tests: — Figure 36
Tests with the equipment installed: — Figure 36

Function	Contact	Voltmeter on:
Zone 1 Trip	AD1-AD2	Pin 35 of DLM
Zone 2 Trip	AD3-AD4	Pin 5 of DLM
Zone 3 Trip	AD5-AD6	Pin 32 of DLM
Zone 4 Trip	AD7-AD8	Pin 55 of DSM
Reclose blocking	AB7-AB8	Pin 2 of DLM

Notes:

1) Pull out modules DOM and RLM.
2) Place modules DLM and DSM on an extender.

E. Power swing check (Three phase condition)

Acceptance tests: Figure 37

Tests with the equipment installed: Figure 37

Function	Contact	Voltmeter on:
Swing Blocking	AC5-AC6	Pin 44

Notes:

1) Pull out modules DOM and RLM.
2) Place module DLM on an extender.

F. Power swing check (Two phase condition with one open pole)

Acceptance tests: Figure 38

Tests with the equipment installed: Figure 46

Function	Contact Fig 38	Voltmeter on: Fig 46
Swing Blocking	AC5-AC6	Pin 44 on DLM

Notes:

1) Pull out modules DOM and RLM.
2) Place module DLM on an extender.
3) Place an empty extender on the RIGHT position of DOM.

G. Line Pick-Up check

Acceptance tests: Figure 39

Tests with the equipment installed: Figure 47

NOTES:

1) Pull out modules DOM and RLM.
2) Place an empty extender on the RIGHT position of DOM.

H. Channel schemes check

Acceptance tests: Figure 40

Tests with the equipment installed: Figure 48

Function	Contact Fig 40	Voltmeter on: Fig 48
Transmission Start	AB1-AB2	Pin 43
Trip per channel	AB5-AB6	Pin 45

Notes:

1) Pull out modules DOM and RLM.
2) Place module DLM on an extender.
3) Place an empty extender on the LEFT position of DOM.

I) Check of auxiliary functions needing contact inputs

Acceptance tests: Figure 41
Tests with the equipment installed: Figure 49

Notes:

1) Pull out modules DOM and RLM.
2) Place an empty extender on the RIGHT position of DOM.
3) Place an empty extender on the LEFT position of DOM.

J. Recloser check

Acceptance tests: Figure 42
Tests with the equipment installed: Figure 50

Function	Contact Fig 42	Voltmeter on: Fig 50
Reclose	BO9-BO10	Pin 12
	BO11-BO12	Pin 12
	BO13-BO14	Pin 12
Three phase trip permission	BO1-BO2	Pin 11
Extended Zone I pull back	BO7-BO8	Pin 39
Recloser in OFF position	AO13-AO14	Pin 7

Notes:

1) Pull out modules DOM and the module RLM inputs and outputs board.
2) Place module RLM on an extender.
3) Place an empty extender on the RIGHT position of RLM.
4) Place an empty extender on the RIGHT position of DOM.
5) Disconnect or unable the reclosing external circuits.

K. <u>Directional comparison blocking and Zone 5 (optional) Check</u>

Acceptance tests: Figure 43
Tests with the equipment installed: Figure 51

Function	Contact	Resistance/ Voltm.
	Fig 43	Fig 51
Transmission Start	AB1-AB2	R1
Transmission Stop	AB3-AB4	R2
Trip per channel	AB5-AB6	R3

Notes:

1) Pull out module DOM.
2) Place module DLM on an extender.
3) Place an empty extender on the LEFT position of DOM.

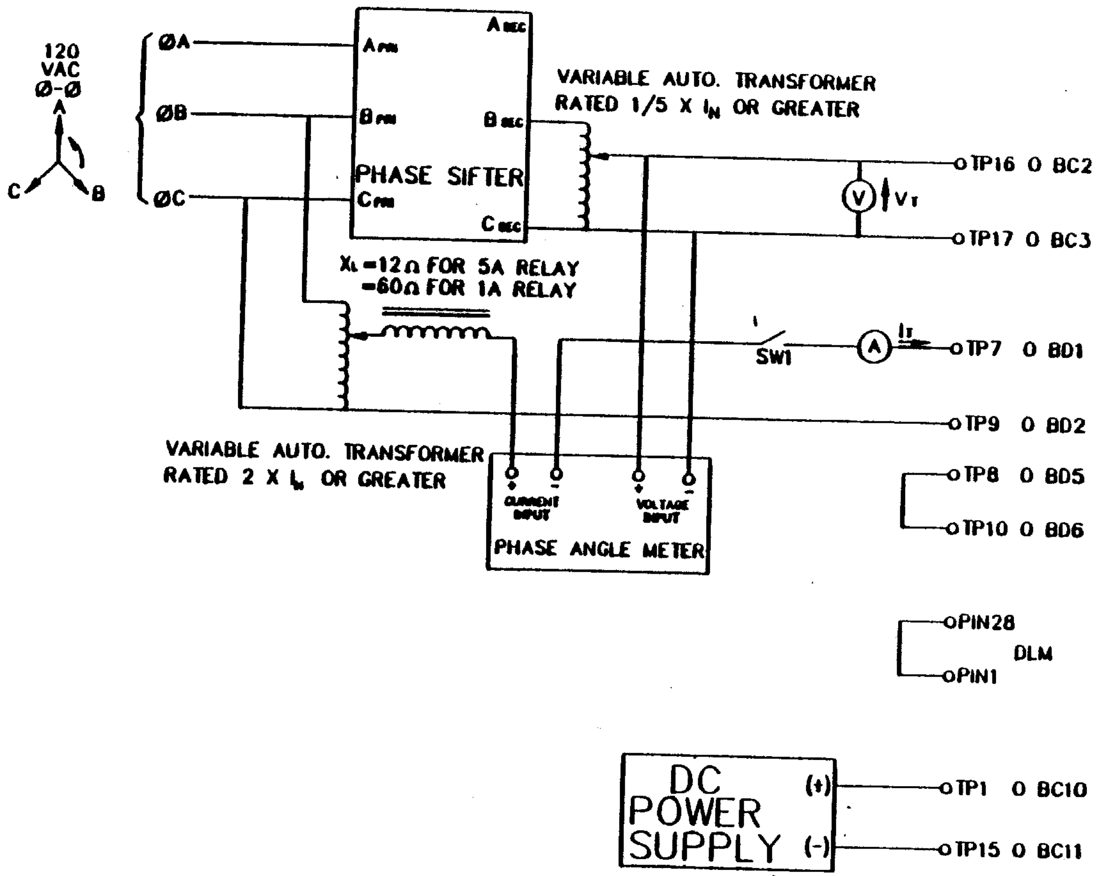


Figure 46 (226B7445 Sh 30): Out-of-Step (ϕ-ϕ) - Periodic Test.

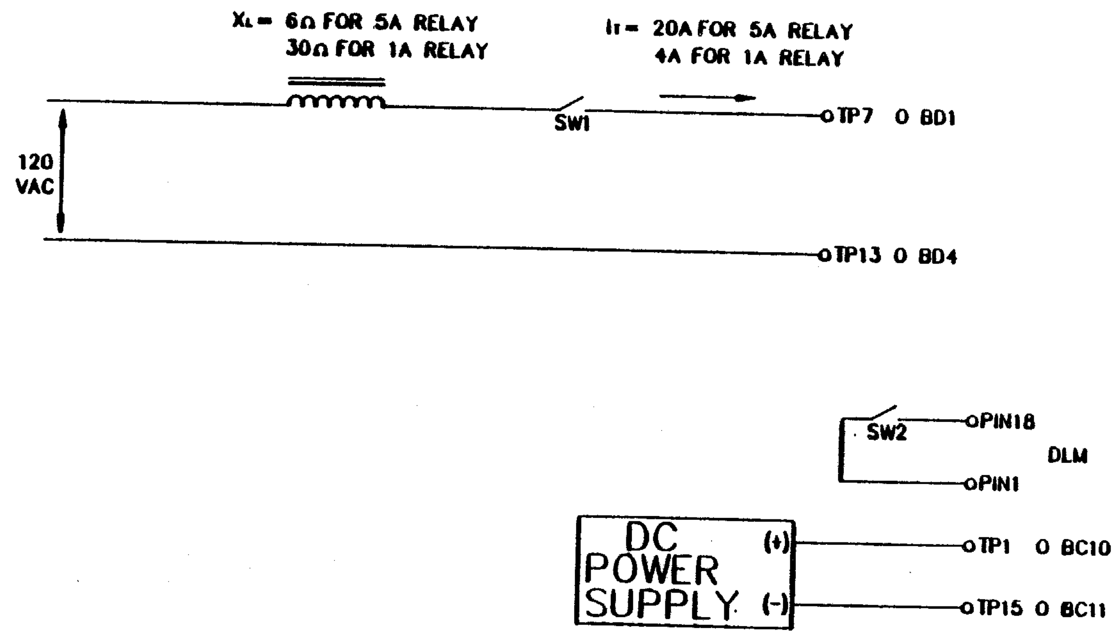


Figure 47 (226B7445 Sh 31): Line Pick-Up - Periodic Test.

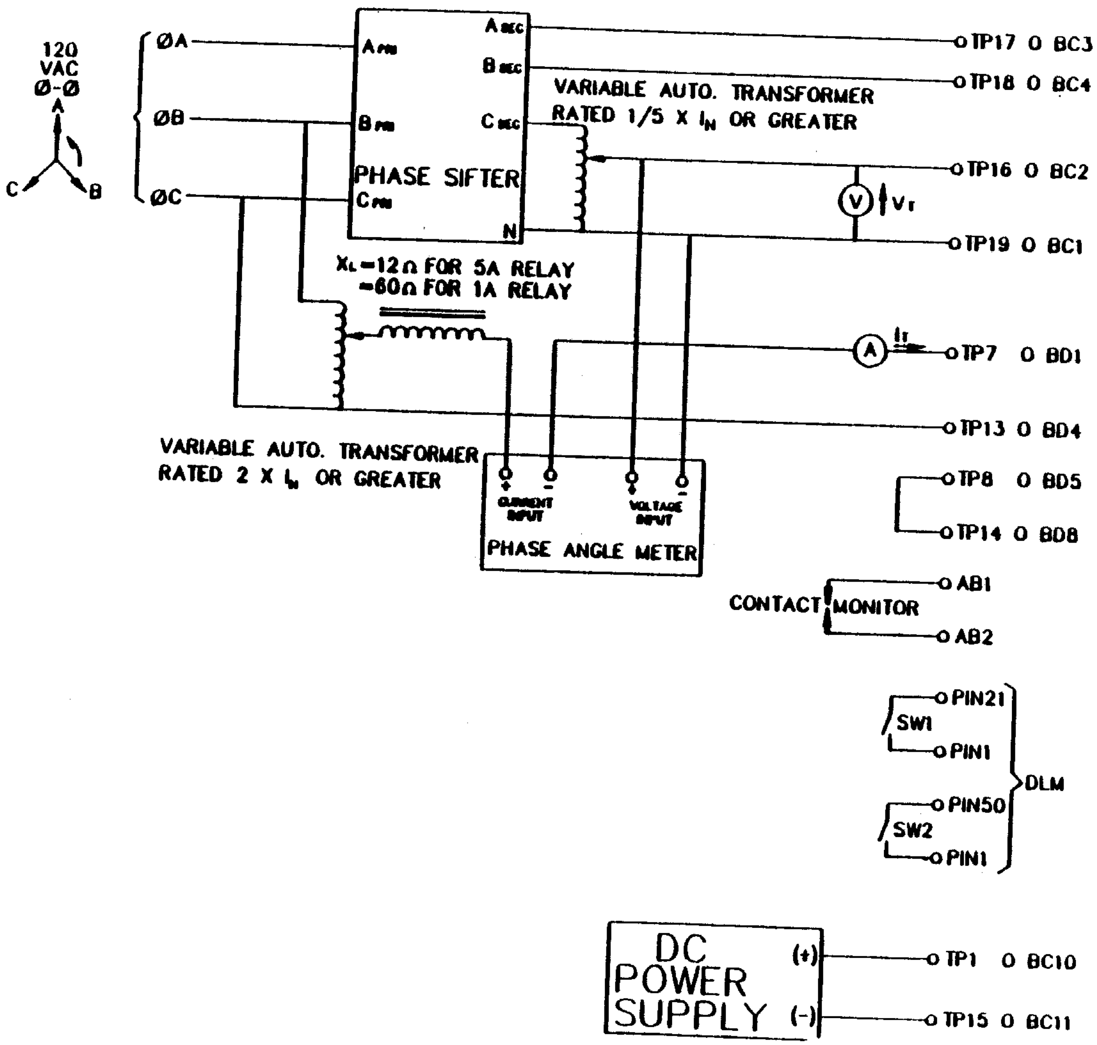


Figure 48 (226B7445 Sh 32): Pilot Schemes - Periodic Tests.

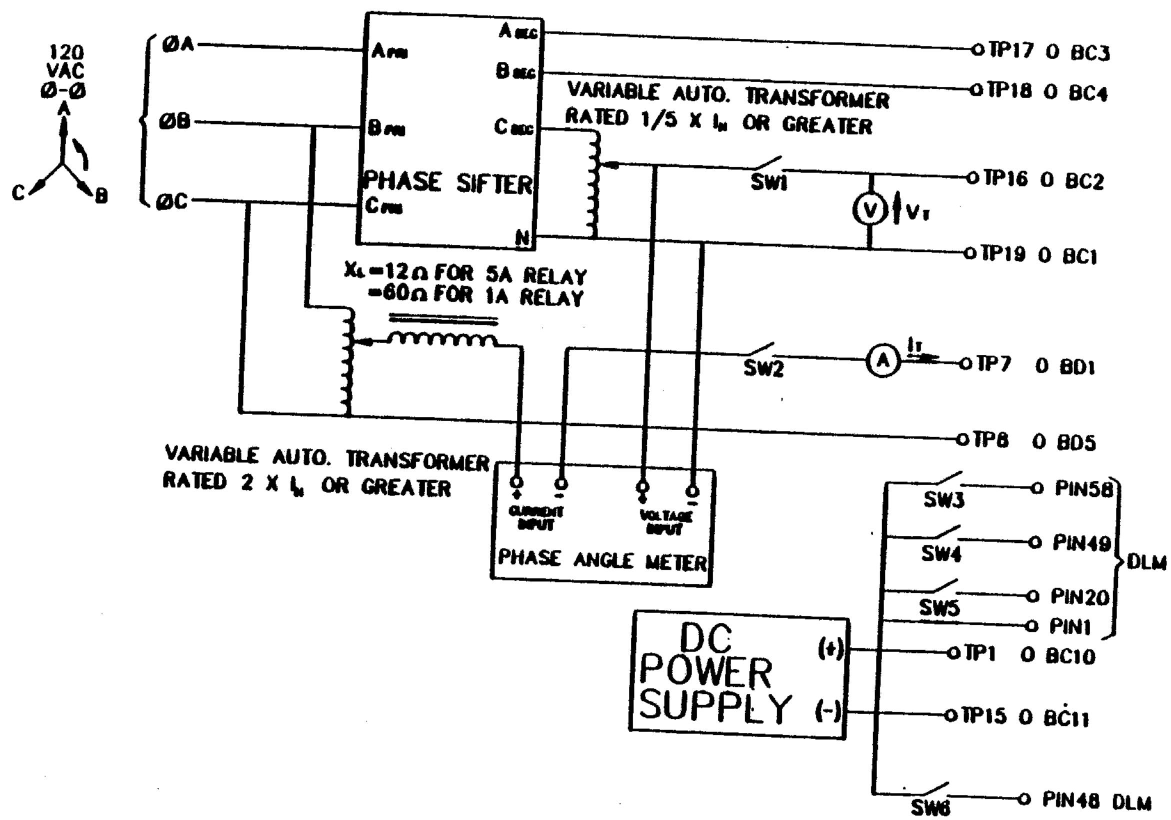


Figure 49 (226B7445 Sh 33): Auxiliary Functions - Periodic Tests.

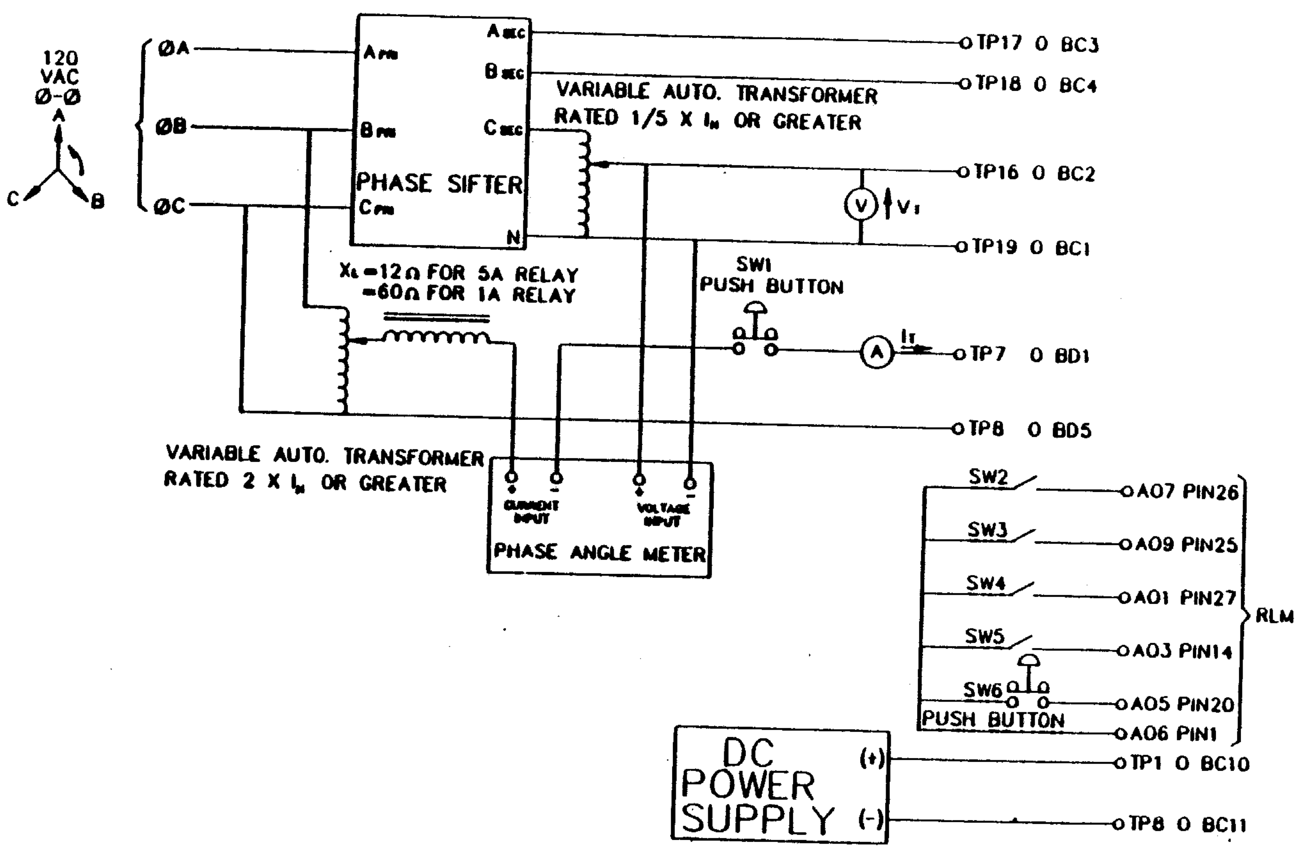
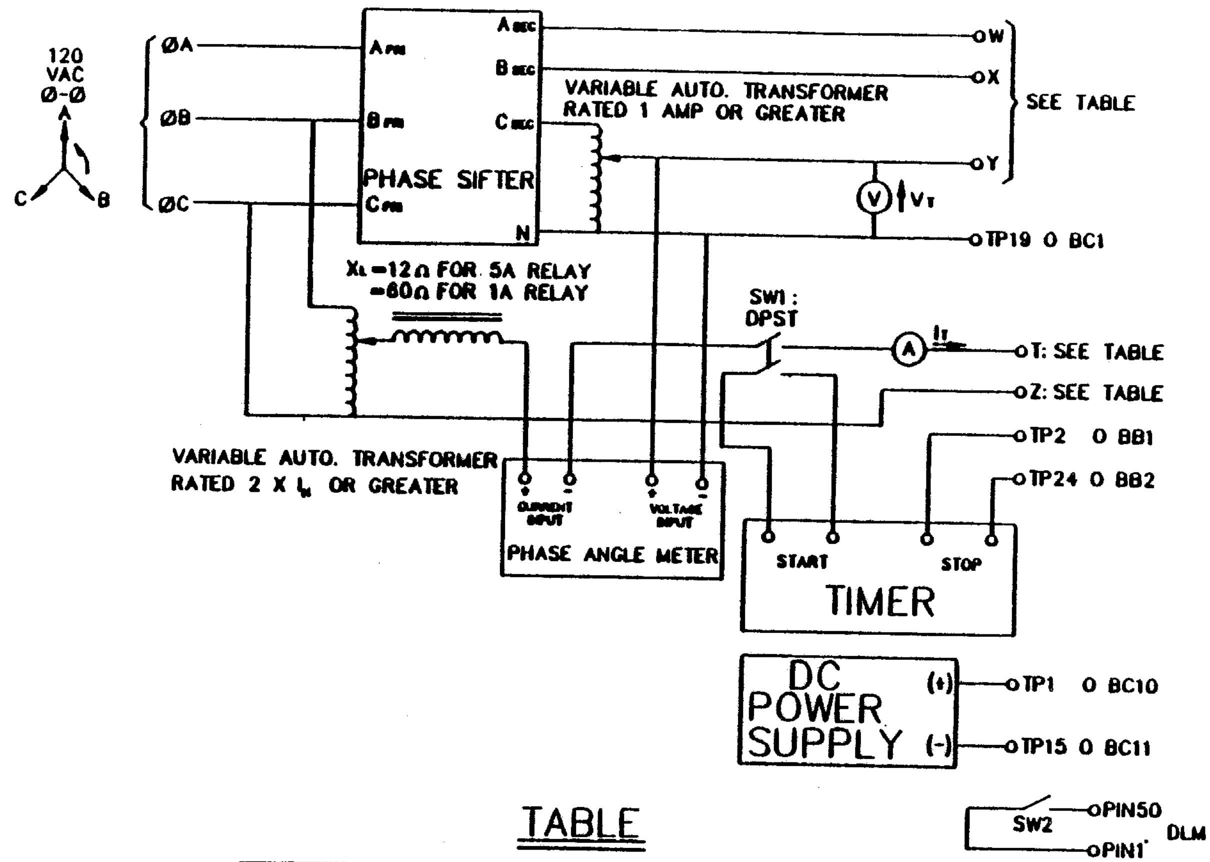


Figure 50 (226B7445 Sh 34): Reclosing - Periodic Test Circuit.



TABLE

PHASE UNDER TEST→	A	B	C
CONNECT "W" TO TERMINAL	TP17 OR BC3	TP18 OR BC4	TP16 OR BC2
"X"	TP18 BC4	TP16 BC2	TP17 BC3
"Y"	TP16 BC2	TP17 BC3	TP18 BC4
"Z"	TP7 BD1	TP9 BD2	TP11 BD3
CONNECT "T" TO TERMINAL	TP8 OR BD5	TP10 OR BD6	TP12 OR BD7

Figure 51 (226B7445 Sh 35): Directional Comparison Blocking Periodic Test Circuit.

SERVICING

There are two basic approaches that may be followed in servicing the MLS. One approach is field service, where an attempt is made to replace defective components at the relay location. Generally, this will take the most time and require the highest degree of skill and understanding. It can also be expected to result in the longest system-outage time.

The preferred approach is module replacement, where a determination is made as to which function has failed and that function is replaced with a spare module. The system can then be quickly returned to service. Considerable time is saved, and there is much less pressure to make a decision about what to do with the defective part. This approach typically yields the shortest down time. It is recommended that a complete set of spare modules be kept at the main maintenance center.

For those who wish to repair at the component level, drawings are available from the factory. When requesting drawings, the following information must be supplied to the factory:

1. The <u>model number</u> of the module. (this is found on the lower part of the front nameplate of each module),

2. The <u>assembly number</u> of the module. (this is found on the component side of-the printed-circuit board. It is an eight digit number with a letter inserted between the fourth and fifth digit and suffixed with a group identification),

3. The <u>revision number</u> (this is also found on the printed-circuit board, e.g. REV.1).

WITHOUT THE CONTINUOUS MONITOR MODULE

The card extenders can be utilized as described in the PERIODIC TEST section to gain acces to various signal points in the MLS.

WITH THE CONTINUOUS MONITOR MODULE

When the MLS is equipped with the optional CONTINUOUS MONITOR, many problems can be quickly located. When a failure occurs that causes one or more internal logic levels to shift, this will normally cause one of the many points monitored by the CONTINUOUS MONITOR to go to an abnormal state. If the monitored point stays in this state for more than 0.5-1 seconds, the CONTINUOUS MONITOR will give a Monitor Alarm contact closure. The front panel MON DATA indicator on the TAM screen to work from the screen and entered in the log.

These abnormal point numbers are the signal input numbers to the CONTINUOUS MONITOR. Refer to Fig. 5.2 to find the mnemonic of the MLS signal connected to this input. Fig. 5.2 also gives the module where the signal. Refer to the system Logic Diagram, Figure 2 in THE SCHEME DESCRIPTION section, and locate the abnormal signal levels on this diagram. Locate the earliest abnormal points, that signal path probably do not indicate a fault at these points. If there is an earlier, monitored, logic level in the same signal path that is normal, then the problem will usually be between the normal and the abnormal points.

If there is no earlier logic point, then the AC inputs to the MLS that drive the abnormal logic point should be checked.

The techniques just described locate failures that resulted in monitor alarms from the continuous monitor. If a failure is suspected of causing a false trip, then the trip data in the continuous monitor must be analyzed. Obtain the trip data point numbers using the front panel controls: DATA SELECT, TRIP DATA, STEP DISPLAY and LCD display, or by using the serial data link. See if point 48 went to its abnormal state, HIGH. If not, the trip did not originate in the trip bus connected to the MLS. If point 48 went abnormal, see if point 47 went HIGH (abnormnal state). If so, then there was a system disturbance and the trip probably was not a false trip. Check the event recorder, if used, and see if a trip condition did exist.

If there was no fault detector signal (point 47 did not go HIGH) then there was an error in the MLS. As in the case of a monitor fault, look for the earliest abnormal point in the signal path. Replace the module where this abnormal point is located. If the fault can not be localized as ocurring between a normal and an abnormal monitored point, then it may be necessary to replace all modules between the abnormal point and the AC inputs that supply signals to the abnormal point.

POWER SUPPLY MODULE

Check the following items if the LED found on the front panel of the PSM module fails to light when the Power Supply is turned on:

- Correct DC supply is applied to the MLS.
- Connection plugs, located on the left side of the MGM module, are properly inserted into the test receptacle.
- Condition of the fuse located on the PSM2 module.
- Correct voltages from the Power Supply Module.

  The voltages should be within ±5% of nominal. Check each of the following voltages with respect to pins 1,30,31 or 60:

Pins 4 or 34	+24 VDC
Pins 2 or 32	+12 VDC
Pins 29 or 59	-12 VDC

  The following voltage is checked with respect to pins 25 or 55, and it should also be within ±5% of nominal:

  Pins 21 or 51 +24Vdc

MONITOR POINT	SIGNAL	FUNCTION	MODULE
5	DU	Directional Unit	DSM
6	A	A Phase Selector	DSM
7	B	B " "	DSM
8	C	C " "	DSM
9	Z4	Zone IV Trip	DSM
10	Z5	Zone V Trip	DBM
25	Z1S	Zone I Trip	DLM
26	Z2S	Zone II Trip	DLM
27	Z3S	Zone III Trip	DLM
28	MONOF	Single Phase Trip	DLM
29	TRIF	Three Phase Trip	DLM
30	MU	Main Measuring Unit	DLM
31	CHTR	Chanel Trip	DLM
32	Z3FLT	Permissive Measuring Unit	DLM
33	OSBR	Power Swing Detector	DLM
34	DFA	Phase A Trip	MGM
35	DFB	" B "	MGM
36	DFC	" C "	MGM
47	FD	Fault Detector	DSM
48	TRIP	Trip	MGM

Figure 52: List of MLS Continuous Monitor Point Assignments.

SPECIFICATIONS

GENERAL

Rated Frequency	• 50 or 60 hertz
Rated Voltage	• 110V at 50 hertz • 120V at 60 hertz
Rated Current	• I_N = 1 or 5 amperes
DC Control Voltage	• 48V range: 34 to 60 volts • 110-125V range: 88 to 156 volts • 220-250V range: 176 to 300 volts
Minimum Operating Current	• 0.15 x I_N
Maximum Permissible Currents	
Continuous	• 2 x I_N
Three Seconds	• 50 x I_N
One Second	• 100 x I_N
Maximum Permissible AC Voltage	
Continuous	• 2.0 x rated
One Minute	• 3.5 x rated
Ambient Temperature Range	
For Storage	• -40 to +65 degrees C
For Operation	• The MLS has been designed for continuous operation between -20°C and +55°C per ANSI Standard C37.90. In addition, the MLS will not malfunction nor be damaged by operation at temperatures up to +65°C.
Insulation Test Voltage	• 2 kV 50/60 hertz, one minute
Impulse Voltage Withstand	• 5 kV peak, 1.2/50 milliseconds, 0.5 joule
Interference Test Withstand	• 1 MHz, 2.5 kV peak longitudinal mode, 1 kV peak transverse mode, decay time of 3 to 6 cycles to ½ value, rate of repetition 500/second.

Burdens

Current Circuits	• 0.03 ohm ∠2 degrees, I_N = 5 amps • 0.04 ohm ∠8 degrees, I_N = 1 amp
Voltage Circuits	• 0.2 VA ∠49 degrees, 60 hertz • 0.024 VA ∠48 degrees, 50 hertz

DC Battery (for Power Supply and Telephone Relays)*	Normal	Tripped
48 VDC	19 watts	34.5 watts
110-125 VDC	22 watts	35 watts
220-250 VDC	32.5 watts	42 watts

*Distance relay without options

**3 Pole zone 1 channel trip w/all targets lit

DC Battery (for Contact Converters)

48 VDC	• 1.6 milliamperes each
110-125 VDC	• 1.5-1.7 milliamperes each
220-250 VDC	• 1.9-2.1 milliamperes each

Contact Data

Trip Outputs

- Continuous rating = 3 amperes
- Make and carry for tripping duty (per ANSI C37.90) 30 amps
- Break 180 VA resistive at 125/250 VDC
- Break 60 VA inductive at 125/250 VDC

Auxiliary Outputs (including Alarms)

- Continuous rating = 3 amperes
- Make and carry for 30 seconds 5 amperes
- Break 25 watts inductive at 125/250 VDC
- Make and Carry continuously 20 watts
- Maximum of 250 volts or 0.5 amp

Channel Control Contacts

- 10 watts
- 250 VDC maximum
- 0.5 amp maximum

DISTANCE RELAY

Features

Single Pole or Three Pole Operation

Number of Zones

- Four zones are standard (includes the phase selector)
- Reverse Zone Five (optional)

Scheme Logic Selection (Field Programmable)

1. Stepped distance
2. Zone-1 extension
3. Zone-2 acceleration
4. Permissive Underreach Transfer Trip
5. Permissive Overreach Transfer Trip
6. Directional Comparison Blocking (optional)
7. Hybrid Scheme

Power Swing Blocking Characteristic

- Reach adjustment equal to third zone setting (120° lenticular characteristic) 16 to 31 millisecond swing timer

Voltage Transformer Fuse Failure Detection

- No setting required
  Pickup on negative sequence voltage in absence of negative sequence current

Line Pickup

- Three pole trip with undervoltage (less than 1.5 percent) and overcurrent (greater than 2.5 per unit) during 128 millisecond interval after reclosing

External Blocking of Tripping

Remote Target Resetting

Operating Characteristics - Main Measuring Unit and Permissive Zone Measuring Unit

Three-phase faults, phase-to-phase and double-phase-to-ground

- Variable mho characteristic
  Integrating action with 120 degree base

Single-phase to ground

- Reactance or variable mho (field selectable).
  Integrating action with 90/135 degree base (may be delayed by 10 to 390 milliseconds).

Operating Characteristics - Phase Selectors and Optional MB Units

All Types of Faults (one unit per phase)

- Variable mho characteristic
  Circular (90 degrees) or Lenticular (105 degrees) characteristic, selectable

Undercurrent Supervision

- 0.15 per unit (establishes sensitivity)

Directional Unit Supervision (single phase-to-ground faults only)

- Operates on negative sequence voltage and current quantities

Compensated reach of 2.4 ohms (5 amp relay)
12 ohms (1 amp relay)

Reach Setting Ranges

Mho Type Phase Selectors

For I_N = one amp

- 20 to 515 ohms in 5 ohm steps

For I_N = five amps

- 4 to 103 ohms in 1 ohm steps

MB Blocking Unit (optional)

- Range same as phase selector range

Zone Measuring Elements

Zone-1 I_N = 1 Amp.

- 0.1 a 2.5 ohms in 0.01 ohm step. 0.5 a 12.5 ohms in 0.05 ohm steps.2.5 a 62.5 ohms in 0.25 ohm steps

Zone 1 IN = 5 Amps

- 0.02 a 0.5 ohms in 0.002 ohm steps . 0.1 a 2.5 ohms in 0.01 ohms steps. 0.5 a 12.5 ohms in 0.05 ohm steps

Extended Zone-1	• 1 to 2 x zone-1 setting in 0.05 multip steps.
Zone-2	• 1 to 5 x zone-1 setting in 0.05 multiple steps
Zone-3 (also permissive zone)	• 1 to 20 x zone-1 setting in 0.1 multiple steps
Zone-4	• Setting equal to phase selector reach setting
Reverse Zone-5 (optional)	• Setting equal to MB unit reach setting

Angle Setting Ranges

Positive Sequence Impedance Characteristic Angle	• 40 to 80 degrees in five degree steps
Zero Sequence Impedance Characteristic Angle	• 10 to 40 degrees in ten degree steps 40 to 80 degrees in five degree steps
Zero Sequence Compensation	• $K_0 = Z_0/Z_1$, K_0 = 2 to 7 in 0.05 steps

Operating Times

Refer to Fig. 53 through 55 (constant Z_S/Z_L curves) or
Fig. 56 through 61 (constant time curves)

NOTE: These curves pertain to 60 hertz operation using PT inputs
For 50 hertz operation, the operating time is increased by up to 20 percent.
For CVT inputs, add two millisconds to the 60 hertz times; 2.4 milliseconds to the 50 hertz times.

Zone Timers

Zone-2 and Zone - 3	• 0.01 to 1.27 second in 0.01 second steps • 0.1 to 12.7 seconds in 0.1 second steps (may be disabled)
Zone-4 (Phase Selector)	• 0.15 to 12.75 seconds in 0.1 second steps (may be disabled)
Reverse Zone-5 (MB Unit-Optional)	• 0.15 to 12.75 seconds in 0.1 seconds steps (may be disabled)

Channel Timers

Coordination Timer	• 0 to 63 milliseconds in 1 millisecond steps
MB Unit Dropout Timer (optional)	• 2 to 30 cycles in 2 cycles steps

RECLOSER

Features

Mode Selection

1. One reclosing attempt, single pole or three pole, depending on type of trip
2. One reclosing attempt, single pole only
3. One reclosing attempt, three pole only
4. Two reclosing attempts, single pole or three pole on first, three pole on second.
5. Two reclosing attempts, three pole only.

Recloser may be taken out of service

Breaker "b" Switch Monitoring	
External Blocking of Reclosing	
Fail-to-Close Logic	• Trips breaker 3 pole and locks out recloser
Manual Closing Through Recloser	• Utilizes recloser circuitry and output contacts. Permits sync check supervision (optional) on manual closures. (may be bypassed)
Hold Feature	• Allows reclosing attempts which are initially blocked by an external signal or by sync check (optional) to be sustained. Reclosing will take place if the blocking condition clears before the reset time elapses.

Reclosing times

First single or three phase reclose (Independently adjustable)	• 0.01 to 2.55 seconds in 0.01 seconds steps.
Second reclose	• 1 to 255 seconds in 1 second steps.
Maintenance time of the reclosing command.	• 0.2 to 255 seconds.
Reset time	• 1 to 255 seconds in 1 second steps.

SYNCHRONISM CHECK CIRCUIT (optional)

Angle Adjustment	• 1 to 99 degrees in one degree steps
High Set Slip Cut-off	• .25 to 2.5 hertz in .25 hertz steps
Low Set Slip Cut-off	• .01 to .1 hertz in .01 hertz steps .1 to 1 hertz in .1 hertz steps
Voltage Check (Live)	• 65 to 110 percent of nominal in five percent steps
Voltage Check (Dead)	• 10 to 70 percent of nominal in five percent steps
"Dead Time" Supervision Timer	• .05 to 3.15 seconds in .05 second steps
Nominal Potential Transformer Secondary Voltage (Phase-to-Neutral)	• 57.7, 63.5, 66.4, 69 volts; selectable

ACCURACY

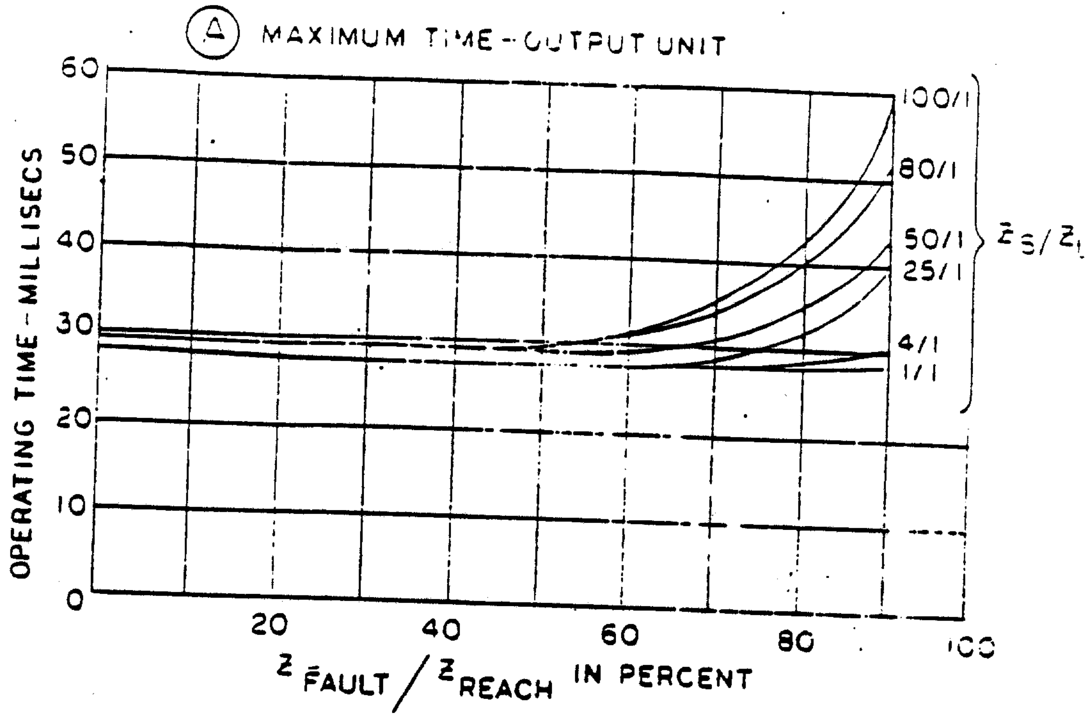
Distance Measuring Units (Phase Selectors, Main Measuring Unit, Permissive Zone Measuring, Optional MB Units)	• Reach: plus and minus five percent of setting at angle of maximum reach • Angle of Maximum Reach: plus and minus three degrees of setting
Zone Timers	• Plus and minus three percent of setting
Reclosing Timers	• Plus and minus three percent of setting

DIMENSIONS

Each standard rack mounted unit:	• 177 millimeters high • 484 millimeters wide (standard 19-inch rack) • 359 millimeters deep (including terminal blocks)

WEIGHT

Each standard rack mounted unit weights approximately 15 kilograms net.



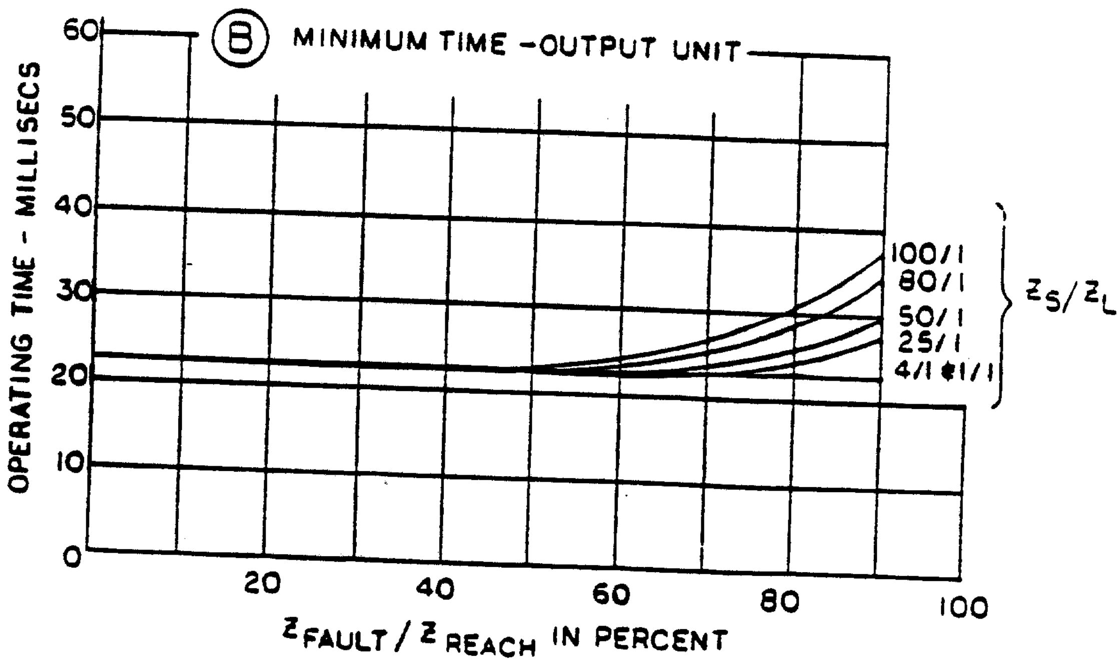


Figure 53 (285A6680-1): Constant Zs/Zl Time Curves - Phase to Ground Faults

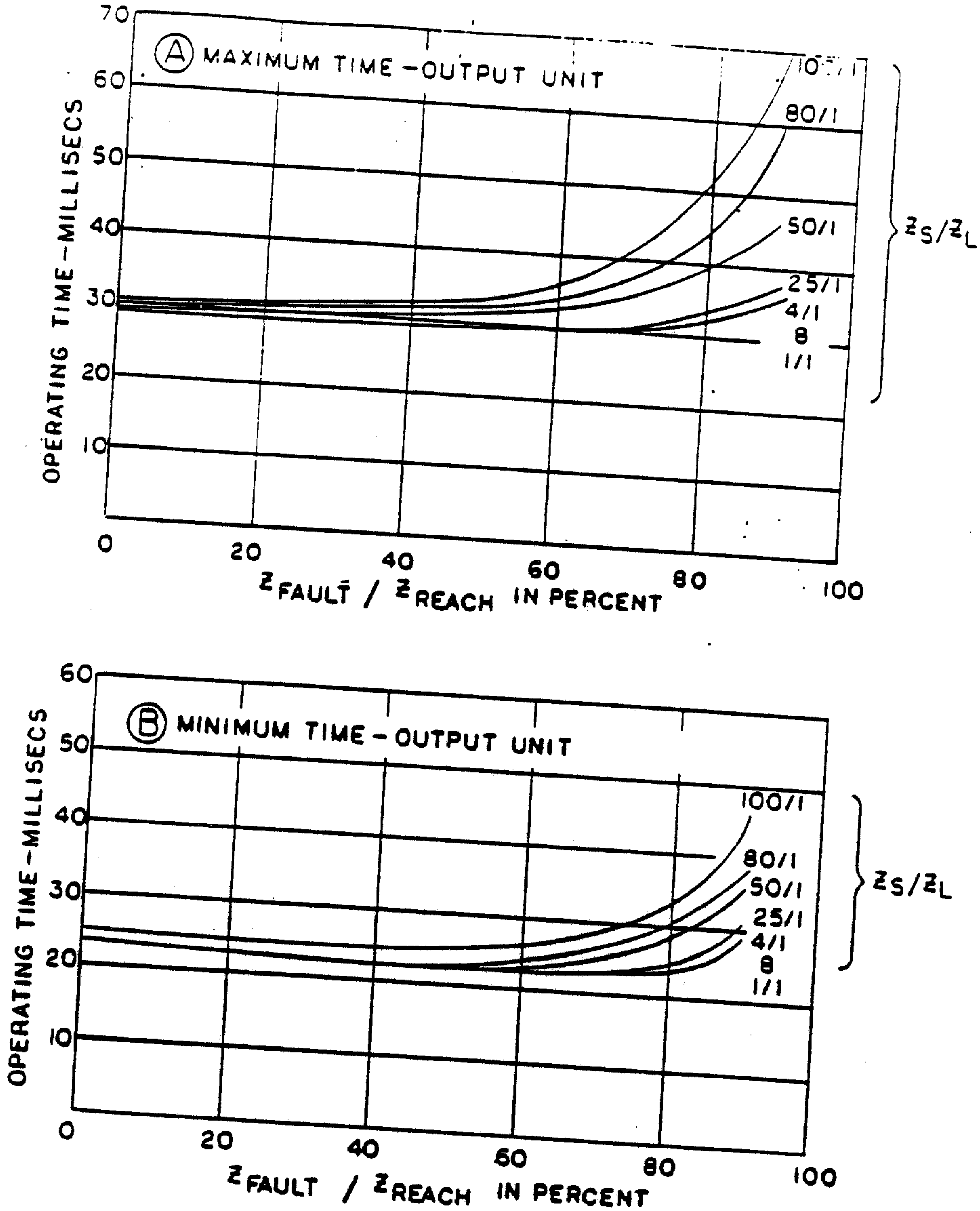
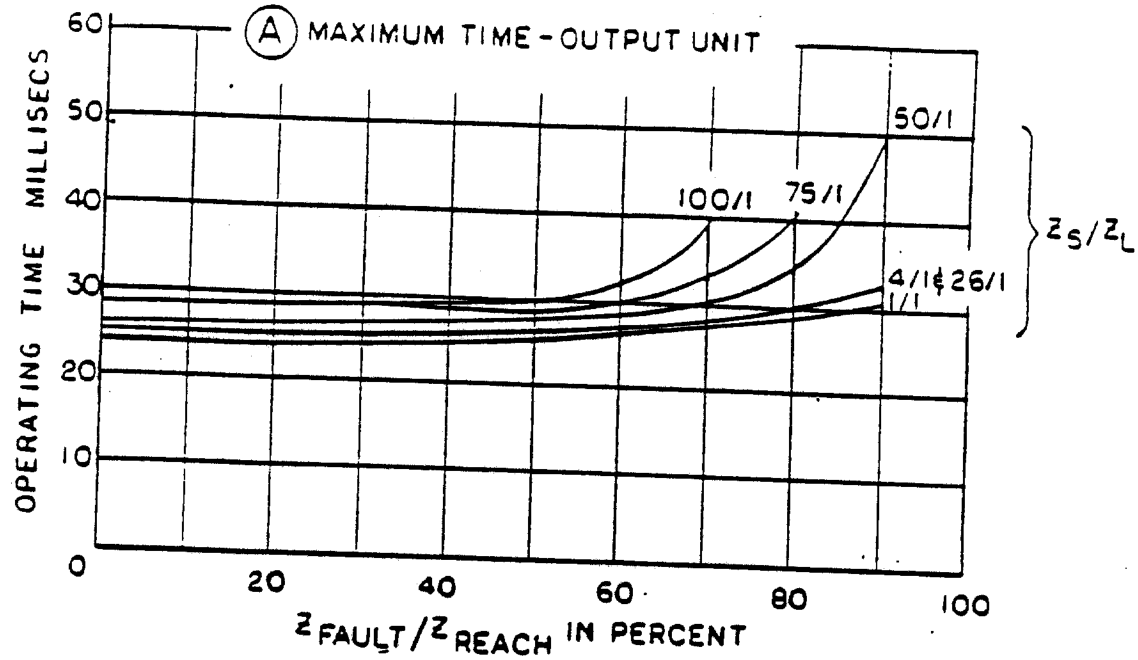


Figure 54 (285A6683-1): Constant Zs/Zl Time Curves - Phase to Phase Faults.



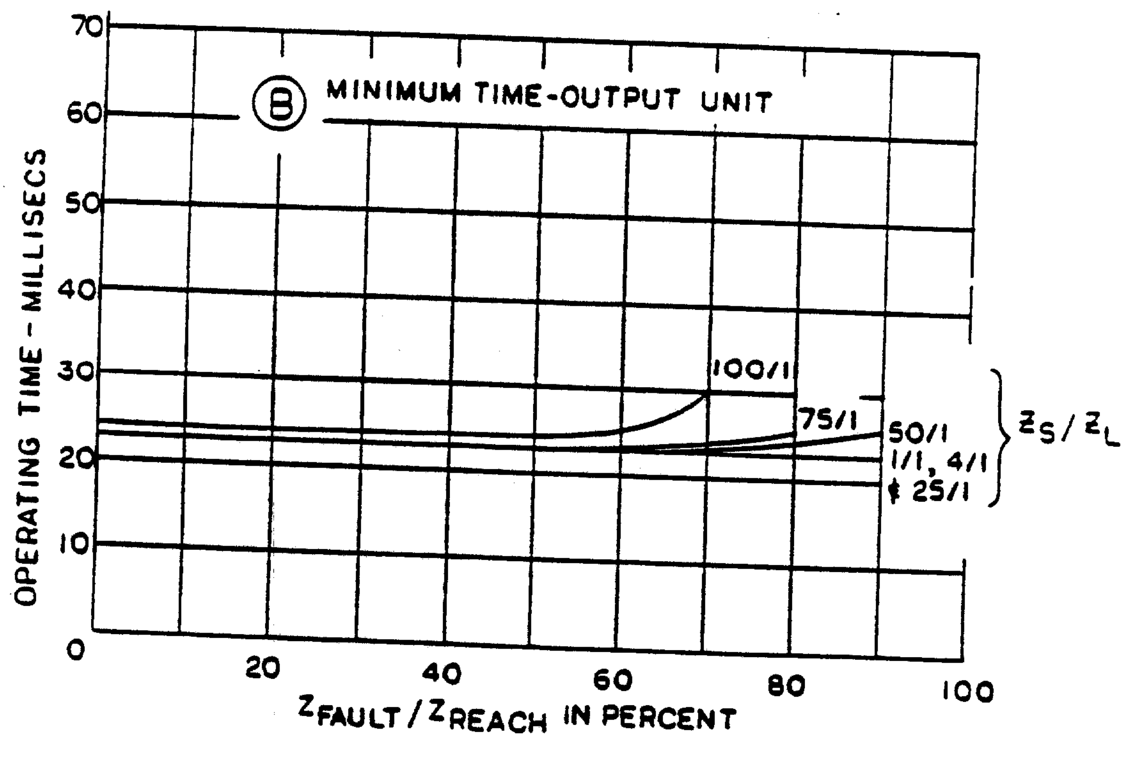


Figure 55 (285A6681-1): Constant Zs/Zl Time Curves - Three Phase Faults.

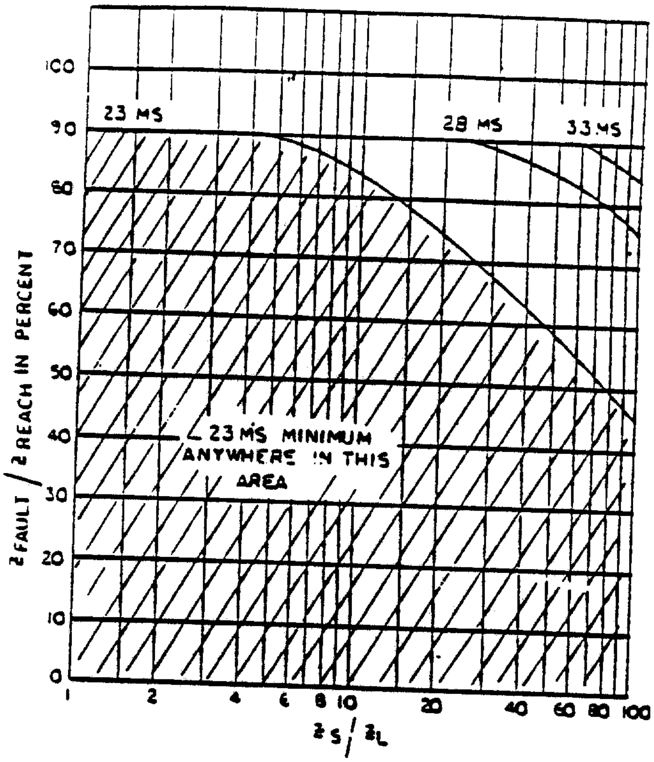
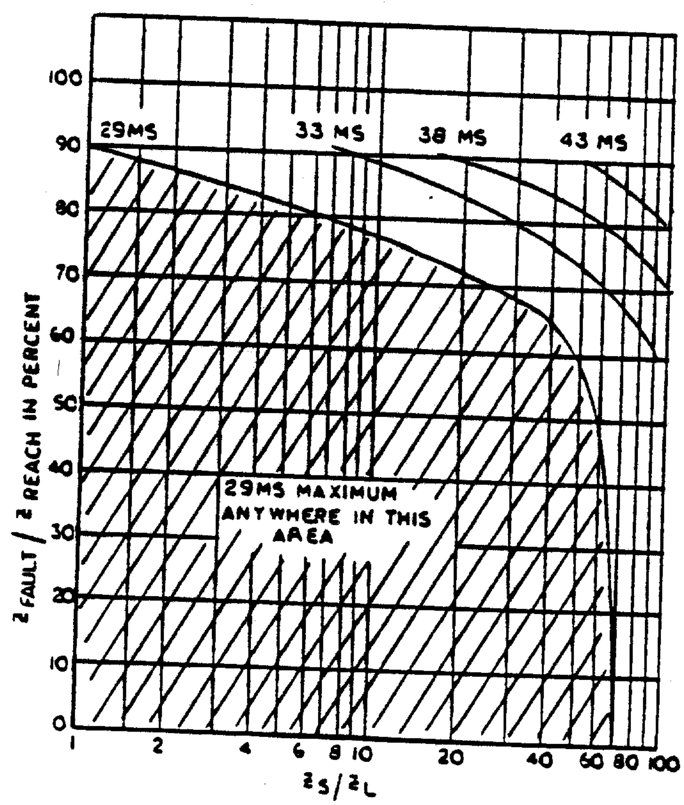


Figure 56 (285A6682-1): Constant Time Operating Curves - Phase to Ground Faults (Minimun).



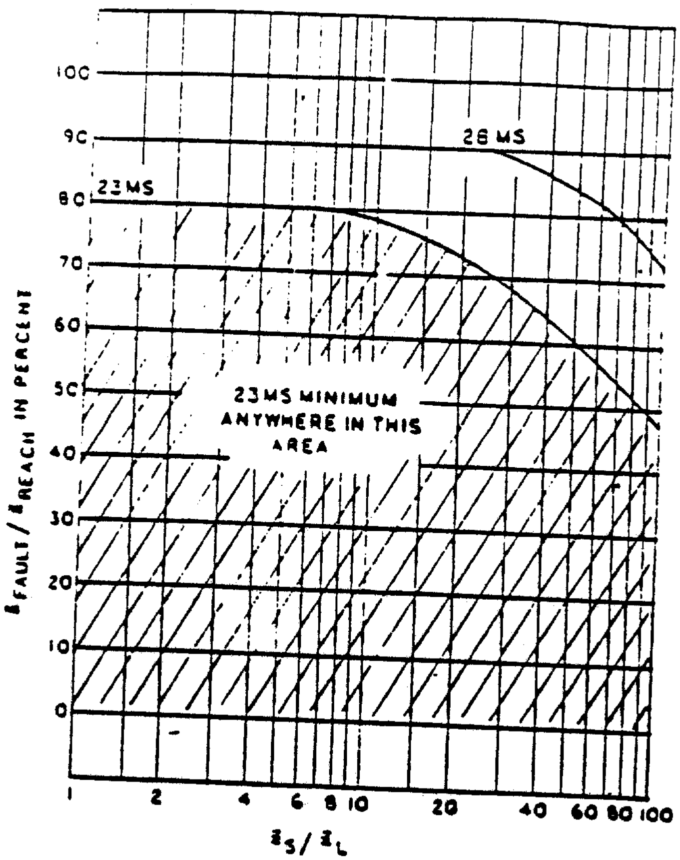
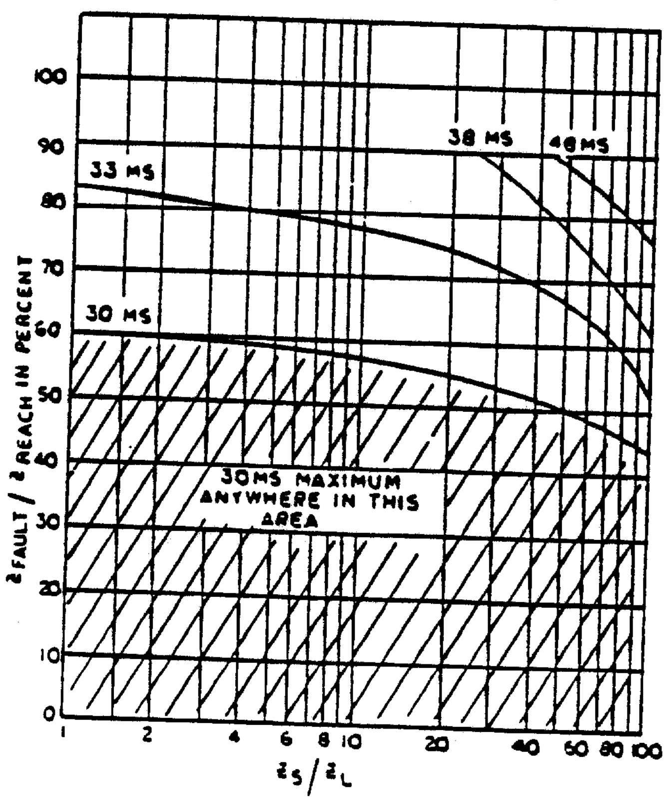


Figure 58 (285A6688-1): Constant Time Operating Curves - Phase to Phase Faults (Minimun).



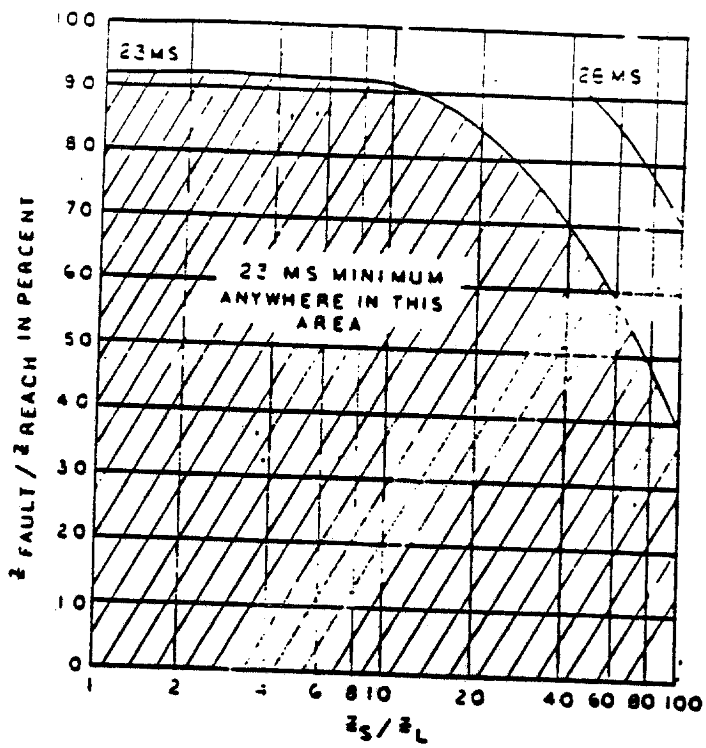


Figure 60 (285A6685-1): Constant Time Operating Curves - Three Phase Faults (Minimun).

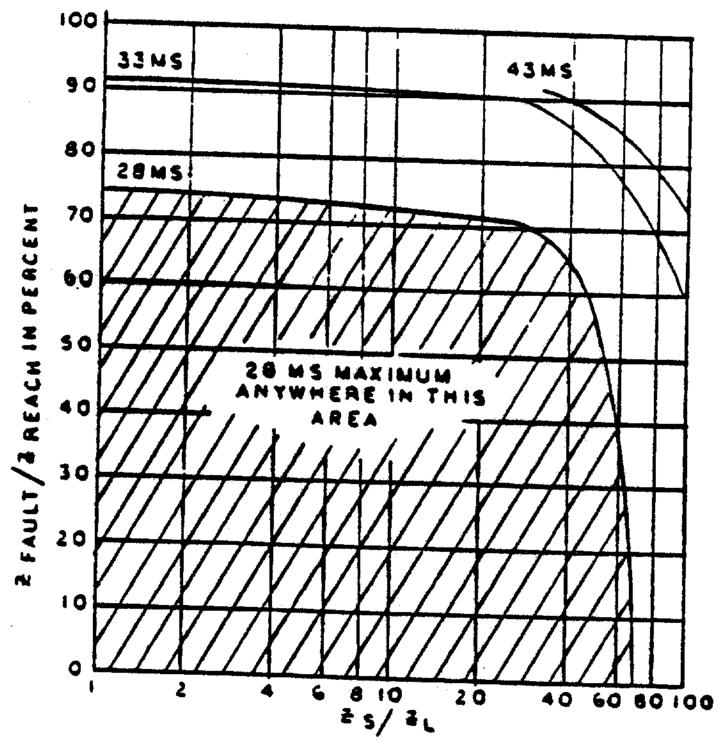


Figure 61 (285A6687-1): Constant Time Operating Curves - Three Phase Faults (Maximun).

CONTINUOUS MONITOR MODULE

BASIC OPERATION

The continuous monitor function works on the principle of recognizing a change in state of one or more of the approximately 40 monitored points (reference Table SE-II in the SERVICING section) as an abnormal relay system condition if this change in state occurs when the power system is in a quiescent state. This means that the process must know the state of the power system at all times (i.e., quiescent or fault). A fault detector (FD) is used to determine the state of the power system. This same fault detector is also used to supervise a trip output from the relay system's scheme logic, even if the optional Continuous Monitor Module is not included. The fault detector responds to negative-sequence current and the change in the positive-sequence current.

A microprocessor, software stored in an EPROM, and other required support chips are the hardware/software that comprise the Continuous Monitor Module. The module operation can be described functionally with the aid of Figure CM-1. If one or more of the monitored points changes state (either logic level 0 to 1 or logic level 1 to 0), the fault detector has not operated, and this condition persists for a minimum of 5 seconds, then the Continuous Monitor Module issues an alarm output to indicate that an abnormal condition - a relay system failure - has occurred. Based on the actual software and hardware implementation, the "A" time delay in Figure CM-1 is not a fixed value, but rather a statistically variable 5 seconds minimum and 10 seconds maximum. An

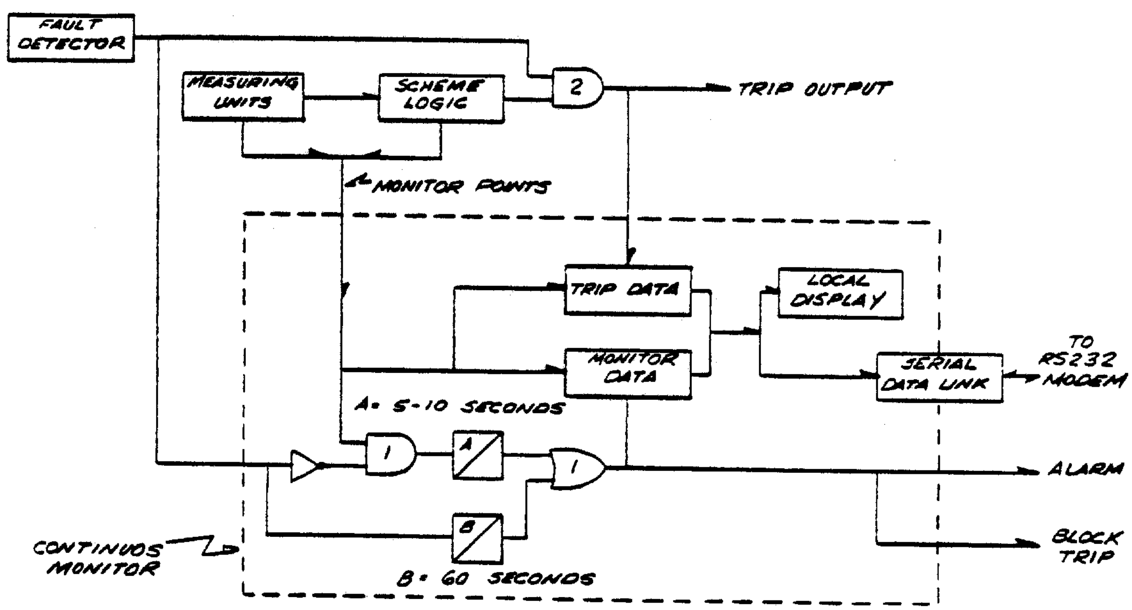


Figure CM-1 (0285A9897) Simplified Functional Diagram Depicting Continuous Monitor Operation alarm output is also produced if a fault detector output persists for 60 seconds. This would be an indication that the fault detector itself had failed.

No monitor data will be taken after a bad fault detector is sensed. To alert the user, the program displays "FD" on the LED numeric display on the front panel after it senses a bad fault detector. It is still possible to use the STEP DISP. pushbutton to step through the trip and monitor data. If this is done, the "FD" does not reappear on the display. For this reason, the LED labeled MON DATA on the front panel is made to blink continuously after a fault-detector failure. This alerts the operator to the fact the unit is not operating normally.

Once OR1 in Figure CM-1 produces an output, indicating a relay system failure, the microprocessor/program stores bit patterns in non-volatile memory that identify which monitored point(s) changed state. These "faulty" monitored points are not stored in chronological order, nor time-tagged, but are simply accumulated in memory. Repeated operation and reset of a particular monitored point does not result in this point being stored more than once. This accumulation of "faulty" monitored points continues until the memory is cleared. Since non-volatile memory is used, the data is not lost if the DC power supply is turned off or the DC is removed externally. To clear the memory, a "clear" command must be given by either (1) the operator pushing a button on the front panel of the module or (2) a remote terminal communicating with the module via a serial data link. When the first relay system failure is detected, the Continuous Monitor Module closes an alarm contact that remains closed until the memory is cleared.

ADDITIONAL FUNCTION

The primary function of the Continuous Monitor Module is to detect and to alarm for a relay-system failure. The other function is to store in non-volatile memory those monitored points that have changed state as the result of a relay-system trip output. Following a trip output, the Continuous Monitor Module scans the monitored points for 10 milliseconds. Any points that change state within this 10 millisecond interval are accumulated in memory as trip data. This can be useful in analyzing relay system response to particular faults. This function and its memory are separate and distinct from the primary function of detecting relay-system failures. The Continuous Monitor Module can have both "trip data" and "monitor data" in memory at the same time.

Data for five (5) trip events will be stored sequentially. If a sixth trip event occurs prior to the memory being cleared, then the data for the first trip event will be overwritten by the data for the sixth trip event. Thus the data for the five most recent trip events will be retained.

The front panel LED numeric display shows "FB" when the trip input to the Continuous Monitor is high. This was done to make the unit easier to test. Without this feature, it is difficult to diagnose the condition when the trip input is accidentally held high.

ACCESS OF STORED DATA

Figure CM-2 shows the front panel of the Continuous Monitor Module with its LEDs, two-digit LED numeric display, toggle switch and pushbutton. The stored data, either monitor or trip, can be accessed locally at the front panel of the module, or it can be accessed from a remote terminal via an optional serial data link.

Local Access

For local access, the two LEDs on the front panel of the module indicate that monitor data and/or trip data are stored in memory. A DATA SELECT toggle switch is used to select which data are to be accessed. The step display (STEP DISP.) pushbutton is then pushed repeatedly to cause the stored points to be displayed via

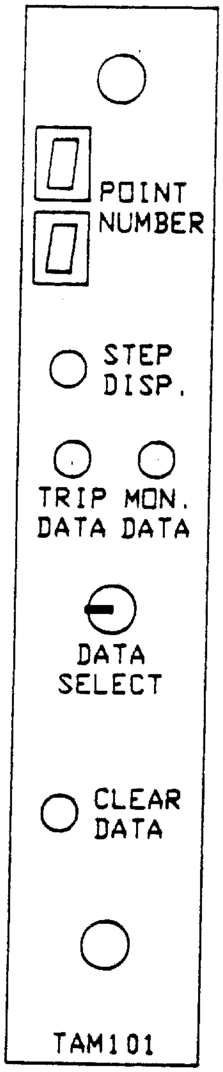


Figure CM-2 (0285A9898) Continuous Monitor Module Front Panel

the two-digit point number (POINT NO.) LED numeric display.

After the DATA SELECT switch is set to the monitor data (MON DATA) position, the LED numeric display should show 0/0 (i.e., the upper and lower display digits are both zero) to indicate the beginning of the monitor data. If 0/0 is not displayed, the STEP DISP. button should be pushed to bring the display to 0/0. The next push of the STEP DISP. button will cause the first stored monitor point to be displayed and this process is continued until 0/0 reappears on the LED numeric display to signal the end of the monitor data.

After the DATA SELECT switch is set to the TRIP DATA position, a 0/0 on the LED numeric display indicates the beginning of the trip data. Once again, successive operations of the STEP DISP. pushbutton cause all the trip data to be displayed between the initial 0/0 and the subsequent 0/0. However, additional codes, E/1, E/2 through E/5, are displayed to differentiate between the trip events. E/1 refers to the last trip event, E/2 to next-to-last trip event, and E/5 to the first trip event, assuming five trip events are stored in memory. When starting from 0/0, the first push of the STEP DISP. button will cause E/1 to appear on the LED numeric display. Successive operations of the STEP DISP. button will cause all trip data points associated with the last trip event to be displayed, followed by E/2 to indicate the beginning of the trip data points associated with the next-to-last trip event. This continues until 0/0 is displayed to indicate the end of the trip data.

Remote Access

For remote access, a serial data link must be supplied. The Continuous Monitor Module includes the necessary software to operate with a serial data link and the chassis backplane wiring connects the input/output ports to a 25-pin connector on the rear of the chassis. This connector resembles an RS-232 connector, but it does **not** provide an RS-232 interface. To provide serial data transmission, an optional fiber-optic transmitter/receiver module can be supplied, which consists of standard Hewlett Packard devices using SMA connectors and packaged by GE into a connector housing. This device is simply plugged into the 25-pin connector on the rear of the chassis. One means of completing the serial data link is to connect one end of a fiber-optic cable to the fiber-optic transmitter/receiver module on the relay chassis and the other end to a commercially available fiber-optic-to-RS-232 converter. The RS-232 side of the converter can then be connected to a

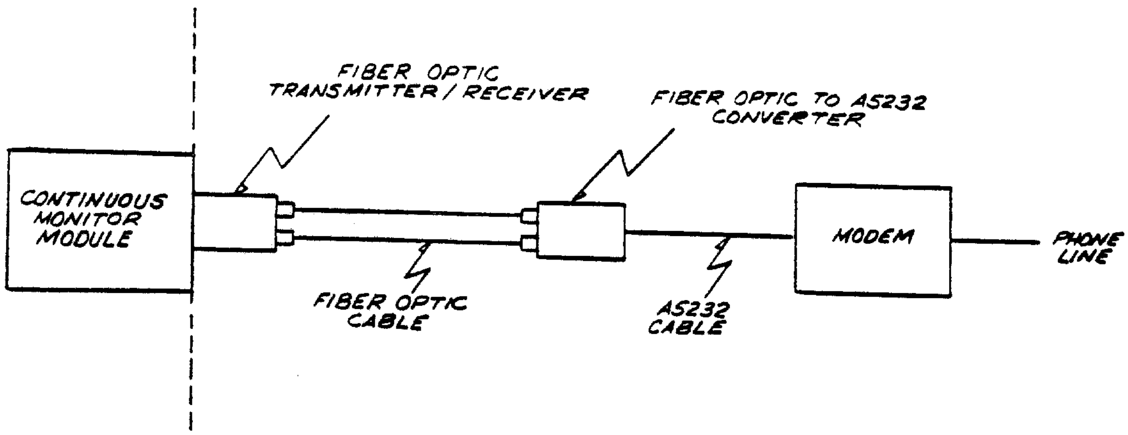


Figure CM-3 (0285A9899) Serial Data Link Connection

modem to provide remote access via telephone lines, as shown in Figure CM-3. Either a "dumb" or a "smart" terminal may be used at the remote site, since no terminal software is required.

The serial data link option provides the user with the capability of remotely interrogating the Continuous Monitor Module to read the data in memory and to clear the memory. Clearing the memory also clears the alarm contact. In the examples below, the full-duplex system as shown in Figure CM-3 is assumed, and the entries by the operator at the terminal are shown in parentheses. Carriage returns are not indicated, but every entry **must** be followed by a carriage return. Entries must be exactly as shown; extra spaces or added punctuation may cause the message to be ignored.

The first step in obtaining data remotely is to address the particular Continuous Monitor Module by its identifying number (up to 16 unit-identification numbers can be assigned via a switch setting on the module). This Module or unit-number designation allows several modules at one substation to be addressed via one serial data link. Assume that unit 2 is to be addressed. Enter the following at the keyboard:

(***2)

The Continuous Monitor Module will respond with one of the following messages:

***2 N	No data in memory
***2 M	Monitor data only in memory
***2 T	Trip data only in memory
***2 M T	Monitor and trip data in memory

Assume that "***2 M T" is received, indicating the presence of both monitor and trip data.

To access the monitor data, enter the following at the keyboard:

(MON)

Assume the response is:

***2 MON
03 09 31

In this case, points 3, 9 and 31 are stored in memory. To access the trip data, enter the following at the keyboard:

(TRIP)

Assume the response is:

***2 TRIP
06 20 21 22 25 37

06 20 21 22 25 37

The first line of data is for the most recent trip, while the last line is for the earliest trip in memory. In this example data are shown for two trip events, but up to 5 events could be present.

If a different Continuous Monitor Module served by the same link is to be accessed at this time, it will be necessary to deselect the present module by issuing a QUIT command and then to address the next module. To quit a module, enter the following at the keyboard:

(QUIT)

The QUIT command does not erase the memory of the currently addressed module.

Clearing the Stored Data

The data can be cleared from memory either locally, via the module's front panel, or remotely, via the serial data link. Local clearing is accomplished by pushing the CLEAR button located on the front of the module. The LED numeric display will show C/C until clearing is complete. Remote clearing is accomplished via the serial data link by entering the following command at the keyboard:

(CLEAR)

The CLEAR command, whether issued locally or remotely, clears both monitor and trip data from memory, and it resets the two contacts associated with the monitor alarm. When issued remotely, the CLEAR command also deselects the present module. If there is only one Continuous Monitor on a communications link, then either QUIT or CLEAR can be used as the final command after interrogation. If there are multiple Continuous Monitor modules, then QUIT should be used, since it will return all the units to the normal state. The monitor alarm contacts close when monitor data is stored in memory, and stay closed until a CLEAR command is issued.

MODES OF OPERATION

The Continuous Monitor Module can be thought of as having three modes of operation: (1) monitor mode, (2) local display mode, and (3) serial data link access mode. Note that regardless of which mode the monitor is in, a relay-system trip will interrupt the program and trip data will be stored. The module is then returned to the monitor mode. Normally the module is in the monitor mode with no local-display-mode bits set. In this condition the module's front panel LED numeric display will show 0/0.

Local Display Mode

To enter the local display mode the operator places the DATA SELECT switch at either the MON DATA or TRIP DATA position and pushes the STEP DISP. button. If there has been no trip since the last pass through the program, the program looks at the status (local-display mode) word to see if a display bit is set. There are two local-display-mode bits. One indicates that monitor data is to be displayed on the front panel LED numeric display. The other bit signifies that trip data is to be displayed. Only one of the two bits can be on at one time, and the presence of either bit will prevent use of the serial data link. To exit the local-display mode and return to the monitor mode, the operator changes the position of the DATA SELECT switch and pushes the STEP DISP. button once so that the LED numeric display shows 0/0. Pushing the CLEAR button will also return the module to the monitor mode. After a 5 minute delay, initiated when the local display mode is first entered, the module will automatically revert to the monitor mode. This prevents the module from unintentionally being left in the local display mode for more than 5 minutes. While in the local-display mode, the module continues its monitoring, as in the monitor mode, except on those program passes when it sees the STEP DISP. button operated.

Serial-Data-Link-Access Mode

When in the serial-data-link-access mode the module does not continue its monitoring, as in the monitor mode. While the Continuous Monitor Module is sending or receiving data, local access via the module's front panel is denied.

Assuming that there is only one Continuous Monitor Module that can be addressed by the remote terminal, the normal way to terminate this mode and return to the monitor mode is to issue a CLEAR or QUIT command. After a 5 minute delay, initiated when the serial-data-link-access mode is first entered, the module will automatically revert to the monitor mode. This prevents the module from unintentionally being left in the serial data link access mode for more than 5 minutes.

When addressing several Continuous Monitor Modules via one serial data link, all the modules will go to the serial-data-link-access mode when a signal is received over the link. In this case, QUIT will deselect the presently addressed module and act as a "site global" command since all of the Continuous Monitor Modules will return to the monitor mode. CLEAR will deselect the presently addressed module and clear its memory, but it will not cause all the modules to revert to the monitor mode. If the terminal operator forgets to issue a QUIT command, each module will automatically revert to the monitor mode following expiration of its individual 5 minute delay.

CONTINUOUS MONITOR ADJUSTMENTS

The only adjustment on this board is the address-setting switch. The location of this switch and the bit values of the individual switches are shown in Figure CM-6. The setting is the sum of the switch values. The setting can range from 0 to 15. Values from 10 to 15 correspond to addresses from A to F. This address is used to select a particular Continuous Monitor using the serial data link.

The front panel controls are as follows:

Panel Marking	Description
Point Number	Two-digit LED to display abnormal point input number. Top digit is the most significant.
Step Display	Pushbutton to step Point Number to next point (in numerical order).
Trip Data	LED that indicates, when lit, that trip data has been stored.
Mon Data	LED that indicates, when lit, that monitoring data has been stored.
Data Select	Two-position switch to select either trip or monitor data on Point Number display.
Clear Data	Recessed pushbutton that clears all memory data when operated.

CONTINUOUS MONITOR SERIAL LINK USE

The continuous monitor serial data link has the following characteristics:

Baud rate	300
Data bits	7
Parity	odd
Stop bits	1

When shipped, the TYS relay system chassis containing the Continuous Monitor is always wired to operate with the serial data link. To provide serial data transmission, a fiber-optic transmitter/receiver module is installed on the 25-pin connector on the rear of the chassis. This connector resembles an RS-232 connector, but it is NOT RS-232 compatible. This fiber-optic transmitter/receiver module is made by GE and contains only the optical transmitter and receiver to couple to and from the fiber-optic cables. The optical transmitter and receiver are standard Hewlett Packard devices, HFBR1402 and HFBR2402, which use SMA connectors. The other end of the fiber-optic cables (HFBR-3000 or equivalent) can be coupled to any suitable optical devices. Under normal conditions (no transmission) the fiber-optic transmitter at the chassis is OFF. The receiver at the chassis expects a similar "OFF" signal.

The simplest means of using the fiber-optic link is to purchase commercially-available fiber-optic-to-RS-232 converters and related communications equipment. Figures CM-4 and CM-5 show two communication schemes that have been implemented.

CHECKSUM

There is a checksum routine that continually checks for EPROM memory errors. If it detects a failure, the front-panel display will reach "C5". The monitor alarm will operate and monitor bit 16 will be set. If this occurs, the Continuous Monitor module should be replaced.

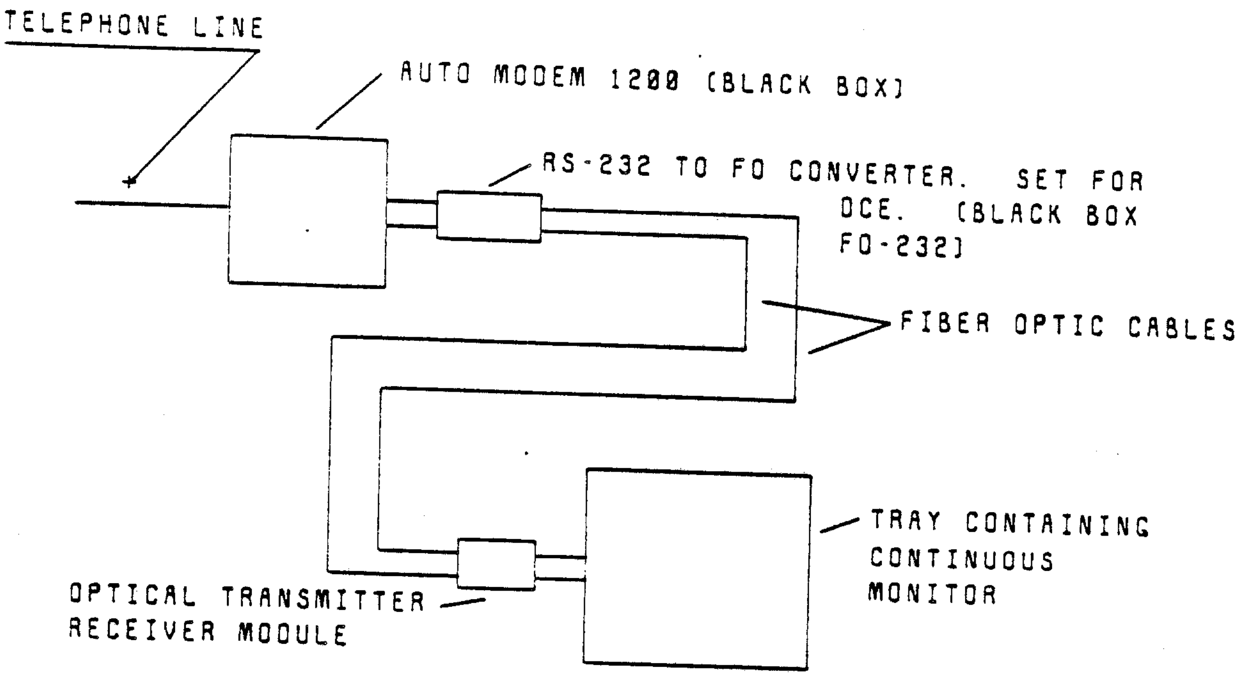


Figure CM-4 (0285A9836-1) Continuous Monitor Phone Connection

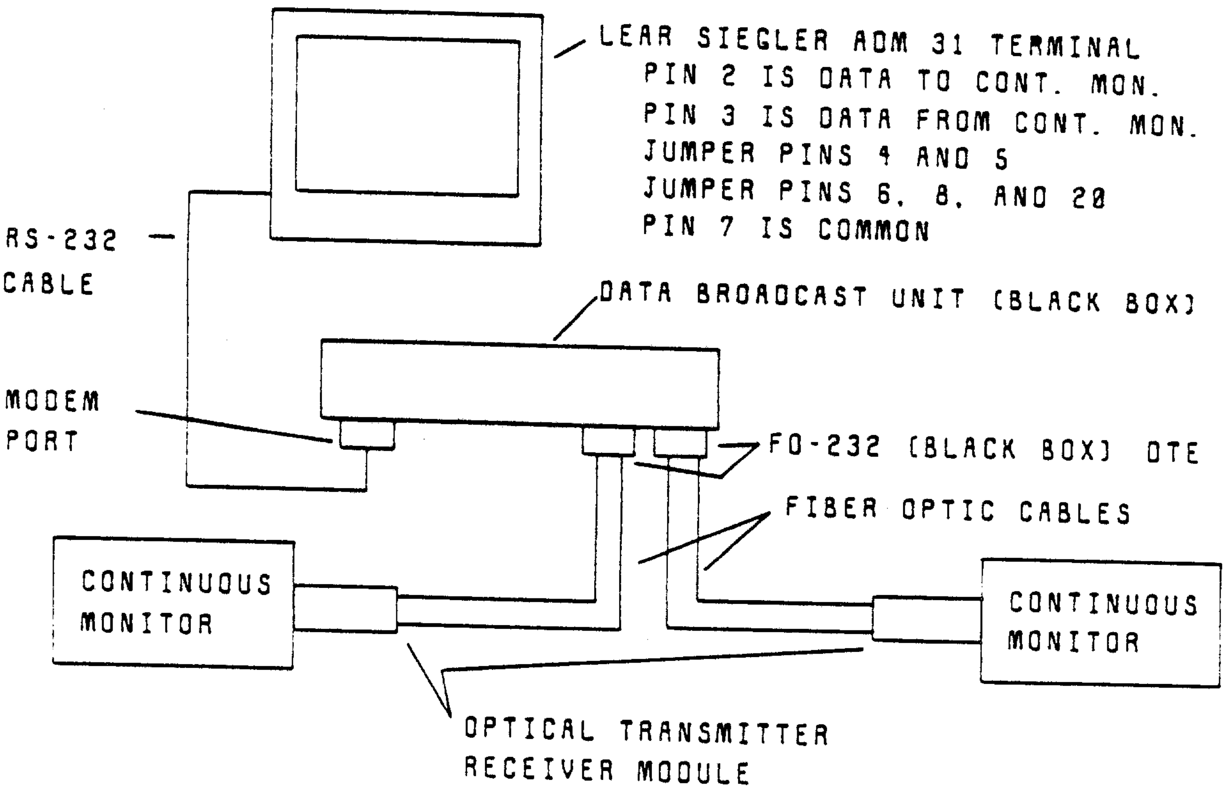


Figure CM-5 (0285A9837-1) Connection for Multiple Continuous Monitors

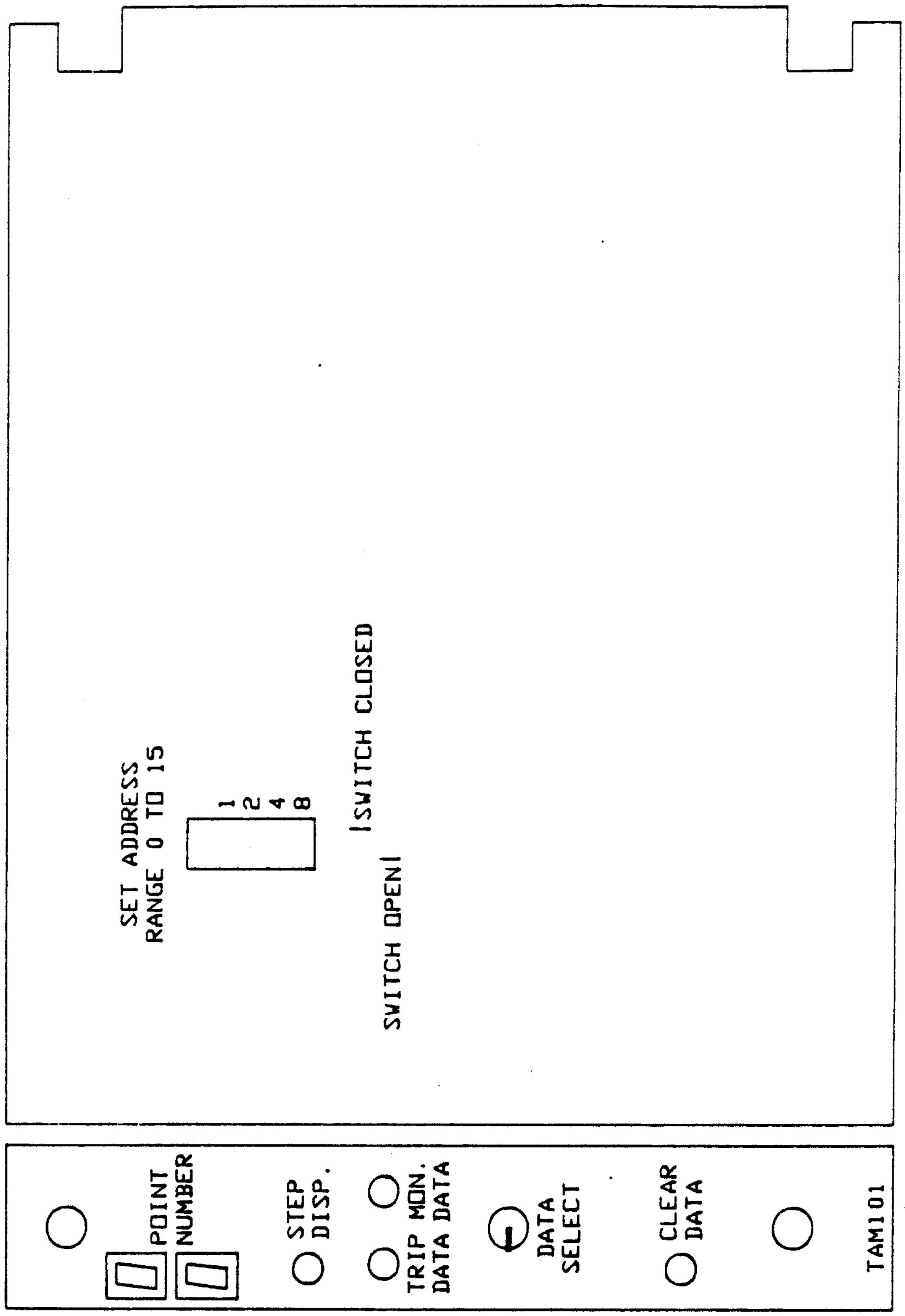


Figure CM-6 (0285A9831-1) Front Panel & Internal Switches, TAM101