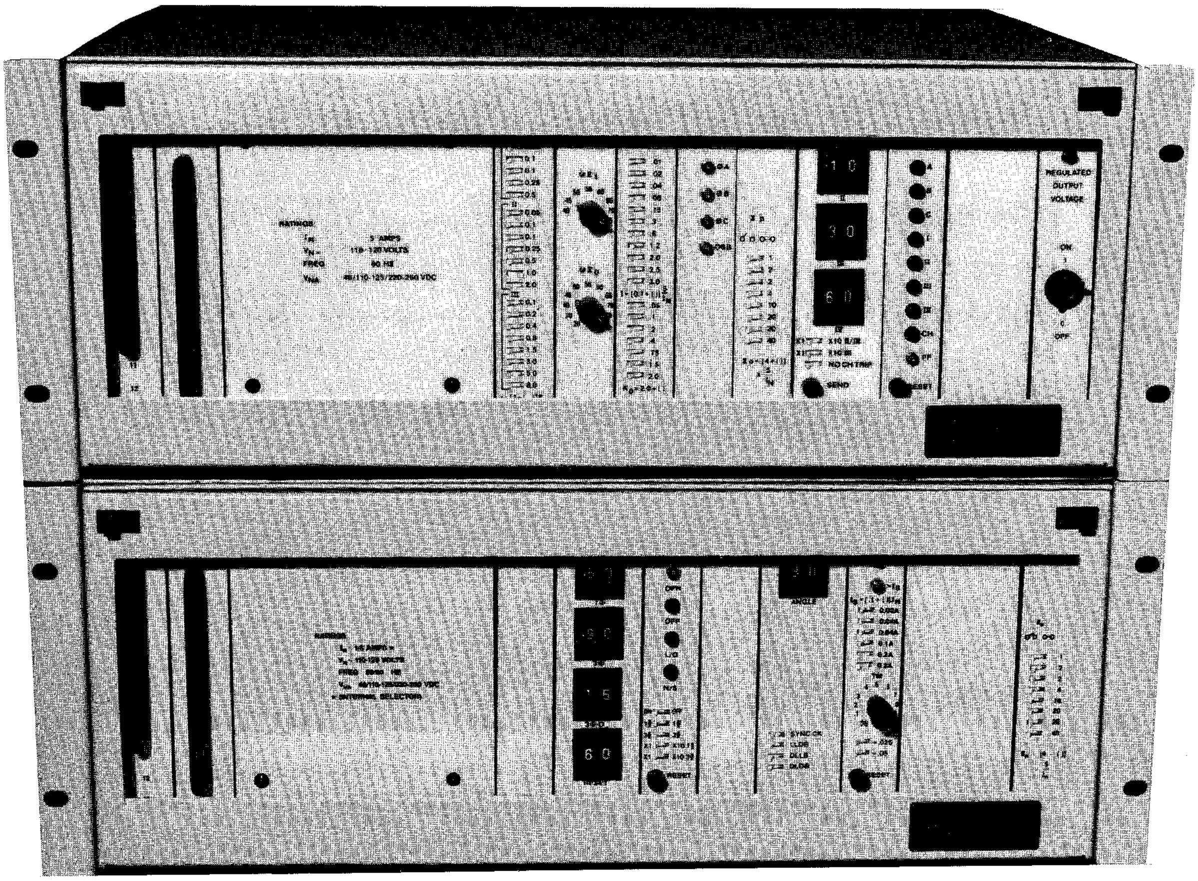
INSTRUCTIONS

GEK-86044D
Supersedes GEK-86044C

SLS
MODULAR RELAYING SYSTEM



GENERAL ELECTRIC

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Cover Photo (8043766-0)

INTRODUCTION

The SLS1000 is a comprehensive relaying system for transmission line protection. Basically, the system consists of a distance relay and a recloser which are interconnected and functionally integrated.

The system is packaged in a modular design consisting of pluggable printed circuit board modules which are housed in two separate cases. The principal magnetic elements (transformers, telephone relays, etc.) are also contained in pluggable modules, there being one magnetics module in each case. A multi-conductor cable (or cables) provides the interconnection between the two cases.

Standard Features

The SLS1000 includes the following standard features:

- Choice of five protective schemes

  1) Stepped Distance - up to four zones
  2) Zone One Extension
  3) Zone Two Acceleration
  4) Permissive Underreaching Transfer Trip
  5) Permissive Overreaching Transfer Trip

- Voltage Transformer Fuse Failure Detection
- Power Swing Detection and Blocking
- Reclosing - one or two attempts
- DC to DC Converter Power Supply

Optional Features

The following features are available on an optional basis:

- Additional protective scheme

  6) Directional Comparison Blocking
     - includes reverse zone five with timer (for backup protection)

- Ground Time Overcurrent Unit

  Type A Curve, IEC255-4 (inverse characteristic)
  Dual Polarized Directional Supervision (available separately)

- Synchronism Check Circuit to Supervise Reclosing

  Monitoring of bus and line voltage magnitudes (live or dead)
  Angle Measurement
  High and Low Slip Measurement Circuits

Protective schemes 3, 4, 5 and 6 above are pilot schemes which require a communication channel.

When a scheme other than stepped distance is used, the SLS will concurrently function in the stepped distance mode as back-up.

Tripping and reclosing may be done on an individual phase basis for faults in the first zone. If this is not desired, three pole only operation may be selected, in which case the individual breaker pole tripping and reclosing relays operate in unison.

For faults in the second, third and fourth zones, the distance relay trips the breaker only on a three pole basis. This is also the case for backup tripping in the reverse fifth zone and for tripping via the ground time overcurrent unit. Reclosing is inhibited when the zone timer advances beyond its first interval (zone two time setting).

Note Regarding Model Numbers

The various available models of the SLS1000 system are listed in Fig. 77A. As indicated therein, the SLS1100B series is the same as the SLS1000B series, except that it contains the directional comparison blocking (and reverse zone five with timer) option.

OPERATING PRINCIPLES

DISTANCE RELAY

Basic Stepped Distance Protection

Fig. 1 is a simplified block diagram of the SLS stepped distance scheme. The inputs from the voltage transformers (PTs or CVTs) are sent into networks which produce a group of voltage signals. Similarly, the inputs from the current transformers (CTs) are sent into networks which produce a group of current signals (actually current x impedance or IZ). These signals are present at all times, on standby for switching into the main measuring unit.

The phase selectors (or starting units) utilize certain voltage and current signals to continuously monitor conditions on the protected line section. The specific signals used will be discussed later. The phase selectors consist of distance measuring units each having a variable mho-type characteristic which should be set to reach beyond the third zone of protection. There are three phase selectors, one for each phase. The reach setting is common to all three. Their function is to determine which phase or phases are faulted.

When a single phase fault occurs within the phase selector reach, the phase selector associated with the faulted phase operates. For a double phase fault, the two phase selectors associated with the faulted phases both operate. For a three phase fault, all three phase selectors operate. The operation of one or more of the phase selectors initiates the zone timer through OR3.

The fault type logic determines the type of fault based on which phase selector or combination of phase selectors has (have) operated. For example, if only the A phase selector has operated, the fault is an A to ground fault and the fault type logic produces an AG signal (refer to Fig. 1). If both the A and B phase selectors have operated, the fault is either an A to B or an A to B to ground fault and the fault type logic produces an AB signal. In the SLS distance scheme, the same quantities are used for the measurement of phase-to-phase and phase-to-phase-to-ground faults. The quantities used for B to C faults are provided with memory action and are also used for measuring three phase faults.

The output of the fault type logic controls the fault type switching network which switches the appropriate voltage and current signals into the main measuring unit. A different set of signals is used for each type of fault. The switching network has three outputs; 1) the preliminary operating quantity, 2) the preliminary restraining quantity, and 3) the polarizing quantity.

The preliminary operating quantity is adjusted for the desired zone one reach and becomes simply the operating quantity, as shown in Fig. 1. The preliminary restraining quantity is simultaneously sent through three paths into the zone switching network; 1) unadjusted, 2) adjusted for zone two reach, and 3) adjusted for zone three reach. The network selects one of these and switches it through as the restraining quantity, basing its selection on the output of the zone timer. The timer operates as long as one or more of the phase selectors continue to give an output (fault still present). Starting in zone one (standby condition), it advances to each successive zone as time elapses, according to the zone timer settings. Note that the phase selectors constitute the fourth zone. Therefore the Z4 signal is not used to control the zone switching network.

The operating and restraining quantities are summed to produce the net operating quantity. This is fed into the main measuring unit where it is compared against the polarizing quantity to determine whether or not the fault is within the prevailing zone. The method of distance measurement used is described in the next subsection.

An output from the main measuring unit initiates a trip signal directly through the tripping logic. The tripping mode, single pole or three pole, is determined from the fault type and zone. Single pole tripping is permitted only in zone one and will occur only for single phase faults. The logic selects the correct pole to be tripped. Double phase and three phase faults always result in three pole tripping, as do single phase faults in zones two, three or four.

The logic diagram (Fig. 5) and its associated written description (section entitled Distance Relay Logic) provide a detailed explanation of the operation of the distance relay, including the fuse failure and power swing detection features, as well as the four alternate schemes of protection.

Principles of Distance Measurement

There are five distance measuring units in the SLS; three phase selectors, the main measuring unit, and a permissive zone measuring unit used in the pilot schemes and in the detection of power swings. When a single line to ground fault is detected, a negative sequence directional unit is used to supervise enabling of the main measuring unit's characteristic timers and consequently provides the required directional supervision 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 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. 2A gives a logical representation of the measurement circuitry, Fig. 2B shows typical waveforms for a fault external to the characteristic, and Fig. 2C 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:

$$\alpha = A \times \frac{f}{1000} \times 360$$

where:

α = pickup pulse width (in degrees)
A = pickup time of timer (in milliseconds)
f = system frequency (in hertz)

The angle α (timer setting) establishes the shape of the characteristc for the mho-type measuring units. α= 90 degrees forms a circular characteristic, $\alpha > 90$ degrees forms a lens-shaped characteristic, and $\alpha < 90$ 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. 3 . The principal quantities are as follows:

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

where:

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

Fig. 3 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 α = 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. 4 . In this case, the operating quantity phasor (IZ_R) is the hypotenuse and the polarizing quantity (V) and net operating quantity (IZ_R-V) phasors are the remaining two legs of the right triangle.

Fig. 3A depicts a fault external to the characteristic, in which case the phase angle β between the polarizing and net operating quantity, exceeds 90 degrees. The coincidence blocks are therefore less than 90 degrees wide (180 - β) and the characteristic timer will not pick up. Fig. 3B depicts a fault internal to the characteristic and Fig. 3C 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 SLS Distance Units

The SLS 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 SLS 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 third zone 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: $I'_\emptyset Z_P = (I_\emptyset - I_0)\, Z_P \angle\theta_1 + K_0 I_0 Z_P \angle\theta_0$

and Z_P = phase selector reach (in ohms)
$V_{\emptyset N}$ = phase to neutral voltage (in volts)
$V_{\emptyset 1M}$ = positive sequence voltage with memory referenced to phase Ø(in volts).
$I_\emptyset$ = phase Ø 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)
Ø = 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}
3Ø	--	--	$(I_B - I_C) Z_R - V_{BC}$	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 Ø (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	$(-I_A^{\prime}Z_P-V_{AN}) + KV_{A1M}$	V_{A1M}
B	$(-I_B^{\prime}Z_P-V_{BN}) + KV_{B1M}$	V_{B1M}
C	$(-I_C^{\prime}Z_P-V_{CN}) + KV_{C1M}$	V_{C1M}

TABLE IV - DIRECTIONAL UNIT MEASURING QUANTITIES

OPERATING QUANTITY	POLARIZING QUANTITY
$V_{A2} - I_{A2}X_R^{\prime}$	$I_{A2}X_R$

where: $X_R^{\prime}$ = 2.4 ohms
All other terms are as defined following tables I and II.

RECLOSER

Basic Automatic Reclosing

Automatic reclosing is initiated when the distance relay issues a trip output. The recloser employs the breaker "b" switches to monitor the status of the breaker poles. A trip signal and a closed "b" switch or switches (open pole or poles) must be present simultaneously (actually within 20 milliseconds of each other) in order for the reclosing cycle to begin.

Consider the case of a single phase to ground fault. The distance relay issues an output to trip one breaker pole. At the moment that the pole opens, the recloser receives both a trip signal (from the distance relay) and a closed "b" switch signal (from the breaker). This initiates the one pole, first reclose timer. When this timer expires, the recloser produces a reclosing output (contact closure) for the open pole.

If the fault persists, the distance relay will again trip the breaker but this time the trip will be three pole because the recloser automatically sets up three pole tripping after the first reclosing attempt. The trip signal and closed "b" switch signals initiate the three pole, second reclose timer (delayed reclose timer). When this timer expires, the recloser produces a three pole reclosing output.

If the fault is still present, the distance relay trips the breaker a third time (three pole). The recloser goes into lockout, inhibiting any further reclosing attempts.

The distance relay and recloser will initially operate in the three pole mode for multi-phase faults. A separately adjustable three pole, first reclose timer is provided for this purpose. The second attempt, however, is always made on a three pole basis. Therefore, there is only one setting to be made for the second (delayed) reclose timer.

The recloser logic diagram (Fig. 9) and its associated written description (section entitled Recloser Logic) provide a detailed explanation of the operation of the recloser. An optional synchronism check module may also be included in the recloser package.

Manual Closing

The SLS recloser offers the capability of manually closing the breaker through the recloser circuitry. When using this feature, a manual close signal need only be input to the recloser. The output contacts of the recloser are used to activate the individual pole breaker closing circuits.

Regardless of whether manual closing is accomplished using the recloser or by means of external circuitry, automatic operation of the recloser is inhibited for the duration of the reset timer setting following the manual closure.

DISTANCE RELAY LOGIC

Fig. 5 is a logic/block diagram which describes the operation of the SLS distance relay. It should be emphasized that this is a functional representation. The logic function designations have been assigned to facilitate this description and are not always directly related to the actual module circuitry.

The complete scheme shown on Fig. 5 includes the following functions:

Phase selectors (ØA, ØB and ØC)
Current supervision (CS - ØA, ØB, ØC)
Main measuring unit (switched phase and zone)
Permissive zone-3 measuring unit (switched phase)
Measuring unit input quantity selection
Measuring unit reach selection
Negative sequence directional unit (DU)
Zone timer logic
Fuse failure protection
Out-of-step blocking function
Trip output units (ØA, ØB, ØC)
Breaker failure output units (ØA, ØB, ØC and 3Ø)
Target lamps
Carrier start functions (MB-ØA, MB-ØB, MB-ØC) - blocking scheme only

OUTPUT CIRCUITS

Trip Outputs

The distance relay includes three separate trip output circuits, identified as ØA, ØB and ØC trip, each with three electrically separate contacts.

Breaker Failure Backup Initiation (BFI)

There are four BFI units included, each with a normally open contact. One unit labelled BFI is energized via OR20 whenever any trip output unit is energized. The other three are separately controlled by the ØA, ØB or ØC trip outputs. Links are provided in the DOM201 module to allow the units to function individually (IND positions) or in unison (COM position).

Reclose Initiation (RI)

Outputs from each of the three trip buses, designated as RI-ØA, RI-ØB and RI-ØC, provide the inputs to the recloser through interconnection cable PL-1.

Transmitter Keying - Permissive Trip Schemes

An output relay with one normally open contact is provided to key the frequency-shift channel to its trip frequency. The scheme selection logic determines which functions operate the keying unit. For example if the scheme selection logic is set for permissive overreach (POTT), the keying unit will be energized by an output from the permissive zone-3 measuring unit via AND33 and OR11.

Or if the scheme selection logic is set for permissive underreach (PUTT), the keying unit will be energized by an output from the main measuring unit, supervised at AND34 by the output of NOT2 which will be present until TL5b operates.

Transmitter Keying - Directional Comparison Blocking Schemes

Two output relays, each with one normally open contact, are provided for carrier control. The key transmitter, or carrier start contact, is energized by an output from one or more of the MB functions via TL17, AND67, TL16, AND70 and OR11. The stop transmitter contact is energized by an output from the permissive zone three measuring unit via AND69.

Targets and Indication

Target lamps are provided for the following:

(CH)	Channel Trip
(A)	ØA Trip
(B)	ØB Trip
(C)	ØC Trip
(I)	Zone-1 Trip
(II)	Zone-2 Trip
(III)	Zone-3 Trip
(IV)	Zone-4 Trip
(FF)	Fuse Failure Indication
(IN)	Ground Time Overcurrent Trip (optional)

An option is available on the DLM101 module to light the red A, B and C trip target lamps for either of the following conditions:

a) Trip type targeting - In this mode, the target lamp will light if its associated trip bus is energized, whether or not that phase is faulted. For example, on a ØAB fault, the relay will trip three pole and the C target lamp will light in addition to the A and B lamps.

b) Fault type targeting - In this mode, only the target lamps associated with the faulted phases will operate. Thus, on a ØAB fault, the relay will trip three pole, but only the A and B targets will light.

The target lamps listed above, except fuse failure, seal-in and must be reset by means of a push button. All the lamps light for a short period of time when the button is depressed, thereby providing a means of testing the lamps. In addition to operating a target lamp, the zone 1, 2, 3, 4 trip outputs and the fuse failure function each operate a separate alarm unit with one normally open output contact. The optional ground time overcurrent function operates an alarm output with a type "c" output contact.

The target lamps listed below do not seal-in:

(ØA)	Phase-A selector
(ØB)	Phase-B selector
(ØC)	Phase-C selector
(OSB)	Out-of-step block

SCHEME OPERATION

The scheme covered in Fig. 5 can be applied in a number of operating modes, as determined by the scheme selection logic. Pilot related schemes are permissive overreaching transfer trip, permissive underreaching transfer trip, zone-2 acceleration, and directional comparison blocking. The zone-1 extension feature, included on the scheme selection logic, does not involve the pilot channel. In addition step distance backup, which is also independent of the pilot channel, is included.

Phase Selector Performance

The three phase selectors (ØA, ØB and ØC) are directional mho functions supervised at AND1, AND2 or AND3 respectively by the current supervising functions CS-ØA, CS-ØB, or CS-ØC. These phase selectors inform the input selection function whether a fault is single-phase-to-ground or multi-phase so that this function in turn can apply the proper quantities to the main measuring unit and the permissive measuring unit.

For example, during an AG fault the AND4 output indicates that the ØA selector has operated but not B or C. This applies the AG input, via AND11, to the input selection function, which in turn provides the proper input to the measuring units. Similarly for BG and CG faults, AND5 or AND6 respectively provide the BG or CG inputs via AND12 or AND13. Note that AND11, 12 and 13 are supervised by the TL4 timer which is started, via OR3, by the operation of any one or more phase selectors. The slight delay introduced by this timer prevents an incorrect output from the input selection function during a multi-phase fault if one phase selector operates ahead of the other (or others).

During an AB or ABG fault the output from AND7 indicates that the ØA and ØB selectors have operated, but not ØC. This applies the AB/ABG input, via AND15, to the input selection function, which in turn provides the proper inputs to the measuring units for that multi-phase fault. Similarly for a CA or CAG fault, the CA/CAG input is applied via AND8 and AND16. The input to the selection function via AND9 and AND17 indicates a BC/BCG or a three-phase fault, since the output from AND9 will be present for either a BC or three-phase (ABC) fault.

The AND functions associated with multi-phase faults (AND15, 16, 17 and 18) are also supervised by timer TL4 for the reason previously described. An output from AND18 indicates that a multi-phase fault is involved and applies an input to OR21 so that tripping will be three-pole.

Performance of Measuring Units

The main measuring unit performance is determined by its input quantity selection logic and its reach selection logic. The input selection logic responds to operations of various combinations of phase selectors, as described in the preceding section. The reach selection logic responds to outputs from the zone timers and their associated logic.

The main measuring unit (MU) has a directional mho characteristic for multi-phase faults, and either a mho characteristic or a reactance characteristic for single-phase-to-ground faults. The choice between the mho or reactance characteristic for ground faults is made by means of a link setting in the DVM101 module. The MU characteristics are determined by the characteristic timers and associated logic in the MU output. The performance of the timers in the overall scheme operation is described in a later subsection.

The permissive zone-3 measuring unit performance is determined by the same input quantity selection logic that controls the main measuring unit. However, its reach is fixed at the zone-3 reach setting of the main measuring unit.

Stepped Distance Performance

Performance of the scheme in the stepped distance mode is dependent upon the settings of the zone timers TL5a-TL5d, and of course the reach settings of the main MU. Operation of these timers is initiated via OR3 by the operation of any one or more of the phase selectors. In the standby condition (i.e., normal load flow over the protected line) no phase selector will be operated, and since no timer will be energized, there will be outputs from both NOT1 and NOT2. The function of TL5a and NOT1 will be discussed in detail later, but suffice it to say that this timer must always be set for a shorter time than the zone-2 timer TL5b. Assume for the time being that the zone limit link (L2) is in position 4. AND21, AND75 and AND24 are therefore enabled at their NOT inputs by "pull-down" resistors R1, R2 and R3, respectively. The output of NOT2 is applied via AND32 to the zone-1 (Z1) input of the reach selection logic in the main measuring unit. Thus in standby the reach of the main measuring unit will be at its zone-1 setting and will remain at this setting until the zone-2 timer TL5b operates. The output of NOT2 also provides a supervisory signal to the SLS recloser through interconnection cable PL-1, and energizes an auxiliary relay for supervision of an external recloser. The intent is to permit reclosing only for trips in the initial zone timer inteval. When timer TL5b operates, the output of NOT2 is cut off by AND21 (de-energizing Z1) and the zone-2 (Z2) input of the MU reach selection is energized via AND21, AND22 and OR8. This condition will then persist until the zone-3 timer, TL5c, operates cutting off AND22 through AND75 and energizing the zone-3 (Z3) input of the MU reach selection via AND23.

The zone-4 reach of the scheme is determined by the reach setting of the phase selectors and occurs when TL5d times out and applies an input directly to the three-pole trip bus via AND24 and OR16. It is important to note that the time delay pickup of timers TL5a, TL5b, TL5c and TL5d must be set progressively longer than the preceding value where TL5a has the shortest delay pickup and TL5d has the longest delay pickup. If the pickup times are not set progressively longer, then the actual delay time of a particular timer may exceed the set value.

Assume that a phase-A to ground fault has occurred within the zone-1 reach setting of the main MU. This will cause operation of the phase-A selector and the negative sequence directional unit (DU). Operation of the ØA selector initiates operation of the zone timers via OR3, applies the lower input to AND20 via OR1 and AND14, supplies the AG signal to the input quantity selection logic via AND11, and applies the top input to AND51 in the pole-A selection logic. Since the directional unit has also operated there will be an output from AND20 which in turn will cut off the output of NOT3, thus removing the "Reset" input to the MU characteristic timers TL9a, TL9b and TL9c, thereby releasing these timers for operation. Also the output of AND14, indicating that only one phase selector has operated, energizes the NOT input of AND42 which feeds TL9a, cutting off this timer which establishes the phase mho characteristic. AND14 also supplies the middle inputs of AND43 and AND44 that feed timers TL9b and TL9c respectively and establish the ground distance characteristic, either reactance or mho as selected.

The function of timer TL5a is to allow time for an "adjustment" to the reactance characteristic to provide additional security against a misoperation during an external ground fault at the remote bus. The pickup setting of timer TL5a is selected to allow time for the external fault to be cleared by the zone-1 protection on the line out of the remote bus. Prior to the fault occurring, there will be no timer output, resulting in an output from NOT1, which blocks AND43 and supplies the lower input of AND44. Thus when the phase to ground fault occurs, it will be timer TL9c that will determine the MU characteristic for the duration of the TL5a pickup setting. Assuming the ground reactance characteristic has bee selected and the A coincidence angle has been set for 120°, the ground distance characteristic will be as depicted in Fig. 6A. Until timer TL5a times out, the R-X diagram characteristic will be between the dotted line labelled "135°" and the solid line labelled "120°." If the initial coincidence block from AND44 is greater than or equal to 135°, then a TL9c output will result for this first block. If the initial coincidence block is greater than or equal to 120° but less than 135°, then TL9c starts to integrate and a TL9c output results if the suceeding coincidence blocks are of sufficient width. If the initial coincidence block is less than 120°, then TL9c will not start the integration process until a succeeding block becomes greater than or equal to 120°. After TL5a operates, TL9c is cut off and the ground distance characteristic will then be determined by timer TL9b. The R-X diagram characteristic will now integrate (i.e., evolve) from the "tent" shaped characteristic labelled "120°" in Fig. 6A to the conventional reactance characteristic labelled "90°" in Fig. 6A.

If the ground mho function is selected, its operation is similar except that the characteristic is initially a 135/120° lens for the duration of the TL5a operate time, and then integrates to the mho circle as shown in Fig. 6B.

If the sequence time feature provided by TL5a is not desired, it can be effectively eliminated by setting the TL5a operate time for ten milliseconds. Timer TL5a will then have timed out before the phase selector supervising timer TL4 releases AND11. Then characteristic timer TL9b will be determining the MU characteristic by the time AND11 energizes the input quantity selection logic.

Operation in zone-1 time on the AG fault will result in a trip output via OR12, AND47 and OR14. The OR14 output is applied to AND51, AND52 and AND53 in the individual pole trip circuits. Since only the phase-A selector has operated, and the trip mode selection link L3 is in the one-pole position, only the phase-A trip unit will be energized.

If the AG fault is beyond the zone-1 reach setting of the MU but on the protected line (i.e., an "end-zone" fault), when the zone-2 timer TL5b operates, it will supply the Z2 input to the main MU via AND21, AND22 and OR8. The TL5b timer also cuts off the Z1 input by energizing NOT2. This zone-2 delayed trip will be via the TL9b characteristic timer of the MU. The Z2 timer output from AND22 also energizes OR21 and the upper input of AND50 so that the delayed zone-2 trip output from OR14 will trip all three poles via AND50 and OR16. A trip in zone-3 time, initiated by timer TL5c, will also be three-pole. If a fourth zone is used, it will be determined by timer TL5d and the reach setting of the phase selectors. This will be a three-pole trip via AND24 and OR16.

Now assume that a multi-phase fault (say AB or ABG) has occurred within the zone-1 reach of the main measuring unit. This will cause operation of the phase-A and -B phase selectors, which initiates operation of the zone timers via OR3 and supplies the AB input to the MU input quantity selection logic, via AND7 and AND15. The AND7 output also energizes AND18 via OR2, indicating a phase-to-phase or three-phase fault. The AND18 output energizes NOT3 thus releasing the characteristic timers TL9a, b, and c, and also providing the top input to AND50 via OR21 so that any trip will now be three-pole. Since there will be no output from OR1 and AND14, the MU mho characteristic will be determined by integrating timer TL9a. Timers TL9b and TL9c, and the sequence timer TL5a, will not be involved with multi-phase faults. The trip output from OR14 will initiate a three-pole trip via AND50 and OR16 for the high-speed zone-1 trip and for any subsequent delayed trips.

The zone limit link (L2) may be used to limit the sequential switching of the stepped distance scheme to a given zone. In the TEST position, the link disables AND21 at its NOT input, thereby invalidating the TL5b output. This in turn disables AND22, AND23 and AND24. NOT2 continues to produce an output so that the reach is locked in zone 1 (or zone 1X).

In the 2 position, L2 disables AND75 so as to invalidate the TL5c output. This in turn disables AND23 and AND24 so that the zone switching is limited to zone 2. Similarly, in the 3 position, L2 disables AND24 which limits the switching to zone 3. In the 4 position, no gates are disabled, and the zone switching goes through its full sequence.

Zone-1 Extension (Z1X)

The zone-1 extension feature is activated by a signal from the Z1 extension output of the scheme selection logic to the top input of AND29 and the absence of an input to the NOT of AND29 from OR29. The OR29 signal is produced by the SLS recloser or by an external recloser through CC5. The output from AND29 feeds the Z1X input of the reach selection function, which causes the reach of the main measuring unit to cover the entire length of the protected line plus margin. The output of AND29 also feeds the NOT of AND32 via OR7, thus cutting off the Z1 input during the period that Z1X is activated. Thus a fault anywhere on the line will be cleared in zone-1 time. Tripping will be single-pole for single-phase-to-ground faults and three-pole for multi-phase faults, provided link L3 is in the 1P position.

Prior to the completion of the intial high-speed reclosure, an input to the NOT of AND29 from the recloser will appear, thus cutting off the zone-1 extension feature and re-establishing the first zone (Z1) input of the reach selection function. If the fault is still present and is within the zone-1 reach setting (typically 90 percent of the protected line), the breaker will again be tripped in zone-1 time, but tripping will now be three-pole for all fault types. This results from the input to OR21 from the recloser, designated as "three-pole trip enable," which will appear prior to the initial reclosure. If the fault is in the end-zone of the protected line, tripping will be in zone-2 time.

Pilot Schemes

The scheme selection logic can be set for one of three schemes involving the frequency-shift pilot channel. These are:

1. Permissive overreach transfer trip (POTT)
2. Permissive underreach transfer trip (PUTT)
3. Zone-2 acceleration (Z2ACC)
4. Directional Comparison Blocking (DCB)

1. Permissive Overreaching (POTT)

The performance of the permissive overreaching transfer trip scheme can be described with the aid of Fig. 7.

For this mode of operation the scheme selection logic will be set in the POTT position, which applies a signal to the bottom input of AND28 and the top input of AND33.

Consider first an external fault at X in Fig. 7. The overreaching permissive zone-3 MU at terminal C will operate and its output from AND48 will key the transmitter, via AND33, OR11 and L-12 (NORM position if transmitter is to be keyed by a contact closure), thereby sending a trip signal to terminal D. The receiver at D will apply a signal to the top input of AND28 via CC1, L-10 (NORM position if a contact closure indicates receipt of channel signal), and AND25, but there will be no trip output from AND28 since the permissive MU at D will not have operated as the fault is behind that terminal.

During an internal fault, as at Y, the overreaching permissive MU at both C and D will operate, keying the transmitter and sending a trip signal from each end, and also applying the middle input to AND28 via timer TL6, the purpose of which is described below. Since the top and bottom inputs of AND28 will also be present, the transfer trip scheme has now established that the fault is internal to the protected line and a channel trip will be initiated, at both ends via OR5, timer TL7b and OR14. Whether this channel trip is one-pole or three-pole will depend on the setting of the tripping mode link L3, and on the type of fault as described below. It will be assumed in the following discussions that link L3 is in the one-pole position.

Assume first that the internal fault is phase-A to ground. As noted in the earlier section on step-distance, this will cause operation of the phase-A selector and an output from AND11, which in turn applies the top input to AND51 in the pole-A selection logic. Although the channel trip output from OR14 is applied to AND51, AND52 and AND53, only the pole-A trip unit will be energized via AND51 since only the phase-A selector has operated.

If the internal fault involves more than one phase, an output from AND18 via OR2 will apply the top input to AND50 via OR21 so that an output from OR14 as a result of the channel trip will trip all three poles.

The purpose of the coordination timer TL6 can be explained as follows. Referring to Fig. 7 assume an external fault on a parallel line is seen by the overreaching permissive MU at C. The resulting output from AND48 will key the transmitter via AND33, OR11 and L-12, sending a trip signal to the equipment at D. The receiver at D applies a signal to the upper input of AND28 via CC1, L-10, and AND25, but there will be no output from AND28 since the permissive MU will not have operated. Now assume that sequential clearing of the fault on the parallel line causes a momentary reversal of fault current in line CD. This will cause operation of the permissive MU at D and the reset of the permissive MU at C. The purpose of the coordination timer TL6 is to delay the application of the permissive signal to the middle input of AND28 until the received signal is removed from the upper input at D. That is, the operating time of TL6 must be slightly longer than the reset time of the channel to prevent an incorrect trip during the power reversal.

2. Permissive Underreaching (PUTT)

For the permissive underreaching mode of operation, the scheme selection logic will be set in its PUTT position, which applies a signal to the bottom input of AND27 and to the top input of AND35 via OR10. In this scheme the transmitter is keyed via AND34, AND35, OR11 and L-12 (NORM position if transmitter is to be keyed by a contact closure), by operation of the measuring unit in zone-1 reach. Consequently for the external fault at X in Fig. 7, the transmitter will not be keyed at either end of the protected line C-D since zone-1 output will not occur at either end. Since the transmitter is not keyed at either end of the line during the external fault, a coordination timer is not necessary in the underreaching scheme.

Now consider an internal phase-AG fault at Y, which is close to breaker D but beyond the zone-1 reach of the relays at C. The phase-A selector at D will operate, applying a signal to AG of the input quantity selection function. Since the Z1 input is already present from NOT2 and AND32, there will be a zone-1 measuring output from AND47 which will initiate a single-pole phase-A trip at D via OR14 and AND51, and which will also apply the lower input to AND34 via OR17, AND57 and OR20. Since the upper input of AND34 is already present from the output of NOT2, the transmitter at D will be keyed and will send a trip signal to C. At end C the receiver output will be applied to the upper input of AND27, the middle input will be supplied by the permissive zone-3 MU, and the lower input is already present from the PUTT output of the scheme selection function. Consequently there will be a single-pole channel trip at C, via OR5, TL7b and OR14.

For a mid-line fault, for example at Z in Fig. 7, there will be a zone-1 measuring unit output at both C and D, a transfer trip signal will be sent in both directions and a channel trip output will be initiated at both ends. In practice the trip bus will usually be energized first by the zone-1 trip output of the measuring unit.

In the case of the external fault at X in Fig. 7, if the zone-2 timer times out and switches the measuring unit to its zone-2 reach, the MU output from AND47 will be applied to the lower input of AND34. However, the channel will not be keyed via AND34 since the operation of the zone-2 timer will remove the output of NOT2 and disable AND34 at its upper input. If the relay trips in the time-delayed mode, the channel will be keyed by the trip bus via TL15 and AND3b, but this does not affect the PUTT mode of operation for the assumed external fault. The purpose of TL15 is to provide an extended trip signal to assure tripping of the remote terminal where the remote end may be slower to operate for an internal fault.

3. Zone-2 Acceleration (Z2ACC)

For this mode of operation the scheme selection logic will be set in its Zone-2 Acceleration position, which applies a signal to the lower input of AND26 and to the upper input of AND35 via OR10.

Referring again to Fig. 7, an end-zone fault at Y will be seen by the zone-1 MU function at D, but not by the zone-1 function at C. The zone-1 trip output from AND47 at D will key the transmitter via AND34, AND35, OR11 and L-12 (NORM position if transmitter is to be keyed by a contact closure). At C the received signal is applied to the upper input of AND26. Since the permissive zone-3 MU will have operated at C and the Z2 acceleration output is provided by the scheme selection logic, the middle and lower inputs of AND26 will be present. The resulting output of AND26 will be applied to the Z2 input of the measuring unit reach selection function via TL7a and OR8, bypassing the zone-2 timer input. Thus the MU at C will operate immediately for the end-zone fault near D and will initiate a single-pole trip if the scheme is set for the one-pole mode.

4. Directional Comparison Blocking (DCB)

For this mode of operation, the scheme selection logic will be set in its directional comparison blocking position, which applies a signal to the second input of AND68 and the lower input of AND70. In this scheme, the transmitter is keyed by operation of one or more of the carrier start functions (MB-ØA, -ØB or -ØC) via OR24, TL17, AND67, TL16, AND70, OR11 and L-12 (NORM position if transmitter is to be keyed by a contact closure).

Referring to Fig. 7, consider an external fault at X. One or more of the carrier start functions will operate at D, initiating carrier transmission from D. Operation of the overreaching permissive zone measurement unit at C will apply a signal to the lower input of the comparer AND68, via coordination timer TL6, at that end of the line. The directional carrier start functions at C will not have operated so there will be an input to AND68 from its NOT. However, receipt of blocking carrier from D will cause the removal of the upper input to AND68 (RCVR link L-10 must be in INV position if a contact closure indicates receipt of channel signal. This applies to DCB scheme only). Hence, tripping via the comparer will be blocked for the external fault at X. Note that following clearing of the external fault at X and reset of the MB functions at D, transmission of the blocking carrier signal from AND70 will be continued for a period equal to the combined reset times of TL17 and TL16.

For an internal fault, at Z in Fig. 7 for example, the permissive MU functions at both ends will operate and apply the lower input to the comparer AND68 at both ends of the line. The directional carrier start functions will not have operated at either end and the permissive measuring unit will apply the lower input to AND69 at both ends, thereby stopping any auxiliary carrier transmission (L-11 in NORM position if contact closure required to stop transmitter). All inputs will hence be present at the comparer AND68 at both ends of the line, which will initiate a channel trip via OR5, TL7b, OR14, and AND51, -52, -53, depending on whether a single-pole or three pole trip is involved. The CH target lamp will be operated via OR9.

The purpose of the two timers, TL17 and TL16, in the carrier-start path between the MB functions and transmitter keying, via AND70, can be explained as follows: Assume first that an external zero-voltage, three phase fault occurs on the line just beyond breaker E in Fig. 7. The MB functions will operate on memory action to start carrier, but will reset when the memory action delay expires. The reset time of TL17 would be set long enough so that the combined reset times of TL17 and TL16 would sustain blocking carrier from D to C longer than the breaker failure backup time setting at E. On the other hand, if an external phase-to-ground fault beyond D evolved to an internal fault at Y in Fig. 7 , the permissive MU function at D would cut off the output of AND67, via OR26 and the NOT of AND67, and blocking carrier would now be prolonged only for the 50 millisecond reset time of TL16.

The reverse looking MB functions can also be used to initiate time delay backup tripping for faults in the reverse direction. The operation of one or more of the MB functions, and the associated current supervision function, results in an output from OR24, which initiates operation of TL18 (zone-5 timer). An output from TL18 results in a three pole trip via OR16.

If total channel time plus propagation time is less than eight milliseconds, the coordination timer TL6 should be set for zero. Total channel time is defined as the time from operation of the keying contact at the sending end to the instant of receiver output of the receiving end, with the equipments connected back-to-back. If the eight millisecond figure is exceeded, refer to the **CALCULATION OF SETTINGS** section for further recommendations.

Power Swing Blocking

The power swing blocking (i.e., out-of-step blocking, OSB) scheme that is included with this equipment can be activated by setting the selection link L4 in its IN position. The diagram in Fig. 8 represents the characteristics involved in this scheme.

The scheme operates as follows: The power swing, represented by the swing locus A-B, exhibits the characteristics of a three-phase fault. Thus when the swing impedance enters the phase selector characteristic, all three selectors will operate. This will result in an output from AND10 which initiates operation of the OSB timer TL11 via OR22, and also switches the permissive zone-3 measuring unit to the lens characteristic as shown in Fig. 8. This is accomplished by blocking the 90° characteristic timer at the NOT of AND45 and activating the 120° characteristic timer at the lower input of AND46.

If the OSB timer TL11 times out before the swing impedance enters the permissive zone-3 MU lens characteristic, the outputs of both measuring units will be blocked, the main MU at the NOT of AND47 and the permissive MU at the NOT of AND48. But if the impedance enters the lens characteristic before the OSB operates, as would be the case during an actual three-phase fault, the output of the permissive zone-3 MU at AND48 resets the OSB timer TL11.

Provision is made to detect a swing that may develop during the interval when one pole is open. This is provided by the AND19 function that receives one input from OR27 when one pole is open and the other from AND18 which indicates that two or more phase selectors have operated. The OR27 signal is provided either from the SLS recloser or from an external recloser via CC6. The output from AND19 initiates operation of the OSB timer TL11 via OR22 and switches the permissive MU characteristic timer to a 120^{o} lens.

Fuse Failure Protection

The fuse failure detector is designed to operate upon the loss of one or two phases of the a-c voltage. Its output operates an indicating lamp and an alarm unit with one normally open contact, and by means of the OFF-BLOCK link, L9, can also be connected to block tripping at the NOT inputs of AND57, AND58 and AND59 via OR30.

Close Onto a Fault

A feature is included to provide a direct trip when the relay potential source is on the line side of the circuit breaker, in the event that the associated breaker is reclosed onto a close-in zero-voltage fault. The upper input to AND49 is supplied from the SLS recloser or from an external contact (CC3) via OR15 and will persist for 220 milliseconds following a reclosure attempt, either automatic or manual. The lower input is supplied from AND63 if the overcurrent detector and the undervoltage function have operated. The overcurrent detector operates at about 2.5 times normal current, and the undervoltage detector operates if the voltage is less than about 1.5 percent of normal voltage.

The output of AND63 initiates a three-pole trip via OR16.

GENERAL COMMENTS

1. Breaker Failure Functions

   There are four BFI output units. Three of these, BFI-ØA, -ØB and -ØC, are associated with the individual trip buses while the fourth one, identified only as BFI, is operated by OR20 when any trip bus is energized. When the scheme is operating in the single-pole mode the BFI links, L6, L7 and L8, would be in the individual pole (IND) position. If the scheme is operating in the three-pole trip mode, these links would be in the common (COM) position so that any trip output operates all BFI units via OR20.

2. Current Seal-in

   The current seal-in feature operates on a per-pole basis by means of AND54, AND55 and AND56. For example for an AG fault and the scheme in the single-pole trip mode, the phase-A trip unit is energized via AND51, OR17 and AND57. The output of AND57 feeds the upper input of AND54 and the lower input is fed by the phase-A current supervision unit. Thus as long as the current in phase-A is above the sensitive phase-A current supervision unit, there will be an output from AND57 even though the distance measuring units should reset, and the BFI unit for phase-A will remain energized. If the scheme is operating in the three-pole mode, the BFI links will be in the COM position so that the seal-in for any one phase will continue to energize all BFI units via OR20 as long as the sensitive current supervision unit is operated.

3. Target Lamp Operation

The nine target lamps discussed below seal-in, that is latch in, (except fuse failure) when operated and may be reset by means of the push button on the front of the target unit or by an external contact (CC8). This is indicated on the logic diagram by "L" in the target lamp symbol.

Step distance trip operations for zone-1 through zone-4 are indicated by the target lamps labelled I, II, III and IV, while any channel trip is indicated by the lamp labelled CH. These lamps are operated via AND functions 37 through 41 respectively. The lower input of each AND function, 37 through 41, is from the trip bus via OR20.

The zone-1 lamp (I) will light on inputs from the main measuring unit output (AND47) and trip bus (OR20) in the absence of a zone-2 timer operation, which blocks at the NOT of AND37 and removes the Z1 input.

A zone-2 trip, initiated by the zone-2 timer TL5b, will operate lamp II via AND38 and will block AND37.

Zone-3 or zone-4 trips, initiated by timers TL5c or TL5d respectively, will cause operation of lamps III or IV via AND39 or AND40 respectively.

A channel trip, either in the permissive overreach or permissive underreach mode, will operate the channel lamp (CH) via OR9 and AND41. Note that the zone-1 lamp I may also light as well as the CH lamp because there may also be zone-1 output from the local measuring unit.

With the scheme selection function set for zone-2 acceleration, a trip will be indicated by both the channel lamp CH via OR9 and the zone-2 lamp II via OR8. The zone-1 lamp I will be blocked.

A trip by the zone-1 extension feature (Z1X) will operate lamp I.

The operation of the three target lamps A, B, and C in the trip output is determined by the settings of target links L5a, L5b and L5c.

For example with the scheme in the one-pole mode and the L5 links in the TRIP position, detection of a single-phase-to-ground fault will result in tripping only the faulted phase and operating the target lamp for that phase. Any multi-phase fault or any delayed trip will trip all poles and operate all three lamps A, B and C.

Connecting the L5 links in the FAULT position provides indication of which phases are faulted even though all three poles are tripped. For example assume a phase-AG fault with the scheme set for the three-pole mode. All three poles will be tripped, but only the "A" lamp will light, as determined by the ØA selector input to AN 60. Similarly, for a phase-AB fault, all poles will be tripped but only the A and B lamps will light.

All the target lamps described above, except the fuse-failure lamp, are of the seal-in type. There are four additional target lamps identified by yellow caps which are self-resetting. Three of these indicate operation of the phase selectors and are identified as ØA, ØB and ØC. These are supervised by the OR4 output through AND71, AND72 and AND73, respectively. This means that the directional unit must operate during phase-to-ground faults (AND20 output) in order for a phase selector lamp to light. The remaining lamp is operated by an output from the out-of-step blocking timer TL11 and is identified as OSB.

RECLOSER LOGIC

The SLS recloser operates according to the logic diagram shown in Fig. 9. It should be emphasized that this is a functional representation. The logic function designations have been assigned to facilitate the following written explanation of the operation of the recloser. They may not be directly related to the actual circuitry.

The recloser may be set for any one of the following modes (refer to **SETTINGS PROCEDURES** section):

1. One reclosing attempt, single-pole or three-pole, depending on 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.

This discussion will begin by describing mode 4 because it encompasses the full capability of the recloser circuitry. The remaining modes will be described subsequently.

The reclosing cycle begins automatically when the SLS distance relay produces a trip output. A reclose initiate (RI) signal is produced simultaneously and input to the recloser through interconnection cable PL-1. Reclosing following single-pole trips is made possible by having a separate signal for each phase, designated RI-ØA, RI-ØB, and RI-ØC.

First Reclosing Attempt after Single Phase Faults

Consider the case of a phase-A to ground fault resulting in a single-pole trip. The recloser receives an RI-ØA signal which provides, through OR1, the lower input to AND1. The upper input to AND1 is a supervisory signal from the distance relay called High Speed Trip Time. This signal is produced by the zone timer and is present for the duration of the zone-two time setting. Beyond that point, the signal is absent and reclosing is prevented.

The output of AND1 is then applied to AND13 through timer TL1. This timer assures that the signal will persist for 20 milliseconds after the removal of the RI input which will disappear almost immediately when the breaker pole is opened to clear the fault. The lower input of AND13 is provided by the breaker "b" switch on pole A (52A/b). When pole A is opened as a result of the distance relay trip signal, the "b" switch closes and its associated contact converter (CC9) sends a signal to AND13 via OR3. Consequently, the "b" switch input to AND13 may occur at any point within 20 milliseconds following the reset of the RI-Ø input(s) and AND13 will still transmit the reclose initiate signal.

The tripping of the breaker indicated by RI-ØA and the actual opening of the pole indicated by 52A/b initiates the reclosing cycle. The output from AND13 will be brief, disappearing when TL1 times out. The RI latch is therefore provided to sustain the signal. It operates as follows. Referring to the latch equivalent in

Fig. 9, the momentary signal is applied to the SET input thereby providing, through the OR gate, the upper input to the AND gate. The NOT input to the AND gate will be absent as long as there is no resetting signal to the latch. The AND gate therefore gives an output which is fed back to its input via the OR gate. Through the feedback loop, the OR gate sustains the input to the AND gate even after the momentary SET input disappears. The AND gate therefore continues to produce an output until reset by a signal at its NOT input. In this manner, the momentary SET signal is latched in. All of the latches depicted in Fig. 9 operate in this manner.

The output from the RI latch causes the OPN (operation) LED (light emitting diode) indicator to light and the RECLOSE IN PROGRESS contacts to close via OR23, indicating that the reclosing cycle is under way. In addition, the latch output is simultaneously applied to AND15, AND16, AND17 and AND18.

Initially, the sequencer is in standby, providing an output at port 1 and no output at ports 2 and 3. AND15 and AND16 are therefore in a position to pass on the RI signal whereas AND17 and AND18 are disabled. The third input to AND15 and AND16 is the three-pole reclose initiate signal. This signal will be absent for the case under consideration (first reclosing attempt after a single-pole trip; recloser set for mode 4). The absence of this signal disables AND16 and enables AND15 through its NOT input. Of the four gates, AND15 is the only one to transmit the RI signal.

The output from AND15 initiates reclosing timer TL3a which is set for the single-pole reclosing time (refer to **SETTINGS PROCEDURES** section). When TL3a times out, its output is fed back through OR11 to reset the RI latch (through OR10) and advance the sequencer to port 2 following the three millisecond delay of TL2. In addition, it initiates the reset timer (TL4) through OR12, sets the zone-1 extension latch (to be discussed subsequently) and sets the delayed synchronism check latch following the TL2 delay (also to be discussed subsequently).

The output from OR11 constitutes the automatic reclosing signal. This is sent through OR13 to the first hold link L3. Assume for the time being that this link is set in the OUT position such that the hold latch is bypassed. The reclosing signal is then applied directly to AND20. It may be blocked at this point by an input to the NOT of AND20, which will be present during an out-of-synchronism condition (AND19 output through OR16) or in the event of an external block reclose signal (CC15 through OR16). These points will be discussed in further detail subsequently.

An output from AND20 indicates that the reclosing signal has been validated. This validated signal is simultaneously applied to AND21, AND22, AND23 and AND24. It also initiates timer TL5 which sends a signal to the distance relay. This will be discussed subsequently.

The lower inputs to AND21, AND22 and AND23 are connected to the pole A, pole B and pole C "b" switches through CC9, CC10 and CC11, respectively. For the case of a single-pole trip clearing an A-G fault, only the pole A "b" switch will be closed. The lower input to AND24 is the three-pole reclosing signal from OR9. This will be absent during the first reclosing attempt for the conditions noted. Therefore, for the case under consideration, of the four gates receiving the validated reclosing signal, only AND21 will transmit the signal to its dwell timer, TL6a.

The TL6a dwell timer is initiated by AND21 through OR17. The timer immediately energizes its associated output relay, operating the CLOSE POLE A contacts which are connected to the breaker closing circuit. The contacts will remain closed for the duration of the dwell timer setting. This completes the first reclosing attempt.

The output of TL6a is sent to the OPN LED indicator and the RECLOSE IN PROGRESS relay through OR21 and OR23 so that they remain energized until the dwell timer times out. In addition, it is applied to the fail to close latch (a) through OR21 where it affects the lockout circuit and direct trip circuit which will be discussed subsequently.

Second Reclosing Attempt After Single Phase Fault

If the fault is still present after the breaker has been reclosed or if it reappears before the reset time elapses, the distance relay will again produce a trip output. This time, however, it will be a three-pole trip as a result of the 3-POLE TRIP ENABLE signal sent from the recloser to the distance relay through interconnection cable PL-1. This signal may be produced by any of the four inputs to OR27. For this case, only the third input will be present. It comes from AND14 and was produced as follows.

The first reclose initiate signal from TL1 set the three-pole trip latch but the latch did not get reset upon reclosing and, would normally not be reset until the reset timer gives an output (through OR28, OR7 and OR8). A continuous input was therefore applied to AND14, but the initial TL1 output blocked AND14 through its NOT input. The clearing of the fault (tripping pole A) removed the RI-ØA signal thereby stopping the TL1 output (20 milliseconds thereafter) and enabling AND14. Thus the 3-POLE TRIP ENABLE signal was produced upon the tripping of breaker pole A and is still present after the pole has been reclosed. Therefore, the continued presence or reappearance of the A-G fault will now result in the distance relay tripping all three poles of the breaker.

In conjunction with its three pole trip output, the distance relay simultaneously sends RI-ØA, RI-ØB, and RI-ØC signals to the recloser. As before, the reclose initiation signal is sent through OR1, AND1, TL1, AND13 and the RI latch from which it is applied to AND15, AND16, AND17 and AND18. This time, however, only AND17 is enabled by the sequencer which has been advanced to port 2. Note that the delayed reclose link, L1, must be in the DLY position for AND17 to be enabled. This is a requirement to obtain reclosing mode 4 (refer to **SETTINGS PROCEDURES** section). Also note that the output from AND13 resets the timing cycle of the reset timer (TL4) and the output from the RI latch once again lights the OPN indicator.

The output from AND17 initiates reclosing timer TL3c which is set for the delayed reclosing time (refer to **SETTINGS PROCEDURES** section). When TL3c times out, its output is fed back through OR11 to reset the RI latch (through OR10) and advance the sequencer to port 3 (after the TL2 delay). It also re-initiates the reset timer (TL4) through OR12.

As before the automatic reclosing signal from OR11 is sent through OR13, L3 and AND20, from which it is applied to AND21, AND22, AND23 and AND24. The lower inputs to AND21, AND22 and AND23 will all be present because the "b" switches will all be closed following the three-pole trip. Furthermore, the lower input to AND24 will be present from the 2 or 3 RI latch through OR9, indicating a three-pole reclose initiation. Consequently, all four gates produce an output, hitting OR17, OR18, and OR19 with double inputs. Dwell timers TL6a, TL6b and TL6c are initiated simultaneously. They immediately energize their respective output relays, resulting in a three-pole closing of the breaker. This completes the second reclosing attempt.

If the fault persists beyond the second reclosing attempt, the distance relay will again trip the breaker three-pole and send three RI-Ø signals to the recloser. The reclose initiate signal will again make its way to AND15, AND16, AND17 and AND18, but only AND18 will be enabled because the sequencer has been advanced to port 3. The output from AND18 will directly send the recloser into lockout, as will be discussed subseqeuntly.

First Reclosing Attempt after Phase-to-Phase or Three-Phase Fault

Consider the case of a phase-to-phase or three-phase fault. The distance relay will trip the breaker three-pole and simultaneously send RI-ØA, RI-ØB, and RI-ØC signals to the recloser. As in the case of a single-pole trip, the reclose initiation signal is sent through OR1, AND1, TL1, AND13 and the RI latch from which it is applied to AND15, AND16, AND17 and AND18. The sequencer is in standby (port 1) thereby enabling only AND15 and AND16. Unlike the case of a single-pole trip, the three-pole reclose initiation signal is present in this situation, enabling AND16 and disabling AND15 at its NOT input.

The three-pole reclose initiation signal is produced simultaneously by AND2, AND3 and AND4, each of which require a pair of RI-Ø signals to give an output. It is sent through OR2 into the 2 or 3 RI latch which operates the same as the other RI latch except that it is reset via OR8 rather than OR10. From this latch, the three pole reclose initiation signal is sent through OR9 from which it is applied to AND15 and AND16.

The resulting output from AND16 initiates reclosing timer TL3b which is set for the three-pole reclosing time (refer to **SETTINGS PROCEDURES** section). When TL3b times out, it produces the automatic reclosing signal. The remaining steps in the reclosing sequence have already been described.

Second Reclosing Attempt After Phase-to-Phase or Three-Phase Fault

The second reclosing attempt after a phase-to-phase or three-phase fault will be identical to the second reclosing attempt after a single-phase fault since the second trip will be three-pole in both cases. Again, the recloser will go into lockout following the third trip.

One Reclose Attempt Only

The second automatic reclosing attempt may be bypassed by placing the delayed reclose link (L1) in the NO DLY position. In this case, after the first reclosing attempt, only AND18 will be enabled by the sequencer and the reclose initiate signal associated with the second trip will send the recloser into lockout.

Single Pole Reclosing Only

If it is desired to attempt automatic reclosing only after single-pole trips, the 1Ø single-pole only switch (SW1) should be closed. This provides the lower input to AND10 such that, in the event of two or three simultaneous RI-Ø signals from the distance relay, the upper input from OR2 will cause AND10 to produce an output which, through OR8 and OR10, will block the reclose initiation signal by disabling the RI latch.

Note that in this mode there can be only one automatic reclosing attempt since the second trip will always be three-pole and the recloser has been set to block three-pole reclose initiations (SW1 closed).

Three Pole Reclosing Only

If it is desired to attempt automatic reclosing only after three-pole trips, the 3Ø three-pole only switch (SW2) should be closed. This provides, through OR9, a continuous three-pole reclose initiation signal, enabling AND16 and disabling AND15. Furthermore, SW2 provides a direct input to OR27 such that the recloser sends a continuous 3-POLE TRIP ENABLE signal to the distance relay. Consequently, the distance relay will trip all three breaker poles for any type of fault and three-pole reclosing will follow automatically.

Note that, unlike single-pole only reclosing, the recloser will make a second reclosing attempt following a second trip when SW2 is closed, provided L1 is in the DLY position.

Manual Closing

Manual closings of the breaker may be made directly using external contacts or, if desired, through the recloser circuitry using the output contacts of the recloser. For direct manual closings, the manual close link (L4) should be placed in the NORM position; to use the recloser circuitry, it should be placed in the AUTO position. In either case, automatic reclosing attempts will be blocked in the event of a manual breaker closing.

The MANUAL CLOSE signal from CC17 is sent through AND9. It may be blocked at this point if the gate is disabled at its NOT input. This will occur when SW3 is in the OFF position (open) in which case NOT1 produces an output.

An output from AND9 sets the manual close latch and initiates the reset timer through OR12. Actually, the reset timer is initiated upon the opening of the manual close switch (falling edge of pulse through OR12). The manual close latch blocks automatic reclosing by disabling the RI latch through OR8 and OR10 and thereby stops the reclose initiate signal. The blocking is sustained until the manual close latch is reset via OR28 when the reset timer (TL4) gives an output.

With L4 in the AUTO position, the manual close signal is routed into the main reclosing circuit (OR13) through a pulse circuit. The pulse circuit is included so that the manual close signal resembles the automatic reclosing pulse from OR11. Once the manual close pulse has been transmitted through OR13, the sequence of events is the same as that described for automatic reclosing attempts.

Note that when L4 is in the AUTO position, the manual close signal is also routed into the synchronism check circuit (OR15). This provides synchronism check supervision of manual close attempts, as will be discussed subsequently.

Synchronism Check Supervision

Synchronism check is available as an option with the SLS recloser. When the voltages on either side of the open breaker are out of synchronism by more than the set limit, the synchronism check circuit (indicated by a box in Fig. 9) gives an output which is applied to AND19. This circuit also performs a voltage magnitude difference check and slip rate checks, if desired.

The other input to AND19 represents those reclosing attempts which are to be supervised by the synchronism check circuit. These include 1) manual close attempts made through the recloser; 2) first and second automatic three-pole reclosing attempts; and 3) second automatic reclosing attempts only. Note that these are all three-pole reclosing conditions. It is not meaningful to make synchronism checks with only one pole tripped.

The manual close signal comes into AND19 through CC17, AND9, L4 (AUTO position) and OR15. When it is desired to conduct a synchronism check on the first and second automatic three pole reclosing attempts, the synchronism check link (L2) should be placed in the ALL3P position (refer to SETTING PROCEDURES section) in which case the automatic three pole reclosing signal is sent into AND19 from the 2 or 3 RI latch through OR9, L2 and OR15. When it is desired to conduct a synchronism check on the second automatic reclosing attempt only, L2 should be placed in the DLY position. In this case, the port 2 sequencer output is applied (indirectly) to AND19. Because the sequencer is advanced to port 3 by TL3c and OR11 at the end of the delayed reclosing time, the port 2 output is not a suitable signal on which to conduct a sustained synchronism check. The delayed sync check latch is included for this purpose. It provides a continuous signal to AND19 through L2 (DLY position) and OR15. TL2 prevents the delayed sync check latch from being set prematurely. This latch will not be reset until the reset timer gives an output (via OR28, OR7 and OR8).

An output from AND19 indicates that the synchronism check circuit is giving a blocking output at the moment of the initiation of a three-pole reclosing attempt. This output invalidates the reclosing signal by disabling AND20 through its NOT input (via OR16).

In addition, the AND19 output is applied simultaneously to AND27 and AND28. The second hold link (L5) determined which of these two gates is to be used to set the synchronism check indicator latch. Assume, for the time being, that L5, like L3, is in the OUT position and thereby utilizes AND27. The other input to AND27 is the reclosing signal from OR13. Thus, when the sync. check circuit is giving a blocking output, AND27 produces an output at the time when a reclosing attempt would normally have taken place. This sets the synchronism check indicator latch which immediately lights the N/S LED indicator. It will remain lit until reset via OR6.

External Blocking of Reclosing

Reclosing attempts may be blocked by the closure of an external contact connected to CC15. A signal from CC15 invalidates the reclosing signal by disabling AND20 at its NOT input (via OR16).

Permit Blocking of Reclosing to Clear (Hold)

In the event that a reclosing signal is initially invalidated by synchronism check supervision or by an external BLOCK RECLOSE contact, the signal may be sustained (put on hold) for the duration of the reset timer setting (TL4) with the hope that the blocking signal will disappear within that time. This is accomplished by placing the first hold link (L3) in the IN position. The second hold link (L5) should also be placed in the IN position to insure that the sync check indicator latch is not set erroneously.

The hold latch is set by the reclosing signal from OR13 and will not be reset (via OR14) until a validated reclosing signal is issued by AND20 or, if that doesn't occur, when the reset timer times out (via OR28, OR7 and OR14). This provides a sustained reclosing signal which is applied to AND20 via L3 (IN position). The signal also energizes the RECLOSE IN PROGRESS relay and OPN LED indicator through OR23.

The presence of a blocking signal inhibits reclosing by disabling AND20 through its NOT input. Should the blocking signal disappear before the reset timer times out, AND20 will be enabled and will transmit the reclosing signal which has been sustained by the hold latch. In this manner, the initially invalid reclosing attempt is validated upon the clearing of the blocking condition. If the blocking does not clear, the recloser will go into lockout when the reset timer times out.

The second hold link (L5), when placed in the IN position, utilizes AND28 to set the synchronism check indicator latch. The upper input to AND28 is provided by AND19 and is present whenever a three-pole reclosing attempt is blocked by the synchronism check circuit. The other input to AND28 is provided by AND25 which gives an output when the reset timer times out, provided that the sustained reclosing signal has not been cleared from the hold latch. Thus, with the hold links (L3 and L5) in the IN position, if a three pole reclosing attempt is blocked by synchronism check and if the out-of-synchronism condition persists for the duration of the reset time, the N/S LED indicator will light at the end of the reset time and will remain lit until reset via OR6.

If the holding feature is not desired, L3 and L5 should be placed in the OUT position. In this case, reclosing signals which are initially inhibited at AND20 expire immediately and reclosing will not take place. When inhibited by synchronism check, the N/S LED will light immediately at the time of the would-be reclosing attempt.

Lockout

The recloser will go into lockout under each of the following three sets of conditions:

1) Lockout Following the Third Trip

If a fault persists or reappears following the second reclosure, the distance relay will trip a third time and the corresponding reclose initiate signal will be transmitted through AND18 (sequencer advanced to port 3) into OR25, from which it sets the lockout latch. Note that if the delayed reclosing link (L1) is in the NO DLY position, the second shot reclosing attempt is bypassed and the recloser will go into lockout following the second trip.

2) Lockout Resulting from a Failed Reclosing Attempt

If an open breaker pole(s) remains open throughout the duration of the dwell time, the reclosing attempt has failed and the recloser should be locked out. This is accomplished by the fail-to-close circuitry shown in Fig. 9. The circuitry consists of the following elements:

OR 20
Fail-to-Close Latch a (FTCa)
Fail-to-Close Latch b (FTCb)
NOT2
TL-7
AND26

The logic functions as follows: The tripping of the breaker and resulting closing of one or more "b" switches sets FTCa through OR3 while at the same time removing the continuous reset which was previously present at FTCb. A validated reclosing signal from one or more poles then sets FTCb via OR20 and the output of this latch is applied to the lower input of AND26 through TL7. At the same time, however, one or more of the dwell timers issues an output which, through OR21, resets FTCa. This signal is present for the duration of the dwell time. Due to the nature of the latch (refer to latch equivalent), the reset input overrides the set input so that the dwell timer signal causes the FTCa output to be cut off, thereby disabling AND26. Since the OR20 and OR21 outputs occur simultaneously, TL7 is included so that FTCa disables AND26 before the FTCb output is applied.

At the end of the dwell time, the resetting signal is removed from FTCa. If at that time, all the "b" switches are open (breaker closed), FTCa receives no set input. Therefore it produces no output and continues to disable AND26. If, on the other hand, the breaker has failed to close, one or more of the "b" switches will remain closed so that, as soon as the dwell timer signal ceases, FTCa issues an output which is applied to the upper input of AND26. The lower input to AND26 is still present due to the fact that FTCb was not reset by NOT2 because the "b" switch(es) did not open. The resulting output from AND26 constitutes the fail-to-close signal.

The fail-to-close signal sets the lockout latch via OR24 and OR25.

3) Lockout Resulting from a Blocked Reclosing Attempt

If the sustained reclosing signal from the hold latch is still present when the reset timer times out, it indicates that the reclosing attempt was not validated and the recloser should be locked out. AND25 is provided for this purpose. Its lower input is connected to the first hold latch output and its upper input is connected to the reset timer output through OR28. An output from AND25 sets the lockout latch via OR24 and OR25.

When the lockout latch is set, its output lights the L/O LED indicator and produces a 3-POLE TRIP ENABLE signal through OR27. It also produces a PULL BACK EXTENDED ZONE-1 signal through OR22 thereby allowing the distance relay to return tc its normal zone-1 reach setting (zone-1 extension scheme only).

In the lockout state, all further reclosing is prevented by disabling the RI latch through OR28, OR7, OR8 and OR10.

The recloser may be taken out of the lockout state by an intentional reset signal from OR6 through OR26 which resets the lockout latch. This will be discussed subsequently. In addition, a manual close attempt will take the recloser out of lockout by resetting the latch via AND9 and OR26.

Signals Sent to Distance Relay

Six signals produced within the recloser circuitry are sent to the distance relay through interconnection cable PL-1. The significance of each is explained in the following subsections:

PULL BACK EXTENDED ZONE-1

With this signal absent, the distance relay will be monitoring the line according to its extended zone-1 reach setting when using the zone-1 extension scheme. The signal is absent in standby because OR22 receives no inputs (the zone-1 extension latch is clear).

The first automatic reclosing signal from OR11 sets the zone-1 extension latch and the signal to the distance relay appears immediately (via OR22) and does not disappear until the latch is reset by an output from the reset timer via OR28. The distance relay is therefore switched from its extended zone-1 reach to its normal zone-1 reach upon the first reclosing attempt.

The PULL BACK EXTENDED ZONE-1 signal will be produced in the event of a lockout (middle input to OR22) or if the recloser is taken out of service by opening the ON/OFF switch, SW3 (lower input to OR22). This is done because it is not desirable to have the distance relay using an extended zone-1 reach when the recloser is not operating and therefore unable to return the distance relay to its normal zone-1 reach.

CLOSE ONTO A FAULT

This signal is sent to the distance relay when AND20 transmits a validated reclosing signal. It is sustained for 128 milliseconds by timer TL5, the first 128 milliseconds for which the output closing contacts (CLOSE POLE A, etc.) are closed.

The CLOSE ONTO A FAULT signal is used in the distance relay in conjunction with an overcurrent detector and an undervoltage detector. If these detectors both issue outputs in the presence of the CLOSE ONTO A FAULT signal, the fault is regarded as a severe close-in fault. The normal measuring unit fault detection is bypassed and the distance relay immediately issues a trip output, as was explained in the previous section.

MANUAL CLOSE

Whenever a manual closing attempt is made, either through the recloser (L4 in AUTO position), or independent of the recloser (L4 in NORM position), a MANUAL CLOSE signal is sent to the distance relay for the same purpose as the CLOSE ONTO A FAULT signal; namely, to cause the distance relay to issue an immediate trip output upon the closing attempt in the event of a severe close-in fault.

ONE POLE OPEN

This signal is produced by a circuit which continuously monitors the breaker "b" switches through CC9, CC10 and CC11. In order to have a ONE POLE OPEN output from AND11, the following three conditions must be met:

1) OR3 must be producing an output which indicates that one or more of the "b" switches is (are) closed (pole or poles open).

2) OR4 must not be producing an output. The absence of an output from OR4 indicates that there are not two poles open because, if there were, two "b" switches would be closed and either AND5, AND6 or AND7 would provide a signal to OR4.

3) AND8 must not be producing an output. The absence of an output from AND8 indicates that not all three poles are open. Note that this is redundant, because the same condition will cause an OR4 output which alone disables AND11.

In summary, with (1) one or more poles open, but (2) not two poles open and (3) not three poles open, we are left with one pole open.

The ONE POLE OPEN signal is used in conjunction with the phase selector outputs in the distance relay such that, in the event that the two phase selectors are picked up and the pole is open on the remaining phase, the power swing detection circuitry will be activated as it is when all three phase selectors are picked up simultaneously. This entails switching the permissive zone measuring unit characteristic from a circle to a lens and initiating the OSB timer. In other words, when two phase selectors are picked up in the presence of a ONE POLE OPEN signal from the recloser, the distance relay acknowledges the possibility of a three phase swing condition and makes measurements accordingly.

TRIP DIRECTLY

The presence of this signal causes the distance relay to issue a three-pole trip output directly. This will occur under either of the following two sets of conditions:

1) Trip in the Event of a Fail-to-Close Condition

   If the breaker fails to close during a reclosing attempt and there are one or two (not three) poles open, the TRIP DIRECTLY signal will be produced. If all three poles are open, it is not meaningful to issue a trip signal since the breaker is already open. The fail-to-close signal is provided by AND26 as described in paragraph 2 of the Lockout subsection. It is applied to the upper input of AND29 through OR24. The one or two poles open signal is provided by AND12 and is applied to the lower input of AND29. In order for AND12 to produce an output, it must receive a signal at its upper input from OR3 which indicates that one, two or three "b" switches are closed. In addition, it must not receive a signal at its lower (NOT) input from AND8 which indicates that all three "b" switches are closed. Therefore, AND12 will produce an output only for the cases of one or two closed "b" switches (open poles).

2) Trip Following a Blocked Reclosing Attempt

   If the sustained reclosing signal from the hold latch is still present when the reset timer times out and one or two poles remain open, the reclosing attempt was not validated. The remaining pole(s) should be tripped and the recloser should be locked out. This is accomplished by AND25 as described in paragraph 3 of the Lockout subsection. AND25 provides the upper input to AND29 through OR24. As before, the lower input to AND29 is provided by AND12.

   TL8 causes the TRIP DIRECTLY signal to have a duration of 100 milliseconds.

3-POLE TRIP ENABLE

This signal switches the distance relay into the three-pole mode such that, in its presence, the detection of any type of fault will result in a three-pole trip output. It is produced under the following four sets of conditions, each of which provide an input to OR27.

1) When the recloser is in lockout.

2) When the recloser is set for three-pole only operation (SW2 closed).

3) Following the first reclosing attempt. In this case, the OR27 input is provided by AND14 as described in the subsection entitled Second Reclosing Attempt After Single-Phase Fault.

4) When the ON/OFF switch (SW3) is in the OFF position (open). In this case, there is no means of reclosing so it is imperative that all three poles of the breaker be tripped.

Resetting

The recloser circuitry will be automatically reset by an output from OR28. This signal will be present when the reset timer gives an output or in the event that the recloser is locked out. The reset timer (TL4) operates as follows. A pulse input from OR12 initiates the timing cycle which is adjustable from one second to 99 seconds (refer to **SETTINGS PROCEDURES** section). At the end of the timing cycle, the timer produces a single pulse output. TL4 may be reset at any point during the timing cycle by a signal at its reset input.

The OR28 output accomplishes the following:

- Resets the zone-1 extension latch directly. This removes the PULL BACK EXTENDED ZONE-1 signal which should be absent in standby.
- Resets the manual close latch directly, thereby terminating the blocking of automatic reclosing by removing the reset on the RI latch (via OR8 and OR10).
- Resets the hold latch through OR7 and OR14. This terminates the sustained reclosing signal which would still be present if the reclosing attempt was never validated at AND20.
- Resets the three-pole trip latch through OR7 and OR8. This removes the 3-POLE TRIP ENABLE signal thereby permitting the distance relay to trip single-pole once again.
- Resets the 2 or 3 RI latch through OR7 and OR8.
- Returns the sequencer to port 1 (standby position) through OR7 and OR8.
- Resets the delayed synchronism check latch through OR7 and OR8.

The recloser may also be reset manually by depressing the RESET push button (PB1) or it may be remotely reset by closing an external contact connected to CC16. In either case, OR5 produces an output which is sent to OR6, from which it accomplishes the following:

- Removes the recloser from lockout by resetting the lockout latch through OR26.
- Extinguishes the N/S LED indicator by resetting the synchronism check indicator latch.
- Resets the hold latch through OR7 and OR14.
- Resets the three-pole trip latch through OR7 and OR8.
- Resets the 2 or 3 RI latch through OR7 and OR8.
- Returns the sequencer to port 1 through OR7 and OR8.
- Resets the delayed synchronism check latch through OR7 and OR8.
- Resets all timers.

ON/OFF Switch

The recloser may be taken out of service by opening the ON/OFF switch (SW3). When the switch is open, NOT1 produces an output which accomplishes the following:

- Sends a 3-POLE TRIP ENABLE signal to the distance relay through OR27.
- Lights the OFF LED indicator.
- Energizes the RECLOSER IN SERVICE relay which operates its associated "C" contacts.
- Blocks manual close signals through the NOT input of AND9.
- Blocks automatic reclosing by disabling the RI latch through OR6, OR7, OR8 and OR10.
- Produces the PULL BACK EXTENDED ZONE-1 signal through OR22 thereby allowing the distance relay to return to its normal zone-1 reach setting (zone-1 extension scheme only).
- Serves all the resetting functions of the RESET push button described above (via OR6).

It should be noted that, when it is desired to take the recloser out of service, it must be done using the ON/OFF switch (SW3) and not by removing the interconnection cable(s). Even when the recloser is out of service, it sends the 3-POLE TRIP ENABLE signal and, when required, the ONE-POLE OPEN signal through a cable, both of which are necessary for the proper operation of the distance relay.

GROUND TIME OVERCURRENT FUNCTION (Optional)

An optional ground time overcurrent function may be included to provide the distance relay scheme with backup protection for high resistance and remote ground faults. The function may be non-directional (CTM module) or supervised by a dual-polarized zero sequence directional unit (CDM module).

The time overcurrent unit pickup current tap setting is adjustable from 0.1 to 0.8 per unit of rated current in 0.02 per unit steps. The inverse time-current characteristic is shown in Fig. 83. This characteristic is an IEC255-4 Type A (BS142 normal inverse) which is similar to the GE type IAC inverse characteristic. The "time dial" is adjustable from 0.05 to 1.0 in 0.025 steps.

A block diagram of the ground time overcurrent relay along with typical waveforms at various points in the circuit are shown in Fig. 11. Referring to the block diagram, the protected line residual current flows through the relay input current transformer, CT1, and develops a voltage proportional to the applied current across resistor R1. This voltage is rectified and then attenuated according to the current pickup tap setting. The "Pickup Level Detector" is used to prevent operation of the timing circuit unless the applied current is greater than the pickup tap setting. If the optional directional supervision is included, AND1 prevents an input signal from being applied to the "Pickup Level Detector" unless the directional unit is producing an output. Thus, AND1 is not a true logic gate, but rather a control gate that transmits the rectified signal only when the directional unit output is present. For the non-directional time overcurrent units, this control input is permanently high. When the "Pickup Level Detector" produces an output, a non-sealed in target LED ($>I_S$) will light, indicating that the applied current is greater than the tap setting ($>I_S$).

The "Function Generator" is a wave shaping circuit which is used to develop the desired time-current characteristic. The "Time Dial," the "Linear Ramp Generator," and the "Trip Level Detector," constitute the timing circuitry. AND2, like AND1, is a control gate which blocks or transmits the signal from the "Function Generator" circuit depending upon outputs of the "Pickup Level Detector." The "Linear Ramp Generator" is a simple integrator that integrates the output from the function generator. The "Time Dial" circuit adjusts the time constant of the integrator. The output of the "Linear Ramp Generator" is applied to the "Trip Level Detector." The "Trip Level Detector" produces an output when the ramp output reaches a predetermined level, indicating that the current has been greater than the pickup level for the required time. An output from the "Trip Level Detector" produces a three pole trip signal in the associated distance scheme via OR16 (refer to Fig. 5). A latching red LED target lamp (IN>) is included on the time overcurrent module, along with an auxiliary relay with a form "c" output contact, to indicate that the unit operated.

If the ground current drops below the pickup tap setting before a trip signal is issued, the "Pickup Level Detector" resets and blocks the input to the "Linear Ramp Generator" via AND2. The "Linear Ramp Generator" has a fast reset time which prevents the relay from "notching up" during multi-shot reclosings.

The optional zero sequence directional unit is included only in the CDM module. The directional unit is a 90 degree phase angle comparator which measures the phase angle between the residual operating current and a) the polarizing current, b) the polarizing voltage, or c) a combination of the polarizing voltage and polarizing current. Refer to the **APPLICATION AND CALCULATION OF SETTINGS** section of the book for a discussion of the polarizing quantities.

Referring to Fig. 11, AND3 produces an output when both the operating and polarizing signals are positive; AND4, when both are negative. The coincidence blocks produced by AND3 and AND4 are supplied to the characteristic timer which produces an output if the width of the blocks is 90 degrees or larger. The blocks into the characteristic timer will be greater than 90 degrees if the phase angle between the operating and polarizing signals is less than 90 degrees.

The characteristic angle of the directional unit is adjustable from 15 to 60 degrees in 15-degree steps.

SYNCHRONISM CHECK FUNCTION
(Optional)

Overall

Figure 12 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 of case B. The remainder of the circuitry depicted in Figure 12 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 and 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 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 be 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 13. 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 Ø (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 θ (adjustable). The timer output consists of a narrow pulse (waveform B) which is issued at the instant that the angle setting delay elapses.

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

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 T_{HS} elapses before the next pulse comes along because each successive pulse resets and re-initiates the timer.

$$T_{HS} = \frac{1}{F_{HS}} \times \frac{2\theta}{360^o}$$

where: F_{HS} 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, F_{HS}.

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 $\emptyset$ between them which exceeds the setting θ. The waveforms will be as illustrated in Figure 13, 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 continuously 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 $\emptyset$ is less than θ, waveforms B, C and D will all be continuously low.

Now consider the example of a frequency difference between the voltages which is less than the high set slip cut-off, F_{HS}. The waveforms will be as illustrated in Fig. 13, item 2. Eleven cycles of V_L are shown in the same interval as 12 cycles of V_B (90^o to 90^o). This is one complete slip cycle and the angular labels above the V_B wave and around the circle are slip degrees. If the V_B sine wave is taken to represent 60 hertz, the V_L 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 (V_L lagging V_B). This is an arbitrary starting 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 mutliples 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^o, the maximum anti-coincidence block in the slip cycle (at 180^o) 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 θ. This dead band is labelled the slip measurement interval on waveform B. It represents a reclosing "window" so to speak, having a dimension of 2θ slip degrees. The slip measurement interval will always have a dimension of 2θ slip degrees, but its duration (t_{SMI}) will decrease as the slip rate increases and vice versa. It therefore provides a convenient means of measuring the slip.

$$t_{SMI} = \frac{1}{f_s} \times \frac{2\theta}{360^o}$$

where: f_s 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 T_{HS} 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 ($f_s > F_{HS}$), t_{SMI} will be less than T_{HS}, the slip timer will not time out, and reclosing will be continuously 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, T_{90^o}, is then compared against the time limit established by the low set slip cut-off, T_{LS}.

$$T_{LS} = \frac{1}{4} \times \frac{1}{F_{LS}}$$

where: F_{LS} is the low set slip cut-off (in hertz) and the factor of 1/4 pertains to one quadrant.

If T_{90^o} is less than T_{LS}, the rate of slip exceeds the cut-off (F_{LS}) and reclosing is blocked. If T_{90^o} is greater than T_{LS}, the rate of slip is less than the cut-off, and reclosing is permitted.

DESCRIPTION OF HARDWARE

The SLS systems consist of plug-in modules housed within two aluminum cases. One case (Case A) contains the distance relay and associated functions, the other (Case B) contains the recloser and options. An interconnection cable is provided for the exchange of information between the cases. For the directional comparison blocking (and reverse zone 5 with timer) option, three interconnection cables are required.

ALUMINUM CASE ASSEMBLY*

Construction

* The cases are fabricated from sheet aluminum. Overall case dimensions are given in the **SPECIFICATIONS** section.

* The front cover consists of plate glass with an aluminum frame. It is hinged on the top and opened from the bottom by way of two spring-loaded plastic latches. The cover may be removed by unlatching and sliding it up and out.

* The cases are painted with a textured-finish baked enamel.

The modules are mounted vertically. The sockets within the case (towards the rear) serve as mechanical supports as well as the means of electrical connection. They hold the modules firmly in position. In addition, the front cover, when closed, provides further restraint on the modules. Proper alignment is maintained by slotted plastic guides, one above and one beneath each module (with the exception of the MGM modules, which require two guides above and two beneath).

Electrical Connections and Internal Wiring

External connections are made to each case through eight terminal blocks mounted on the rear cover plates. Each block contains 14 terminal points, which consist of a Number 6 screw threaded into a flat contact plate.

* Revised since last issue

As mentioned earlier, in SLS systems made up of more than one case, the cases are electrically tied together with interconnection cables. Depending on the complexity of the system, one or three cables may be required. Sockets for three cables are always provided at the left-hand edge of the rear cover plate (rear view), even when only one cable is needed. Connection is made by means of a 15-pin Type D miniature connector. The plug and socket are keyed to insure proper polarity. The cables are reversible because the connectors at both ends are identical. When three cables are required, the cables are identical and therefore interchangeable.

Connection to the printed circuit board modules is made by means of 60-pin edge connectors. Connection to the MGM modules (one in each case) is made by means of two connector sockets; an eight contact current block and a 104-pin signal block. The current block contacts are rated to handle current transformer (CT) secondary currents.

The printed circuit board edge connectors and the MGM module connector sockets are mounted on the same backplane assembly approximately 23 centimeters (nine inches) from the front of the case. The receptacle for the connection plugs and test device (test receptacle) on the other hand, is mounted only four centimeters (1.6 inches) from the front of the cases. This receptacle will be discussed in detail in a subsequent section.

With the exception of the leads which carry the CT secondary currents, internal wiring between module connectors, to the test receptacle, and to the rear cover terminal blocks utilizes the wire wrap method. For wiring between the module connectors, the pattern is random except for signal paths sensitive to coupling. The sensitive wires are arranged in harnesses and the harnesses are routed such that they cross at right angles in order to minimize the electrostatic and electromagnetic coupling effects. All wires connecting to the test receptacle and to the rear terminal blocks are arranged in harnesses. The internal wires leading to the interconnection cable sockets are also arranged in harnesses.

All the current inputs are brought in on the same rear cover terminal block (lower right-hand block, rear view). This block is rated to handle the CT secondary currents. The internal current leads are made from substantially heavier gage wire than the remainder of the internal wiring. They are held to the shortest length practical to minimize the resistive burden on the CT's. Connection is made via crimped-on terminals. These leads are arranged in their own harnesses and are segregated as much as possible from the other wiring. Again this is done to minimize the coupling of the fields associated with the current-carrying conductors onto the low level signal conductors.

It should be noted that certain standard internal wiring arrangements are used in the construction of SLS systems. This of course means that in some instances internal wiring is not used because a particular functional module is not included. The use of standard wiring permits simple additions of features in the field.

Identification

The SLS system model number is indicated on a label located on the inside of the front cover.

A marking strip which indicates the name and position of every module in a given case is included on the lower inside edge of the front cover. It is placed to be read when the front cover is fully opened.

The interconnection cable sockets on the rear cover plate are designated as PL-1, PL-2 and PL-3, as indicated by the labels located directly above each socket.

The terminal blocks are identified by two letter codes which are given on labels directly beneath the left-hand edge (rear view) of each block. There are eight terminal blocks on each case, each of which have a unique code (AA through DD) in order to avoid confusion when making external connections.

On each terminal block, the screw terminals (1 through 14) are labelled top and bottom by stamped numbers. The numbers are visible even when the protective covers are in place.

PRINTED CIRCUIT BOARD MODULES

Basic Construction

Each module consists of a printed circuit board and attached front panel mounted perpendicular to the board. (The DOM201 module is an exception. It contains two printed circuit boards.) Two knobs are provided on the front panel for removing and inserting the module. Electrical connection is made by contact pads at the back edge of the board.

In those cases where the circuit modules do not fill the available space, dummy modules are inserted. These consist simply of a blank board and a blank front panel.

Identification

Each module has its own model number consisting of a three letter code followed by a three digit number. These are given at the bottom of each front panel and may be read only when the case cover is opened.

RLM101 - Recloser Logic Module

This module contains the reclosing logic circuitry. The decision whether a reclose attempt should be made single pole or three pole is made in this module. If single pole, the proper phase is selected based on the status of the breaker "b" switches. The three command signals which initiate reclosure (phase A, B, C) are produced in this module.

In addition, the module contains

1) fail-to-close (breaker failure) logic which sends a trip command to the distance relay

2) lock-out circuitry which blocks further reclose attempts

3) supervision of manually initiated breaker closures (if desired)

4) a dwell timer which establishes the length of time for which the reclose output contacts, once closed, remain in the closed position.

5) circuitry which permits an initially invalidated (blocked) reclosing attempt to be sustained for the duration of the reset time (if desired).

Front Panel Light Emitting Diodes (LED's)

Identity	Color	Indication Given	Description
OPN	Yellow	Reclose in Progress (Operation)	Lights while the reclosing cycle is in progress. It remains lit for the duration of the reclose time plus the dwell time.
OFF	Red	Recloser Out-of-Service	Lights when the recloser is taken out of service by switching the ON/OFF switch on this module to the OFF position.
L/O	Red	Lockout	Lights when the recloser goes into lockout.
N/S	Red	No Reclose Due to Synchronism Check Module Output	Lights whenever a reclose attempt is blocked because of an output from the sync check module (SVM101). This is so whether the output is due to an angle check, slip check, or voltage magnitude check (dead or live line or bus). Thus, an N/S indication may be given when the voltages are actually in synchronism.

Front Panel Switches

Identity	Type	Function	Description
ON/OFF	Toggle	Recloser in Service	When in the OFF position, the recloser is taken out of service and a signal is sent to the distance relay which causes all trips to be three pole. Single pole trips are undesirable when there is no means of reclosing.

Front Panel Switches (continued)

Identity	Type	Function	Description
1Ø	Toggle	Single Pole Reclosing Only	When set to the right, reclosing is attempted only after single pole trips.
3Ø	Toggle	Three Pole Reclosing Only	When set to the right, a signal is sent to the distance relay which causes all trips to be three pole. Consequently, subsequent reclose attempts will be three pole.
X1/X10, 1Ø	Toggle	Single Pole Reclose Time Multiplier	Allows the single pole reclosing time to be one or ten times the setting of the 1Ø switch on the RTM101 module.
X1/X10, 3Ø	Toggle	Three Pole Reclose Time Multiplier	Allows the three pole reclosing time to be one or ten times the setting of the 3Ø switch on the RTM101 module.
RESET	Push Button	Reset	Momentarily depressing this push button resets all timers and flip-flops within the recloser to their initial states.

Internal Links

Identity	Function	Description
0.25/0.5/1.0/2.0	Dwell Timer Setting	Establishes the dwell time (contact closure time) of the reclose output contacts. The settings are given in seconds.
1/2	One or Two Breaker Reclosing	This link should always be set in the 1 position for use in SLS systems.
MAN CLOSE	Supervised Manual Close	When placed in the AUTO position, manually initiated reclose attempts may be made through the recloser. When in the NORM position, the recloser is essentially by-passed.
ALL3P/DLY	Synchronism Check Supervision	The position of this link determines whether all three-pole reclose attempts are to be supervised by synchronism check (ALL3P position) or only delayed (second shot) attempts (DLY position).

Internal Links (continued)

Identity	Function	Description
HOLD (#1)	Permit Blocking of Reclosing to Clear	When placed in the IN position, reclose attempts which have been invalidated by a blocking signal (synchronism check or inhibit) will be sustained for the duration of the reset time. Therefore if the blocking signal disappears before the reset time expires, the reclose attempt will be validated. When placed in the OUT position, if an attempt is blocked initially, there will be no reclosure.
HOLD (#2)	Synchronism Check	In the IN position, when a reclosing attempt is blocked by an out-of-synchronism condition which persists for the duration of the reset time, the N/S LED indicator will light at the end of the reset time. In the OUT position, the N/S LED indicator will light immediately when a reclosing attempt is blocked by synchronism check. This second hold link must be set the same as the first hold link.

ROM101 - Interface Module for Recloser

This module contains the interface circuitry for translating external contact operation (48, 110-125, or 220-250 volts DC) to signals compatible with the internal electronic circuitry. Isolation is provided between the external and internal circuits. Eleven contact converters are included for the following external contacts:

Breaker 1 "b" switches (3)
Breaker 2 "b" switches (3)
Inhibit Reclose, Breaker 1
Inhibit Reclose, Breaker 2
Manual Close, Breaker 1
Manual Close, Breaker 2
Remote Reset

In addition, this module contains two board mounted auxiliary relays with output contacts to indicate the following:

Reclose Operation in Progress ("a" contact)
Recloser in Service ("c" contact)

Internal Links

Identity	Quantity	Function	Description
48V/110-125V/220-250V	11	DC Control Voltage	These links set the interface circuitry for the proper DC control voltage. There is a separate link for each contact converter.

RTM101 - Recloser Timer Module

This module contains timing circuits for the recloser, specifically the main reclosing timer and the reset timer. The main reclosing timer requires three separate settings:

1) single pole reclosing time

2) three pole reclosing time

3) delayed reclosing time.

Each of these settings is individually adjustable.

The timers are of the digital type, that is, the time ranges are established by counting a prescribed number of reference pulses (clock pulses). These reference pulses are produced by a fixed frequency oscillator included in this module.

In addition, this module receives the reclose initiate signals and it contains logic to determine whether the initiation is single pole or three pole.

Front Panel Switches

Identity	Type	Function	Description
1Ø	Double Digit Thumbwheel	Single Pole Reclosing Time	Determines the time delay in seconds before the first reclosing attempt following a single pole trip.
3Ø	Double Digit Thumbwheel	Three Pole Reclosing Time	Determines the time delay in seconds before the first reclosing attempt following an initial three pole trip.
3Ø-D	Double Digit Thumbwheel	Delayed Reclosing Time	Determines the time delay in seconds before the second reclosing attempt. The second trip, if it occurs, will always be three pole and this switch is therefore designated as 3Ø-D.

Front Panel Switches (continued)

Identity	Type	Function	Description
RESET	Double Digit Thumbwheel	Reset Time	Determines the time delay in seconds before the recloser is reset to its initial state following the final reclose attempt.

Internal Link

Identity	Function	Description
DLY/NO DLY	One or Two Reclose Attempts	In the NO DLY position there will be no second reclose attempt (delayed reclosure). The recloser will go to lockout following a second trip.

DVM101 - AC Voltage Processing Module for Distance Relay

This module contains the voltage interfaces between the internal voltage transformer secondaries and the remainder of the electronic circuitry. It provides analog switching to direct the desired polarizing signal and restraint voltage into the main measuring unit and permissive zone measuring unit, based on inputs received from the DLM101 logic module.

The restraint voltage quantity is operated upon to determine the extended Zone One, Zone Two and Zone Three reaches as multiples of the Zone One reach.

In addition, this module contains circuitry to detect a failed fuse in the potential transformer and a positive sequence undervoltage detector used to supervise line pickup.

Front Panel Switches

Identity	Type	Function	Description
Ix	5 Stage Toggle	Extended Zone One Reach Setting	These switches determine the reach for the extended first zone when using the Zone One extension scheme. The reach is given as a multiple of the Zone One reach (set on DIM101 module). The procedure for positioning these switches to obtain the desired reach is described in the **SETTINGS PROCEDURES** section of this book.

Front Panel Switches (continued)

Identity	Type	Function	Description
II	7 Stage Toggle	Zone Two Reach Setting	These switches determine the Zone Two reach as a multiple of the Zone One reach. Refer to the **SETTINGS PROCEDURES** section.
III	8 Stage Toggle	Zone Three Reach Setting	These switches determine the Zone Three reach as a multiple of the Zone One reach. Recall that the permissive zone reach equals the Zone Three reach. Again, refer to the **SETTINGS PROCEDURES** section.

Internal Links

Identity	Function	Description
X/Y	Characteristic Selection for Single Phase Faults	Determines whether single phase-to-ground faults are measured with a reactance characteristic (X position) or a mho-type characteristic (Y position).

DIM101 - AC Current Processing Module for Distance Relay

This module provides analog switching to direct the desired operating signal ("IZ-V") into the main measuring unit and permissive zone measuring unit, based on inputs received from the DLM101 logic module.

The Zone One reach is established in this module by operating on the selected "IZ" quantity. The magnitude of the zero sequence current compensation factor, "K_0" is also adjusted in this module.

Compensated "IZ" signals (zero sequence current compensation) to be used by the phase selectors (DSM101 module) are developed in this module. Circuitry is provided to switch off the compensation when the fault current exceeds 2.5 per unit. This same overcurrent signal is used to supervise line pickup.

In addition, this module contains an undercurrent detector for each phase. These are used to

1) supervise pickup of the phase selectors

2) seal in the trip signal (DLM101 module) such that it be sustained until the current disappears.

Front Panel Switches

Identity	Type	Function	Description
I	11 Stage Toggle	Zone One Reach Setting	These switches establish the first zone reach in ohms. The procedure for positioning these switches to obtain the desired reach is described in the **SETTINGS PROCEDURES** section of this book.
K_0	7 Stage Toggle	Zero Sequence Current Compensation Factor	These switches establish the magnitude of the zero sequence current compensation factor. Refer to the **SETTINGS PROCEDURES** section.

DSM101 - Phase Selector Modules for Distance Relay

The circuitry in this module comprises the phase selectors for each of the three phases, plus a directional unit based on negative sequence quantities. The restraint quantities for each of the three phase selectors are operated upon in order to determine the phase selector reach.

The phase selectors, in addition to serving as starting units, constitute the fourth zone of protection.

Front Panel Switches

Identity	Type	Function	Description
Zp	8 Stage Toggle	Phase Selector Reach Setting	These switches establish the phase selector reaches (Zone Four reach) in ohms. All the phase selectors will have the same reach. The procedure for positioning these switches to obtain the desired reach is described in the **SETTINGS PROCEDURES** section of this book.

Internal Link

Identity	Function	Description
LENS/CIRCLE	Shape of Phase Selector Mho Characteristic	This link provides a choice for the phase selector mho characteristic. The circle requires 90 degrees of coincidence between the operating and polarizing quantities; the lens, 105 degrees. The three phase selectors will have the same characteristic.

DFM101, 102 - Filter Modules for Distance Relay

These two modules differ only in their frequency ratings. The 101 model is used in 60 hertz systems, the 102 model in 50 hertz systems.

The circuitry contains interfaces between the transactor secondaries and the remainder of the electronic circuitry. Sequence networks are used to produce the various polarizing signals. There are four sets of networks included in this module:

1) Positive sequence voltage networks - one corresponding to each phase

2) Negative sequence current networks - one corresponding to each phase

3) Combined sequence voltage networks - one corresponding to each pair of phases

4) A negative sequence voltage network corresponding to phase A.

Filter circuits are included at the outputs of certain sequence networks in order to provide memory action.

This module also includes variable angle phase shifting circuits. These operate on the current signals for the purpose of establishing the positive (and negative) sequence impedance characteristic angle and, separately, the zero sequence impedance characteristic angle.

Front Panel Switches

Identity	Type	Function	Description
$\emptyset Z_1$	9 Position Rotary	Positive (and Negative) Sequence Impedance Angle	Determines the relay's positive (and negative) sequence impedance characteristic angle. This angle will be the same for the phase selectors, main measuring unit, and permissive zone measuring unit. The settings are given in degrees.
$\emptyset Z_0$	12 Position Rotary	Zero Sequence Impedance Angle	Determines the relay's zero sequence impedance characteristic angle. Again, this angle is the same for the phase selectors, main measuring unit, and permissive zone measuring unit. The settings are given in degrees.

DMM101 - Measuring Unit Module for Distance Relay

This module contains the main measuring unit and permissive zone measuring unit. Separate circuitry is included to detect power system swings (out-of-step condition). A switch is included which allows tripping to be blocked during system swings.

A fixed frequency oscillator is included in the module to furnish reference pulses (clock pulses) for all the digital-type timers in the distance relay.

In addition, this module contains driver circuits for the phase selector indicators.

Front Panel Light Emitting Diodes (LED's)

Identity	Color	Indication Given	Description
ØA	Yellow	A-Phase Selector Picked up	Lights when a fault (or other abnormal condition) is within the A-phase characteristic.
ØB	Yellow	B-Phase Selector Picked up	Lights when a fault (or other abnormal condition) is within the B-phase characteristic.
ØC	Yellow	C-Phase Selector Picked up	Lights when a fault (or other abnormal condition) is within the C-phase characteristic.
OSB	Yellow	Out-of-Step Blocking	Lights when a power swing occurs, provided the detector is enabled (OSB switch IN).

Internal Switches

Identity	Function	Description
OSB	Out-of-Step Blocking	When placed in the IN position, the power swing detection circuitry is operable. Tripping will be blocked for swings. In the OUT position, the circuitry is disabled.
50/60 HZ	System Frequency Setting	This switch adjusts the characteristic timers for the proper system frequency.

Internal Switches

Identity	Type	Function	Description
GND CHAR ANGLE	4 Stage Miniature Toggle	Initial Angle for Single Phase to Ground Fault Characteristic	Determines the initial coincidence angle between the net operating and polarizing quantities required for a fault to plot within the single phase-to-ground fault characteristic (reactance or mho-type). In other words, these switches establish the steepness of the reactance tent or the narrowness of the mho lens. The settings are given in degrees.
OSB TIME	6 Stage Miniature Toggle	Power Swing Limit	These switches establish the minimum time permitted for the apparent system impedance to swing from the phase selector (outer) characteristic to the permissive zone (inner) characteristic. This criterion discriminates between swings and three phase faults.
SEQ TRIP TIME	6 Stage Miniature Toggle	Sequential Trip Time	These switches establish the length of time for which, following the onset of a fault, the main unit characteristic (tent or lens) is held at its initial angle before integration begins. Note that this applies only for single phase-to-ground faults. The settings are given in milliseconds.

DTM101 - Timer Module for Distance Relay

This module contains the zone timer. It includes individually adjustable set points for the Zone Two, Zone Three and Zone Four times.

In addition, this module contains the logic circuitry for the six different schemes of protection (scheme logic):

1) Stepped Distance
2) Zone One Extension
3) Zone Two Acceleration
4) Permissive Underreaching Transfer Trip
5) Permissive Overreaching Transfer Trip
6) Directional Comparison Blocking (optional)

The desired scheme is selected by positioning a series of miniature toggle switches in this module, as described in the **SETTINGS PROCEDURES** section of this book.

Schemes 3 through 6 (above) are pilot schemes which require the use of a communication channel. Logic for sending a signal over the channel and for acknowledging the receipt of a channel signal is included in this module. A coordination timer is included for use in the permissive overreaching transfer tripping and the directional comparison blocking schemes.

Front Panel Switches

Identity	Type	Function	Description
II	Double Digit Thumbwheel	Zone Two Time Setting	Determines the time in seconds before the relay switches into Zone Two reach following the pickup of a phase selector (or selectors).
III	Double Digit Thumbwheel	Zone Three Time Setting	Determines the time in seconds before the relay switches into Zone Three reach following the pickup of a phase selector (or selectors).
IV	Double Digit Thumbwheel	Zone Four Time Setting	Determines the time in seconds when the relay trips in Zone Four reach (phase selector reach) following the initial pickup of a phase selector(s).
X1/X10, II/III	Toggle	Zone Two and Three Time Multiplier	Multiplies Zone Two and Zone Three time settings (switches II and III) by one or ten.
X1/X10, III	Toggle	Zone Three Time Multiplier	Multiplies Zone Three time setting only (switch III) by one or ten.
NO CH TRIP	Toggle	Block Channel Tripping	Prohibits pilot tripping of the local breaker by invalidating the receipt of a channel signal.
TO SEND	Push Button	Send Channel Signal	Manually initiates transmitter keying to send a signal over the channel.

Internal Switches

Identity	Type	Function	Description
LOGIC	6 Stage Miniature Toggle	Scheme Logic Selection	Establishes the scheme of protection to be employed. Refer to the **SETTINGS PROCEDURES** section for the required switch positions.

Internal Switches (continued)

Identity	Type	Function	Description
CORD TIME	6 Stage Miniature Toggle	Coordination Time for Permissive Overreaching Transfer Tripping and Directional Comparison Blocking	Determines the time delay in milli-seconds before the local breaker is permitted to be tripped following the pickup of the permissive unit in the local relay. This applies only for the permissive overreaching transfer tripping and the directional comparison blocking schemes.

Internal Links

Identity	Function	Description
2/3/4/TEST	Zone Limit	Determines the outermost zone in which direct tripping is permitted. The TEST position is equivalent to a Zone One limit.
SEND	State of Keying Contact	Determines whether the KEY TRANSMITTER contact ("send" contact) is open or closed under normal conditions. In the non-invert position, the contact will be open under normal conditions, and will close when it is desired to key the transmitter. In the INV position, the contact will be closed under normal conditions, and will open to key the transmitter.
RCVR	State of Receiver Contact Monitor	In the non-invert position, the monitor interprets an open receiver contact to indicate normal channel conditions and a closed receiver contact to indicate the presence of a channel signal. In the INV position, the monitor functions in the opposite manner.
CHSP	State of Channel Stop Contact	Determines whether the STOP TRANSMITTER contact is open or closed under normal conditions. In the non-invert position, the contact will be open under normal conditions, and will close when it is desired to stop the transmitter. In the INV position, the contact will be closed under normal conditions, and will open to stop the transmitter.

DLM101 - Logic Module for Distance Relay

This module contains the logic circuitry pertaining to

1) fault type
2) trip outputs
3) targets.

The type of fault (A-Ground, A-B, etc.) is determined by monitoring the phase selectors (DSM101 module). This information is used to switch the proper operating and polarizing quantities into the measuring units.

A switch is included to coordinate the relay with the type of voltage transformer being used. Compensation is provided for the transient response of capacitor coupled voltage transformers in order to prevent transient overreach.

Single pole or three pole tripping is determined in this module based on the fault type and/or recloser inputs. A switch is included that provides the option of all trips to be three pole.

The front panel light emitting diodes (LED's) described below serve as target indicators following a trip output. Latching circuits are included (except for FF) so that once lit, the LED's will remain lit until manually reset via the button at the bottom of the front panel or electrically reset by the closure of an external contact (remote target reset).

Front Panel Light Emitting Diodes (LED's)

Identity	Color	Indication Given	Description
A	Red	Phase A Trip Output	With the TRIP/FAULT switch in the TRIP position, the target will light for any pole A trip output whether it be single pole or part of a three pole trip. With the link in the FAULT position, it will light only when the trip output results from a fault involving phase A. Refer to the Internal switch subsection.
B	Red	Phase B Trip Output	Similar to A above, except lights for phase B trip outputs.
C	Red	Phase C Trip Output	Similar to A above, except lights for phase C trip outputs.

Front Panel Light Emitting Diodes (LED's) (continued)

Identity	Color	Indication Given	Description
I	Red	Trip in Zone I	Lights following a trip output resulting from the detection of a fault within Zone One reach (phase selector reach).
II	Red	Trip in Zone II	Lights following a trip output resulting from the detection of a fault within Zone Two reach (phase selector reach).
III	Red	Trip in Zone III	Lights following a trip output resulting from the detection of a fault within Zone Three reach (phase selector reach).
IV	Red	Trip in Zone IV	Lights following a trip output resulting from the detection of a fault within Zone Four reach (phase selector reach).
CH	Red	Trip Due to a Channel Signal	Lights whenever a trip results from the receipt of a channel signal when using one of the pilot schemes (or when a trip ocurs in the absence of a channel signal in the directional comparison blocking scheme). In the transfer tripping schemes, one or both relays may issue trip outputs due to fault detection in Zone One before the channel signal is received. In such cases, the CH LED will light neverthe-less (in addition to the I LED).
FF	Amber	Fuse Failure in Potential Transformer	Lights when a failed fuse is detected in the potential transformer. This is the only LED on this module that is not a trip target indicator. It serves as an alarm and operates directly with the fuse failure output contact (DOM201 module). This LED does not have a latching circuit.

Front Panel Switch

Identity	Type	Function	Description
RESET	Push Button	Resets LED Target Indicators	Depressing this button electrically unlatches all the LED's (except for FF) so they will go out provided the condition which caused them to light initially no longer exists. It should be noted that when the button is depressed, all the LED's (except FF) will light temporarily.

Internal Switches

Identity	Function	Description
CVT/PT	Voltage Transformer Type	The positioning of this switch coordiates the relay with the type of voltage transformer being used. CVT corresponds to capacitor coupled voltage transformer. PT corresponds to potential transformer.
FF/BLOCK	Fuse Failure Supervision	In the BLOCK position, tripping will be blocked when a failed fuse is detected in the potential transformer. In the OFF position, the fuse failure detector does not supervise tripping, but will still give a target indication (and alarm contact closure).
3P/1P	Tripping Mode	Determines whether single pole tripping will be employed for single phase faults. The 3P position causes all tripping to be three pole.
TRIP/FAULT	Targeting Mode	For two phase faults, three pole tripping will result. If this SWITCH is in the TRIP position, all three target LEDs will light. If the switch is in the FAULT position, only those two LEDs associated with the faulted phases will light. For single pole tripping, only the faulted phase LED will light, regardless of the switch position.
.5 1 cycle 2 cycles	Target trip time	Prevents additional setting of targets after the initial trip signal. This should be set for less than breaker operating time. All three switches closed is three and one half cycles.

DOM201 - Interface Module for Distance Relay (Two Layer Module)

This module is made up of two printed circuit boards which are attached to one another with hinged hardware. The component sides of the two boards face each other so that when the top retaining screws are removed, the module may be unfolded in order to access the links on both boards.

The left hand board (to which the front panel is attached) contains eleven board mounted auxiliary relays with type "a" output contacts for the following functions:

Oscillograph Start (any phase selector picked up)
Alarms: Zone 1 Trip
Zone 2 Trip
Zone 3 Trip
Zone 4 Trip
Power Swing - Block Tripping
Fuse Failure in Potential Transformer
Breaker Failure Initiation, Phase A
Phase B
Phase C
Breaker Failure Initiation, Any Phase
(logical OR of above three)

This board also contains two fast operating reed relays which provide output contacts for the following channel control functions:

Key Transmitter
Stop Transmitter

In addition, the left hand board contains the interface circuitry for translating external contact operation (48, 110-125, or 220-250 volts DC) to signals compatible with the internal electronic circuitry. Isolation is provided between the external and internal circuits. Two contact converters are included, one for a channel receiver contact (channel signal received) and the other for an external contact used to block transfer tripping through the channel (block channel trip).

The right hand board contains six contact converters (rated 48, 110-125, or 220-250 volts DC) and five board mounted auxiliary relays with type "a" output contacts. The following functions are served:

Contact Converters: Line Pickup
3 Pole Trip Enable
Pull Back Extended Zone One
One Pole Open
Block Tripping
Remote Target Reset

Auxiliary Relays: Enable Reclosing
Channel Trip (Alarm)
A Phase Selector (Alarm)
B Phase Selector (Alarm)
C Phase Selector (Alarm)

Internal Links

Identity	Quantity	Function	Description
48V/110-125V/220-250V	6 (right hand board) 2 (left hand board)	DC Control Voltage	These links set the interface circuitry for the proper DC control voltage. There is a separate link for each contact converter.
IND/COM	3 (left hand board)	Individual or Common Breaker Failure Initiation	These links determine whether breaker failure initiation (BFI) will be done on a per pole basis. For single pole tripping, the IND position will result in the operation of the BFI relay for the tripped pole plus the supervisory BFI relay (any pole). The COM position causes all four BFI relays to operate simultaneously.

PSM - Power Supply Module for Entire SLS System

* This module contains the power supply used by all of the functions in the SLS system (both cases). It consists of a DC-to-DC flyback type converter with a single-rated input (Available at 48V, 110/125V, or 220-250V) and three regulated outputs:

1) Plus and minus 12 volts DC around a center reference; 1 amp capacity. This is used to power the electronics.

2) 25 volts DC above the same reference as in (1); 1 amp capacity. This is used to energize the board mounted relays and light emitting diodes. In addition, it provides all of the voltage for operating the telephone type reclosing relays in the case B magnetics module and one half of the voltage for operating the telephone type tripping relays in the case A magnetics module.

3) A second independent 25 volt DC output; 0.2 amp capacity. This provides the other half of the voltage for operating the tripping relays.

***WARNING**

BATTERY VOLTAGE IS PRESENT ON THIS MODULE AT ALL TIMES. BATTERY VOLTAGE SHOULD BE REMOVED WHEN INSERTING OR REMOVING THIS MODULE.

*Revised since last issue

In addition, this module contains a board mounted relay which provides an externally accessible form c contact. The relay is energized under normal conditions and drops out, operating the contact, when the power supply output goes out of regulation for any reason, including the loss of DC control voltage from the station battery.

Front Panel Light Emitting Diodes (LED)

Identity	Color	Indication Given	Description
Regulated Output Voltage	Green	Power Supply Functioning	This LED is lit continuously so long as regulation is maintained in the output voltages. It provides a visual check-point to verify proper operation of the power supply.

Front Panel Switch

Identity	Type	Function	Description
ON/OFF	Toggle	Shuts off Power Supply	This switch disconnects both the positive and negative station battery leads from the primary circuit of the power supply. It provides a convenient means of removing DC power from the relay, as opposed to disconnecting the wires on the rear terminal.

Internal Link

Identity	Function	Description
48V/125V/250V	DC Control Voltage Setting	This link sets the primary circuit of the power supply to correspond to the DC control voltage being used. The 125V position also pertains to a nominal input of 110V and the 250V position also pertains to a nominal input of 220V.

CTM - Ground Time Overcurrent Module (Optional)

This module contains a ground fault detector with an inverse time overcurrent characteristic. It directly activates the trip relays in the distance relay through interconnection cable PL-1 (always a three pole trip).

The circuitry is broken down into a current detector with adjustable pickup (top setting) and an inverse time delay circuit with an adjustable time dial.

This module contains a board mounted relay which provides an externally accessible contact.

Front Panel Light Emitting Diodes (LEDs)

Identity	Color	Indication Given	Description
$>I_S$	Yellow	Current Exceeding Tap Setting	This LED Lights whenever the ground current exceeds the tap setting. It remains lit only so long as the current is above that level.
IN>	Red	Three Pole Trip Due to CTM Output	This LED lights to indicate a trip via the ground time overcurrent circuit. It is a latching target which remains lit until reset by the pushbutton on the front panel.

Front Panel Switches

Identity	Type	Function	Description
I_S	6-Stage Toggle	Pickup Tap Setting	These switches establish the ground current threshold for the CTM detector. The procedure for positioning these switches to obtain the desired tap setting is described in the **SETTINGS PROCEDURE** section of this book.
TM	Rotary	Time Dial	This switch selects one of the characteristic time current curves (see Fig. 76) to be used in determining the delay before tripping.
+.25, +.05	2 Toggles	Supplementary Time Dial Switches	These two switches add directly to the time dial setting so as to provide finer resolution than allowed by the position of the TM dial.
RESET	Pushbutton	Target Reset	Momentarily depressing this push button resets the red IN LED target, provided that fault current is no longer present.

CDM - Directional Ground Time Overcurrent Module (Optional)

This module is similar to the CTM module except, in addition to the CTM circuitry, it contains a directional unit which supervises operation of the ground fault detector. The directional unit may be dual polarized with zero sequence voltage and zero sequence current.

Front Panel Light Emitting Diodes (LEDs)

Same as for CTM module

Front Panel Switches

Same as for CTM module

Internal Links (not included in CTM)

Identity	Function	Description
50/60 HZ	System Frequency Setting	This link adjusts the characteristic timer on the directional unit for the proper system frequency.
60/45/30/15 50 and 60 HZ	Characteristic Angle for Voltage Polarization	This link establishes the characteristic angle for voltage polarization of the directional unit. The directional unit most strongly tends to operate when the ground current lags the polarizing voltage by this angle.

DBM101 - Directional Comparison Blocking Module (Optional)

The circuitry in the module comprises the blocking units (MB) used in the directional comparison blocking scheme. These units are similar to the phase selectors except the current is connected such that they reach in the reverse direction. There is one unit for each phase and the outputs of the three units are ORed together to produce a single blocking signal.

The blocking units may also be used for backup protection in the form of a fifth zone (reverse zone). A timer is included for this purpose to provide delayed tripping (always three pole tripping) in the reverse direction.

Front Panel Switches

Identity	Type	Function	Description
Z_B	8-stage Toggle	Blocking (MB) Unit Reverse Reach Setting	These switches establish the blocking unit reaches (zone 5 reach) in ohms. All the units will have the same reach. The procedure for positioning these switches to obtain the desired reach is described in the **SETTINGS PROCEDURES** section of this book.

Internal Link

Identity	Function	Description
LENS/CIRCLE	Shape of Blocking Unit Mho Characteristic	This link provides a choice for the blocking unit mho characteristic. The circles requires 90 degrees of coincidence between the operating and polarizing quantities; the lens, 105 degrees. The three blocking units will have the same characteristic.

Internal Switches

Identity	Type	Function	Description
CYCLES DROPOUT	4-Stage Miniature Toggle	Dropout Time for Blocking Signal	These switches establish the time for which the blocking signal is sustained after the MB unit(s) cease to produce an output. The settings are given in cycles.
ZONE 5	8-Stage Miniature Toggle	Delay Time for Reverse Zone 5 Tripping	These switches determine the time in seconds when the relay trips three pole on a backup basis for a fault in the reverse fifth zone following the initial pickup of an MB unit(s). When the infinity position is open, fifth zone tripping is disabled.

SVM - Synchronism Check Module (Optional)

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

(1) Voltage detectors to determine if the line and bus are dead or live. Reclosing may be permitted or blocked for any combination of dead and live line and bus.

(2) An angle measurement circuit to determine if the phase angle between the two voltages is within the selected limit. Reclosing is blocked when the angle is outside the limit.

(3) A low set slip measurement circuit to determine if the frequency difference between the two voltages is within the selected limit (low set slip cut-off). Reclosing is blocked when the slip exceeds the setting.

(4) A special high set slip measurement circuit which permits a fast synchronism check in the interval before the low set slip circuit has enough time to make its measurement, provided the angle between the bus and line voltages does not at any point exceed the angle setting (V_L phasor never leaves reclosing window).

(5) A "dead time" timer set to coordinate with the reclosing time of the remote breaker. If the remote breaker does not close in the allotted time, the high set slip detector may issue an erroneous output. The "dead time" timer prevents this by disabling the high set slip detector after the allotted time has elapsed. Slip measurement is then made by the low set slip detector only.

Front Panel Switches

Identity	Type	Function	Description
ANGLE	Double Digit Thumbwheel	Angle Setting	Determines the phase angle limit (in degrees) between the bus and line voltages for which reclosing is permitted.
SYNC CK	Toggle	Synchronism Check Mode	Places the SVM module in the synchronism check mode so that reclosing is supervised by the angle and slip detectors. In addition, both voltages must be above their respective live thresholds to permit reclosing.
LLDB	Toggle	Live Line, Dead Bus Mode	Permits reclosing only when the line voltage is above its live threshold (adjustable) and the bus voltage is below its dead threshold (also adjustable).
DLLB	Toggle	Dead Line, Live Bus Mode	Permits reclosing only when the line voltage is below its dead threshold and the bus voltage is above its live threshold.
DLDB	Toggle	Dead Line, Dead Bus Mode	Permits reclosing only when the line and bus voltages are below their respective dead thresholds.

Internal Switches

Identity	Type	Function	Description
PT VOLTAGE	4 stage Miniature Toggle (1 stage not used)	Nominal PT Secondary Voltage	The setting of these switches determines the nominal phase-to-neutral AC voltage from which the live and dead thresholds are established.
BUS LIVE	4 stage Miniature Toggle	Threshold for Live Bus Detector	The setting of these switches determines the percentage of the nominal voltage above which the bus is considered live.
BUS DEAD	4 stage Miniature Toggle	Threshold for Dead Bus Detector	The setting of these switches determines the percentage of the nominal voltage below which the bus is considered dead.

Internal Switches (continued)

Identity	Type	Function	Description
LINE LIVE		Same as for Bus Live (adjusted separately)	
LINE DEAD		Same as for Bus Dead (adjusted separately)	
LOW SET SLIP	4 stage Miniature Toggle	Low Slip Detector Setting (Cut-off)	The setting of these switches establishes the slip rate (F_{LS}) beyond which reclosing will be blocked (except instantaneous reclosing).
HIGH SET SLIP	4 stage Miniature Toggle	High Slip Detector Setting (Cut-off)	The setting of these switches establishes the cut-off (F_{HS}) for the special high speed slip detector used to supervise instantaneous reclosing.
DEAD TIME	6 stage Miniature Toggle	"Dead Time" Timer Setting	The setting of these switches establishes the time (following the trip) after which the high set slip detector is disabled.
50 Hz/60 Hz	First Quarter of 4 stage Miniature Toggle (Double Stages)	System Frequency Setting	This switch adjusts the synchronism check circuitry for the proper system frequency
1	Second Quarter of 4 stage Miniature Toggle	Low Set Slip Cut-off Multiplier	When set to the right (positioned towards bottom edge of the board) this switch multiplies the slip frequency setting on the LOW SET SLIP switches by ten
2	Third Quarter of 4 stage Miniature Toggle	Low Set Slip Control for second breaker	This switch is not used in the SLS. It should be set to the left (positioned towards top edge of board).
LOW SET ONLY	Fourth Quarter of 4 stage Miniature Toggle	Cancels High Set Slip	This switch effectively cancels synchronism check via the high set slip detector by requiring a low set slip measurement to be made before permitting reclosing.

Internal Light Emitting Diodes (LEDs)

Identity	Color	Indication Given	Description
TL1	Red	Angle Out-of-Limits	This LED lights whenever the phase angle between the line and bus voltages exceeds the angle setting on the front panel of the module.
TL2	Red	Slip Exceeding Low Set Cut-off	This LED lights if the frequency difference between the line and bus voltages exceeds the low set cut-off, but it lights only after the slip measurement has been made.
TL3	Red	OK to Reclose	This lights whenever the SVM module is outputting a signal which is permitting reclosing. It works in conjunction with the voltage check modes (DLDB, etc.) as well as with the sync check mode.

MAGNETICS MODULES

Basic Construction

The magnetics modules, designated MGM, consist of a steel framework which houses the magnetic circuit components. These include current transformers, potential transformers, transactors and telephone-type output relays with tripping duty contacts. In addition, one printed circuit board is included for each set of three telephone relays. It contains interface circuitry such that these relays are driven directly by the DC control voltage (48 or 110-125 volts DC).

Electrical connection is made by means of two connector blocks; a 104-pin signal block and a eight-pin current block having substantially heavier contact fingers. On those modules which do not receive current inputs, the current block is not included.

Handles are provided top and bottom for removing and inserting the module.

Identification

The MGM model number is given at the bottom of the front panel. Rating information for the module is given in the center of the front panel as indicated below:

I_N - AC current rating (Amperes)
V_N - AC voltage rating (AC volts)
FREQ - Frequency rating (Hertz)
V_{NA} - DC control voltage rating (DC volts)

The front panel identification includes only those ratings which apply to that particular MGM module. For example, MGM201 has no AC inputs. Therefore, V_{NA} is the only rating given on its front panel.

Internal Links

DC Control Voltage Setting:

There is one link on the printed circuit board within the module for the DC control voltage setting (48 volts or 110-125 volts). For those modules containing six telephone-type relays, there are two printed circuit boards, each including a DC voltage link.

AC Current Setting:

For those modules which have a dual AC current rating (one amp/five amps) each magnetic element associated with the current circuit(s) has a tapped winding. A link(s) is provided to connect the proper number of turns for the desired rating.

NOTES

SETTINGS PROCEDURES

Unless otherwise noted, the switches referred to in this section are located on the front panels of the modules. Internal switches and links, where indicated, may be accessed by removing the module (or modules) in which they are contained. Figs. 28 through 40 are included expressly for the purpose of locating and setting the internal switches and links.

DC CONTROL VOLTAGE SETTINGS

Internal links must be set in each of the modules indicated in Table V below to correspond to the DC control voltage being used. In the power supply, the range labelled 125V is designed for use with 110V supplies as well, and the range labelled 250V is designed for use with 220V supplies.

TABLE V - DC CONTROL VOLTAGE LINKS

MODULE	LOCATION	NUMBER OF DC CONTROL VOLTAGE LINKS	FUNCTION
DOM201	Case A	2 - Left Hand Board** 6 - Right Hand Board**	Contact Converters
PSM201	Case A	1	Power Supply
ROM101	Case B	11	Contact Converters

** These links may be accessed by pulling out the DOM201 module, removing the two retaining screws on the upper stand-offs which hold the boards together, and unfolding the boards about the lower hinged stand-offs.

AC CURRENT SETTING

For those MGM modules which have a dual AC current rating (one ampere/five amperes) the desired rating is obtained by positioning a tap or taps in the rear of the module (see Fig. 41). There will be one tap for each current transformer in the module. Access is gained from the back of the module. A screwdriver is required to reposition the current tap (or taps).

RECLOSER SETTINGS

Mode of Operation

There are five modes of operation for the recloser:

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.

The desired mode is selected by positioning the switches and links indicated in Table VI below:

TABLE VI - RECLOSER MODE OF OPERATION

	SWITCHES ON RLM101 FRONT PANEL		
MODE	1Ø	3Ø	RTM101 INTERNAL LINK
1	LEFT	LEFT	NO DLY
2	RIGHT	LEFT	DOES NOT MATTER
3	LEFT	RIGHT	NO DLY
4	LEFT	LEFT	DLY
5	LEFT	RIGHT	DLY

The recloser is taken out of service by simply moving the ON/OFF switch on the front panel of the RLM101 module to the OFF position.

Time Settings

First Reclosing Attempt - Single Pole

The time between a reclose initiation (trip) and the first reclosing attempt is set by the top double-digit thumbwheel switch on the RTM101 module, designated 1Ø. The digits are advanced by the lower push buttons labelled (+) and reduced by the upper push buttons labelled (-). The left digit indicates tenths of seconds, the right digit indicates hundredths of seconds.

The time setting may be made to equal ten times the reading on the 1Øthumbwheel switch by moving the X1/X10, 1Ø toggle switch on the RLM101 module to the X10 (right) position.

First Reclosing Attempt - Three Pole

If the first reclosing attempt is three pole, the reclosing time will be according to the setting on the second double-digit thumbwheel switch on the RTM101 module, designated 3Ø. Again, the left and right digits indicate tenths and hundreths of seconds, respectively.

This time setting may also be made to equal ten times the reading on the 3Øthumbwheel switch by moving the X1/X10, 3Ø toggle switch on the RLM101 module to the X10 (right) position.

Second Reclosing Attempt (Always Three Pole)

The time between the second reclose initiation (first attempt failed) and corresponding reclosing attempt (delayed reclosure) is according to the setting on the third double-digit thumbwheel switch on the RTM101 module, designated 3Ø-D. In this case, the left digit indicates tens (not tenths) of seconds and the right digit indicates seconds. This time must always be set longer than the dwell time.

Reset Time

The reset time is according to the setting on the bottom double-digit thumbwheel switch on the RTM101 module, designated RESET. The left and right digits indicate tens of seconds, and seconds, respectively. The reset time must always be set longer than the dwell time.

Dwell Time

The dwell time is set by positioning a link within the RLM101 module. There are four possible settings; 0.25 second, 0.5 second, 1.0 second and 2.0 second.

Auxiliary Functions

Manual Close Through Recloser

In order for manual closing to be accomplished using the recloser circuitry, the MAN CLOSE link within the RLM101 module must be placed in the AUTO position. Otherwise it should be placed in the NORM position.

Number of Breakers

For SLS systems, the 1/2 link in the RLM101 module must be placed in the 1 position.

Supervision of Reclosing by Synchronism Check

If the recloser purchased includes the synchronism check option, it will contain an SVM module. Three pole reclosing attempts may then be supervised by the synchronism check signal. If it is desired to have this supervision on both first and second reclosing attempts, the ALL3P/DLY link in the RLM101 module should be placed in the ALL3P position. If it is desired to supervise only the second (delayed) reclosing attempt, place the link in the DLY position.

Permit Blocking of Reclosing to Clear

By placing the HOLD links in the RLM101 module in the IN position, reclosing attempts which have been initially invalidated by a blocking signal (be it from the synchronism check module or from an external contact) will be sustained for the duration of the reset time with the hope that the blocking signal will disappear. This feature may be disabled by placing the link in the OUT position. Both links must be set the same. The first controls the reclosing signal, the second controls the N/S LED indicator.

GROUND TIME OVERCURRENT MODULES (CTM or CDM - Optional)

Pickup Current Settings

The pickup current for the SLS ground time overcurrent unit is set by positioning the six toggle switches on the CTM or CDM module. The setting, in amperes, is given by the following expression which appears on the module front panel:

$$I_S = [.1 + (\ )]\ I_N$$

I_N represents the current rating which is set by the tap in the rear of the case B MGM module.

The value in parentheses represents the composite setting of the six toggle switches. This number is arrived at by summing the values corresponding to all the switches in the closed (right) position.

Time Dial Setting

The time delay between the pickup of the overcurrent unit and its output trip command is adjusted using the rotary TM time dial on the CTM or CDM module. The dial settings are given in .1 increments. For finer resolution, two supplementary toggle switches are provided which add .025 or .05 to the TM setting when either is closed (right), or .075 when both are closed.

It is necessary to refer to the time curves (Fig. 83) to translate the time dial setting into actual operating times.

Frequency Setting - CDM Only

The directional unit used to supervise the ground time overcurrent function must be set for the nominal system frequency by positioning the 50 Hz/60 Hz link within the CDM module.

Characteristic Angle for Directional Unit with Voltage Polarization - CDM Only

When current polarization is in effect, the directional unit will permit the ground time overcurrent unit to issue a trip output as long as the phase angle between the operating and polarizing currents is within 90 degrees (plus or minus).

For voltage polarization, it is necessary to establish a characteristic angle. This is accomplished by positioning a link within the CDM module. Four settings are provided: 15, 30, 45 and 60 degrees. Note that the setting is dependent on the system frequency. Fig. 46 shows the resulting directional unit characteristic on an R-X diagram. Tripping is permitted only in the operating area, which spans 90 degrees either side of the characteristic angle.

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 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 hertz) 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 hertz) 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 (T_D) 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 SLS. 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 65 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 nominal system frequency by positioning the 50 HZ/60 HZ miniature switch within the SVM module.

DISTANCE RELAY SETTINGS

Selection of Protective Scheme

The distance relay includes five standard schemes of protection and one optional scheme:

1) Stepped Distance
2) Zone One Extension
3) Zone Two Acceleration
4) Permissive Underreaching Transfer Trip
5) Permissive Overreaching Transfer Trip
6) Directional Comparison Blocking (optional)

The desired scheme is selected by positioning four miniature toggle switches within the DTM101 module, as indicated in Table VII below. These switches are identified as LOGIC A, B, C, D.

TABLE VII - SELECTION OF PROTECTIVE SCHEME

DESIRED SCHEME	POSITION OF SWITCHES			
	A	B	C	D
1	Open	Open	Open	Open
2	X	X	X	Closed
3	X	X	Closed	Open
4	Closed	Open	Open	Open
5	Open	Closed	Open	Open
6	Closed	Closed	Open	Open

X = Don't care condition; has no effect.

Reach Settings

Phase Selector Reach

The phase selector reach is set by positioning the eight toggle switches on the DSM101 module. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$Z_P = [4 + (\quad)] \times 5/I_N$$

I_N represents the current rating which is given on the distance relay MGM model.

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 I_N = 5 amperes, the phase selection reach is then

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

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 DBM101 module. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$Z_B = [4 + (\ )] \times 5/I_N$$

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 uits (phase A, B, C) and that the reach also constitutes the reach for the reverse zone five.

Zone One Reach

The procedure for setting the Zone One reach is similar to that for setting the phase selector reach. It entails positioning the upper eleven toggle switches on the DIM101 module. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$I = [0.1 + (\ \ )] \times 5/I_N$$

Again, the value in parentheses represents the composite setting of the toggle switches.

Extended Zone One Reach

This reach, which is to be used in the Zone One extension scheme, is set by positioning the upper five toggle switches on the DVM101 module, designated I_X. The reach, in ohms, is given by the following expression which appears on the module front panel:

$$r = [1 + (\ \ )]\ Z_I$$

Z_I represents the Zone One reach as set on DIM101. The value in parentheses represents the composite setting of the five I_X 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 middle seven toggle switches on the DVM101 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 lower eight toggle switches on the DVM101 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.

Zero Sequence Compensation Factor

This factor, designated K_0, is adjusted by positioning the lower seven toggle switches on the DIM101 module. Its value is given by the following expression which appears on the module front panel:

$$K_0 = 2.0 + (\quad)$$

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

Characteristic Impedance Angles

The relay's positive (and negative) sequence impedance angle is set by rotating the upper switch on the DFM module (designated $ØZ_1$) to the desired position. The values are given in degrees.

The relay's zero sequence impedance angle is set by rotating the lower switch (designated $ØZ_0$) 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 Time Settings

Zone Two, Three and Four Times

The time delays between the pickup of a phase selector and the switching of the main measuring unit into the succeeding zones are set by the three double-digit thumbwheel switches on the DTM101 module, designated II, III and IV. The digits are advanced by the lower push buttons labelled (+) and reduced by the upper push buttons labelled (-). For switches II and III, the left digit indicates tenths of seconds and the right digit indicates hundredths of seconds, provided the X1/X10 multiplier switches are in the X1 position. For switch IV, the first digit indicates seconds and the second digit indicates tenths of seconds.

It should be noted that the II, III and IV switch settings indicate time delays from the same initial starting point as opposed to intervening delays between zone switching points. Therefore, IV must be set longer than III and III must be set longer than II. If they are not, the relay will still switch zones in the proper sequence, but additional time delays will be incurred.

Zone Five Time (Optional)

The time delay between the pickup of one or more of the reverse looking MB units and a backup three pole trip is set by positioning eight miniature toggle switches within the DBM101 module, designated SEC ZONE 5. The delay is equal to the composite switch setting, determined by summing the values corresponding to all the switches in the closed position, with the exception of the infinity switch. When this switch is open, the zone five timer is disabled. It must be closed to permit reverse backup tripping. The values for the other switches are given in seconds on the printed circuit board.

Time Setting Multipliers

The Zone Two and Zone Three time settings may both (together) be multiplied by ten by moving the X1/X10, II/III toggle switch on the DTM101 module to the X10 (right) position. The Zone Three time setting alone may be multiplied by ten by moving the X1/X10 III toggle switch on the DTM101 module to the X10 (right) position. If both multiplier switches are moved to the X10 position, the Zone Three time setting will still be multiplied only by ten, not by one hundred.

Zone Limit for Tripping

The sequential stepping of the relay reach (main measuring unit reach) into successive zones (one-two-three-four) as time elapses, may be restricted to a given zone by placing the 2/3/4/TEST link within the DTM101 module in the desired zone limit position. In the 2 position, for example, the reach will not advance beyond zone 2. The TEST position locks the relay reach in zone one.

Selection of Phase Selector Mho Characteristic

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 DSM101 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 DBM101 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 DBM101 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 cycles on the printed circuit board.

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-to-ground faults. The desired characteristic is selected by positioning the X/Y link within the DVM101 module. X corresponds to reactance, Y corresponds to mho. Whichever is selected, both measuring units will have the same type of characteristic.

Characteristic Timer Angle Setting

The initial angle (prior to integration) of the main measuring unit characteristic for single phase-to-ground faults (reactance or mho-type) is set by positioning four miniature toggle switches within the DMM101 module, designated GND CHAR ANGLE. The angle is equal to 80 degrees plus the composite switch setting. The composite switch setting is determined by summing the values corresponding to all the switches in the closed position. The switch values (in degrees) are given in parentheses on the printed circuit board. The useable range of settings is 90^{o}-135^{o}.

This setting determines the initial steepness of the reactance tent characteristic or the initial narrowness of the mho lens characteristic. Subsequent integration expands the characteristic to a straight line or a circle, respectively.

Sequential Trip Time

The sequential trip time is set by positioning six miniature toggle switches within the DMM101 module, designated SEQ TRIP TIME. The time is equal to the composite switch setting, determined by summing the values corresponding to all the switches in the closed position. The switch values (in milliseconds) are given on the printed circuit board. The minimum time is ten milliseconds. The switches should not be set to zero. The maximum obtainable value is 390 milliseconds.

Frequency Setting

The relay is set for the nominal system frequency by positioning the 50 hertz/60 hertz switch within the DMM101 module. If the SLS purchased includes the directional ground overcurrent option, a 50 HZ/60 HZ link must also be set within the CDM module. If it includes the synchronism check option, a 50 Hz/60 Hz miniature switch must be set within the SVM module

Tripping Mode

The 1P/3P switch within the DLM101 module establishes the tripping mode. The 1P position results in a single pole trip output for single phase faults (faulted phase tripped) and a three pole trip output for two phase and three phase faults. The 3P position results in three pole trip outputs for all types of faults.

Trip Targeting

The choice of lighting targets (LEDs) to indicated faulted phases or poles tripped is made by positioning the TRIP/FAULT switch in the DLM101 module. With the switch in the TRIP position, the A, B and C targets on DLM101 will light when a trip output is issued for the respective pole. For two phase faults, three pole tripping will result and all three targets will light.

With the switch in the FAULT position, only those targets associated with the faulted phases will light. Thus, for an A-B fault there will be a three pole trip output but only targets A and B will light.

Note that for single pole tripping, only the faulted phase target will light regardless of the switch position.

Voltage Transformer Type

The relay is set to coordinate with the type of voltage transformer being used by changing the CVT/PT switch in the DLM101 module. CVT corresponds to capacitive coupled voltage transformer. PT corresponds to potential transformer.

Block Tripping Due to Fuse Failure

The potential transformer fuse monitor may be used to block tripping in the event of a fuse failure. This supervision is obtained by placing the FF/BLK switch within the DLM101 module in the BLOCK position. With the switch in the OFF position, detection of a failed fuse is ignored by the tripping logic circuitry, but a non-latching FF target indication (and non-latching alarm contact closure) will still be given.

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

The power swing detector may be used to block undesired tripping and give an alarm indication in the event of an out-of-step condition. This supervision is obtained by placing the OSB switch in the DMM101 module in the IN position. With the switch in the OUT position, the power swing detector is disabled.

Out-of-Step Timer Setting

This timer is set according to the time required for the apparent system impedance to swing from the phase selector (outer) characteristic to the permissive zone (inner) characteristic during an out-of-step condition. The time setting is made by positioning four miniature toggle switches within the DMM101 module, designated OSB TIME. The value is equal to 16 milliseconds plus the composite switch setting which is determined by summing the values corresponding to all the switches in the closed position. The switch values (in milliseconds) are given on the printed circuit board. For 50 hertz systems, the timer should not be set less than 20 milliseconds (one cycle).

Pilot (Channel) Scheme Settings

Block Channel Tripping

Tripping resulting from the receipt of a channel signal in the pilot schemes (Zone Two acceleration, permissive underreaching transfer tripping, and permissive overreaching transfer tripping) may be blocked by moving the NO CH TRIP toggle switch on the DTM101 module to the right. This switch may also be used to block tripping in the optional directional comparison blocking scheme. It will not, however, block tripping via the basic stepped distance mode which operates concurrently with any scheme selected.

Coordination Time for Permissive Overreaching Transfer Tripping and Directional Comparison Blocking

This time is set by positioning six miniature toggle switches within the DTM101 module, designated CORD TIME. The value equals the composite switch setting, determined by summing the values corresponding to all the switches in the closed position. The switch values (in milliseconds) are given on the printed circuit board. The coordination time may be set to zero by opening all six switches.

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 DTM101 module. This permits the SLS to be used with different types of channel equipment.

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

Normal Position: An open receiver contact is taken to indicate normal conditions on the channel. Channel tripping is inhibited while the contact is open. A closed receiver contact is taken to indicate 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).

Inverted Position: Just the opposite of the above
(INV)

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

Normal Position: Referring to the distance relay logic diagram (Fig. 5), 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.

Inverted 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 SEND link in the DTM101 module in the normal position, the transmitter keying contact is open for normal conditions and closes when it is desired to send a channel signal. With the link in the INV (inverted) 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 CHSP link in the DTM101 module in the normal position, the STOP TRANSMITTER contact is open for normal conditions and closes when it is desired to stop the channel signal. With the link in the INV (inverted) position, the contact operation is reversed.

APPLICATION AND CALCULATION OF SETTINGS

The **SETTINGS PROCEDURES** section lists 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 $\emptyset Z_1$ and $\emptyset Z_0$ 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. 43, set $\emptyset Z_1$ at 70^o and $\emptyset Z_0$ at 65^o. 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, K_0, is determined by the ratio of the line zero sequence impedance to the line positive sequence impedance, i.e., Z_0/Z_1. In the example of Fig. 43:

$$Z_0/Z_1 = \frac{4.92}{1.44} = 3.42$$

Therefore, the K_0 setting on the DIM101 module should be at 2 + (.75 + .4 + .2 + .05) = 3.4, where the numbers in (-) indicate the K_0 switches which should be closed (right-hand position).

Phase Selector Settings

Characteristic Timer Setting

The characteristic timer can be set for either a 90^o coincidence angle, which results in a circular mho characteristic, or a 105^o 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, Z_0/Z_1, for a fault at the remote end of the line is less than 0.75, and the ratio of the positive sequence source impedance (Z_S) to the zone-3 reach is unity or less.

In the example of Fig. 43, the ratio of Z_0/Z_1 is less than 0.75, but the ratio of the positive sequence source impedance to the zone-3 reach is greater than unity. Thus a 90^o timer setting will be used (circular characteristic).

Reach Setting

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

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 KV_{IM} 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 relays will see during their normal service for a particular application.

The maximum allowable phase selector reach setting is determined from:

$$PSR = \frac{Z_L \sin \emptyset}{\sin (180^o + \theta_L - \emptyset Z_1 - \emptyset)}$$

where: PSR = maximum allowable reach
θ_L = angle of minimum load impedance
$\emptyset Z_1$ = positive sequence impedance angle (characteristic impedance angle as set on relay)
$\emptyset$ = 60^o for the 90^o mho characteristic; 75^o for the 105^o lens characteristic
Z_L = magnitude of minimum load impedance

Fig. 46 is an R-X diagram plot showing the above quantities for the example of Fig. 45 . In the example:

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

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^{o} phase selector characteristic timer:

$$Z_{III} \leq (0.7) \text{ (phase selector reach setting on DSM module)}$$

2. 105^{o} phase selector characteristic timer:

$$Z_{III} \leq (0.65) \text{ (phase selector reach setting on DSM module)}$$

Zone-1 Reach Setting

The zone-1 reach setting determines the reach of both the phase and ground first zone functions. It is suggested that this reach be set for no greater than 85 percent of the positive sequence line impedance.

In the example of Fig. 43, the zone-1 reach is:

$$Z_I = (0.85)(1.44) = 1.22 \text{ ohms}$$

The required setting to obtain this is 0.1 + (0.6 + 0.3 + 0.15 + 0.04 + 0.02 + 0.01) where the numbers in (-) indicate the switches that should be closed (right-hand position).

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 utilized, the zone-1 extension reach (Z_{1X}) 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 Z_{1X} be set to assure operation during a remote fault on the line. However, Z_{1X} 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. 43, this reach is:

$$Z_{1X} = 1.1\ (1.44) = 1.58 \text{ ohms}$$

Since the zone-1 reach is 1.22 ohms, the required multiple for I_X 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. 43, this reach is:

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

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. 43, the maximum zone-3 reach that will allow coordination with the phase selectors is:

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

The above calculation is based on the recommendations in the section, "Phase Selector Setting," 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 numbers 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. 6A, 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. 6A, should be used. This characteristic is obtained by setting the GND CHAR ANGLE (A setting of timers TL9b and TL9c in Fig. 5) in the DMM module. The objective here is to discuss the determination of the "tilt" angle in Fig. 6A, and the setting of the SEQ TRIP TIME in the DMM module (timer TL5a in Fig. 5) which keeps the characteristic from immediately reverting to a conventional reactance characteristic.

In Fig. 43, the impedance angle of $(Z_{1A} + Z_{1L})$ is 79°. $(Z_{1A} + Z_{1L})$ is the impedance which determines the angle of the current at the relay location A for a fault at B. Z_{1B} in parallel with $(Z_{1A} + Z_{1L})$ 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. 6A. For this example, the GND CHAR ANGLE is set for 95° to yield a 5° tilt.

The SEQ TRIP TIME setting determines how long the "tent" characteristic will persist after the occurrence of a fault. The setting should 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 DMM101 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. 5 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 realized 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 recommended that the GND CHAR ANGLE be set for 125 degrees.

Zone Timer Settings

Settings of the zone timers will vary with operating practices of individual users. However, some general observations can be made. All forward zone timers are initiated by operation of one or more of the phase selectors. The sequential stepping of the zone timers may be restricted to the zone-one, two or three timers by the zone limit link in the DTM module. The full sequence includes the zone-four timer. The zone-5 timer is present only when the optional MB blocking units are supplied. The zone-5 timer is effective only when the phase switch in the DBM101 module is closed.

Typical zone-2 timer settings are in the range of 0.2 to 0.5 second. If selectivity with zone-2 units on adjoining line sections can be realized on the basis of reach setting, then the zone-2 time on the line in question need only be long enough to provide selectivity with the slowest of (a) zone-1 line relays of adjoining line sections; (b) bus differential relays on the remote bus; or (c) transformer differential relays on transformers on the remote bus. If it is not possible to obtain selectivity on the basis of the zone-2 reach setting, then the time delay must be long enough to be selective with the zone-2 times of the adjoining lines out of the remote bus. This may occur when one or more of the lines out of the remote bus are short with respect to the protected line.

Third zone timer settings are typically in the range of 0.4 to 1.0 second. If selectivity with zone-3 units on adjoining line sections has been obtained by reach setting, then the zone-3 time on the line in question need only be set long enough to be selective with the slowest zone-2 time settings on these adjoining lines. If it was not possible to obtain selectivity on the basis of the zone-3 reach setting, then the zone-3 time setting must be long enough to be selective with the zone-3 times on the adjoining lines.

The zone-4 timer setting, when used, must be long enough to be selective with all zone timers on lines out of the remote bus.

The zone-5 timer can be thought of as providing third zone protection for the relaying at the remote bus. This is often referred to as "reversed third zone" protection, and is beneficial where infeed at the local bus, combined with a practical zone-3 reach setting at the remote bus, results in a remote bus zone-3 unit that underreaches for a fault at the end of the longest line out of the local bus. Setting considerations 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 $ØZ_1$ and $ØZ_0$ switches. The MB characteristic timer (coincidence angle) setting should be 90 degrees (circular mho characteristic).

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. 7, 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. 43, 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. 47, 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 charactreristic, 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. 45). 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. 45 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.

Ground Overcurrent Function

The optional ground overcurrent function is intended to provide the distance relay scheme with back-up protection for high resistance and remote ground faults. The function may be non-directional or supervised by a dual-polarized zero-sequence directional unit. The inverse time-current characteristic is shown in Fig. 81.

If the directional unit is present, the potential polarizing circuit may be energized from the broken delta secondary connection of three potential transformers whose primary windings are connected in wye. The current polarizing circuit may be energized from a current transformer in the neutral of a grounded neutral power transformer. Alternative current polarizing sources may be available or required, depending upon the power transformer connections and characteristics, as well as system characteristics. GE publication GER-3182 entitled, "Polarizing Sources for Directional Ground Relays," may be consulted for the basic considerations involved in selecting a reliable polarizing source.

It is desirable to use both voltage and current polarization simultaneously where system facilities are available. The advantage of doing so is that some system conditions result in appreciable zero sequence voltage, but little zero sequence current being available to polarize the relay during ground faults while other system conditions result in appreciable zero sequence current, but little zero sequence voltage. In general, high polarizing currents and low polarizing voltages are available in stations where strong ground sources are present and in service. Little or no polarizing current and relatively high polarizing voltages are available in stations where there are weak or no ground sources available.

The only required setting for the directional unit is selection of the characteristic angle. The significance of the characteristic angle is shown on the R-X diagram of Fig. 46. The characteristic angle link should be set on the available tap value that is closest to the actual angle of the protected line's zero sequence impedance. In the example of Fig. 43, the zero sequence impedance angle of the protected line is 67^{o}, and the characteristic angle tap should be set at 60^{o}.

The pickup current setting of the overcurrent function must be above the residual (i.e., $3I_0$) current that can exist during maximum load conditions. Any current pickup setting above this value will be dependent upon the minimum ground fault for which protection is desired and coordination with similar downstream functions. The time overcurrent unit pickup tap setting should be low enough to ensure that the minimum current for which operation is desired is at least 1.5 times the tap setting. The time dial setting is selected based on time coordination with the local tripping units and other downstream overcurrent units.

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

The synchronism check function used in the SLS 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 a 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. 47 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, V_L, at breaker 1.

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

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

CASE 1:

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

A. If the angle between V_L and V_B 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 V_L and V_B 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, F_{HS}, and the set closing angle θ. This time delay is expressed as follows:

$$T_{HS} = \frac{1}{F_{HS}} \times \frac{20}{360} \times 1000$$

where: T_{HS} is the time delay in milliseconds
F_{HS} 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 set equal to the slip frequency required to traverse $(270 - \theta)^{o}$ during the time that the line is dead; that is:

$$F_{HS} = \frac{(270 - \theta)}{(360)\ (T_{LD})}$$

where: T_{LD} 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, F_{HS}, is based on (270 - θ) to insure that, if the slip rate is less than F_{HS}, V_L 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 F_{HS}, V_L will return in quadrant III for clockwise rotation, or quadrant II for counterclockwise rotation (Fig. 47). If V_L does return in 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 V_L to appear in quadrants I or IV when the line is re-energized. One condition is a slip frequency that is higher than F_{HS}. 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 V_L remains within the closing angle for the time associated with the high set slip measurement (T_{HS}). If V_L 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 V_L 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, V_L 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:

$$T_D = [(\text{time that the line is de-energized}) + (\text{channel time}) \times 1.1]$$

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 V_L is rotating relative to V_B

A. If the voltage V_L 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 (T_{HS}).

B. If the line voltage V_L 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 V_L remains within the closing angle for the time established by the high slip cut-off setting (T_{HS}).

   The low set slip frequency cut-off circuit establishes the slip rate by comparing the time that V_L 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, V_L, to traverse 90^o (one quadrant) at a frequency equal to the low slip cut-off setting. This is expressed by:

$$T_{LS} = \frac{1}{4} \times \frac{1}{F_{LS}}$$

   where: F_{LS} is the low slip cut-off setting
   T_{LS} is the time required to traverse 90^o

   If V_L 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 V_L 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 V_L returns in quadrant II (Fig. 47) 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 V_L remains in quadrant II longer than the time established by the low slip cut-off setting (T_{LS}). After V_L enters quadrant I, reclosing will be permitted after V_L has entered the set closing angle and remained there for a time established by the high set slip cut-off frequency (T_{HS}). If on the other hand, V_L 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 V_L enters quandrant I, a new measurement will be started and if V_L remains in quadrant I longer than the time established by the low slip cut-off setting, (T_{LS}), 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 V_L 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 (T_{HS}).

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

Note that if V_L 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 V_L 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 measurement 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 V_L must still remain within the closing angle for a time established by the high set slip cut-off circuit (T_{HS}). 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.

TESTING

NOTE:

When hipot testing, it is necessary to remove the jumpers between terminals BD13 and BD14. This removes the grounding connection between the surge capacitors and case ground. Failure to do so could result in damage to the filter capacitors on the PSM module when the DC supply terminals are tested.

DIELECTRIC TESTS

Dielectric testing may be performed 1) between all terminals (tied together) and the case, and 2) between independent circuit groups (refer to elementary diagram, Fig. 82). The recommended voltage is 2200 volts rms for initial testing and 1600 volts rms for subsequent periodic testing. The test voltage should be applied for one second.

ACCEPTANCE TESTS

It is recommended that the operational tests described in this section be conducted prior to the installation of the SLS system. These may be done on a "bench-top" basis.

Initial Test Settings

To begin the acceptance tests, the module settings should be as indicated in Tables IX and X. Note that it is necessary to remove the modules in order to gain access to the links and switches referred to in Table IX.

Test Equipment

The acceptance tests may be conducted in a conventional manner using the following test equipment:

- Three phase power source of rated frequency
- DC control voltage source (48, 110-125 or 220-250 volts DC)
- One phase shifter
- One phase angle meter
- Two variable auto-transformers:
  - One rated 1 ampere (or greater)
  - One rated 2 x rated currrent (or greater)*
- Three test reactors:
  - Tapped for 6/12/24 ohms for 5 amp relays (use GE #6054975G1 reactor)
  - Tapped for 30/60/120 ohms for 1 amp relays
- Two AC voltmeters
- One AC ammeter
- One Timer
- Eight contact monitors

*Two of these are required for testing the directional ground time overcurrent function (optional)

Switches: Five single pole single throw (one capable of interrupting 4 x rated current)
One double pole single throw
One three pole single throw
Three normally open, momentarily closed pushbuttons (one capable of interrupting 2 x rated current)

One card extender (GE #0138B7406G1)

The specific requirements for this equipment are given in the text of this **TESTING** section, and in the associated test circuit diagrams.

It is essential that the applied three phase voltage consists of balanced and undistorted sine waves.

As an alternative, a three phase electronic test source may be used. These sources have the advantages of accuracy, wave form purity, and ease of adjustment. In many cases, their versatility allows the test circuits given herein to be simplified considerably.

Test Connections

The test circuit diagrams indicate SLS terminal numbers (rear cover terminals) and the corresponding XTM test plug terminal numbers. For the acceptance tests, it is recommended that test connections be made to the rear cover terminals. The test plug is intended for post-installation testing and is described in a separate subsection under PERIODIC TESTING.

TABLE VIII - Internal Link and Switch Settings For Acceptance Tests

Module	Link or Switch Identity	Initial Position
DVM101	X/Y LINK	Y
DMM101	OUT-OF-STEP BLK SWITCH	OUT
"	50/60 HZ SWITCH	ACCORDING TO SYSTEM FREQUENCY
"	GND CHAR ANGLE SWITCHES	90 DEGREES
"	OSB TIME SWITCHES	31 MILLISECONDS
"	SEQ TRIP TIME SWITCHES	10 MILLISECONDS
DSM101	LENS/CIRCLE LINK	CIRCLE
DTM101	2/3/4/TEST LINK	TEST
"	CHSP Normal/INV LINK	Normal
"	RCVR Normal/INV LINK	Normal
"	SEND Normal/INV LINK	Normal
"	LOGIC SWITCHES	ALL OPEN (STEPPED DISTANCE)
"	CORD TIME SWITCHES	3 MILLISECONDS
DLM101	1P/3P SWITCH	1P
"	FF/BLK SWITCH	OFF
"	PT/CVT SWITCH	PT
"	TRIP/FAULT SWITCH	FAULT
"	TARGET SET TIME SWITCH	3.0 CYCLES
DOM201	IND/COM LINKS (3)	IND
"	48/110-125/220-250V LINKS (8)	ACCORDING TO AVAILABLE DC SUPPLY
PSM201	48/110-125/200-250V LINK	" " " " "
ROM101	48/110-125/220-250V LINKS (11)	" " " " "
RTM101	DLY/NO DLY LINK	DLY
RLM101	.25/.5/1.0/2.0 LINK	2.0 SECONDS
"	1/2 LINK	1
"	MANUAL CLOSE AUTO/NORM LINK	AUTO
"	SYNC CHECK ALL3P/DLY LINK	ALL3P
"	HOLD IN/OUT LINKS (2)	OUT
MGM311, 312	1/5A CURRENT TAP(S)	ACCORDING TO CURRENT RATING
DBM101 (optional)	LENS/CIRCLE LINK	CIRCLE
"	CYCLES DROPOUT SWITCHES	0 (ALL OPEN)
"	SEC. ZONE-5 SWITCHES	ALL OPEN
CDM (optional)	50 HZ/60 HZ LINK	ACCORDING TO SYSTEM FREQUENCY
"	60/45/30/15 LINK	15
	(50 HZ/60 HZ)	ACCORDING TO SYSTEM FREQUENCY
SVM (optional)	50 HZ/60 HZ SWITCH	ACCORDING TO SYSTEM FREQUENCY
'	LOW SLIP CUT-OFF MULTIPLIER SW	ON
"	LOW SLIP ONLY SWITCH	ON
"	LOW SLIP SECOND BREAKER SWITCH	OFF
"	LOW SET SLIP CUT-OFF	0.2 HZ
"	HIGH SET SLIP CUT-OFF	1 HZ
"	PT VOLTAGE SWITCHES	69V
"	BUS LIVE SWITCHES	80%
"	LINE LIVE SWITCHES	80%
"	BUS DEAD SWITCHES	20%
"	DEAD LINE SWITCHES	20%
"	DEAD TIME SWITCHES	3.0 SEC

TABLE IX - Front Panel Switch Settings for Acceptance Tests

Module	Switch Identity	Initial Setting or Position
DVM101	I_X	1.5
"	II	2.0
"	III	4.0
DFM101,102	ØZ_1	75 DEGREES
"	ØZ_0	75 DEGREES
DIM101	I	2 OHMS (5 AMP RELAY) 10 OHMS (1 AMP RELAY)
"	K_0	4.0
DSM101	Z_P	4 OHMS (5 AMP RELAY) 20 OHMS (1 AMP RELAY)
DTM101	II	.10 SECONDS
"	III	.30 SECONDS
"	IV	6.0 SECONDS
"	X1/X10, II/III	X10
"	X1/X10, III	X1
"	NO CH TRIP	LEFT
RTM101	1Ø	.50 SECONDS
"	3Ø	.90 SECONDS
"	3Ø-D	15 SECONDS
"	RESET	60 SECONDS
RLM101	ON/OFF	OFF
"	1Ø	LEFT
"	3Ø	LEFT
"	X1/X10, 1Ø	X10
"	X1/X10, 3Ø	X10
DBM101 (optional)	Z_B	4 OHMS (5 AMP RELAY) 20 OHMS (1 AMP RELAY
CDM, CTM (optional)	I_S	.1 x I_N (ALL LEFT)
"	TM	1.0
"	+.025, +.05	LEFT
SVM (optional)	ANGLE	30
"	SYNC CK	LEFT
"	LLDB	LEFT
"	DLLB	LEFT
"	DLDB	RIGHT

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 DLM101 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. 48. The interconnection cable(s) should be removed for these tests.

A1. Phase Selector Tests

Apply a voltage of V_T = 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 I_T = 7 (five amp relay) or 1.4 amperes (one amp relay) to the phase under test.

Vary the phase angle between I_T and V_A (I_T lagging) until the phase selector picks up, indicated by the steady lighting of the yellow LED on the DMM101 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 A_1.

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 A_2.

Calculate the characteristic angle of the phase selector as follows:

$$\text{Ø-Sel Characteristic Angle} = \frac{A_1 + A_2}{2}$$

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

Now adjust the phase angle between I_T and V_A to 75 degrees (I_T 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:

$$I_{\emptyset\text{-SEL}} = \frac{2.75\ (V_T - 12.55)}{Z_P\ (2\ \angle\theta_1 + K_0\ \angle\theta_0)\ \cos\ (\propto - \theta_R)} \qquad \text{(Eq. 1)}$$

where:
- $I_{\emptyset\text{-SEL}}$ = pickup current for phase selector (in amperes)
- Z_P = phase selector reach as set on DSM101 module (in ohms)
- V_T = phase-to-neutral voltage applied to phase under test (in rms volts)
- θ_1 = positive sequence impedance characteristic angle of relay as set on DFM101, 102 module ($\emptyset Z_1$: in degrees)
- θ_0 = zero sequence impedance characteristic angle of relay as set on DFM101, 102 module ($\emptyset Z_0$: in degrees)
- K_0 = zero sequence compensation factor as set on DIM101 module ($=Z_0/Z_1$)
- $\propto$ = angle between I_T and V_T (in degrees lagging)
- θ_R = resultant relay characteristic angle (in degrees)

θ_R is determined as follows:

$$\text{Let } K_R\ \angle\theta_R = 2\ \angle\theta_1 + K_0\ \angle\theta_0$$

where: K_R = resultant mangitude factor (for calculation purposes only)

θ_R and K_R are calculated by breaking down $2\ \angle\theta_1$ and $K_0\ \angle\theta_0$ 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 V_T 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:

Z_P = 20 ohms
θ_1 = 65 degrees
θ_0 = 40 degrees
K_0 = 7
V_T = 60 volts
$\propto$ = 20 degrees

Begin by determining K_R and θ_R:

$$\begin{aligned} K_R\ \angle\theta_R &= 2\ \angle\theta_1 + K_0\ \angle\theta_0 \\ &= 2\ \angle 65^\circ + 7\ \angle 40^\circ \\ &= (0.85 + j1.81) + (5.36 + j4.50) \end{aligned}$$

$$= 6.21 + j6.31$$
$$= 8.85 \underline{/45.5^o}$$

$$\therefore K_R = 8.85 \text{ and } \theta_R = 45.5^o$$

Now substitute the conditions stated into equation 1:

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

A2. Phase to Ground Measuring Unit Tests - Mho Type Characteristic

Increase the phase selector reach to its maximum value of Z_P = 103 ohms (five amp relay) or 515 ohms (one amp relay) by positioning all of the switches to the right on the DSM101 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. 48, apply V_T = 20 volts and I_T = 6.7 amperes (5 amp relay) or 1.34 amperes (1 amp relay) to the phase under test. Vary the phase angle between I_T and V_T (I_T lagging) until the measuring unit produces a trip output, indicated by the lighting of two red target LEDs on DLM101; 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 and 41 degrees. Record the angle as A_3. 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 contact between terminals AD1 and AD2.

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 A_4. 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 DLM101 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:

$$\emptyset\text{-G MU Characteristic Angle} = \frac{A_3 + A_4}{2}$$

This angle must be between 72 and 78 degrees.

Now adjust the phase angle between I_T and V_T to 75 degrees (I_T 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 should be used:

$$I_{MU,\ Y} = \frac{3V_T}{Z_R\ (2\ \angle\theta_1 + K_0\ \angle\theta_0)\ \cos\ (\alpha - \theta_R)} \qquad \text{(Eq. 2)}$$

where: $I_{MU,\ Y}$ = pickup current for measuring unit: mho type characteristic (in amperes)
Z_R = zone one reach as set on DIM101 module (I: in ohms)
and all other terms as previously described

Again, V_T should never exceed 69 volts and $I_{MU,\ Y}$ 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. Phase to Ground Measuring Unit Tests - Reactance Characteristic

De-energize the test circuit, remove the DVM101 module, and place the X/Y link in the X position. Reinsert the module and reapply power. With V_T = 20 volts and the phase angle between I_T and V_T set to 90 degrees (I_T lagging), increase I_T 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:

$$I_{MU,\ X} = \frac{3V_T}{Z_R\ (2\ \angle\theta_1 + K_0\ \angle\theta_0)} \times \frac{\sin \alpha}{\sin \theta_R} \qquad \text{(Eq. 3)}$$

where: $I_{MU,\ X}$ = 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, V_T should not exceed 69 volts. $I_{MU,\ Y}$ 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 DVM101 module to the Y position for the remainder of these tests.

B. Fuse Failure Detector Test

Leave the relay connected in the test circuit of Fig. 48. The "phase under test" selection for this test is arbitrary. Set the relay as follows:

Switch	Location	Setting
Zp (1 amp relay)	DSM101	60 ohms
(5 amp relay)	"	12 ohms
I (1 amp relay)	DIM101	40 ohms
(5 amp relay)	"	8 ohms
$ØZ_1$	DFM101, 102	75 degrees
$ØZ_0$	"	75 degrees
K_0	DIM101	4

Adjust V_T to 69 volts so that the relay receives balanced three phase voltage. Apply a single phase test current (I_T) of five amperes (five amp relay) or one ampere (one amp relay) at α= 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 (ØA, ØB or ØC) 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 DLM101 module.

Switch off one phase of the voltage by opening SW3 in the test circuit. The amber FF LED on the DLM101 module should not light.

Adjust the current (I_T) 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 DLM101 module does light, and the contact between terminals AC7 and AC8 does close.

Remove the current by opening SW2. Adjust the current (I_T) 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 DLM101 module and set the FUSE FAILURE BLOCK switch to the BLOCK position. 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 DLM101 module to the OFF position.

C. Phase to Phase Reach Tests

Connect the relay according to the test circuit shown in Fig. 50. Again, the interconnection cable(s) should be removed.

Set Zp on DSM101 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 V_T 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 DLM101 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	$\theta 1$	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 θ_0 and K_0 setting.

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

$$I_{MU} = \frac{V_T}{2\, Z_R \cos(\alpha - \theta_1)} \qquad \text{(Eq. 4)}$$

When using equation 4, the test voltage, V_T, 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. Zone Switching Time Tests

Connect the distance relay according to the test circuit shown in Fig. 51. Note that the set-up is the same as for the previous test (Fig. 50) 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
Z_P (1 Amp Relay)	DSM101	150 ohms
(5 Amp Relay)	"	30 ohms
I (1 Amp Relay)	DIM101	15 ohms
(5 Amp Relay	"	3 ohms
II	DVM101	2 x Z_I
III	"	4 x Z_I
$\emptyset Z_1$, $\emptyset Z_0$	DFM101, 102	75 degrees

Remove the DTM101 module and set the 2/3/4/TEST link in the 4 position. Also remove the DLM101 module and set the FAULT/TRIP switches in the TRIP position in order to check the three pole trip targeting. Reinsert both modules.

Apply a test voltage (V_T) of 40 volts. Suddenly apply a test current (I_T) 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 DLM101 module. The zone one trip contact between terminals AD1 and AD2 should close. The yellow ØA and ØC phase selector LEDs on the DMM101 module should also light. The timer should register 24 to 32 millisecnds 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 DLM101 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 DLM101 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 ØA and ØC phase selector LEDs on the DMM101 module should light. The timer should register one second (ten times the reading of the II thumbwheel switch on the DTM101 module with II/III toggle switch in X10 position).

Remove the test current, reset the targets, and repeat with a test current of three amperes (five ampere relay) or 0.6 ampere (one ampere relay). Verify a zone three trip (A, B, C and III LEDs) with a measured trip time of three seconds (ten times the reading on the III thumbwheel switch). 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.

De-energize the test circuit, remove the DTM101 module, and return the 2/3/4/TEST link to the TEST position. Leave the FAULT/TRIP switch in the DLM101 module in the TRIP position.

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

Connect the distance relay according to the test circuit shown in Fig. 53. Set the relay as follows:

Switch	Location	Setting
Zp (1 Amp Relay)	DSM101	75 ohms
(5 Amp Relay)	"	15 ohms
I (1 Amp Relay)	DIM101	20 ohms
(5 Amp Relay	"	4 ohms
III	DVM101	2.5 x Z_I
$ØZ_1$, $ØZ_0$	DFM101, 102	75 degrees

Remove the DMM101 module and set the OUT OF STEP BLOCK switch in the BLOCK position. Reinsert the module and apply a balanced test voltage of V_T = 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 I_T = approximately 2.9 amperes (five amp relay) or I_T = 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 V_T 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 ØA, ØB, ØC and OSB LEDs on the DMM101 module. The out-of-step block contact between terminals AC5 and AC6 should close.

Again remove the current. Decrease V_T 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 V_T 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 DLM101 module. All three yellow phase selector LEDs (ØA, ØB, and ØC) should also light.

F. Out-of-Step 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 SLS 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. 55. This is similar to the test circuit for the phase-to-phase reach test (Fig. 50) 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)	DSM101	50 ohms
(5 amp relay)	"	10 ohms
I (1 amp relay)	DIM101	20 ohms
(5 amp relay)	"	4 ohms
III	DVM101	1.5 x Z_I
$ØZ_1$, $ØZ_0$	DFM101, 102	75 degrees

The OUT OF STEP BLOCK switch in the DMM101 module should be left in the IN position.

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

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

Again remove the current. Decrease V_T to 30 volts. Reapply current and verify that the ØA and ØB phase selectors pick up, but not the out-of-step blocking unit.

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

De-energize the test current, remove the DMM101 module, and return the OUT OF STEP BLOCK switch to the OUT position.

G. Line Pickup Tests

The SLS 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. 57. 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 220 milliseconds), and verify a three pole trip, indicated by the lighting of the A, B and C red LEDs on the DLM101 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. 59. Note that the set-up is similar to that used for the single phase to ground reach tests (Fig. 48) 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
Z_P (1 amp relay)	DSM101	60 ohms
(5 amp relay)	"	15 ohms
I (1 amp relay)	DIM101	20 ohms
(5 amp relay)	"	4 ohms
II	DVM101	1.5 x Z_I
III	"	2.0 x Z_I
$ØZ_1$	DFM101, 102	75 degrees
$ØZ_0$	"	75 degrees
K_0	DIM101	4

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 DTM101 module and set the LOGIC switches as follows:

A - don't care
B - don't care
C - closed
D - open

Reinsert the module and check that the NO CH TRIP switch is to the left. Leave SW1 open. Apply power and with V_T at 40 volts, increase the current from zero. The a phase selector should pick up when I_T 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 I_T 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 DLM101 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 I_T 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 I_T 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 NO CH TRIP 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 DTM101 module and set the logic switches as follows.

A - closed
B - open
C - open
D - open

Reinsert the module. Leave the NO CH TRIP switch to the left and open SW1. Apply power and, with V_T at 40 volts, increase the current from zero. The A phase selector should pick up when I_T reaches 0.84 amperes (five amp relay) or 0.17 amperes (one amp relay). Continue to increase the current and verify a single pole channel trip when I_T 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 DLM101 module. The KEY TRANSMITTER and CHANNEL TRIP contact should also close at this point. If the current is increased further, a zone one trip indication should be given when I_T reaches 5.00 amperes (five amp relay) or 1.00 amperes (one amp relay). This consists of the lighting of the I LED on the DLM101 module.

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 I_T 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 I_T 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 using SW1 to block channel tripping instead of the NO CH TRIP switch on DTM101. The results should be the same.

H3. Permissive Overreaching Transfer Tripping Tests

To check the permissive overreaching transfer tripping scheme, remove the DTM101 module and set the logic switches as follows.

A - open
B - closed
C - open
D - open

Reinsert the module. Leave the NO CH TRIP switch to the left and open SW1. Apply power and, with V_T 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 I_T 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 I_T reaches 2.50 amperes (five amp relay) or 0.50 amperes (one amp relay); and there should be a zone one trip indication when I_T reaches 5.00 amperes (five amp relay) or 1.00 amperes (one amp relay).

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 I_T reaches 2.50 amperes (five amp relay) or 0.50 amperes (one amp relay). The KEY TRANSMITTER contacts, however, should close at this point, unlike the case for the permissive underreaching test. In this mode the contacts are not sealed-in and will drop out as soon as the current is decreased below 2.50 amperes (five amp relay) or 0.50 amperes (one amp relay).

If the current is increased further, a zone one trip indication should be given when I_T reaches 5.00 amperes (five amp relay) or 1.00 amperes (one amp relay). The KEY TRANSMITTER contacts will now seal-in (they are already closed) and should not open until the current is lowered below 0.10 per unit.

Repeat the previous test using SW1 to block channel tripping instead of the NO CH TRIP switch on DTM101. The results should be the same.

De-energize the test circuit, remove the DTM101 module, and open all of the logic switches.

I. Tests for Auxiliary Functions

The SLS includes contact converter inputs for the following three auxiliary functions (among others):

3 Pole Trip Enable
Block Tripping
Remote Target Reset

To test these functions, connect the distance relay according to Fig. 61. Note that the setup is similar to that used for the single phase to ground reach tests (Fig. 48), except for the addition of the three DC switches to simulate external contact operations for the auxiliary functions. The terminals shown correspond to an A-G test. Set the relay as follows:

Switch	Location	Setting
Z_P (1 amp relay)	DSM101	30 ohms
(5 amp relay)	"	6 ohms
I (1 amp relay)	DIM101	20 ohms
(5 amp relay)	"	4 ohms
$ØZ_1$, $ØZ_0$	DFM101, 102	75 degrees

With SW3, 4 and 5 open, apply V_T = 40 volts and I_T = 6 amps (five amp relay) or 1.2 amps (one amp relay). Verify a phase A single pole zone one trip. Remove current and close SW3 to set up three pole tripping. Reapply current and verify a three pole zone one trip (the FAULT/TRIP switch in the DLM101 module must be in the TRIP position). Remove current.

Close SW5 momentarily and verify that it resets the latching LED trip targets on DLM101.

Now close SW4 to block tripping. Reapply the test current and verify that the relay does not trip. The phase selector indicators on DMM101 should light while the current is applied, but there should be no trip targets lit on DLM101.

J. Recloser Tests

Connect the SLS system according to the test circuit shown in Fig. 63. Note that the set-up is similar to that used for checking the phase A to ground reach (Fig. 48) with added DC wiring to the recloser. Interconnection cable PL-1 must be inserted for these tests. Set the distance relay as follows:

Switch	Location	Setting
Z_P (1 amp relay)	DSM101	75 ohms
(5 amp relay)	"	15 ohms
I (1 amp relay)	DIM101	50 ohms
(5 amp relay)	"	10 ohms
$\emptyset Z_1$	DFM101, 102	75 degrees
$\emptyset Z_0$	"	75 degrees
K_0	DIM101	4

The recloser should be set according to Tables IX and X.

Adjust V_T to 20 volts. With push button SW1 closed, adjust I_T to 1.7 amperes (five amp relay) or 0.24 amperes (one amp relay). This is sufficient to cause a zone one trip. Release the push button and reset the targets. Also reset the recloser by depressing the RESET push button on the RLM101 module. The time settings recommended in the following tests have been made sufficiently long to dispense with the need for using a special timing device. A stop watch or even an ordinary wristwatch with a sweep second hand are adequate.

J1. Automatic Reclosing: Two Attempts

Apply a pulse of test current by momentarily depressing SW1. Simultaneously close (and leave closed) SW2 which simulates the pole A "b" switch of a breaker. The other switches in the test circuit should be left open. Verify that the reclosing cycle is under way, indicated by the lighting of the yellow OPN LED on the RLM101 module, and the closure of the contact between CC13 and CC14. In addition, the distance relay should immediately indicate a phase A zone one trip.

Verify that the pole A reclosing contacts close five seconds after the trip by watching the contact monitor between terminals DA1 and DA2. The five seconds corresponds to the setting of the 1Ø thumbwheel switch on the RTM101 module, multiplied by ten due to the X10, 1Ø toggle switch on the RLM101 module. Promptly open SW2 within two seconds (dwell timer setting) after the pole A reclosing contacts close to simulate that the breaker has been successsfully reclosed. Verify that these same contacts reopen in two seconds. The yellow OPN LED should go out when the contacts reopen. In summary:

1) Momentarily depress SW1 and close SW2: Phase A zone 1 trip, OPN indication, and contact closure between CC13 and CC14

↓ 5 seconds

2) Verify contact closure between DA1 and DA2 - Open SW2

↓ 2 seconds

3) Verify contact reopening between DA1 and DA2. OPN LED should go out and contact between CC13 and CC14 should open.

Reset the distance relay targets (DLM101) but do not reset the recloser. Before the reset time expires (60 seconds, as set on DTM101), apply a second pulse of test current by depressing SW1. Simultaneously close SW3 which simulates the opening of all three breaker poles (three "b" switches). The yellow OPN LED should light, the contact between CC13 and CC14 should close, and the distance relay should immediately indicate a three pole zone one trip. Verify that the pole A, B, and C reclosing contacts close 15 seconds after the trip by watching the contact monitors between terminals DA1 and DA2, DA3 and DA4, and DA5 and DA6, respectively. The 15 seconds corresponds to the setting of the 3Ø-D thumbwheel switch on the RTM101 module. Promptly open SW3 within two seconds (dwell timer setting) after the reclosing contacts close. Verify that these contacts reopen in two seconds and that the OPN LED goes out. In summary:

1) Momentarily depress SW1 and close SW3: Three pole zone 1 trip and OPN indication, and contact closure between CC13 and CC14

↓ 15 seconds

2) Verify contact closure between DA1 and DA2, DA3 and DA4, DA5 and DA6 - Open SW3

↓ 2 seconds

3) Verify contact reopening between contacts noted above. OPN LED should go out, and contacts between CC13 and CC14 should open.

Again reset the distance relay targets but do not reset the recloser. Before the reset time expires, apply a third pulse of test current and simultaneously close SW3. Note that the reset timer was re-initiated on the second attempt and will not expire until 60 seconds thereafter. Verify that the recloser immediately goes to lockout, indicated by the lighting of the red L/O LED on the RLM101 module. This distance relay should indicate a three pole zone one trip. In summary:

1) Momentarily depress SW1 and close SW3: 3 pole zone one trip and L/O indication.

Open SW3, reset the distance relay targets, and reset the recloser.

J2. Automatic Reclosing: Single Pole Only

Move the 1Ø toggle switch on the RLM101 module to the right. Apply a pulse of test current and simultaneously close SW2. Verify a single pole trip and five second single pole reclosure. Open SW2 within two seconds thereafter. Reset the distance relay targets.

Apply a second pulse of test current before the reset time expires. Verify a three pole trip but no recloser operation. The OPN LED should not light and the reclosing contacts should not close.

Open SW3, reset the distance relay targets, and reset the recloser. Return the 1Øtoggle switch on RLM101 to the left.

J3. Automatic Reclosing: Three Pole Only

Move the 3Ø toggle switch on the RLM101 module to the right. Apply a pulse of test current and simultaneously close SW3. Verify a three pole trip and nine second three pole reclosure. The nine seconds corresponds to the setting of the 3Ø thumbwheel switch on the RTM101 module, multiplied by ten due to the X10, 3Ø toggle switch on the RLM101 module. Open SW3 within two seconds thereafter. Reset the distance relay targets.

Apply a second pulse of test current before the reset time expires and again simultaneously close SW3. Verify a three pole trip and 15 second three pole reclosure. This corresponds to the 3Ø-D switch setting. Open SW3 within two seconds. Reset the distance relay targets.

Apply a third pulse of test current before the reset time expires and again simultaneously close SW3. Verify that the recloser immediately goes to lockout. The distance relay should again indicate a three pole trip.

Open SW3, reset the distance relay targets, and reset the recloser. Return the 3Ø toggle switch on RLM101 to the left.

J4. Automatic Reclosing: One Attempt

De-energize the test circuit, remove the RTM101 module, and move the delay link to the NO DLY position. Reinsert the module and reapply power. Apply a pulse of test current and simultaneously close SW2. Verify a single pole trip and five second single pole reclosure. Open SW2 within two seconds. Reset the distance relay targets.

Apply a second pulse of test current and simultaneously close SW3. Verify that thr recloser immediately goes to lockout. The distance relay should again indicate a three pole trip.

Open SW3 and reset the distance relay targets. De-energize the test circuit, remove RTM101, and return the link to the DLY position.

J5. External Blocking of Reclosing

Close SW4 in the test circuit thereby simulating the operation of an external BLOCK RECLOSE contact. Apply a pulse of test current and simultaneously close SW2. The OPN LED should light and the distance relay should indicate a single pole trip. Verify that the OPN LED remains lit for the single pole reclosing time (set for 5 seconds). The recloser should go into lockout at the end of the reset time (set for 60 seconds). It is important to note that the reclosing contacts do not close at any point (the RECLOSE IN PROGRESS contacts between terminals CC13 and CC14 should close while the OPN LED is lit).

De-energize the test circuit, remove the RLM101 module, and move the two HOLD links to the IN position. Reinsert the module and reapply power. Again close SW4, apply a pulse of test current, and simultaneously close SW2. The distance relay should indicate a single pole trip, and the OPN LED should light and remain lit beyond 5 seconds. Before the reset time expires, open SW4 and verify that the pole A reclosing contacts (DA1, DA2) close immediately. Open SW2 within two seconds.

De-energize the test circuit, remove RLM101, and return the HOLD Links to the OUT positions.

J6. Manual Reclosing

Close SW2 and then momentarily depress push button SW5 which simulates an external manual close contact. Verify that the pole A reclosing contacts (DA1, DA2) close immediately and that the OPN LED lights. Open SW2 within two seconds.

To test the fail-to-close logic, repeat the above test but do not reopen SW2. The recloser should go to lockout two seconds after the reclosing attempt, and the distance relay should trip three pole.

Reset the recloser using SW6 in the test circuit rather than the RESET pushbutton on the RLM101 module. Close SW3, and again depress SW5 momentarily. Verify that all three reclosing contacts close immediately and that the OPN LED lights. Open SW3 within two seconds.

De-energize the test circuit, remove the RLM101 module, and move the MANUAL CLOSE link to the NORM position. Reinsert the module, apply power, and close SW2. Momentarily depress SW5 and verify that the pole A reclosing contacts remain open and that the OPN LED does not light. Immediately open SW2. Before the reset time expires, attempt an automatic reclosure by applying a pulse of test current (SW1) and simultaneously closing SW2. Verify that the reclosing contacts remain open and that the OPN LED does not light. Recall that automatic reclosing is blocked for the duration of the reset time following a manual close. The distance relay should indicate a single pole trip.

J7. Zone One Extension

De-energize the test circuit and set the system for the zone one extension scheme by removing the DTM101 module and closing LOGIC switch D. Reinsert the module. In addition, change the reach of zone one from ten ohms to seven ohms (five amp relay) or from 50 ohms to 35 ohms (one amp relay) by re-positioning the I switches on the DIM101 module. The I_X switches on the DVM101 module should be set for 1.5, as specified earlier in Table IX.

Reapply power and check that the test current is still 1.2 amperes (five amp relay) or 0.24 amperes (one amp relay). The current level is critical in this test. Reset the distance relay targets and reset the recloser, using either the RESET pushbutton on RLM101, or SW6 in the test circuit.

Apply a pulse of test current through SW1 and simultaneously close SW2. Verify a single pole trip and five second single pole reclosure. Open SW2 within two seconds Reset the distance relay targets but do not reset the recloser.

Before the reset time expires, apply a second pulse of test current and verify that the distance relay does not trip. The yellow ØA phase selector LED should blink as current is momentarily applied, but the relay should not trip because the extended zone one has been "pulled back" following the first reclose attempt. Note that the recloser does not operate because there has been no trip.

Close SW7 in the test circuit. This provides an external PULL BACK EXTENDED ZONE 1 signal. Apply a pulse of test current through SW1 and verify that the distance relay does not trip. Again, the yellow ØA phase selector LED should blink as current is momentarily applied. Note that the recloser does not operate.

De-energize the test circuit, remove DTM101, and return the system to the stepped distance scheme by opening LOGIC switch D. Reinsert the module and return the zone one reach to ten ohms (five amp relay) or 50 ohms (one amp relay) by adjusting the I switches on DIM101.

J8. Recloser Out-of-Service

Reapply power and move the ON/OFF switch on the RLM101 module to the OFF position. Verify that the red OFF LED on the same module lights. The contact between terminals CD12 and CD13, which was open, should now close, and the contact between terminals CD13 and CD14, which was closed, should now open. Apply a pulse of test current through SW1 and verify that the distance relay trips three pole. This is a result of the recloser being out-of-service. Also verify that the reclosing contacts remain open.

K. Directional Comparison Blocking Tests (optional)

Insert all three interconnection cables. Remove the DTM101 module and set the relay for the directional comparison blocking scheme by closing logic switches A and B. The SEND and CHSP links should be left in the normal position but the RCVR link should be placed in the INV position.

K1. Reach Tests for MB Blocking Units

Connect the distance relay according to the test circuit shown in Fig. 67. 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 V_T = 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 I_T = 7 amperes (five amp relay) or 1.4 amperes (one amp relay) to the phase under test.

Vary the phase angle between I_T and V_T (I_T 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 A_7.

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 A_8.

Calculate the characteristic angle of the MB unit as follows:

$$\text{MB Unit Characteristic Angle} = \frac{A_7 + A_8}{2}$$

This angle should fall between 72 and 78 degrees.

Now adjust the phase angle between I_T and V_T to 75 degrees (I_T 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 (page 102), substituting I_{MB} for $I_{\emptyset\text{-sel}}$ and Z_B for Zp.

K2. <u>Zone Five Timer Tests</u>

De-energize the test circuit, remove the DBM101 module, and set the zone five timer to 6.4 seconds. The infinity switch must now be closed. Reinsert the module and 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 ON/OFF switch on the RLM101 module is in the OFF position 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 within the DBM101 module and repeat the timing test. Open the infinity switch in 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. 65 so that the fault now appears in the forward direction. Using phase A as a reference, this is accomplished by connecting the lead labelled "Z" to TP13A or BD4, and by connecting the lead labelled I_T 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
Z_P (1 amp relay)	DSM101	60 ohms
(5 amp relay)	"	15 ohms
I (1 amp relay)	DIM101	20 ohms
(5 amp relay)	"	4 ohms
III	DVM101	2.0 x Z_I
$\emptyset Z_1$, $\emptyset Z_0$	DFM101, 102	75 degrees
K_0	DIM101	4

Adjust the variable auto-transformers so that V_T = 40 volts and I_T 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 DLM101, and the closure of the CHANNEL TRIP contacts between terminals AB5 and AB6. The STOP TRANSMITTER contacts between terminals AB3 and 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 NO CH TRIP switch on the DTM101 module to the right. Reapply current and again verify no trip. As before, the STOP TRANSMITTER contact should close. Remove current and return the NO CH TRIP switch to the left.

De-energize the test circuit, remove the DTM101 module, and open logic switches A and B in order to return the relay to the stepped distance mode. Also return the RCVR link to the normal position.

L. Non-Directional Ground Time Overcurrent Tests (Optional

L1. Pickup Current Check

Insert interconnection cable PL-1. Connect the SLS according to the test circuit given in Fig. 67. It is not necessary to connect the timer at this point. Close SW1 and increase the current slowly from zero until the yellow I_S LED on the CTM module just lights. The current should be within five percent of 0.5 amperes (five amp relay) or 0.1 amperes (one amp relay) because the I_S tap setting is 0.1 X I_N. The current pickup may be checked at other tap values if desired.

L2. Time Checks

Adjust the variable auto-transformer so that I_{OP} will be twice the pickup current when SW1 is closed. Connect the timer and close SW1. Verify a three pole trip after a delay of approximately ten seconds (refer to the time curves in Fig. 81). The normally open contact between terminals CA1 and CA2 should close, and the normally closed contact between terminals CA2 and CA3 should open at the time of the trip, and remain open so long as current is still applied. The red I_N> LED on the CTM module should light and latch in, along with the A, B and C trip targets on the DLM101 module.

Remove current and reset the trip targets via the pushbuttons on the CTM and DLM101 modules. Repeat the time tests for varying multiples of pickup current and different TM time dial settings, as desired, to verify the time curves given in Fig. 81.

M. Directional Ground Time Overcurrent Tests (optional)

M1. Pickup Current Check (with Current Polarization)

Insert interconnection cable PL-1. Connect the SLS according to the test circuit given in Fig. 68. It is not necessary to connect the timer at this point. Adjust I_{POL} to 1.0 amperes (five amp relay) or 0.2 amperes (one amp relay). Close SW1 and adjust the phase shifter so that I_{POL} and I_{OP} are in phase. Increase I_{OP} slowly from zero until the yellow >I_S LED on the CDM module just lights. The current (I_{OP}) should be within five percent of 0.5 amperes (five amp relay), or 0.1 amperes (one amp relay) because the I_S tap setting is 0.1 x I_N. The current pickup may be checked at other tap values, if desired.

M2. Time Checks (with Current Polarization)

Maintain I_{POL} as above to enable the pickup level detector. Connect the timer and conduct the time checks, as described in the previous section (Non-Directional Ground Time Overcurrent Tests).

M3. Current Polarization Test

Leave the SLS connected according to Fig. 68. The timer may be disconnected. Apply I_{OP} = I_{POL} = 5 amperes (five amp relay), or 1 ampere (one amp relay), in phase. The unit should trip (yellow >I_S and red I_N> LEDs on the CDM module both light). Adjust the phase shifter and verify that the yellow >I_S LED goes out when the angle between the two currents reaches 90 degrees (plus or minus four degrees). The directional unit is now blocking operation of the pickup level detector in the ground time overcurrent unit. Repeat to cover both a leading and lagging phase shift. The red IN> LED will remin lit, because it is latched-in.

M4. Voltage Polarization Test

Connect the SLS according to the test circuit given in Fig. 69. Apply V_{POL} = 69 volts, and I_{OP} = 5 amperes (five amp relay) or 1 ampere (one amp relay) lagging V_{POL} by 15 degrees. This is the setting on the voltage polarization link within the CDM module. Verify a trip. Increase the phase shift and verify that the yellow >I_S LED goes out when the angle reaches 90 + 15 = 105 degrees lagging (plus or minus four degrees).

Repeat with I_{POL} leading V_{POL}. The cut-off point should now be 90 - 15 = 75 degrees leading (plus or minus four degrees). This test may be conducted using the other three angle settings (30, 45, 60) of the voltage polarization link in the CDM module, if desired.

N. Synchronism Check Tests (optional)

Recloser Supervision Tests

In order to test the capability of the SVM101 module to permit and to block reclosing, connect the SLS system according to the test circuit shown in Fig. 63. Interconnection cable PL-1 must be inserted for this test. Set the distance relay as follows:

Switch	Location	Setting
Zp (1 amp relay)	DSM101	75 ohms
(5 amp relay)	"	15 ohms
I (1 amp relay)	DIM101	50 ohms
(5 amp relay)	"	10 ohms
$ØZ_1$, $ØZ_0$	DFM101, 102	75 degrees
K_0	DIM101	4

Adjust V_T to 20 volts. With pushbutton SW1 closed, adjust I_T to 1.7 amperes (five amp relay) or 0.24 amperes (one amp relay). This is sufficient to cause a zone one trip. Release the pushbutton and reset the targets. Also reset the recloser by depresing the RESET pushbutton on the RLM101 module.

Move the 3Ø toggle switch on RLM101 to the right. Apply a pulse of test current and simultaneously close SW3. Verify a three pole trip and nine second three pole reclosure. Open SW3 within two seconds thereafter. Reset the distance relay targets. The recloser should operate as described herein because no connections have been made to the sync check bus and line voltage inputs. They therefore both register as dead, and the SVM101 module is set to permit reclosing under dead line, dead bus conditions.

Reset the recloser by depressing the RESET pushbutton onthe RLM101 module. Move the DLDB switch to the left and the SYNC CK switch to the right on SVM101.

Again apply a pulse of test current and simultaneously close SW3. Verify another three pole trip but this time verify that there is no reclosure (the reclosing contacts should not close at any point). After nine seconds the red N/S LED on the RLM101 module should light. This indicates that the reclosing attempt has been blocked by the synchronism check module. In the SYNC CK mode, live line and bus voltages are required to permit reclosing. As mentioned above, with no connections to their inputs, they both register dead and hence reclosing 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 output 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 SLS according to the test circuit given in Figure 70. Interconnection cable PL-1 must be inserted. The SVM 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 RLM101 module altogether in order to preclude operation of the recloser.

Apply the line and bus voltages and adjust V_{bus} and V_{line} 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 lit only when:

1. LLDB a) V_{line} is above 55 volts and
   b) V_{bus} is below 14 volts

2. DLLB a) V_{line} is below 14 volts and
   b) V_{bus} is above 55 volts

3. DLDB a) V_{line} is below 14 volts and
   b) V_{bus} is below 14 volts

Angle Tests

Connect the SLS according to the test circuit of Fig. 71. Interconnection cable PL-1 should remain inserted, SVM should remain on a card extender and RLM101 should still be out.

Place the SVM module in the SYNC CK mode. With SW1 closed, adjust V_{bus} and V_{line} to 69 volts each. Wait approximately 20 seconds for the circuit to stabilize, then vary the angle between the two voltages (test angle) with the phase shifter. When the angle is less than the setting (plus or minus 30 degrees), TL3 should be lit and TL1 should be out. When the angle exceeds the setting, TL3 should go out and TL1 should light. Other settings may be checked if desired. In order to avoid activating the low set slip detector, the test angle should never be rotated to or beyond 90 degrees either side of zero.

"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, T_{LS}, where:

$$T_{LS} = \frac{1}{4} \times \frac{1}{F_{LS}} = \frac{1}{4} \times \frac{1}{.02} = 12.5 \text{ seconds}$$

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 degrees, but TL1 should remain lit and TL3 should remain out.

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 degree span in greater than 12.5 seconds. Again, TL1 should light and TL3 should go out when the angle exceeds 30 degrees. However, since the simulated slip is slower than the cut-off, TL2 should not light at any point.

PERIODIC TESTS (Post Installation)

It is recommended that a periodic test program be developed which checks all of the SLS 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:

Six 1.2K ohm resistors (1 watt or greater)

Six DC voltmeters (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 SLS 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 SLS 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 magnetics 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 (Fig. 82) and test circuit diagrams (Fig. 48 through 71) as TP1A through TP28A for the distance relay (case A) and TP1B through TP28B for the recloser and options (case B).

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 SLS. 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 SLS for those signals which are wired through the test receptacle (refer to TP points on elementary diagram, Fig. 82). For the terminals connected to the current transformer secondaries, shorting bars are included on the system side of the test receptacle. These are clearly visible through the transparent plastic face plate on the receptacle. 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 SLS 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 (Fig. 82) 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 distance relay case (case A, far left positions). It may also be disconnected by removing the distance relay magnetics module.

Connections and Procedural Notes for Post Installation Tests

The procedures described for the acceptance tests ("bench-top") may also be used for periodic testing (post-installation) so long as steps are taken to isolate the pertinent inputs and outputs from the connected power system. The XTM test plugs serve this purpose for the basic functions, but special measures must be taken for certain auxiliary and alarm functions. These measures include the removal of selected modules and the use of card extenders.

Subsections A through N following, together with their corresponding Acceptance Test subsections, constitute the periodic test instructions for each of the SLS functions. If the test circuits and notes given therein are followed, it is not necessary to disturb the external connection wiring or remove the interconnection cables(s).

It is recommended that the RLM101 and RTM101 modules be removed in tests A through I to prevent recloser operation. In addition, the DOM201 module must be removed to isolate the breaker failure initiation circuits.

Jumpers and switches are used on the card extenders to simulate the closure of external contacts. Resistor/voltmeter combinations are used to monitor driver signals for board mounted auxiliary relays as follows:

"Bench-top" Test	Post-Installation Test
Relay de-energized, contact open	Voltage across resistor: 0 VDC
Relay energized, contact closed	Voltage across resistor: 20-30 VDC

Using these methods, the contact converters (inputs) and auxiliary relays (outputs) are by-passed.

WARNING

CAUTION MUST BE EXERCISED WHEN A CARD EXTENDER IS INSERTED IN AN ROM101, DOM201 OR PSM MODULE POSITION SINCE STATION BATTERY POTENTIAL WILL LIKELY BE PRESENT ON CERTAIN POINTS. FAILURE TO OBSERVE THIS WARNING MAY RESULT IN PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT.

If the complete modular relay is to be tested without extracting any of the individual modules (RLM, RTM, DOM), the following should be noted.

When testing the modular relay, only the trip circuits can be isolated from the system logic using the XTM test plugs. All other output contacts remain connected to the system and may function, depending upon the test being performed. To avoid an undesired system operation, disenable or disconnect the appropriate leads from the modular relay terminals. After testing is complete, be sure to enable and reconnect all leads that were removed.

A. Single Phase to Ground Reach Tests and, B. Fuse Failure Detector Test

Bench-top Test - Fig. 48
Post-Installation Test - Fig. 49

Function	Contact Terminals (Fig. 48)	Test Plug Terminals (Fig. 49)
Trip Pole A	BB1-AC14	TP2A-TP25A
Trip Pole B	BB5-AD12	TP4A-TP27A
Trip Pole C	BB9-AD14	TP6A-TP23A

Function	Contact Terminals (Fig. 48)	Resistor/Voltmeter (Fig. 49)
Oscillograph Start	AC1 -AC2	R1
Fuse Failure	AC7 -AC8	R2
BFI	AC13-AC14*	R3
"A" Phase Selector	AB9 -AB10	R4
"B" Phase Selector	AB11-AB12	R5
"C" Phase Selector	AB13-AB14	R6
Zone 1 Trip	AD1 -AD2	R7

*Included in series combination with Trip Pole A contacts

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Place DLM101 module on a card extender
3) Place DMM101 module on a card extender

C. Phase-to-Phase Reach Tests

Bench-top Test - Fig. 50
Post-Installation Test - Fig. 50 (same)

D. Zone Switching Time Tests

Bench-top Test - Fig. 51
Post-Installation Test - Fig. 52

Function	Contact Terminals (Fig. 51)	Resistor/Voltmeter (Fig. 52)
Zone 1 Trip	AD1-AD2	R1
Zone 2 Trip	AD3-AD4	R2
Zone 3 Trip	AD5-AD6	R3
Zone 4 Trip	AD7-AD8	R4
Enable Reclosing	AB7-AB8	R5

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Place DLM101 module on a card extender
3) Place DTM101 module on a card extender

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

Bench-top Test - Fig. 53
Post-Installation Test - Fig. 54

Function	Contact Terminals (Fig. 53)	Resistor/Voltmeter (Fig.54)
Out-of-Step Block	AC5-AC6	R1

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Place DMM101 module on a card extender

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

Bench-top Test - Fig. 55
Post-Installation Test - Fig. 56

Function	Contact Terminals (Fig. 55)	Resistor/Voltmeter (Fig.56)
Out-of-Step Block	AC5-AC6	R1

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Place DMM101 module on a card extender
3) Insert blank card extender in right-hand position of DOM201

G. Line Pickup Tests

Bench-top Test - Fig. 57
Post-Installation Test - Fig. 58

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Insert blank card extender in right-hand position of DOM201

H. Pilot Scheme Tests

Bench-top Test - Fig. 59
Post-Installation Test - Fig. 60

Function	Contact Terminals (Fig. 59)	Resistor/Voltmeter (Fig. 60)
Key Transmitter	AB1-AB2	R1
Channel Trip	AB5-AB6	R2

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Place DTM101 module on a card extender
3) Insert blank card extender in left-hand position of DOM101

I. Tests for Auxiliary Functions Requiring Contact Inputs

Bench-top Test - Fig. 61
Post-Installation Test - Fig. 62

Notes:

1) Remove DOM201, RLM101 and RTM101 modules
2) Insert blank card extender in right-hand position of DOM201

J. Reclosing Tests

Bench-top Test - Fig. 63
Post-Installation Test - Fig. 64

Function	Contact Terminals (Fig. 63)	Resistor/Voltmeter (Fig. 64)
Close Pole A	DA1-DA2	R1
Close Pole B	DA3-DA4	R2
Close Pole C	DA5-DA6	R3
Reclose Operation in Progress	CC13-CC14	R4
Recloser in Service	CD12-CD13-CD14	R5

Notes:

1) Remove MGM module in case B (recloser case)
2) Remove DOM201 and ROM101 modules
3) Place RLM101 module on a card extender
4) Insert blank card extender ROM101 position
5) Insert blank card extender in right-hand position of DOM201

K. Directional Comparison Blocking and Zone 5 Tests (Optional)

Bench-top Test - Fig. 65
Post-Installation Test - Fig. 66

Function	Contact Terminals (Fig. 65)	Resistor/Voltmeter (Fig. 66)
Key Transmitter	AB1-AB2	R1
Stop Transmitter	AB3-AB4	R2
Channel Trip	AB5-AB6	R3

Notes:

1) Remove DOM201 module
2) Place DTM101 module on a card extender
3) Insert blank card extender in left-hand position of DOM101

L. Non-Directional Ground Time Overcurrent Tests (Optional)

Bench-top Test - Fig. 62
Post-Installation Test - Fig. 62 (same)

Notes:

1) Remove DLM101 module. This prevents the distance relay from tripping during these post-installation tests. Operation of the GTOC unit should be monitored by watching the LEDs on the CTM module only

2) Output alarm contact (type "C") may be isolated during post-installation tests only by removing connections to terminals CA1, 2, 3. This contact will operate during these tests.

M1, 2, 3. Directional Ground Time Overcurrent Tests Using Current Polarization (Optional)

Bench-top Test - Fig. 63
Post-Installation Test - Fig. 63 (same)

Notes:

1) Remove DLM101 module. This prevents the distance relay from tripping during these post-installation tests. Operation of the GTOC unit should be monitored by watching the LEDs on the CDM module only

2) Output alarm contact (type "C") may be isolated during post-installation tests only by removing connections to terminals CA1, 2, 3. This contact will operate during tests.

M4. Directional Ground Time Overcurrent Tests Using Voltage Polarization (Optional)

Bench-top Test - Fig. 64
Post-Installation Test - Fig. 64

Notes:

1) Remove DLM101 module. This prevents the distance relay from tripping during these post-installation tests.

2) Output alarm contact (type "C") may be isolated during post-installation tests only by removing connections to terminals CA1, 2, 3. This contact will operate during these tests.

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 SLS1000 has been designed for continuous operation between -20°C and +55°C per ANSI Standard C37.90. In addition, the SLS 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 $\angle$ 2 degrees, I_N = 5 amps • 0.04 ohm $\angle$ 8 degrees, I_N = 1 amp
Voltage Circuits	• 0.2 VA $\angle$ 49 degrees, 60 hertz • 0.024 VA $\angle$ 48 degrees, 50 hertz

DC Battery (for Power Supply and Telephone Relays)*	Normal	Tripped**
48 VDC	7.0 watts	32.0 watts
110-125 VDC	8.5 watts	32.5 watts
220-250 VDC	12.5 watts	39.0 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)

Power Swing Blocking Characteristic

- Reach adjustment equal to third zone setting (120^{o} 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	• 0.5 to 50 ohms in 0.05 ohm steps for I_N = 1 amp • 0.1 to 10 ohms in 0.01 ohm steps for I_N = 5 amps

Extended Zone-1	• 1 to 2 x zone-1 setting in 0.05 multiple 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. 72 through 74 (constant Z_S/Z_L curves) or
Fig. 75 through 81 (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	• 0.01 to 0.99 second in 0.01 second steps • 0.1 to 9.9 seconds in 0.1 second steps (may be disabled)
Zone-3	• 0.01 to 0.99 second in 0.01 second steps • 0.1 to 9.9 seconds in 0.1 second steps (may be disabled)
Zone-4 (Phase Selector)	• 0.1 to 9.9 seconds in 0.1 second steps (may be disabled)
Reverse Zone-5 (MB Unit-Optional)	• 0.1 to 12.7 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. (may be disabled)
Reclosing Attempts to be Supervised by Sync Check (optional)	• Supervision on all 3 pole reclosing attempts or only on delayed (second shot) reclosing attempts, selectable.

Reclosing Timers

Single and Three Pole Reclose Timers (independently adjustable)	• 0.01 to 0.99 second in 0.01 second steps • 0.1 to 9.9 seconds in 0.1 second steps

Reclosing Timers (continued)

Delayed Second Reclosure	• 1 to 99 seconds in 1.0 second steps (may be disabled)
Dwell Time of Reclosing Contacts	• 0.25, 0.5, 1.0, 2.0 seconds
Reset Time	• 1 to 99 seconds in one 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

GROUND TIME OVERCURRENT CIRCUIT (optional)

Pickup Current	• 10 to 80 percent of nominal in 2 percent steps
Time "Dial"	• 0.05 to 1.0 in 0.025 steps. IEC 255-4 Type A Curve: See Fig. 83 (BS 142 Normal Inverse Curve) NOTE: This curve is similar to the GE Type IAC relay inverse curve

DIRECTIONAL UNIT FOR GROUND TIME OVERCURRENT CIRCUIT (optional)

Dual Polarization	• Using zero sequence voltage and zero sequence current
Characteristic Angle for Voltage Polarization	• 15, 30, 45 or 60 degrees; 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.

LINE OVERLOAD MONITORING RELAY

Level 1 Pickup	• 100 to 400 percent of nominal in five percent steps
Time Delay	• 10 to 99 seconds in one second steps • 100 to 990 seconds in ten second steps
Level 2 Pickup	• 200 to 800 percent of nominal in ten percent steps
Time Delay	• 10 to 99 seconds in one second steps

RECEIVING, HANDLING AND STORAGE

CAUTION

This relay contains electronic components which could be damaged by electrostatic discharge currents if those currents flow through certain terminals of the components. The main source of electrostatic discharge currents is the human body, and the conditions of low humidity, carpeted floors and isolating shoes are conducive to the generation of electrostatic discharge currents. Where these conditions exist, care should be exercised when removing and handling the modules to make settings on the internal switches. The person handling the module should make sure that his/her body has been discharged by touching some surface at ground potential before touching any of the components on the modules.

The SLS systems are shipped in two separate cartons, one for case A (distance relay) and one for case B (recloser and options). The interconnection cable(s) is (are) included in the case B carton.

Immediately upon receipt, the equipment should be unpacked and examined for any damage sustained in transit. If injury or damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the nearest General Electric Sales Office.

If the equipment is not to be installed immediately, it should be stored indoors in a location that is free from moisture, dust, metallic chips, and severe atmospheric contaminants.

INSTALLATION

ENVIRONMENT

The location should be clean and dry, free from dust and excessive vibration, and well lighted to facilitate inspection and testing.

MOUNTING

The SLS cases have been designed for standard rack mounting. Each case measures four rack units in height. The outline diagram is given in Fig. 76.

The units may also be flush mounted on a panel with an appropriate cutout. Refer to Fig. 75 for the required dimensions.

Provision has been made for surface panel mounting as well. This is accomplished by removing and reversing the side brackets so that the mounting wings are in the rear. For surface mounting, cutouts must be made in the panel to allow for the terminal blocks and interconnection cable(s).

EXTERNAL CONNECTIONS

External connections are made according to the elementary diagram given in Fig. 75. This is a general diagram incorporating all of the available options. Connection need not be made to those terminals associated with options not included in the equipment purchased.

The terminal block points indicated in Fig. 75 may be located without having the equipment in hand by referring to Fig. 76.

INTERCONNECTION CABLES

For models of the SLS1000A series, one interconnection cable is required between the two cases. It should be connected from the PL-1 socket of case A to the PL-1 socket of case B. The connections simply snap onto the sockets. They are keyed for proper polarity. The length of the standard cable provided is suited for the two cases being mounted one atop the other.

For models of the SLS1100A series (includes the directional comparison blocking option), three interconnection cables are required, to be connected between the respective PL sockets on the two cases. The three cables are identical, and therefore interchangeable.

LIST OF ILLUSTRATIONS

* Revised since last issue

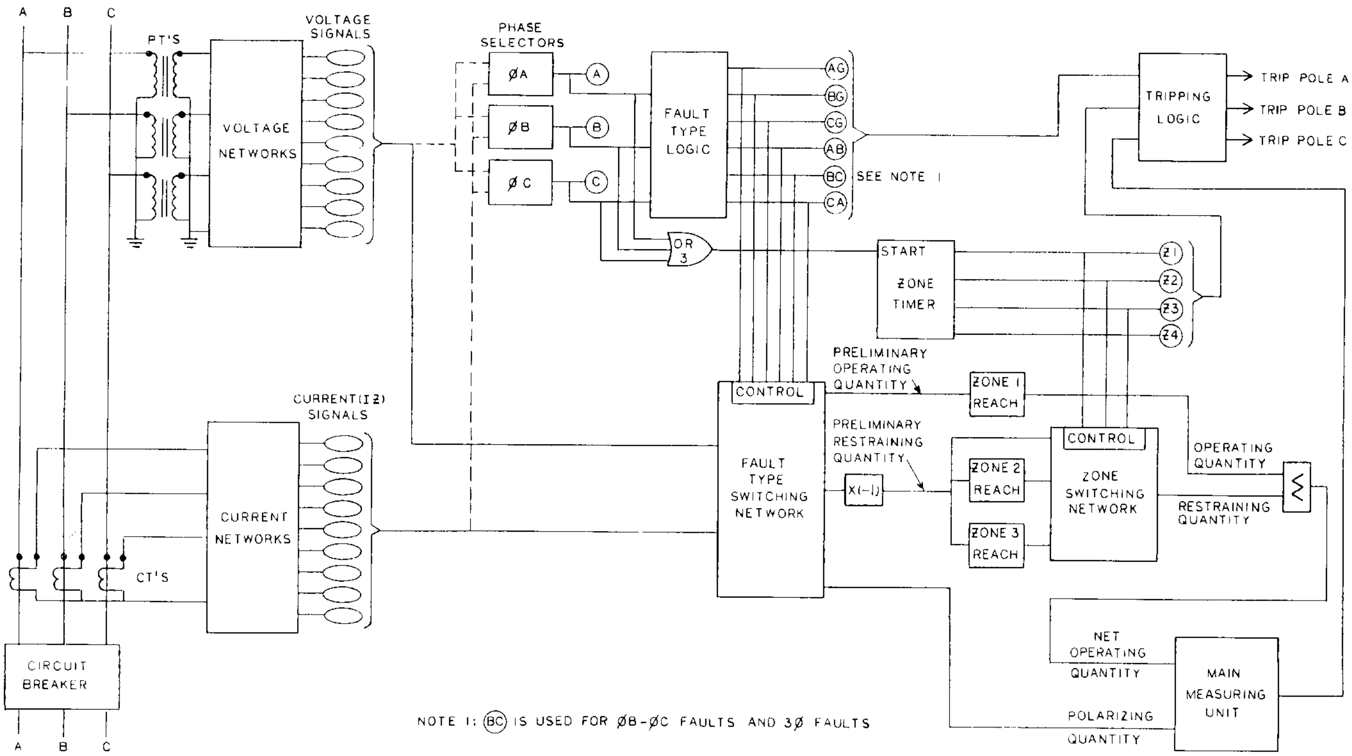


Figure 1 (0138B7648-0) Simplified Block Diagram
of SLS1000 Stepped Distance Scheme

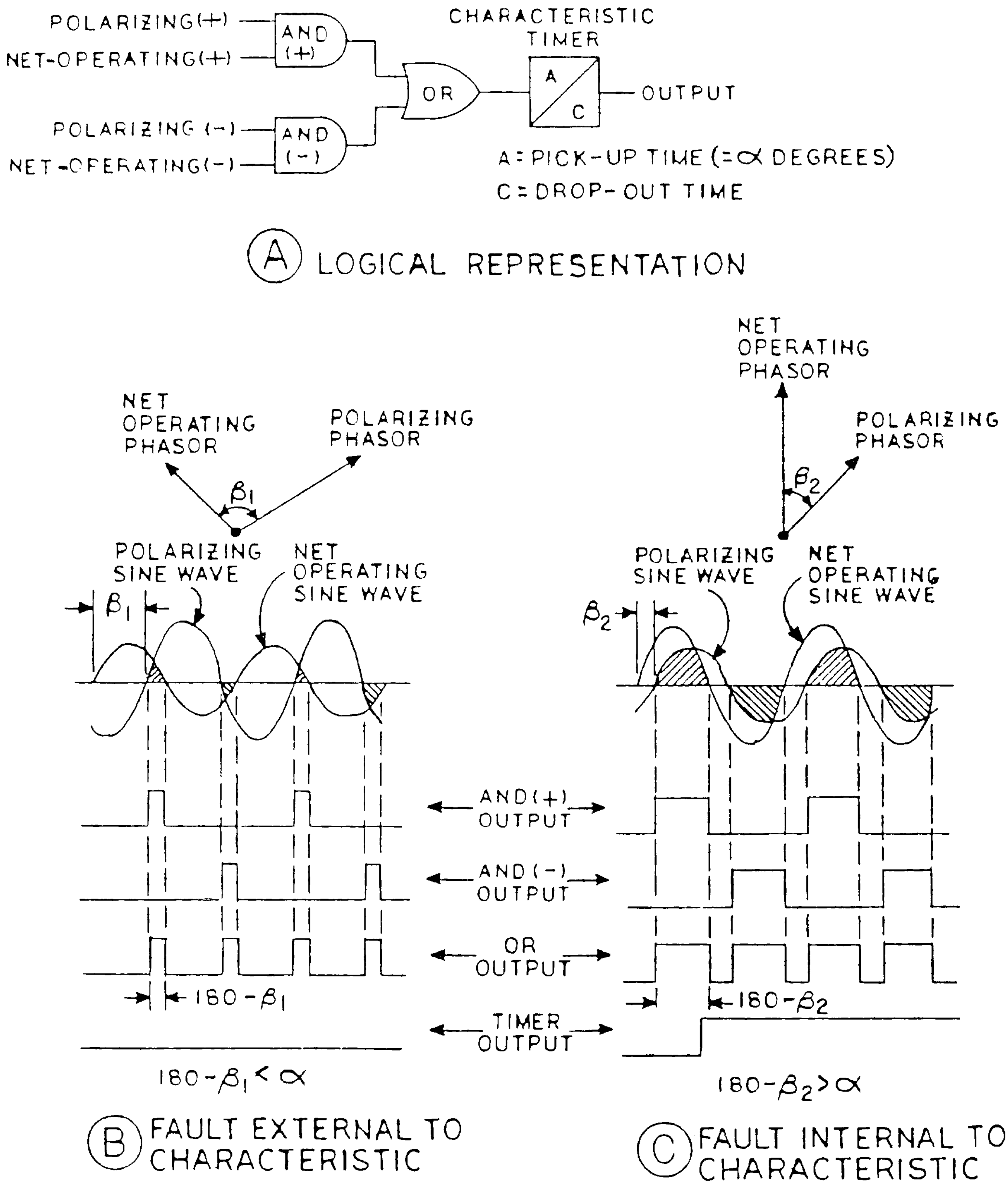


Figure 2 (0285A6691-0) "Block-Block" Principle of Distance Measurement

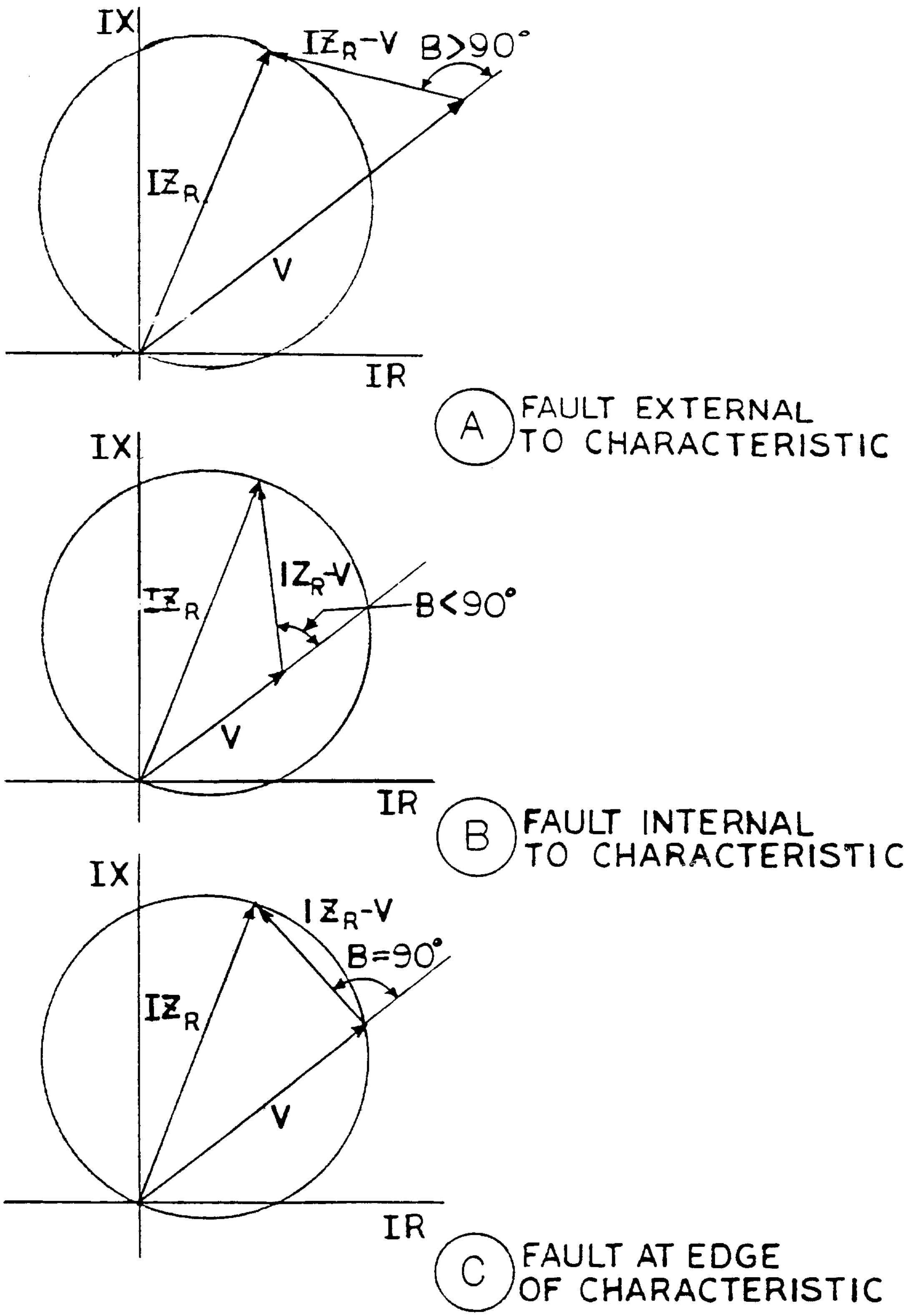


Figure 3 (0285A6690-0) Voltage Diagrams of Circular Mho-Type Characteristic

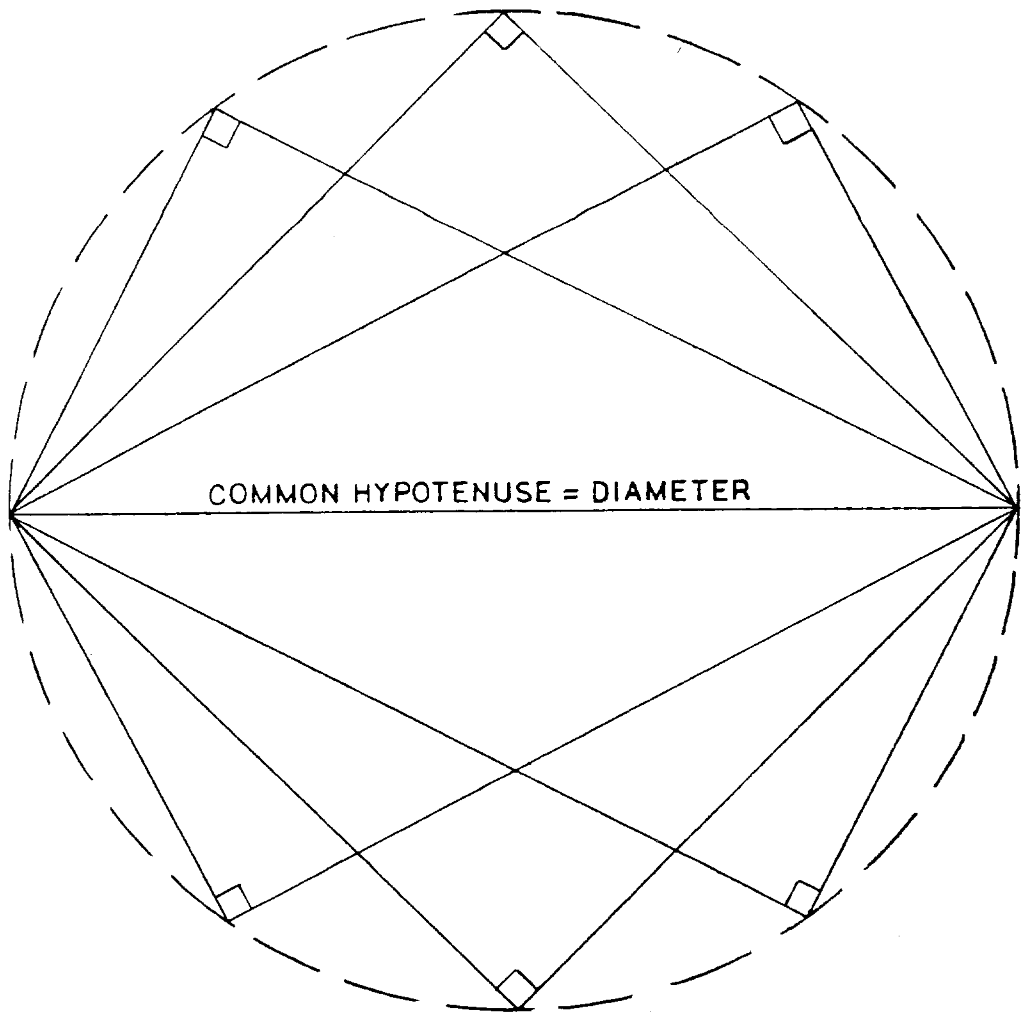


Figure 4 (0285A6689-0) Formation of a Circle by Constructing Right Triangles About a Common Hypotenuse

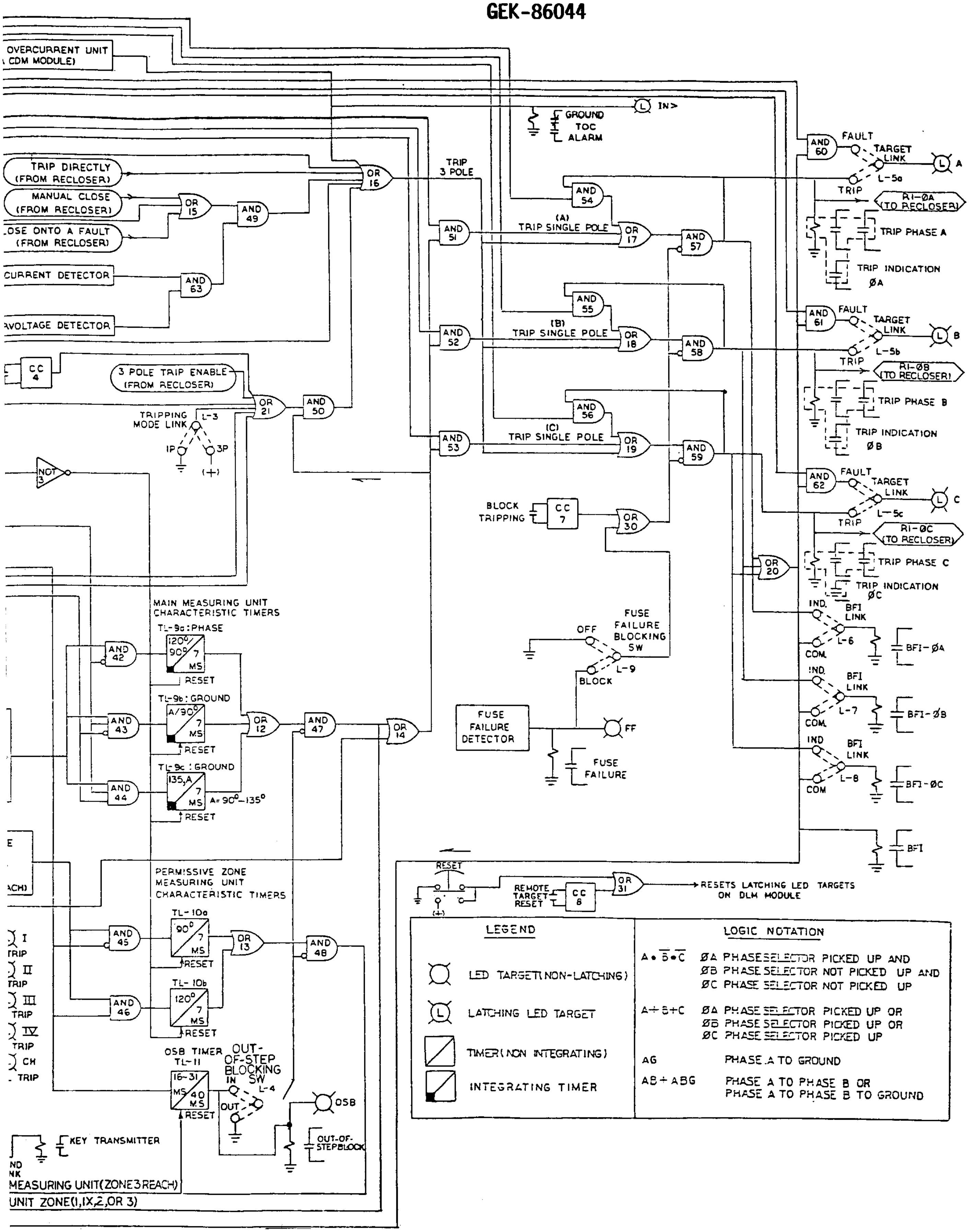
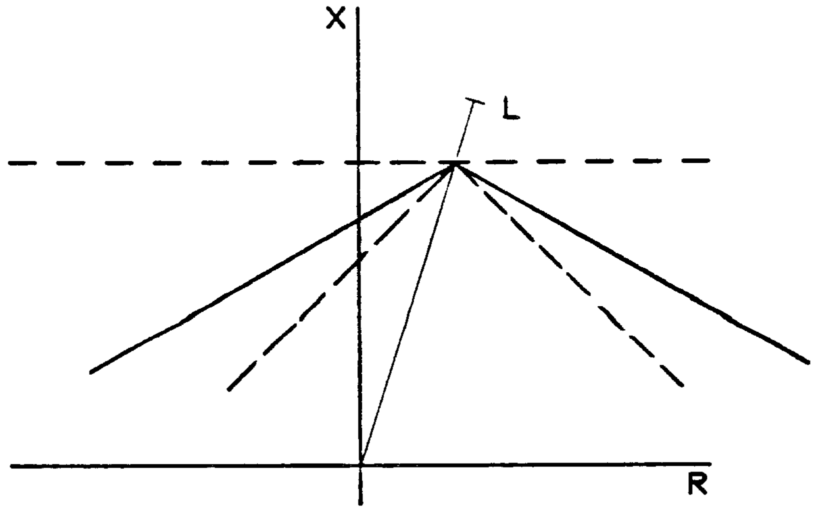
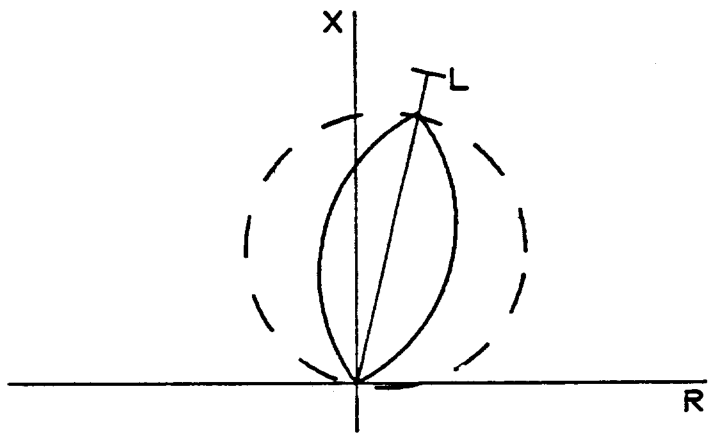


*Figure 5 (0145D8908-5) Logic Diagram of SLS Distance Relay

*Revised since last issue



(A) - REACTANCE



(B) - MHO-TYPE

Figure 6 (0285A6628-1) Reactance and Mho Ground Characteristics

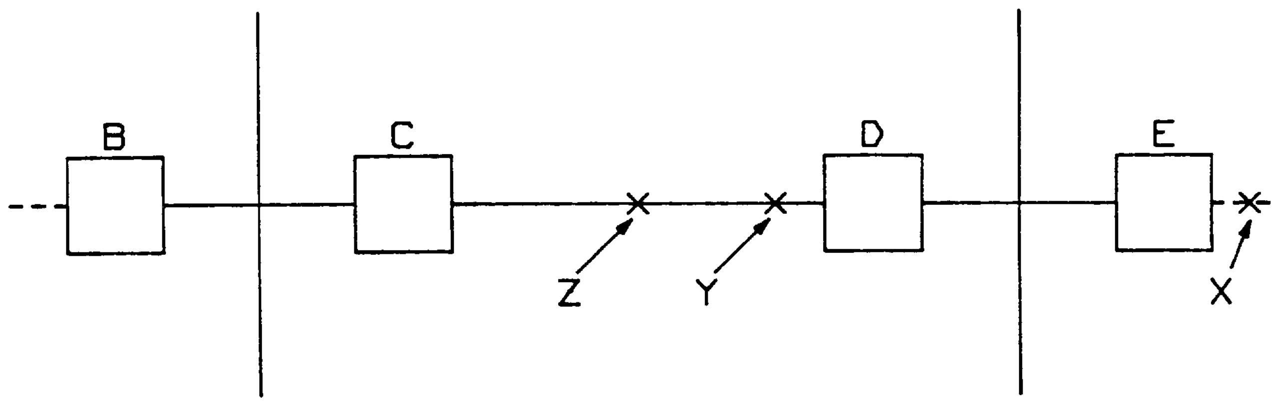


Figure 7 (0285A6629-0) One Line Diagram of Typical Line Section

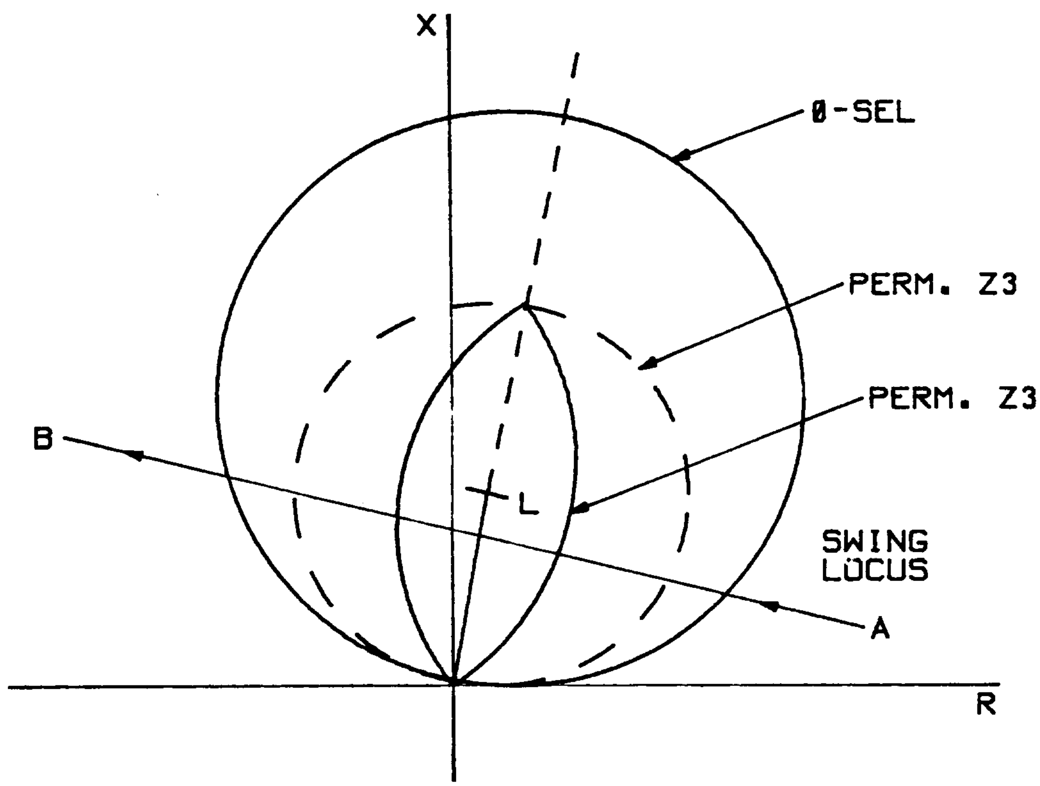


Figure 8 (0285A6630-0) Characteristics for Out-of-Step Detector Scheme

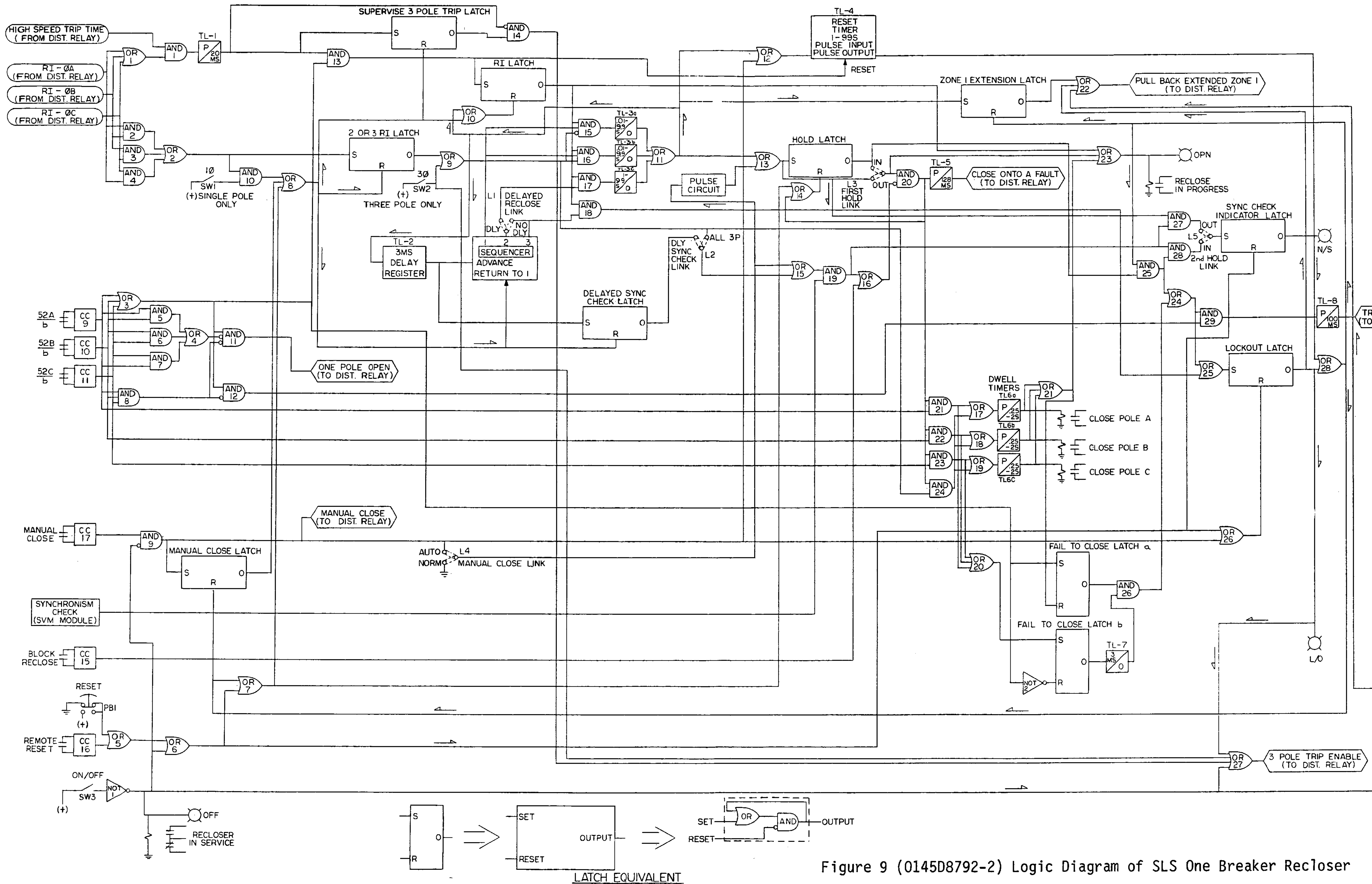


Figure 9 (0145D8792-2) Logic Diagram of SLS One Breaker Recloser

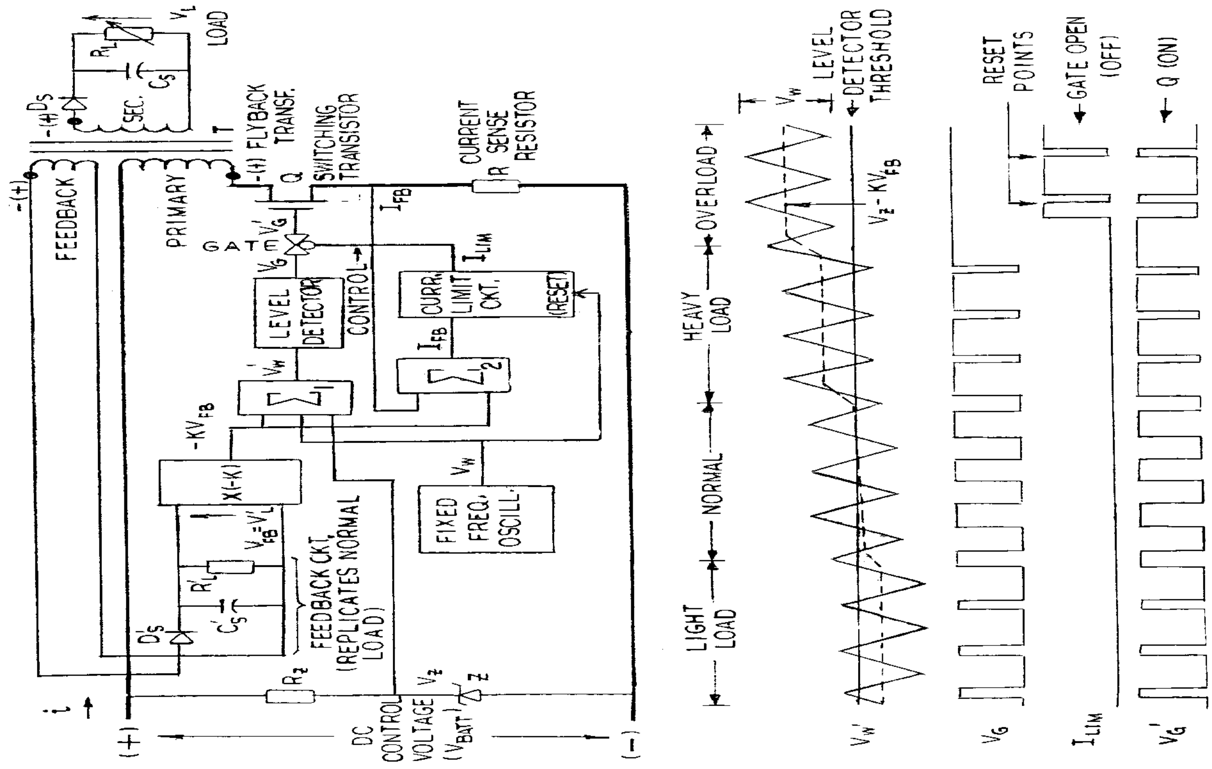


Figure 10 (0285A8200-0) Simplified Functional Diagram of SLS Power Supply

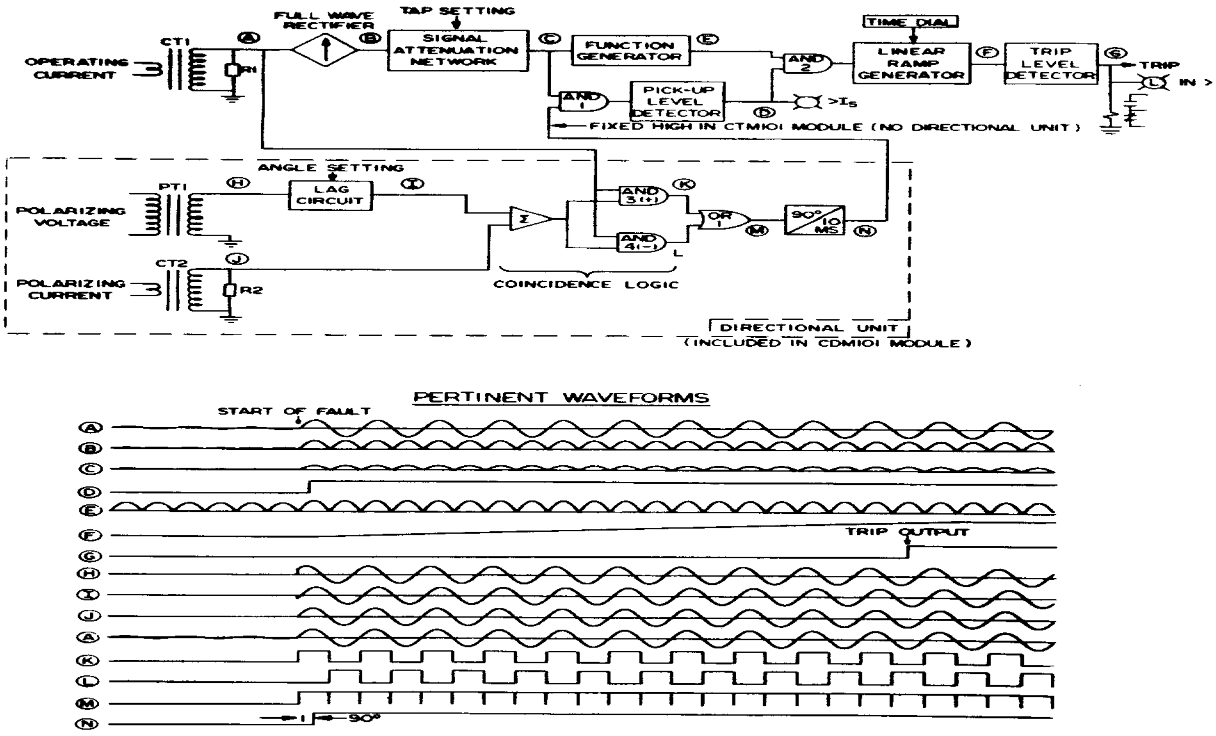


Figure 11 (0285A7552-0) Logic/Block Diagram of SLS Ground Time Overcurrent Circuit

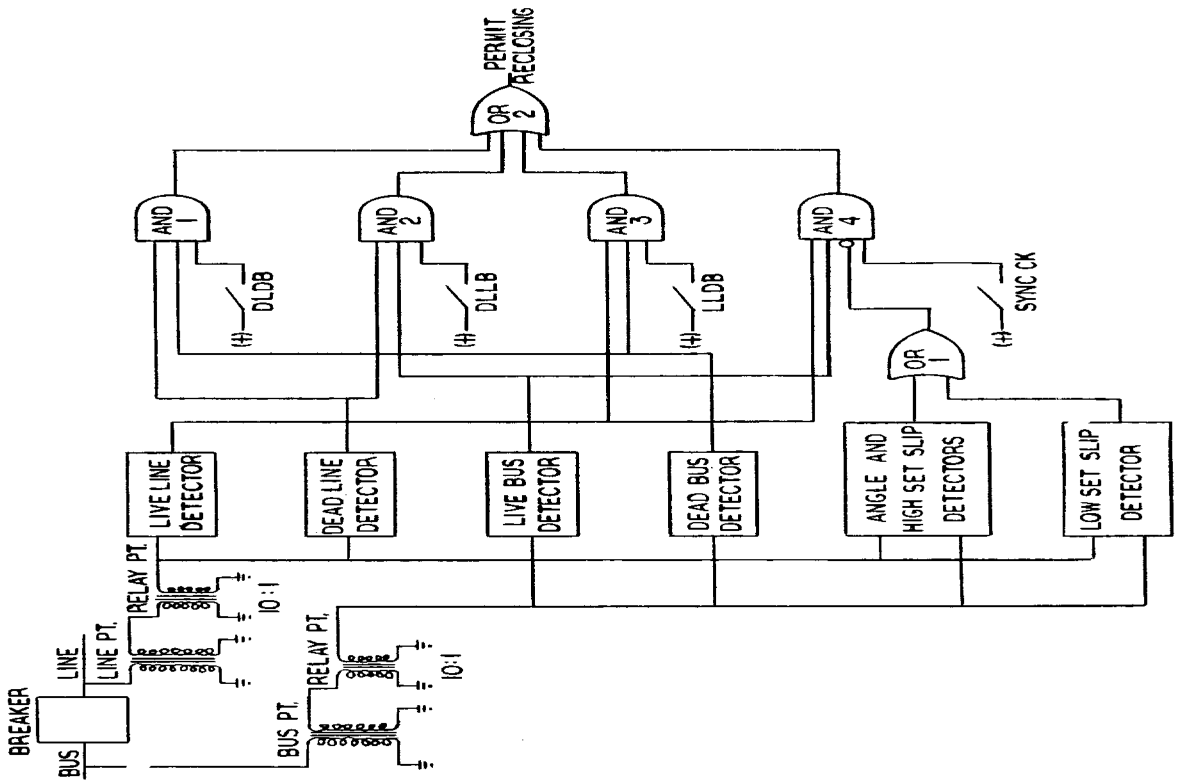


Figure 12 (0285A7556-0) Logic/Block Diagram of
SLS Synchronism Check Circuit

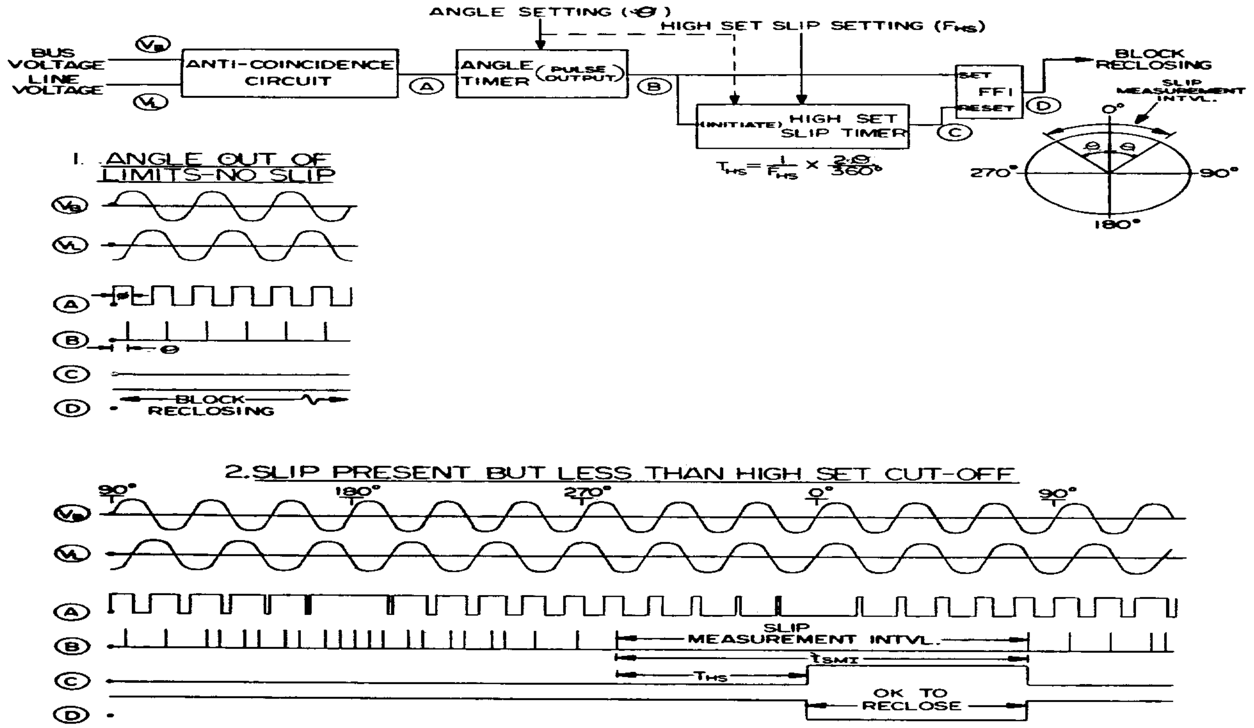


Figure 13 (0285A7549-1) SLS Angle and High Set Slip Detector

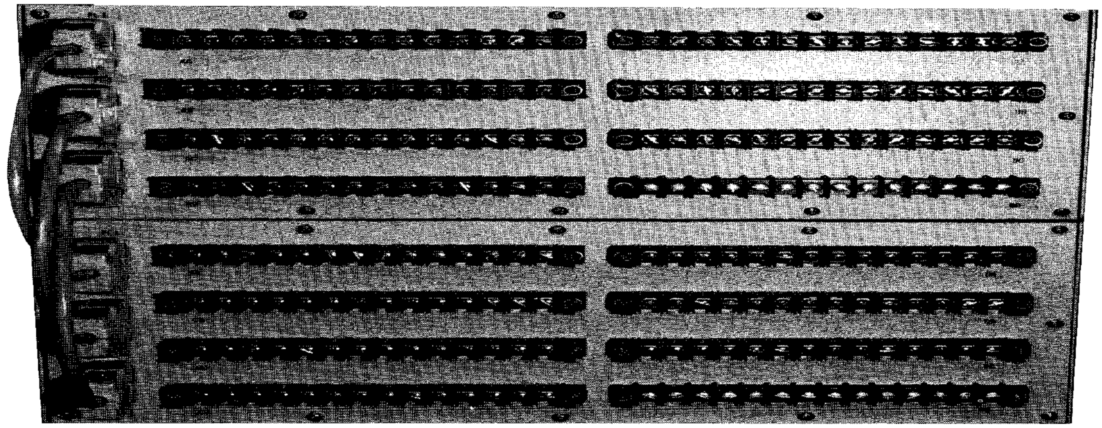


Figure 14 (8043767-0) Rear View Photograph of SLS System
Showing Interconnection Cable

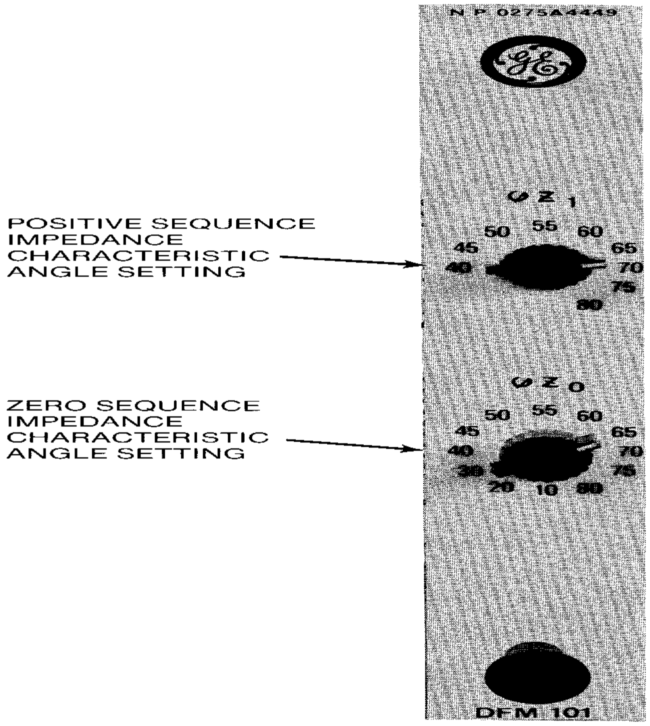


Figure 15 (8043733-0) Front View Photograph of DFM101 Module

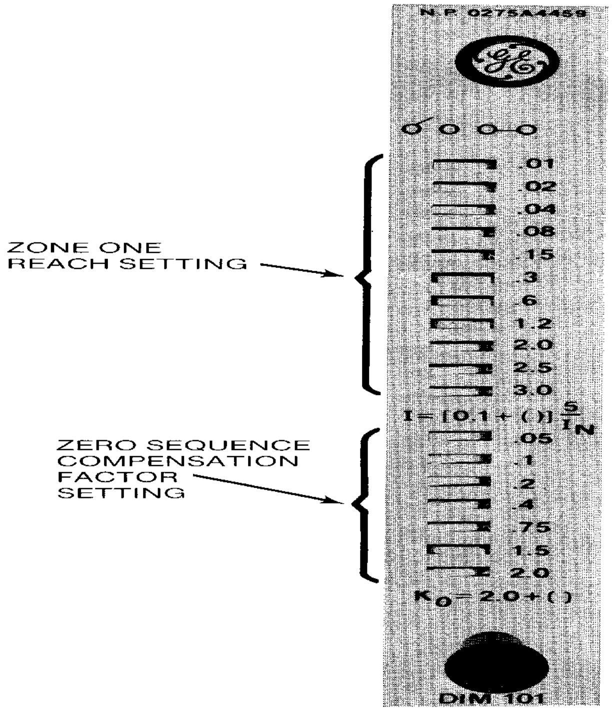


Figure 16 (8043731-0) Front View Photograph of DIM101 Module

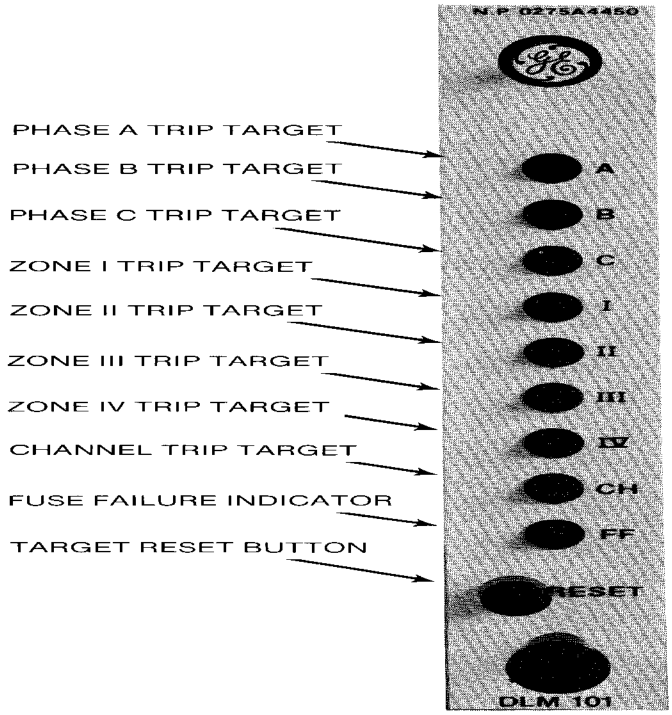


Figure 17 (8043728-0) Front View Photograph of DLM101 Module

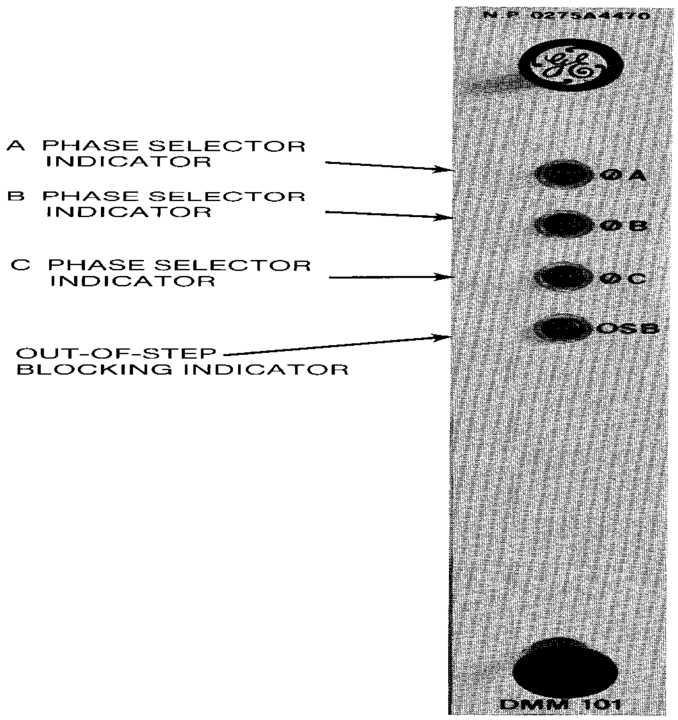


Figure 18 (8043732-0) Front View Photograph of DMM101 Module

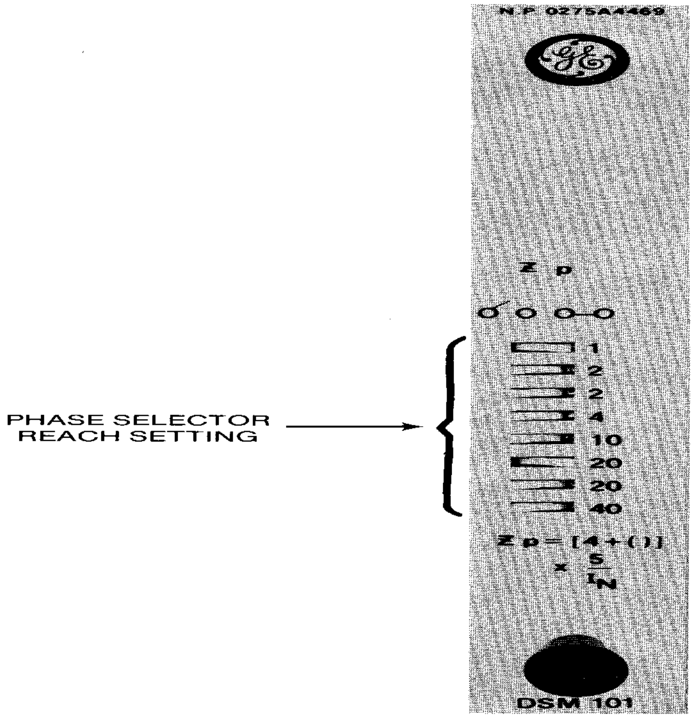


Figure 19 (8043724-0) Front View Photograph of DSM101 Module

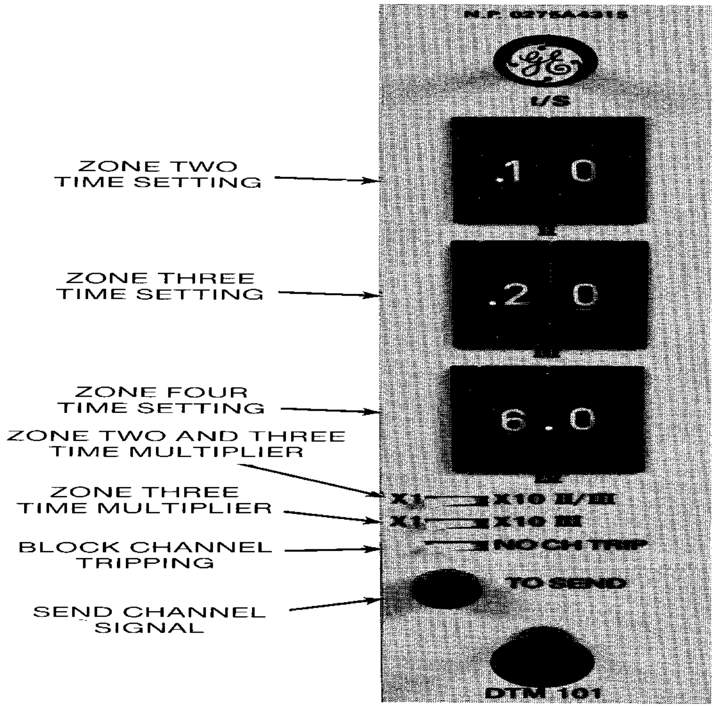


Figure 20 (8043730-0) Front View Photograph of DTM101 Module

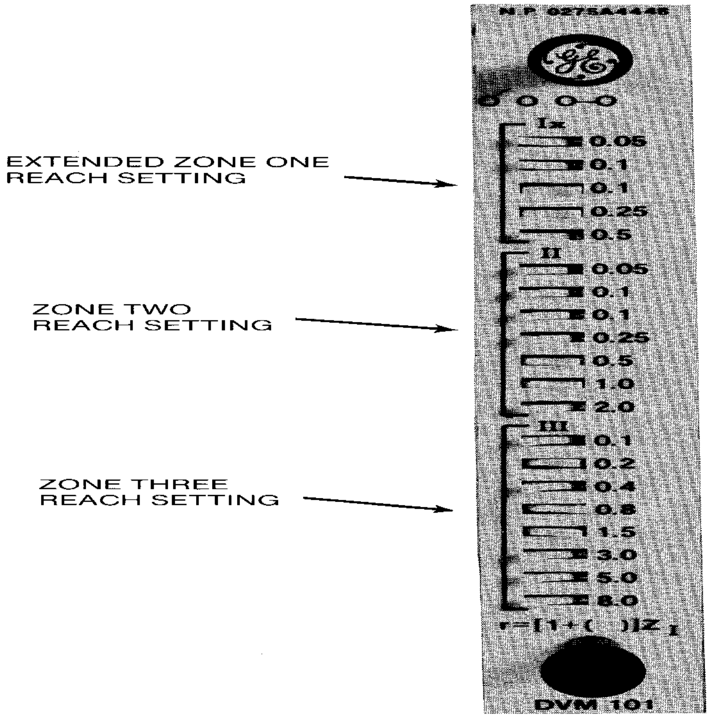


Figure 21 (8043725-0) Front View Photograph of DVM101 Module

*   Figure 22 deleted

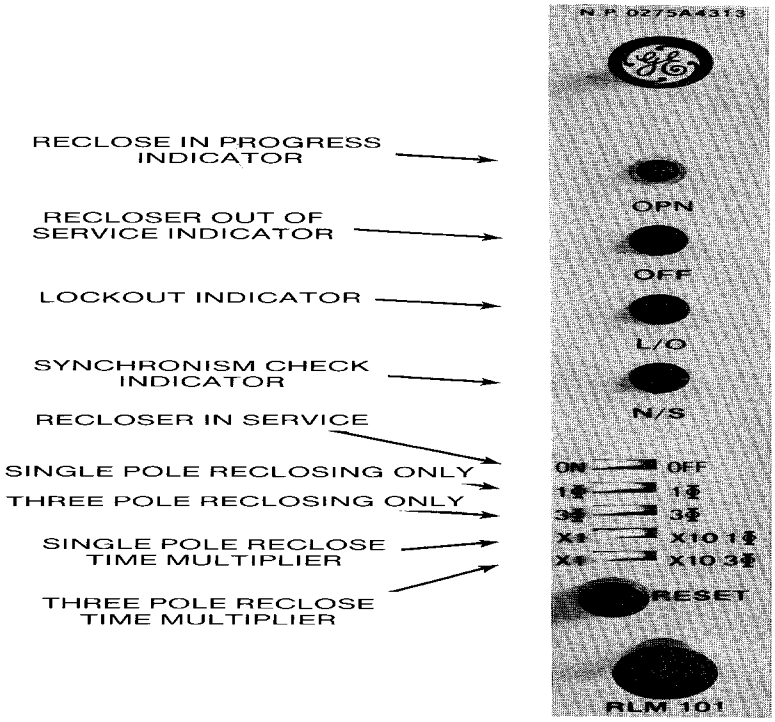


Figure 23 (8043727-0) Front View Photograph of RLM101 Module

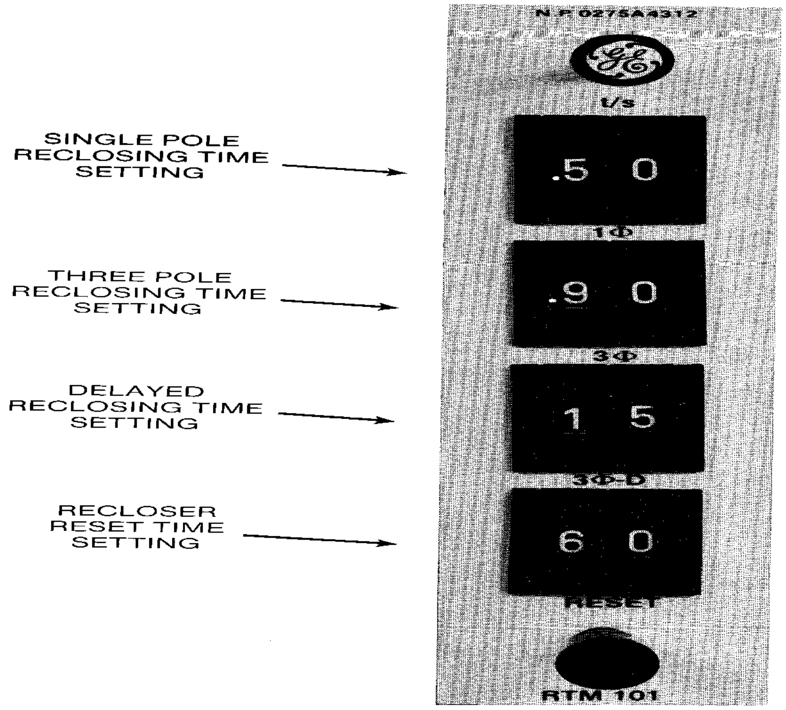


Figure 24 (8043726-0) Front View Photograph of RTM101 Module

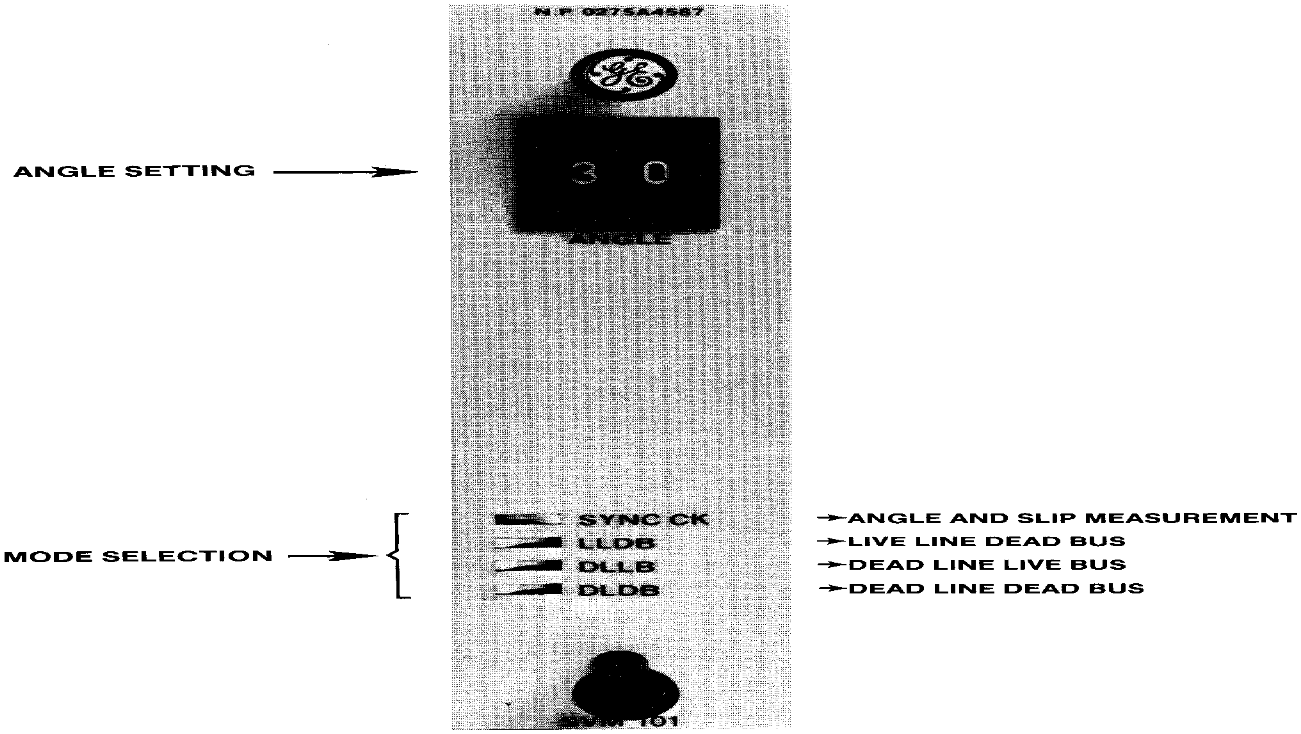


Figure 25 (8043760-0) Front View Photograph of SVM Module

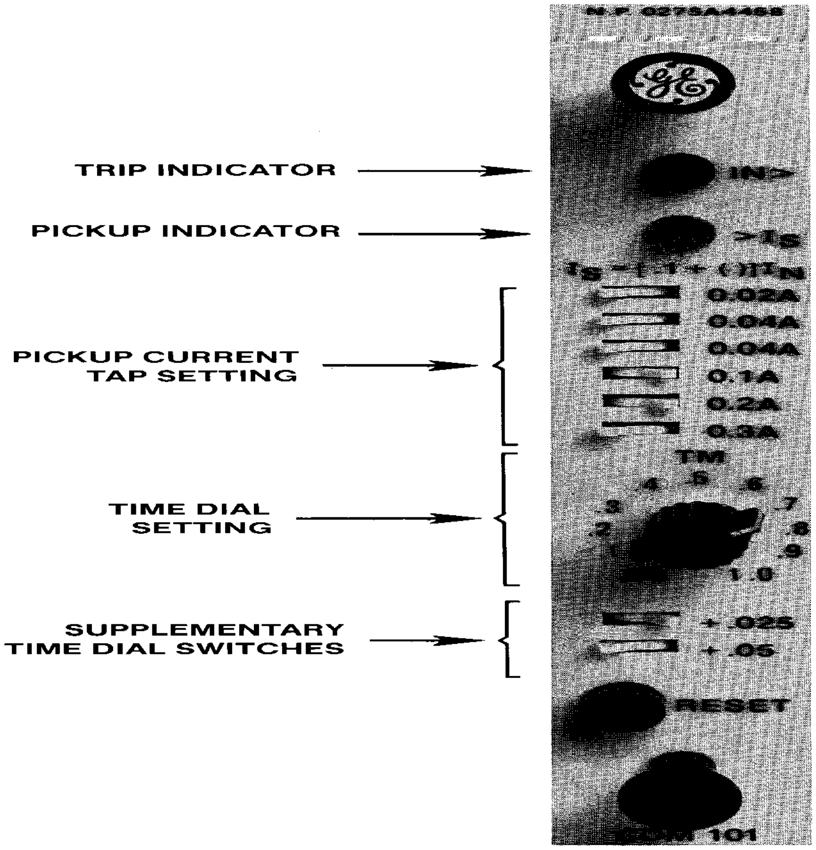


Figure 26 (8043758-0) Front View Photograph of CDM Module

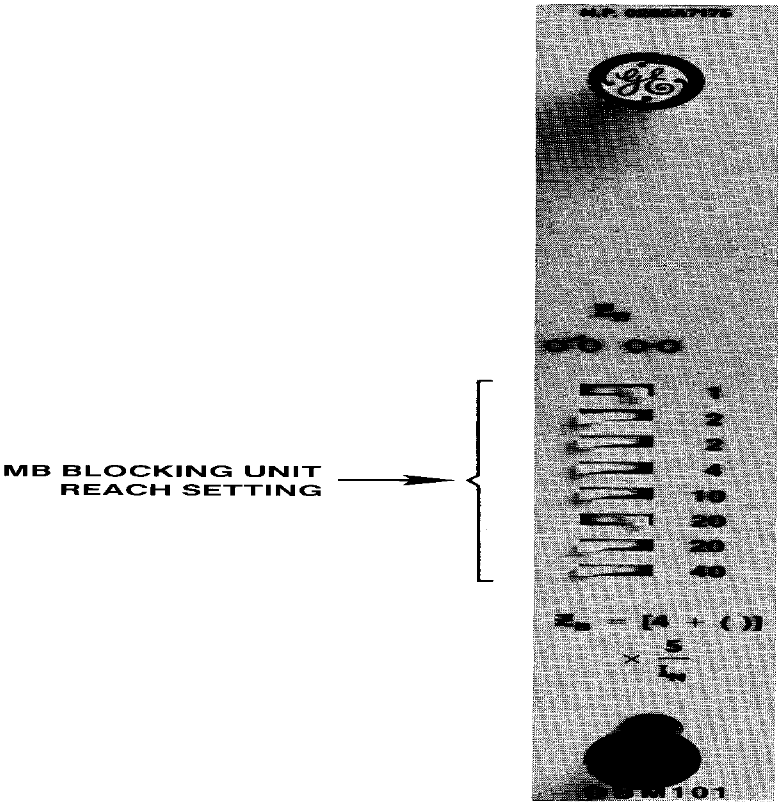


Figure 27 (8043759-0) Front View Photograph of DBM101 Module

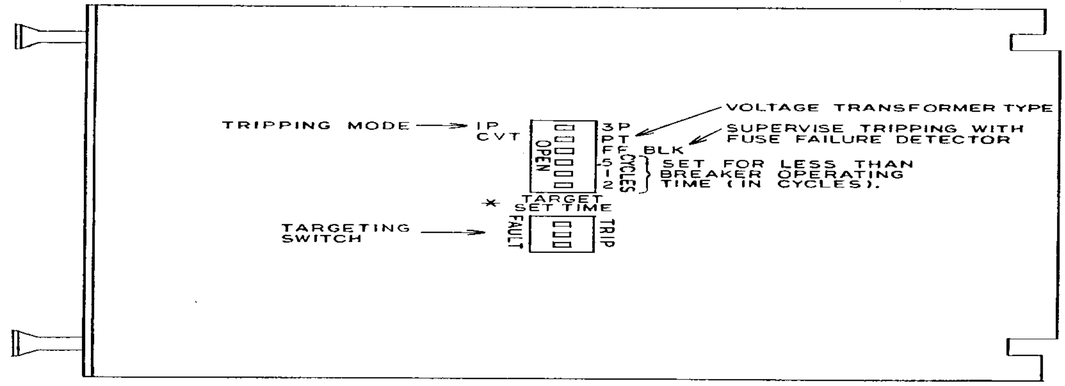


Figure 28 (0285A9108-0) Internal Links - DLM101 Module

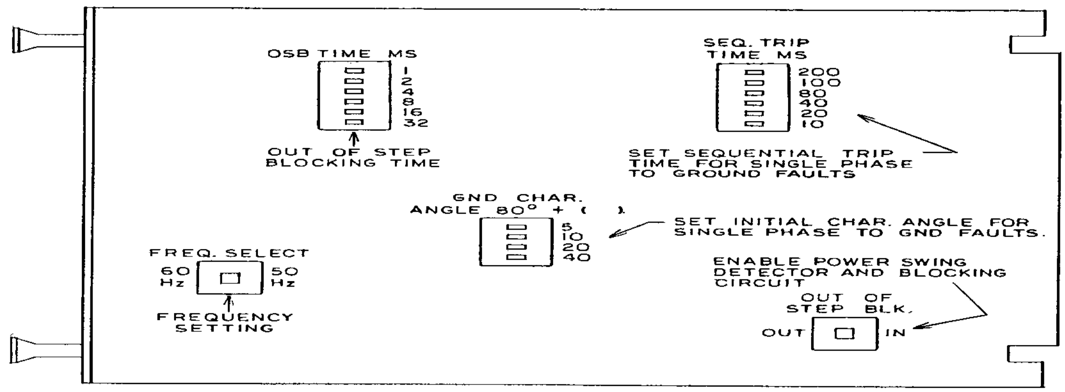


Figure 29 (0285A9109-0) Internal Links and Switches - DMM101 Module

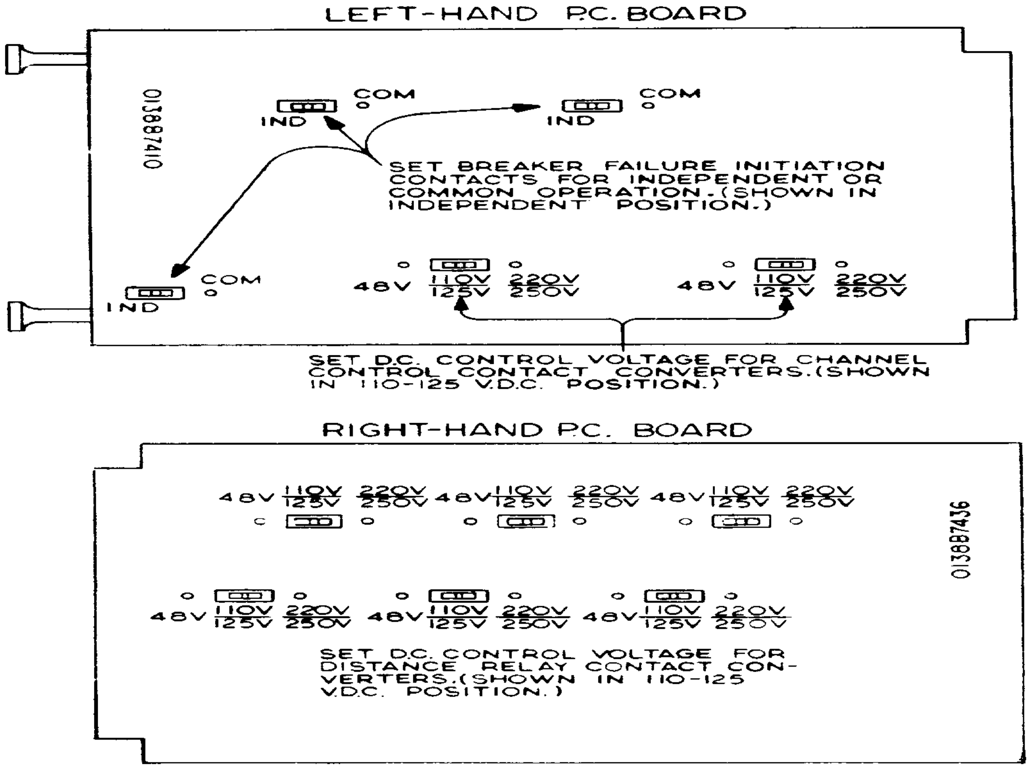


Figure 30 (0285A7558-0) Internal Links - DOM201 Module (Two Layers)

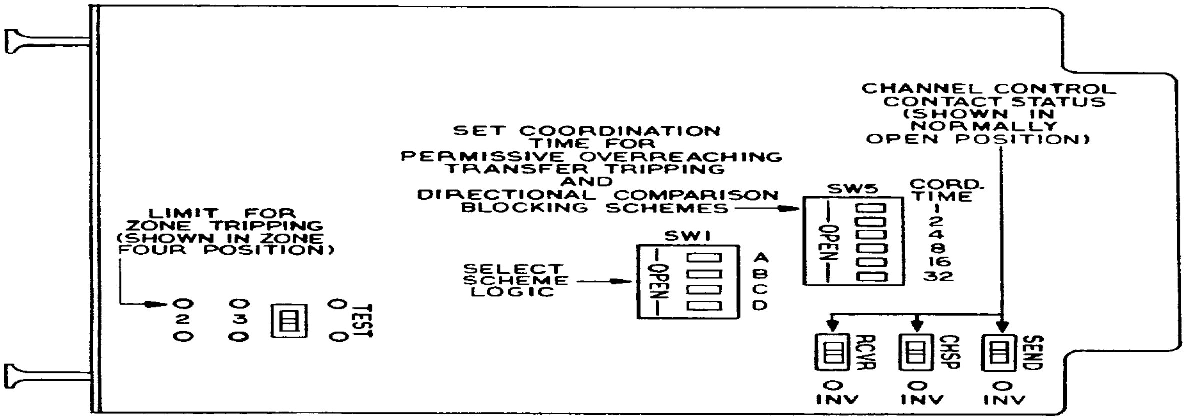


Figure 31 (0285A6620-1) Internal Links and Switches - DTM101 Module

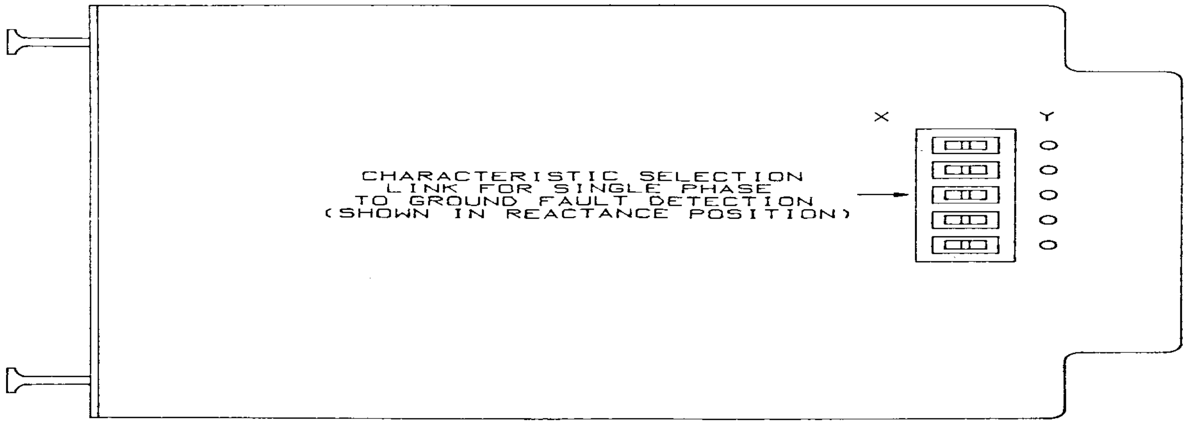


Figure 32 (0285A6621-0) Internal Link - DVM101 Module

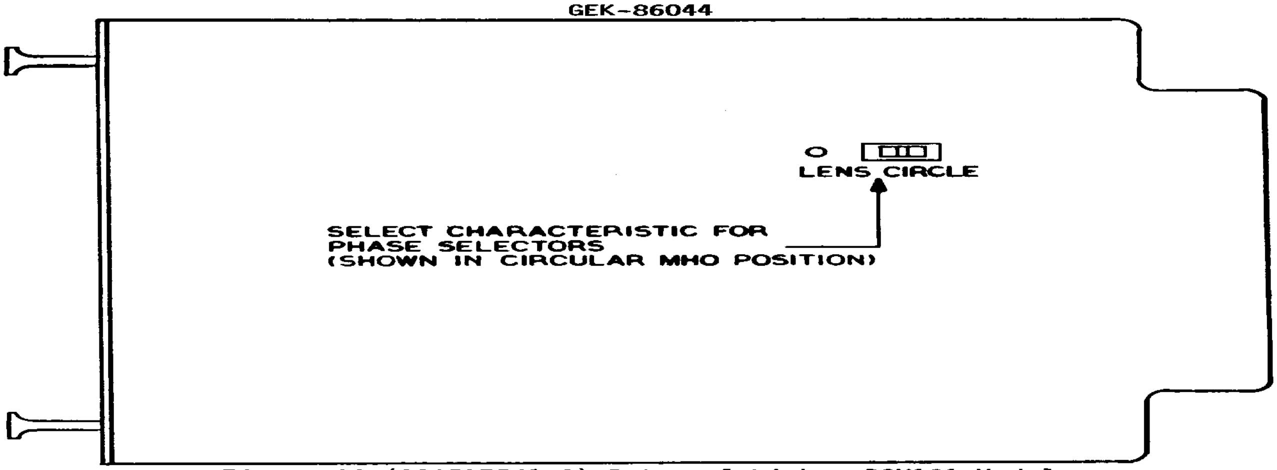


Figure 33 (0285A7561-0) Internal Link - DSM101 Module

* Figure 34 deleted

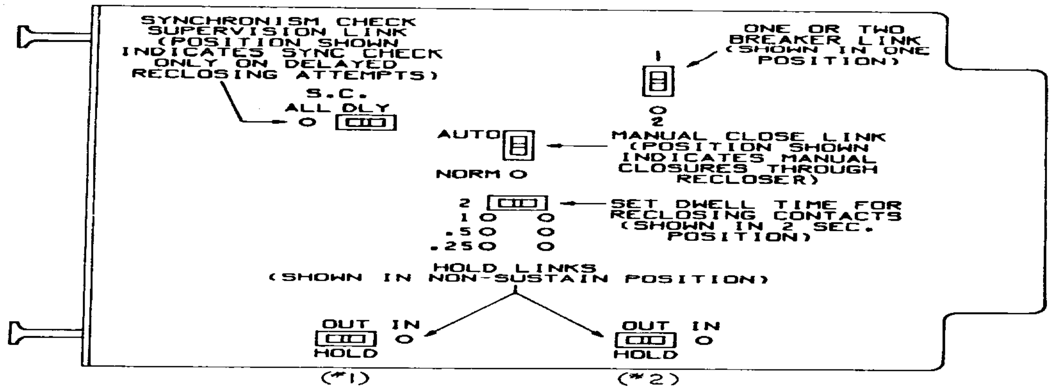


Figure 35 (0285A6623-1) Internal Links - RLM101 Module

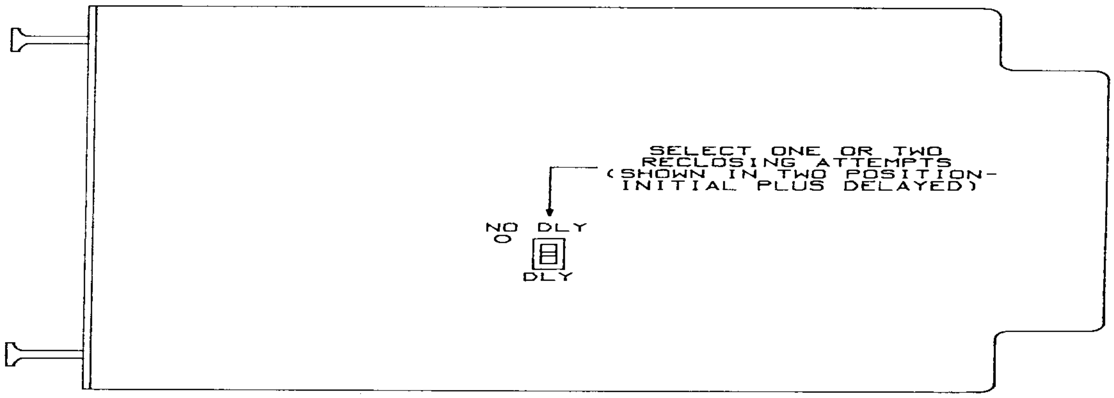


Figure 36 (0285A6624-0) Internal Link - RTM101 Module

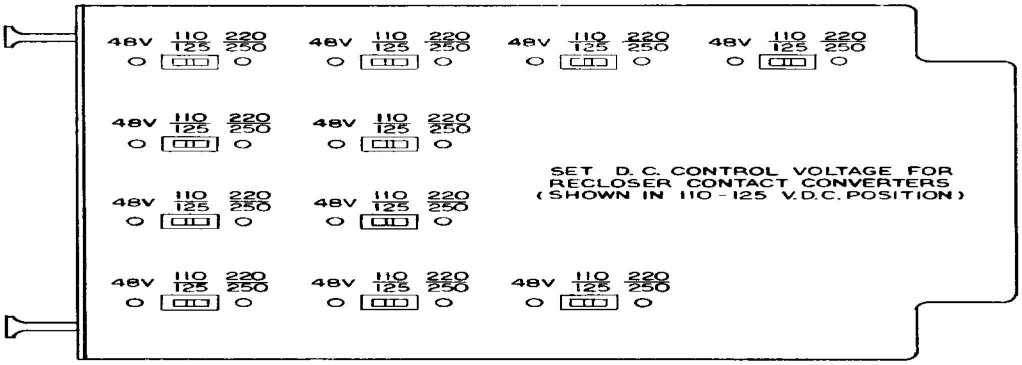


Figure 37 (0285A6625-1) Internal Links - ROM101 Module

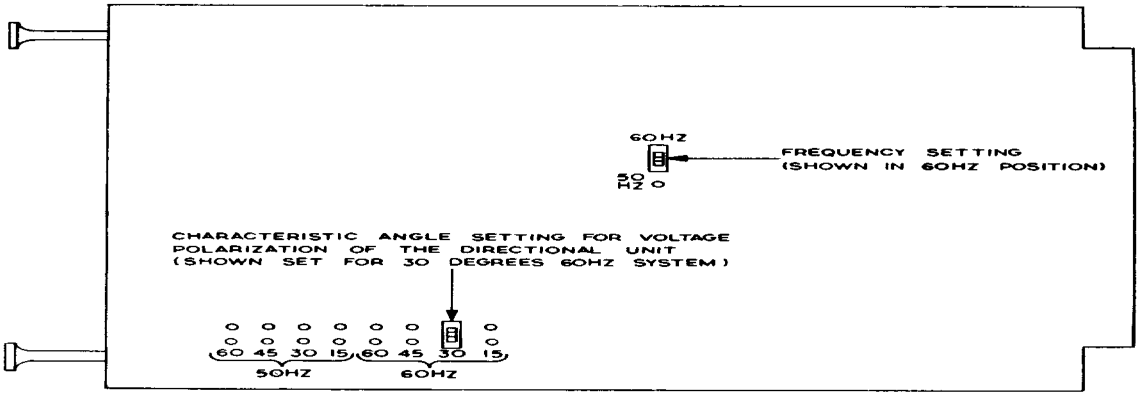


Figure 38 (0285A7563-0) Internal Links - CDM Module

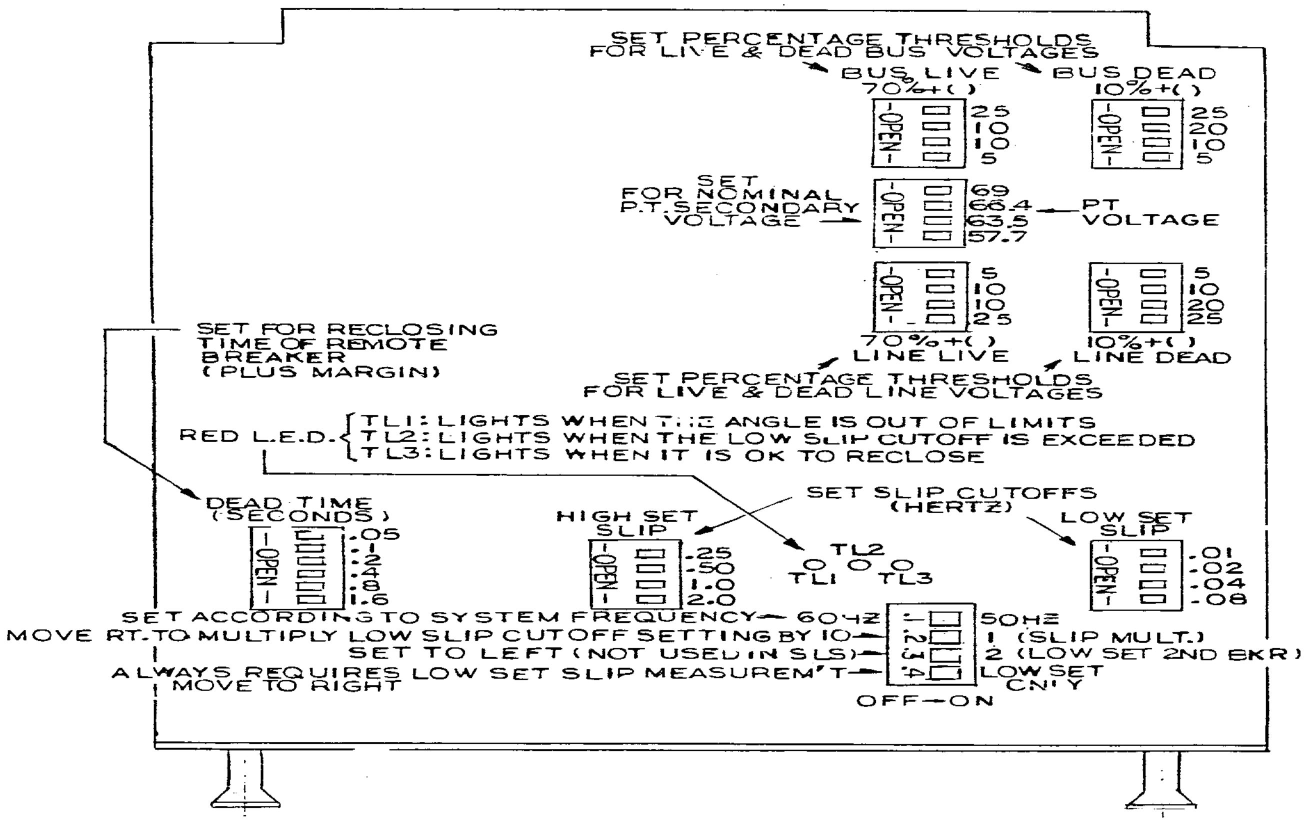


Figure 39 (0285A7564-2) Internal Switches and LEDs, SVM Module

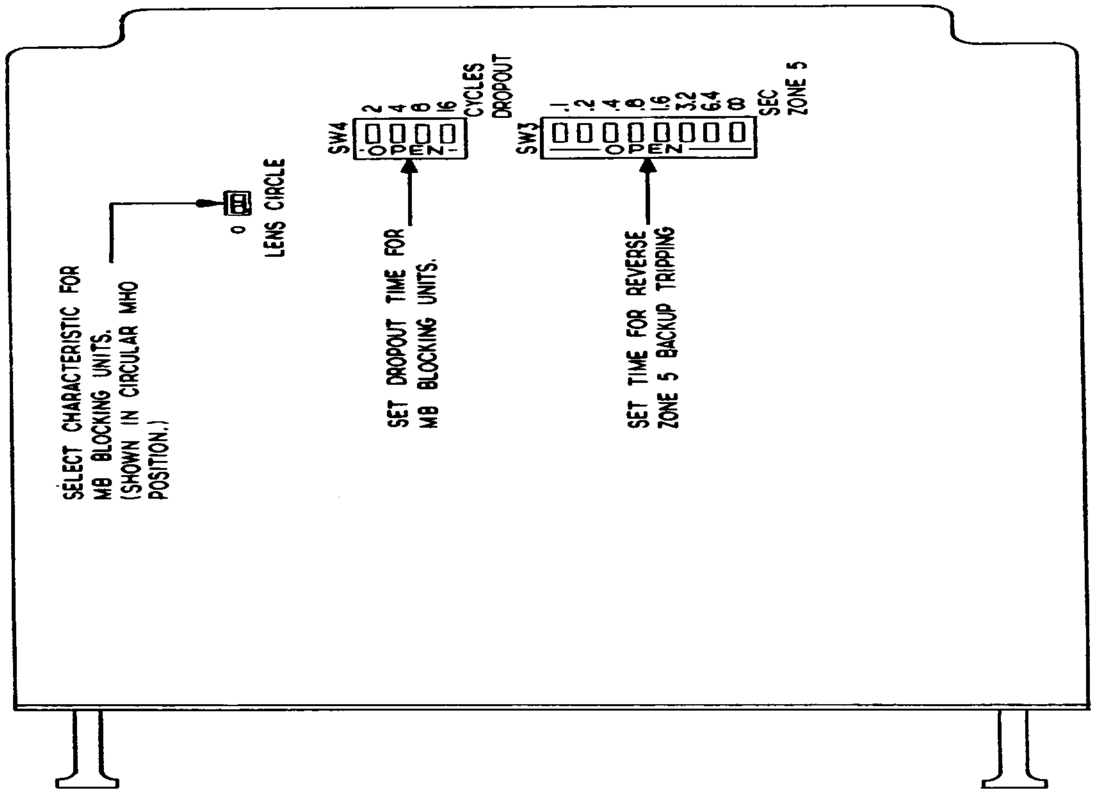


Figure 40 (0285A7559-0) Internal Links and Switches - DBM101 Module

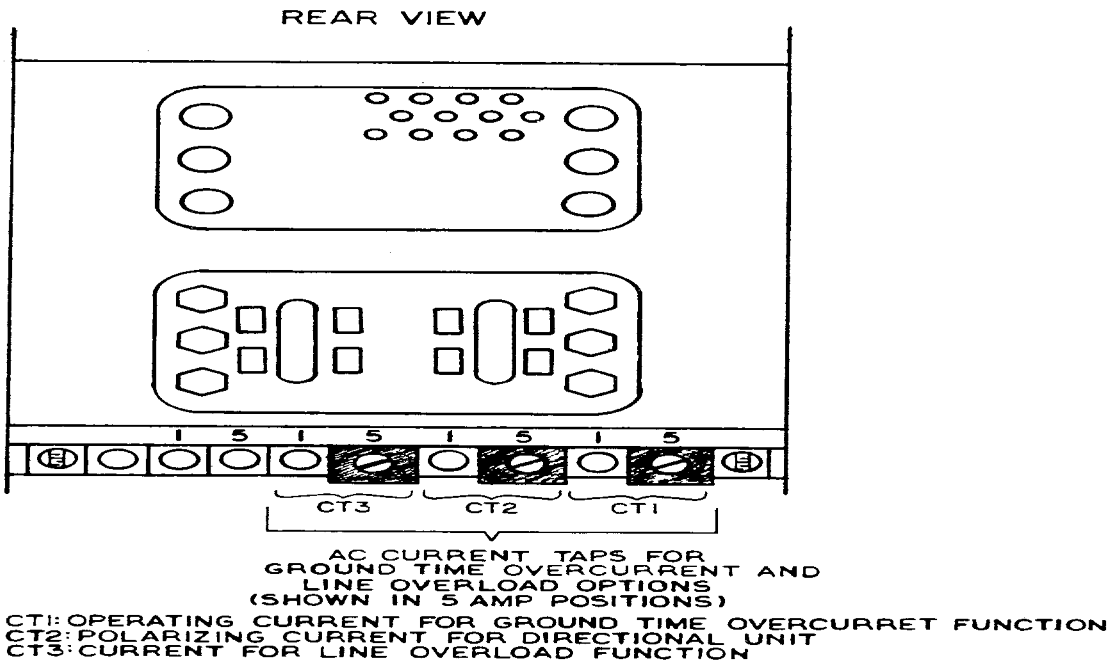
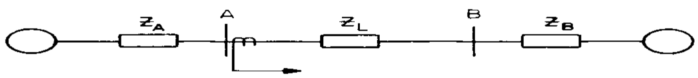


Figure 41 (0285A7560-0) Current Taps for Optional Functions In Case B MGM Module

*



SYSTEM VOLTAGE = 115KV
CTR = 120
PTR = 1000

SOURCE A (SECONDARY OHMS)
$Z_{1A} = Z_{2A} = 12 \angle 80^\circ$
$Z_{0A} = 3.96 \angle 85^\circ$

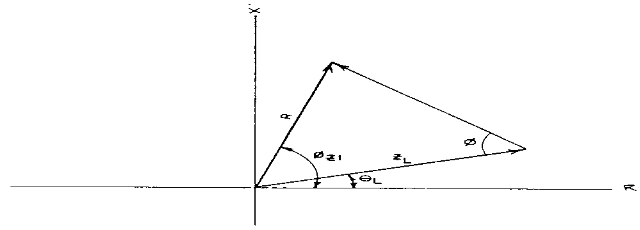
LINE (SECONDARY OHMS)
$Z_{1L} = Z_{2L} = 1.44 \angle 72^\circ$
$Z_{0L} = 4.92 \angle 67^\circ$

SOURCE B (SECONDARY OHMS)
$Z_{1B} = Z_{2B} = 6.0 \angle 85^\circ$
$Z_{0B} = 2.4 \angle 85^\circ$

MINIMUM LOAD IMPEDANCE (SECONDARY OHMS)
$Z_L = 20 \angle 15^\circ$

Figure 43 (0285A7566-0) One Line System Diagram Showing Source and Line Impedances

*Figure 42 deleted



$$R = \frac{Z_L \sin \phi}{\sin(180 + \theta_L - \phi_{Z1} - \phi)}$$

WHERE:

R - MAX. ALLOWABLE PHASE SELECTOR REACH
θ_L = ANGLE OF ASSUMED MIN. LOAD IMPEDANCE
ϕ_{Z1} = CHARACTERISTIC ANGLE OF PHASE SELECTOR
Z_L = MINIMUM LOAD IMPEDANCE
ϕ = 60° FOR 90° MHO CHARACTERISTIC;
75° FOR 105° LENS CHARACTERISTIC.

Figure 44 (0285A7554-0) Analytical Reach Determination for Phase Selector Setting

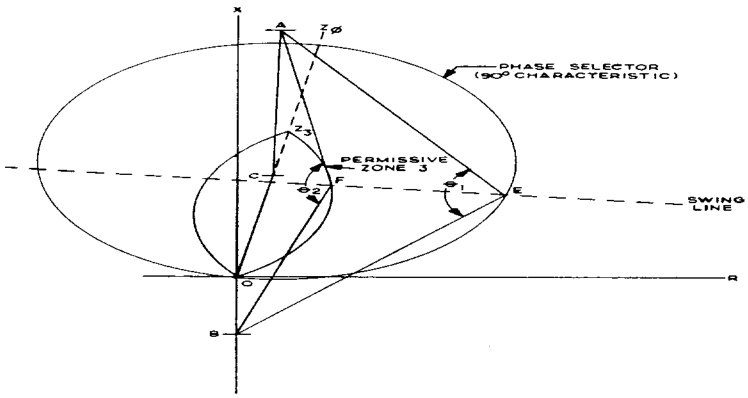


Figure 45 (0285A7565-0) Typical Out-of-Step Blocking Characteristics

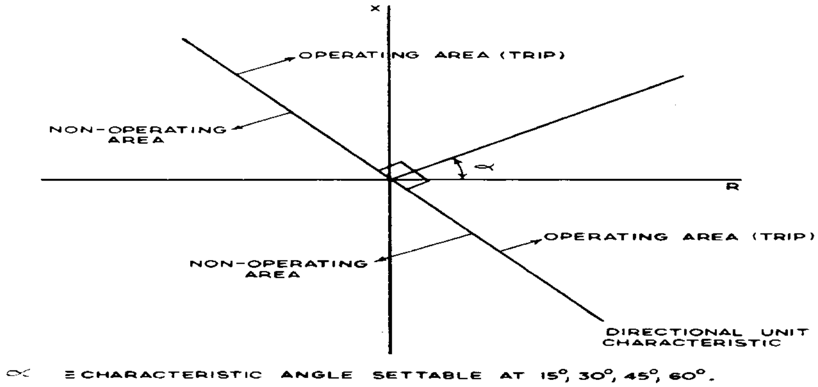


Figure 46 (0285A7553-0) R-X Characteristic for Directional Unit with Voltage Polarization

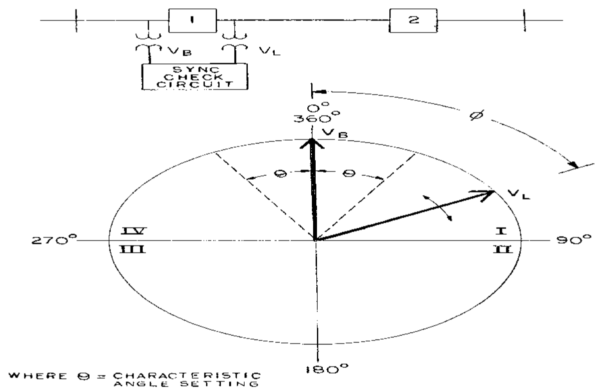


Figure 47 (0285A8201-0) System and Phasor Diagram for Synchronism Check Discussion

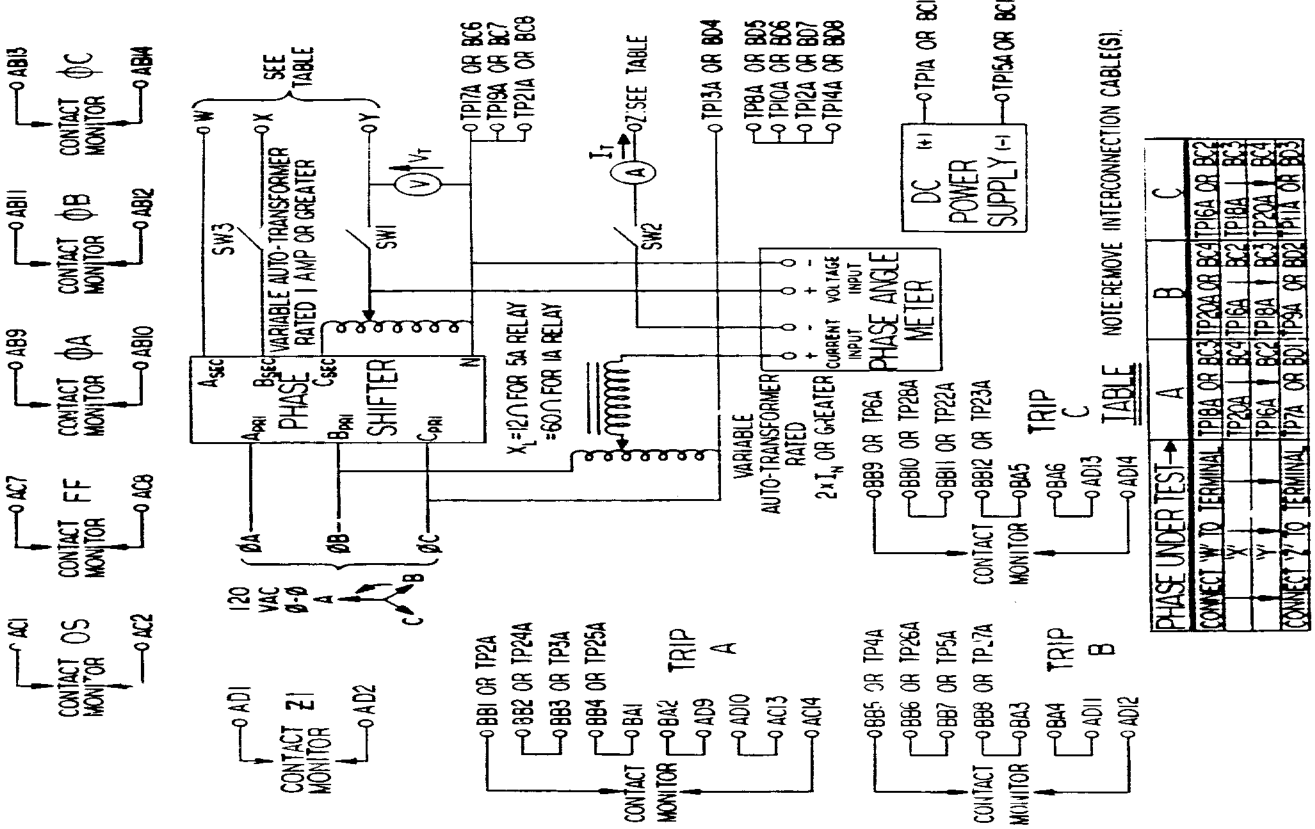
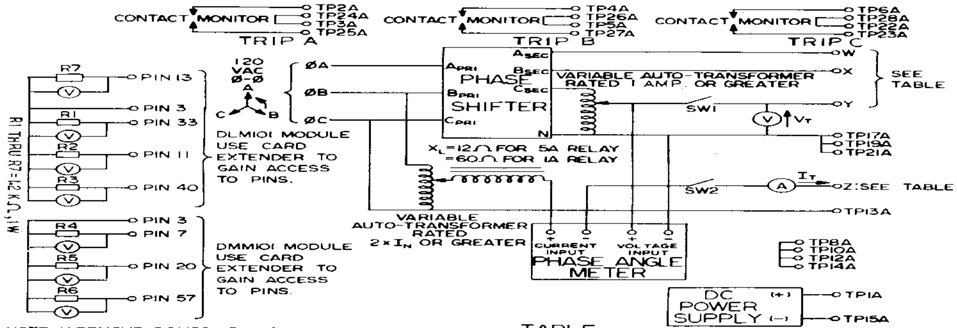


Figure 48 (0285A6609-3) Test Circuit for Single Phase-to-Ground Reach Tests

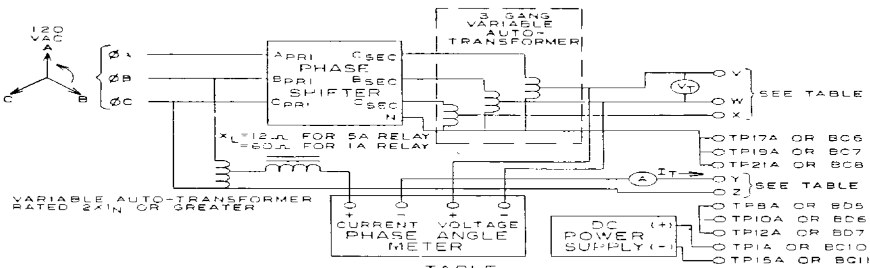


NOTE 1: REMOVE DOM201, RLM101 AND RTM101 MODULES.

TABLE

PHASE UNDER TEST →	A	B	C
CONNECT 'W' TO TERMINAL	TP18A	TP20A	TP16A
'X'	TP20A	TP16A	TP18A
'Y'	TP16A	TP18A	TP20A
CONNECT 'Z' TO TERMINAL	TP7A	TP9A	TP11A

Figure 49 (0285A7574-1) Test Circuit for Post-Installation Single Phase-to-Ground Reach Tests



TABLE

PHASE PAIR UNDER TEST →	A-B	B-C	C-A
CONNECT 'V' TO TERMINAL	TP16A OR BC2	TP18A OR BC3	TP20A OR BC4
CONNECT 'W' TO TERMINAL	TP18A OR BC3	TP20A OR BC4	TP16A OR BC2
CONNECT 'X' TO TERMINAL	TP20A OR BC4	TP16A OR BC2	TP18A OR BC3
CONNECT 'Y' TO TERMINAL	TP7A OR BD1	TP9A OR BD2	TP11A OR BD3
CONNECT 'Z' TO TERMINAL	TP9A OR BD2	TP11A OR BD3	TP7A OR BD1

NOTE 1: REMOVE INTERCONNECTION CABLE(S) FOR ACCEPTANCE TESTS.
NOTE 2: REMOVE DOM201 RLM101 AND RTM101 MODULES FOR PERIODIC TESTS.

Figure 50 (0285A6610-2) Test Circuit for Phase-to-Phase Reach Tests

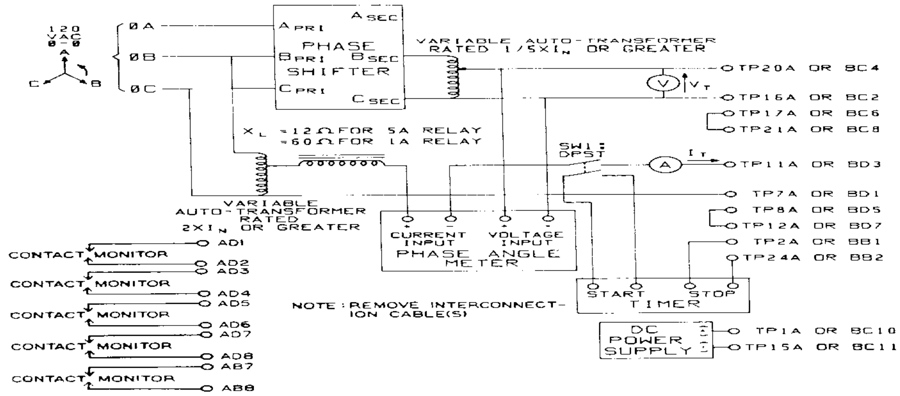


Figure 51 (0285A6611-1) Test Circuit for Zone Timer Tests

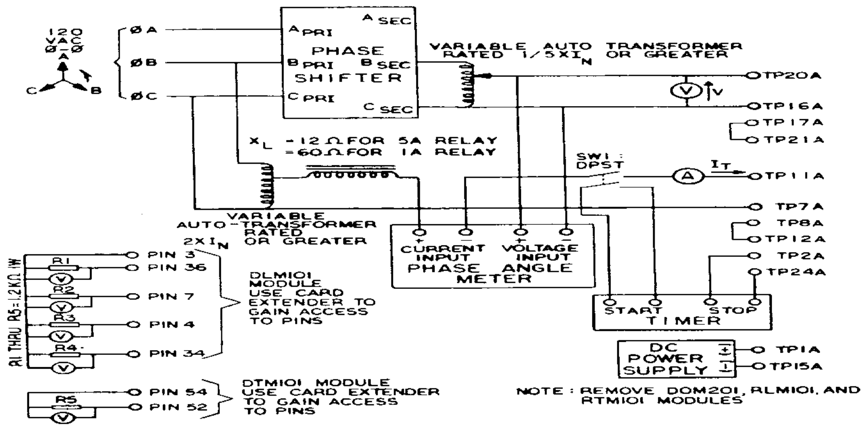


Figure 52 (0285A7567-0) Test Circuit for Post-Installation Zone Timer Test

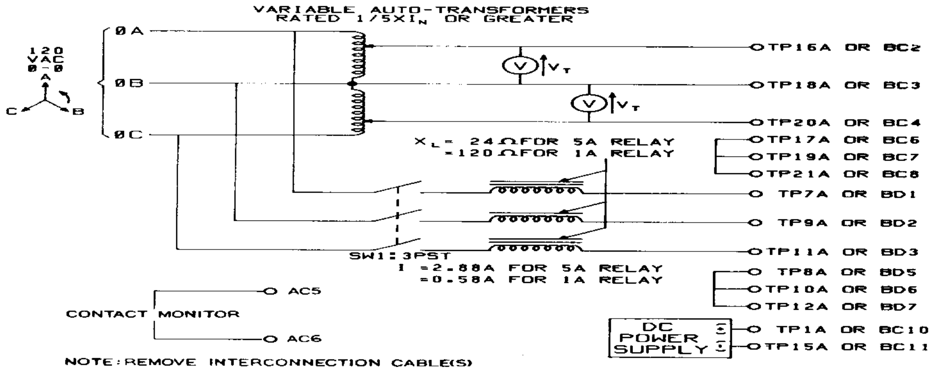


Figure 53 (0285A6612-1) Test Circuit for Out-of-Step Blocking Test

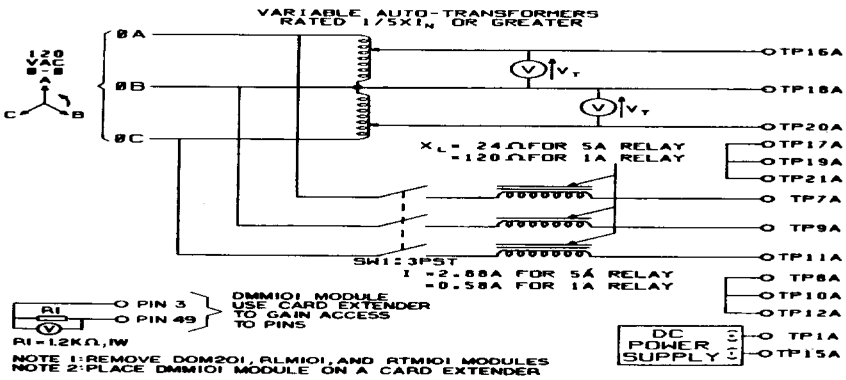


Figure 54 (0285A7582-0) Test Circuit for Post-Installation Out-of-Step Blocking Test

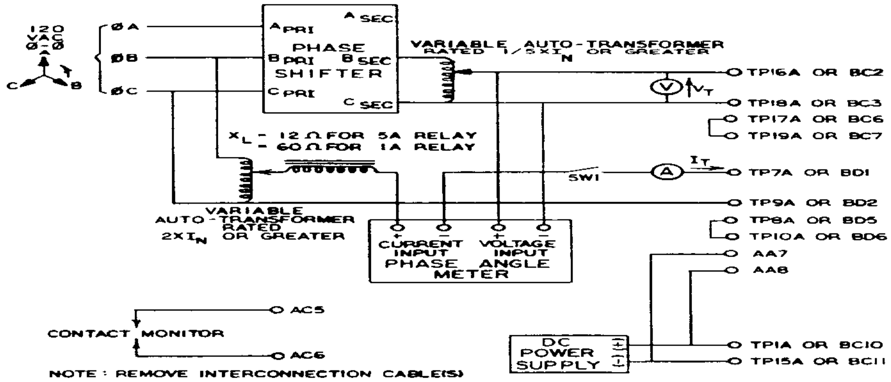


Figure 55 (0285A7573-0) Test Circuit for Out-of-Step Blocking Tests with One Pole Open

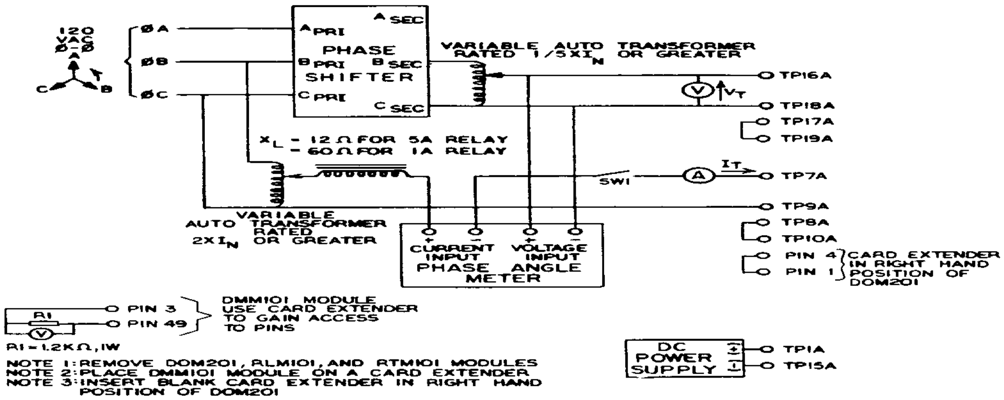


Figure 56 (0285A7570-0) Test Circuit for Post-Installation Out-of-Step Blocking Tests with One Pole Open

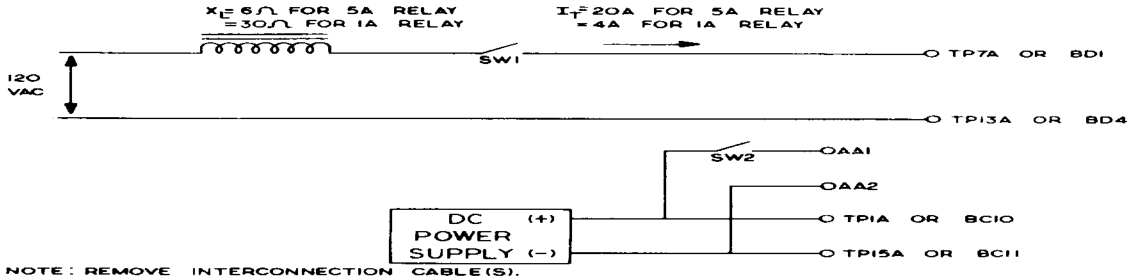


Figure 57 (0285A7584-0) Test Circuit for Line Pickup Test

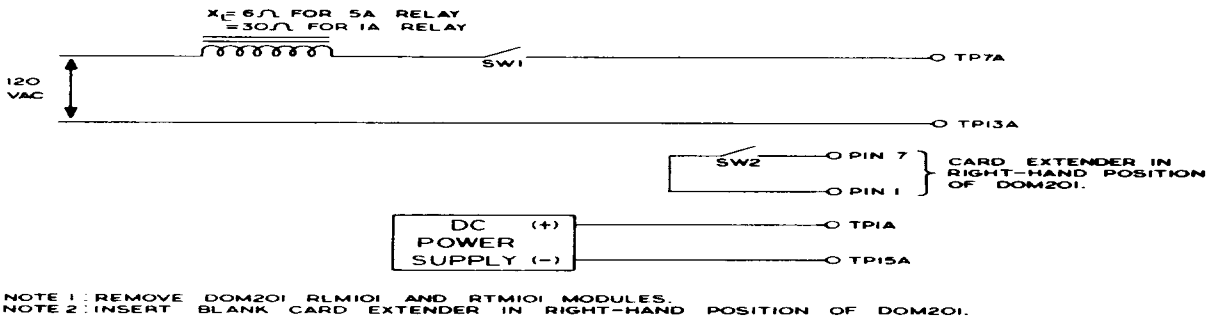


Figure 58 (0285A7583-0) Test Circuit for Post-Installation Line Pickup Test

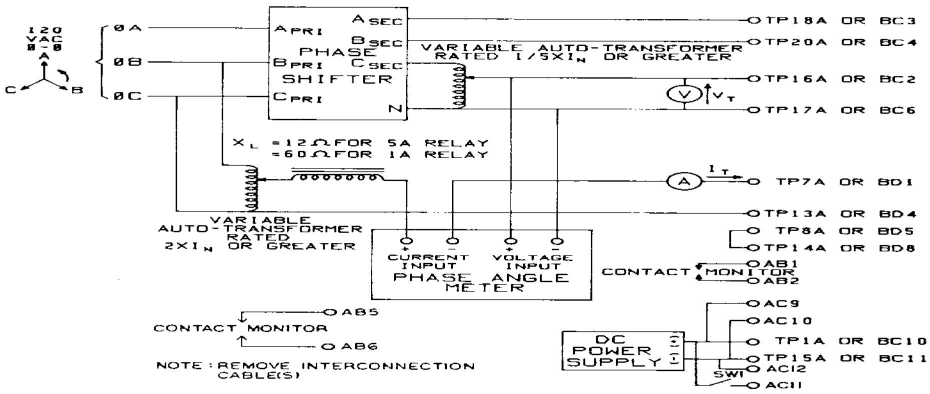


Figure 59 (0285A6613-1) Test Circuit for Testing Pilot Schemes

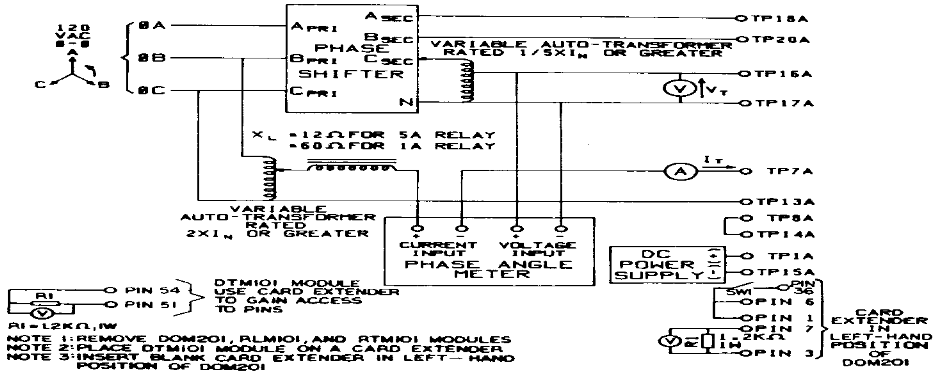


Figure 60 (0285A6615-1) Test Circuit for Post-Installation Tests of Pilot Schemes

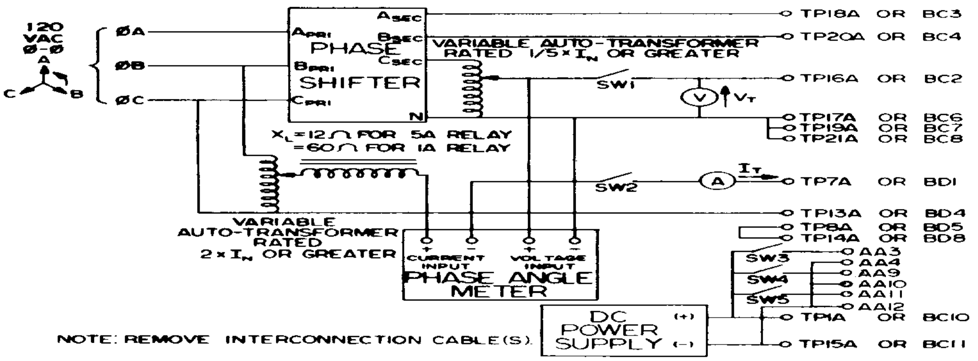


Figure 61 (0285A7576-0) Test Circuit for Auxiliary Functions Requiring Contact Inputs

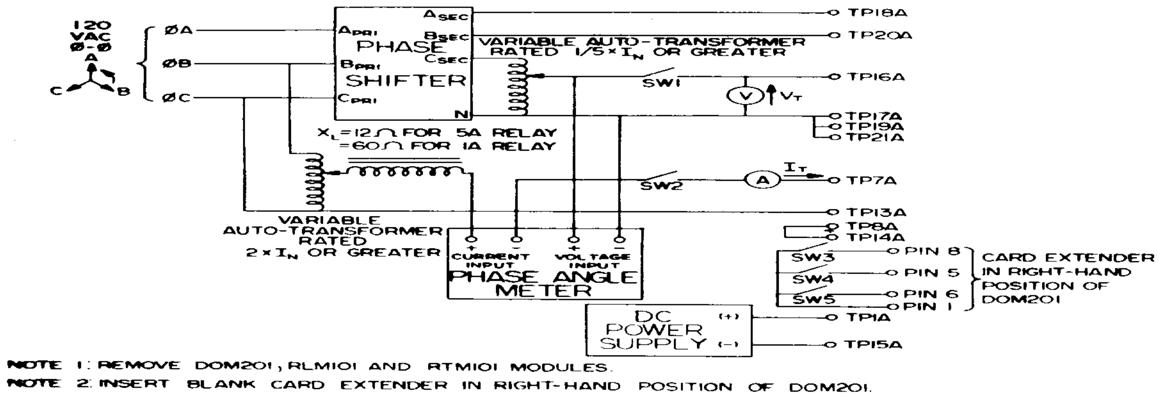


Figure 62 (0285A7575-0) Test Circuit for Post-Installation Tests of Auxiliary Functions Requiring Contact Inputs

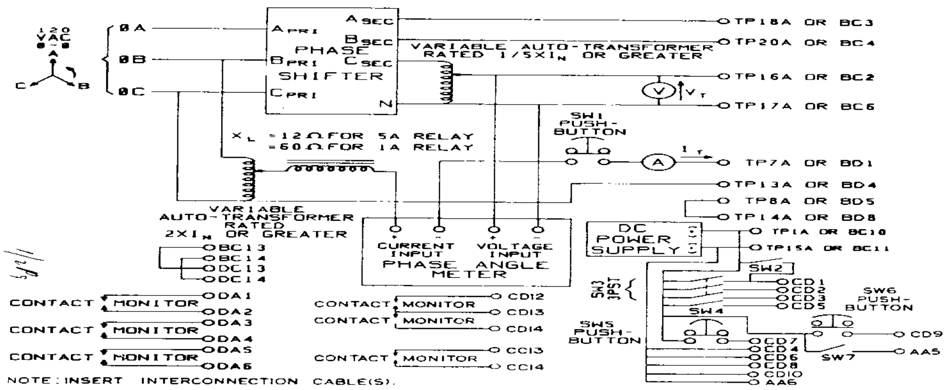


Figure 63 (0285A6614-1) Test Circuit for Reclosing Tests

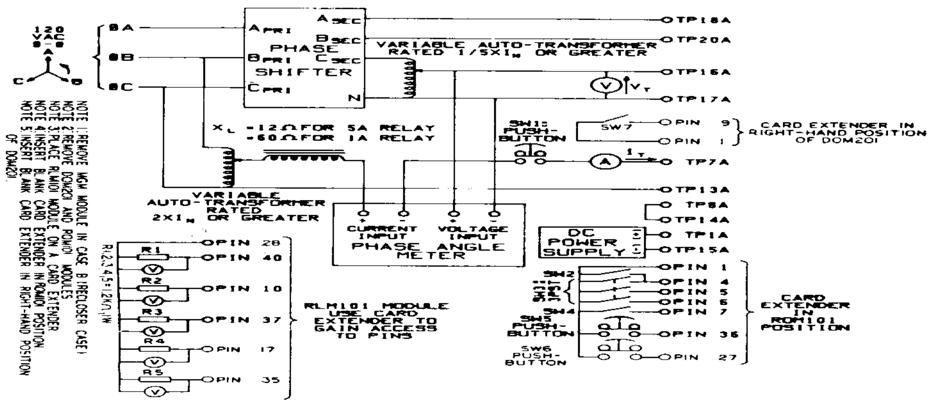
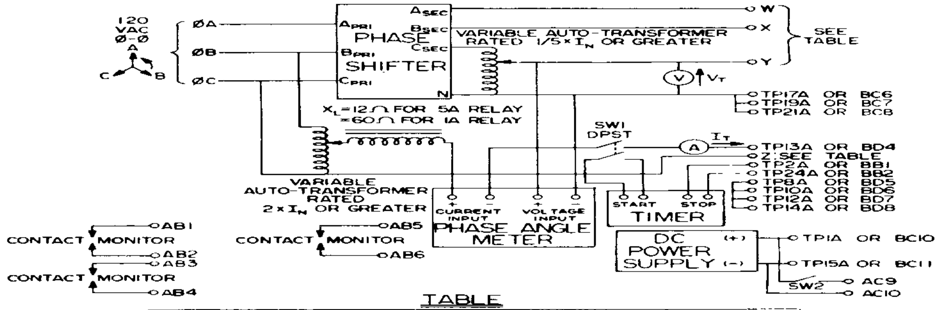


Figure 64 (0285A6616-1) Test Circuit for Post-Installation Reclosing Tests

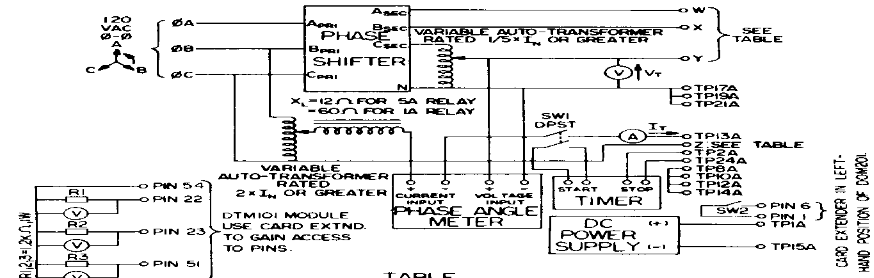


TABLE

PHASE UNDER TEST →	A	B	C
CONNECT 'W' TO TERMINAL	TP18A OR BC3	TP20A OR BC4	TP16A OR BC2
'X'	TP20A ↓ BC4	TP16A ↓ BC2	TP18A ↓ BC3
'Y'	TP16A ↓ BC2	TP18A ↓ BC3	TP20A ↓ BC4
CONNECT 'Z' TO TERMINAL	TP7A OR BD1	TP9A OR BD2	TP11A OR BD3

NOTE: INSERT INTERCONNECTION CABLES (3)

Figure 65 (0285A7569-0) Test Circuit for Directional Comparison Blocking and Zone 5 Tests



TABLE

PHASE UNDER TEST →	A	B	C
CONNECT 'W' TO TERMINAL	TP18A	TP20A	TP16A
'X'	TP20A	TP16A	TP18A
'Y'	TP16A	TP18A	TP20A
CONNECT 'Z' TO TERMINAL	TP7A	TP9A	TP11A

NOTE 1: REMOVE DOM201, RLM101 AND RTM101 MODULES.
NOTE 2: PLACE DTM101 MODULE ON A CARD EXTENDER.
NOTE 3: INSERT BLANK CARD EXTENDER IN LEFT-HAND POSITION OF DOM201.

Figure 66 (0285A7571-0) Test Circuit for Post-Installation Directional Comparison Blocking and Zone 5 Tests

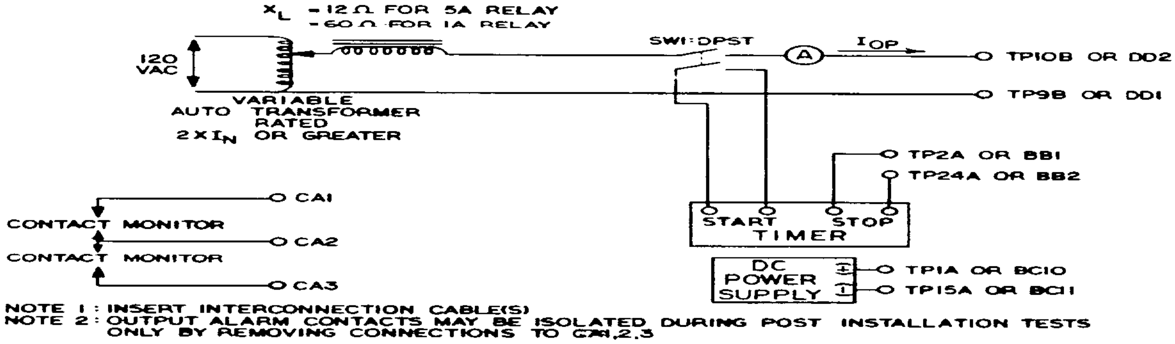


Figure 67 (0285A7578-0) Test Circuit for Non-Directional Ground Time Overcurrent Function

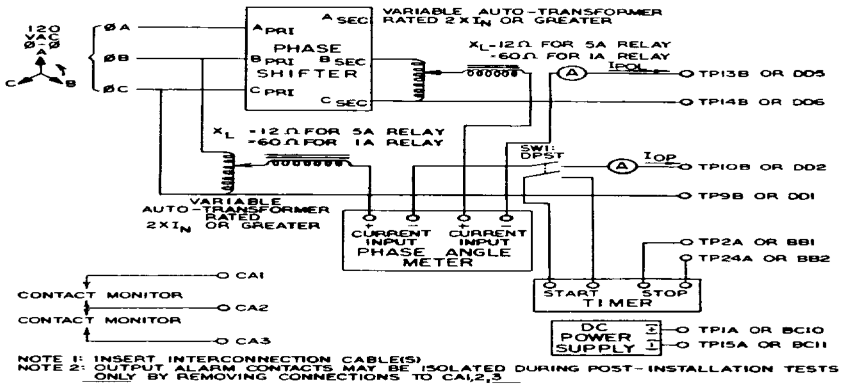


Figure 68 (0285A7568-0) Test Circuit for Directional Ground Time Overcurrent Function Using Current Polarization

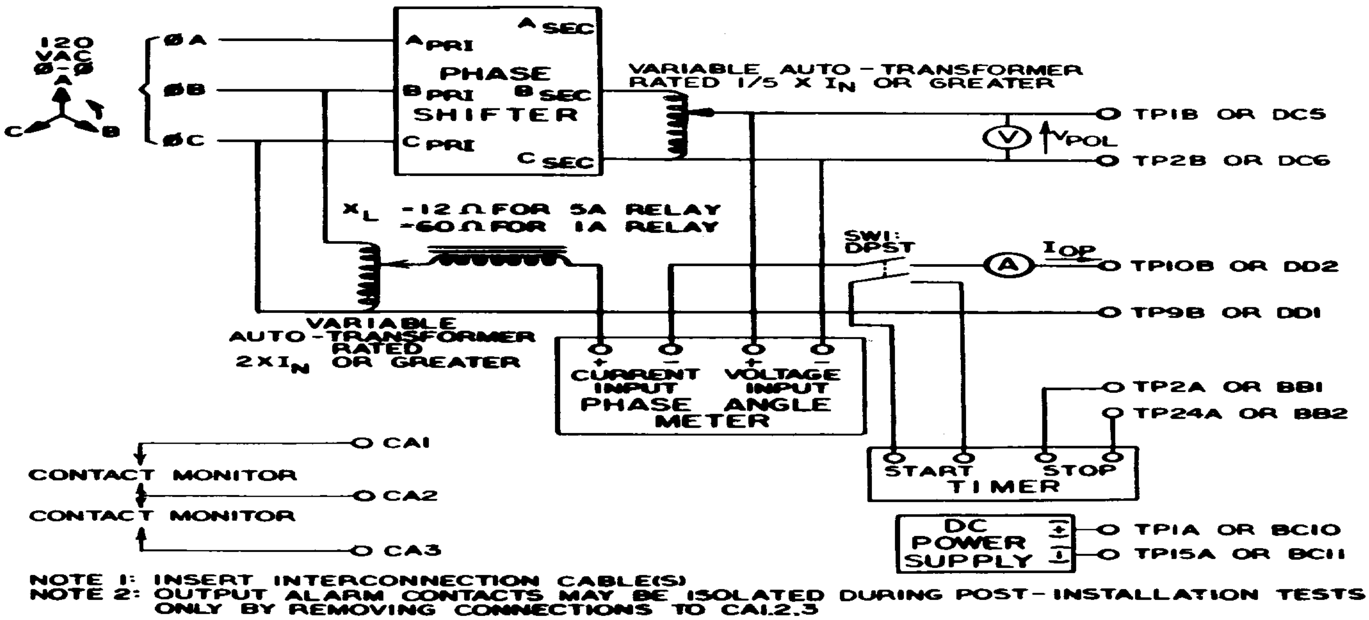


Figure 69 (0285A7572-0) Test Circuit for Directional Ground Time Overcurrent Function Using Voltage Polarization

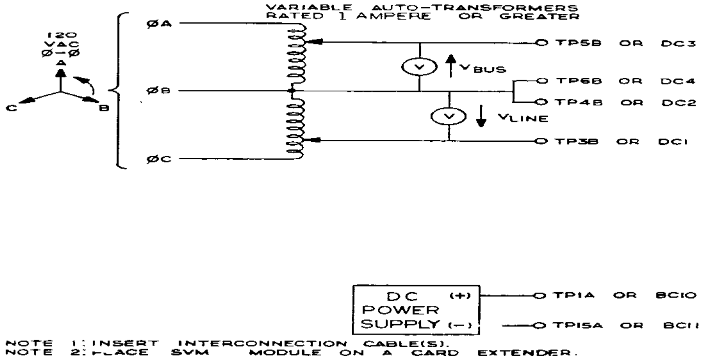


Figure 70 (0285A7581-2) Test Circuit for Synchronism Check Voltage Level Tests

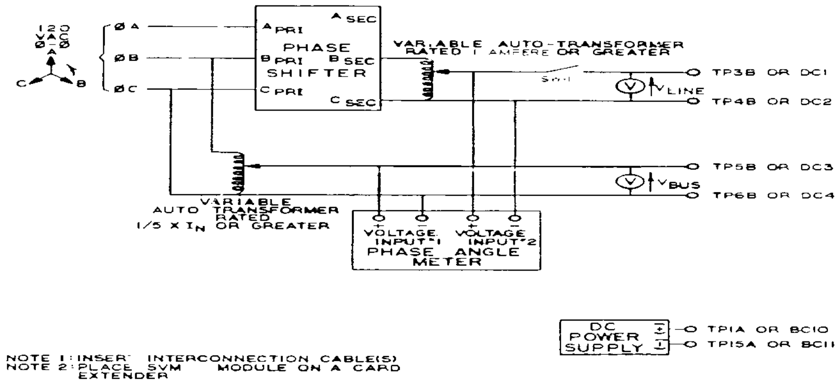


Figure 71 (0285A7580-2) Test Circuit for Synchronism Check Angle and Slip Tests

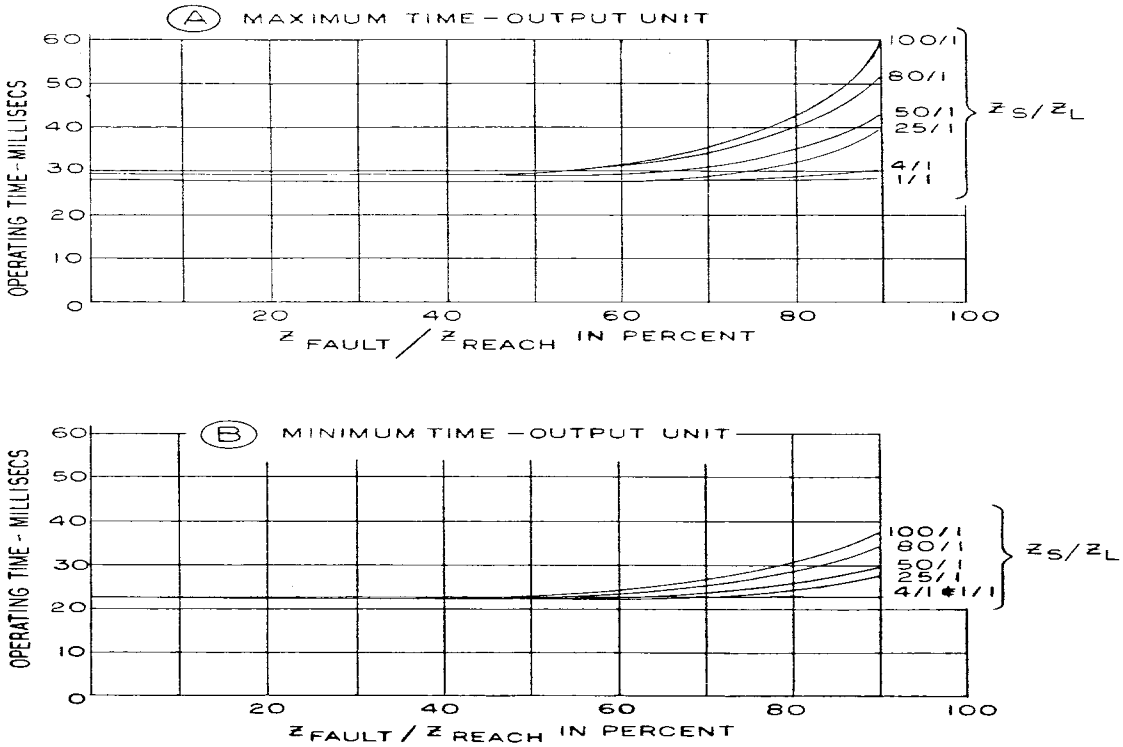


Figure 72 (0285A6680-1) Constant Z_S/Z_L Time Curves - Phase-to-Ground Faults

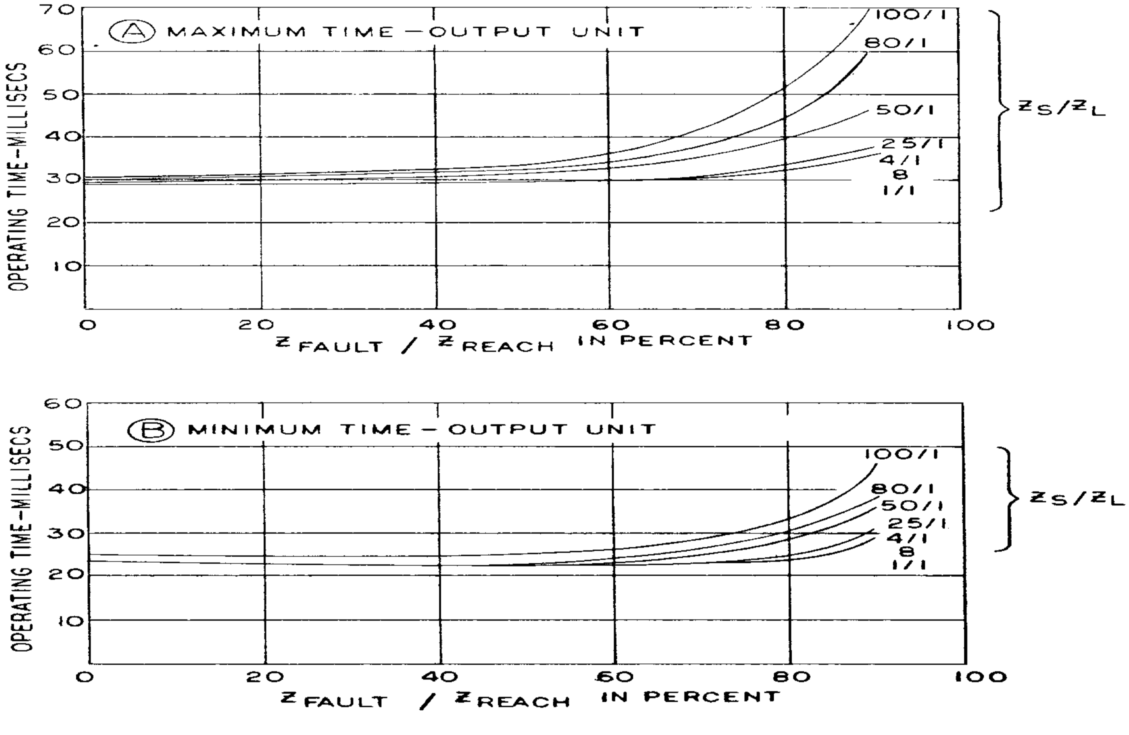


Figure 73 (0285A6683-1) Constant Z_S/Z_L Time Curves - Phase-to-Phase Faults

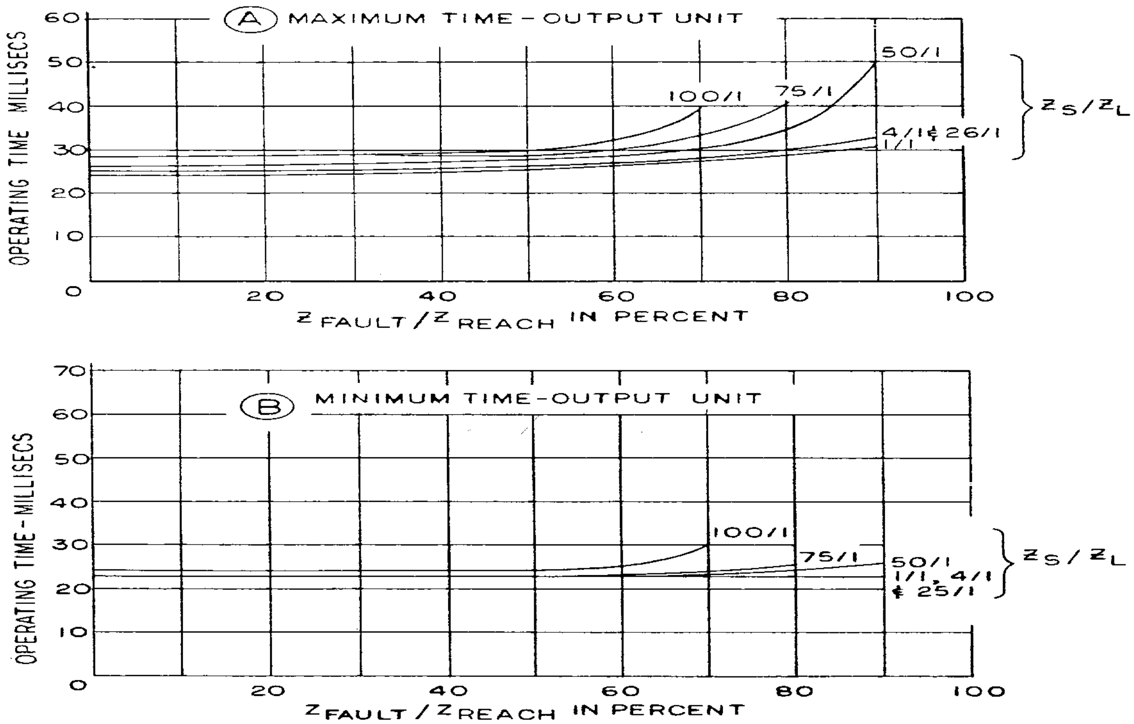


Figure 74 (0285A6681-1) Constant Z_S/Z_L Time Curves - Three Phase Faults

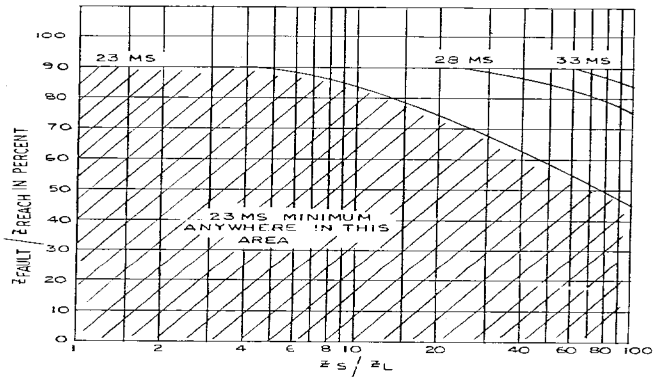


Figure 75 (0285A6682-1) Constant Time Operating Curves - Phase-to-Ground Faults (Minimum)

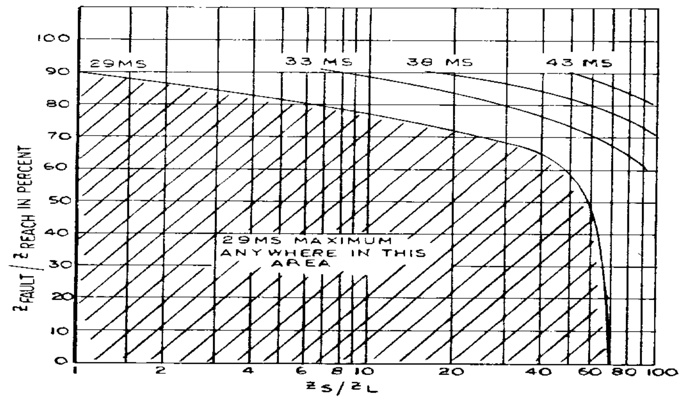


Figure 76 (0285A6684-1) Constant Time Operating Curves - Phase-to-Ground Faults (Maximum)

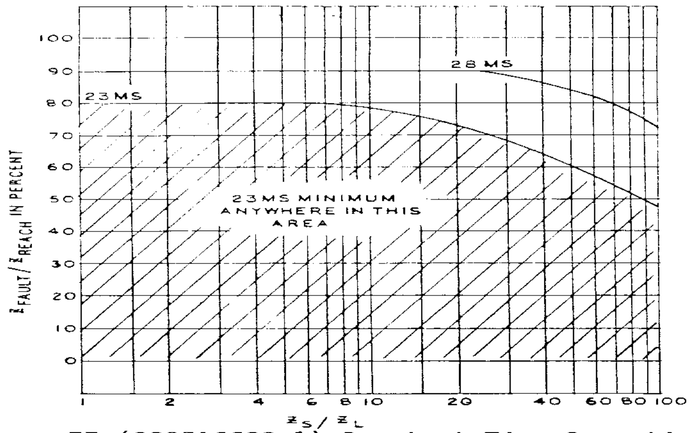


Figure 77 (0285A6688-1) Constant Time Operating Curves - Phase-to-Phase Faults (Minimum)

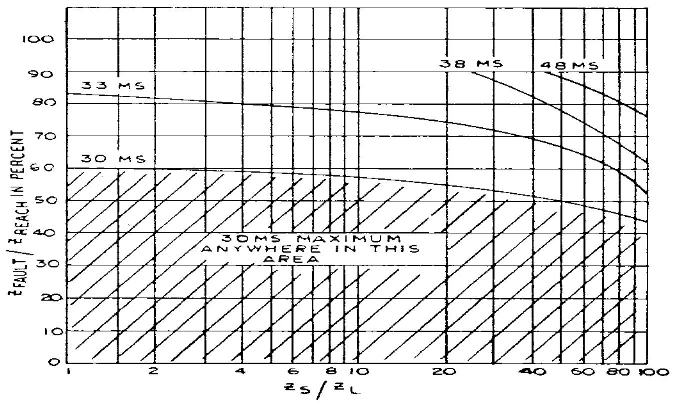


Figure 78 (0285A6686-1) Constant Time Operating Curves - Phase-to-Phase Faults (Maximum)

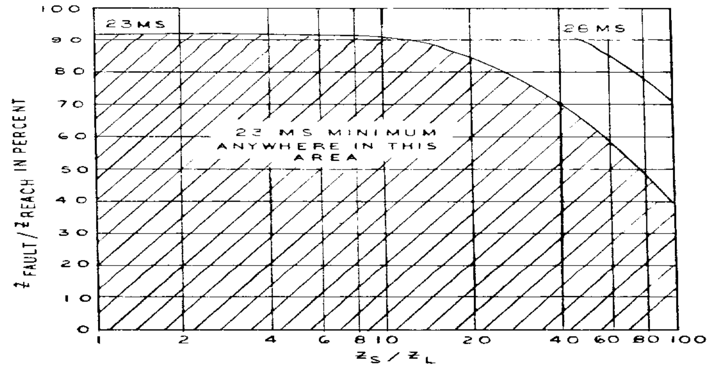


Figure 79 (0285A6685-1) Constant Time Operating Curves - Three Phase Faults (Minimum)

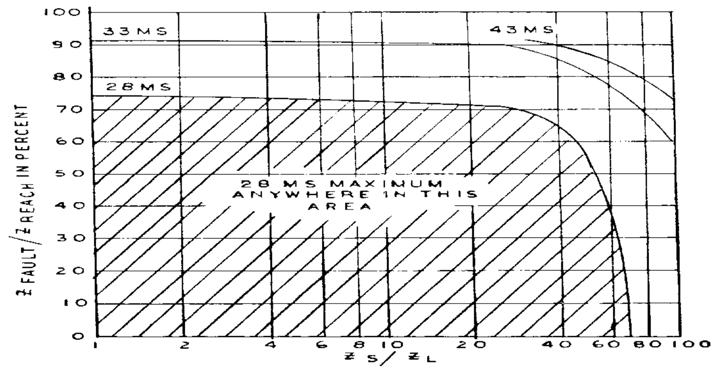


Figure 80 (0285A6687-1) Constant Time Operating Curves - Three Phase Faults (Maximum)

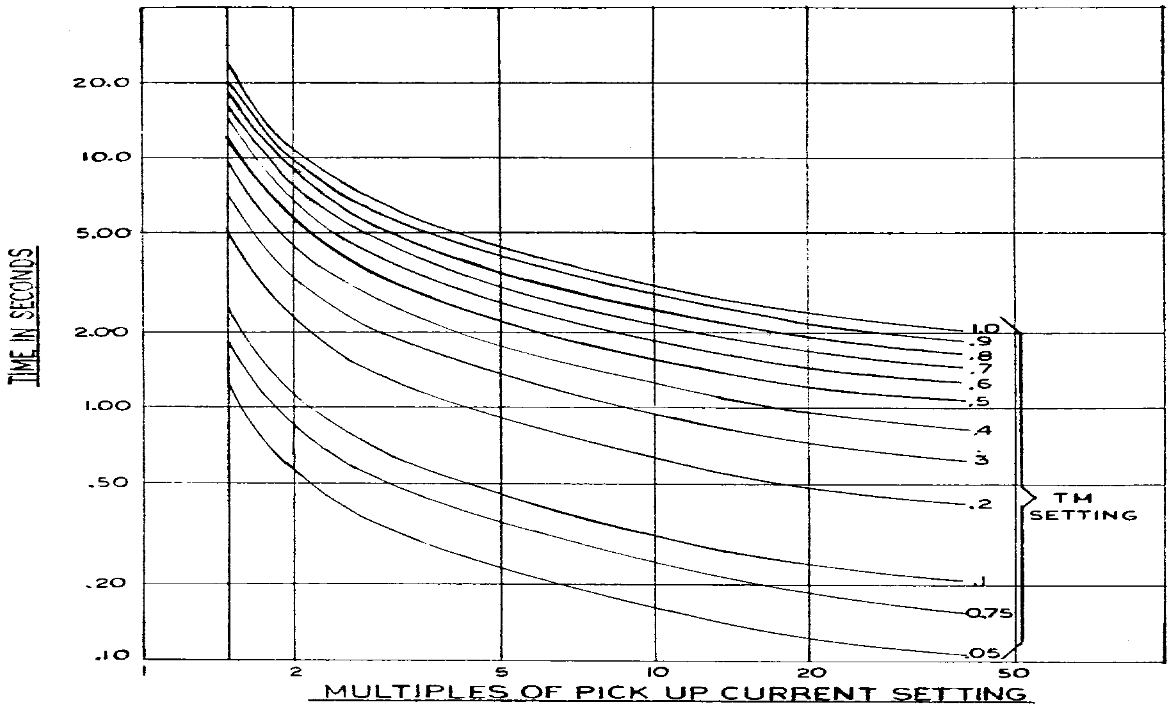


Figure 81 (0285A7557-0) Time Current Characteristics for SLS Ground Time Overcurrent Unit

NOTES:-

1. SLS10__A MODELS REQUIRE ONE(1) INTERCONNECTION CABLE (PL-1) BETWEEN THE CASES.
2. SLS11__A MODELS REQUIRE THREE(3) INTERCONNECTION CABLES (PL-1,2,3) BETWEEN THE CASES.
3. ALL MODELS ARE TRIPLE RATED FOR DC CONTROL VOLTAGE; 48V; 110-125V; 220-250V

LEGEND	
(A)	REFERS TO CASE "A"
(B)	REFERS TO CASE "B"
O AA THRU BD	TERMINAL BLOCK POINTS ON REAR OF CASE 'A' FOR EXTERNAL CONNECTIONS
O CA THRU DD	TERMINAL BLOCK POINTS ON REAR OF CASE 'B' FOR EXTERNAL CONNECTIONS
O CM	CURRENT CONNECTION POINTS MAGNETICS MODULE (MGM)
O PM	VOLTAGE & CONTACT CONNECTION POINTS MAGNETICS MODULE (MGM)
[illegible] TP	TEST RECEPTACLE CONNECTION POINT
BFI	BREAKER FAILURE INITIATION
CC-1	CONTACT CONVERTERS
TOC	TIME OVERCURRENT
POL	POLARIZING
↑	PRINTED CIRCUIT BOARD MODULE CONNECTION POINT

DISTANCE RELAY CASE-A
RECLOSER & OPTIONS CASE-B

MODEL NO. SLS10__A			STANDARD DISTANCE RELAY AND RECLOSER	OPTIONS *				
5A,120V 60HZ	5A,110V 50HZ	1A,110V 50HZ		SC	GTOC	LOL-1	LOL-2	DGTOC
01	02	03	X					
04	05	06	X	X				
07	08	09	X	X	X			
10	11	12	X	X		X		
13	14	15	X	X			X	
16	17	18	X	X	X	X		
19	20	21	X	X	X		X	
22	23	24	X	X				X
25	26	27	X	X		X		X
28	29	30	X	X			X	X
52	53	54	X		X			
55	56	57	X			X		
58	59	60	X				X	
61	62	63	X		X	X		
64	65	66	X		X		X	
67	68	69	X					X
70	71	72	X			X		X
73	74	75	X				X	X

MODEL NO. SLS11__A: SAME AS ABOVE PLUS DIRECTIONAL COMPARISON BLOCKING AND REVERSE ZONE 5 WITH TIMER

* OPTIONS:

- SC : SYNCHRUNISM CHECK
- GTOC : GROUND TIME OVERCURRENT, NON-DIRECTIONAL
- LOL-1 : LINE OVERLOAD, ONE SET POINT
- LOL-2 : LINE OVERLOAD, TWO SET POINTS
- DGTOC : DIRECTIONAL GROUND TIME OVERCURRENT

Figure 82A (0138B7593, Sh. 1, Rev. 6) Elementary Diagram - General Information

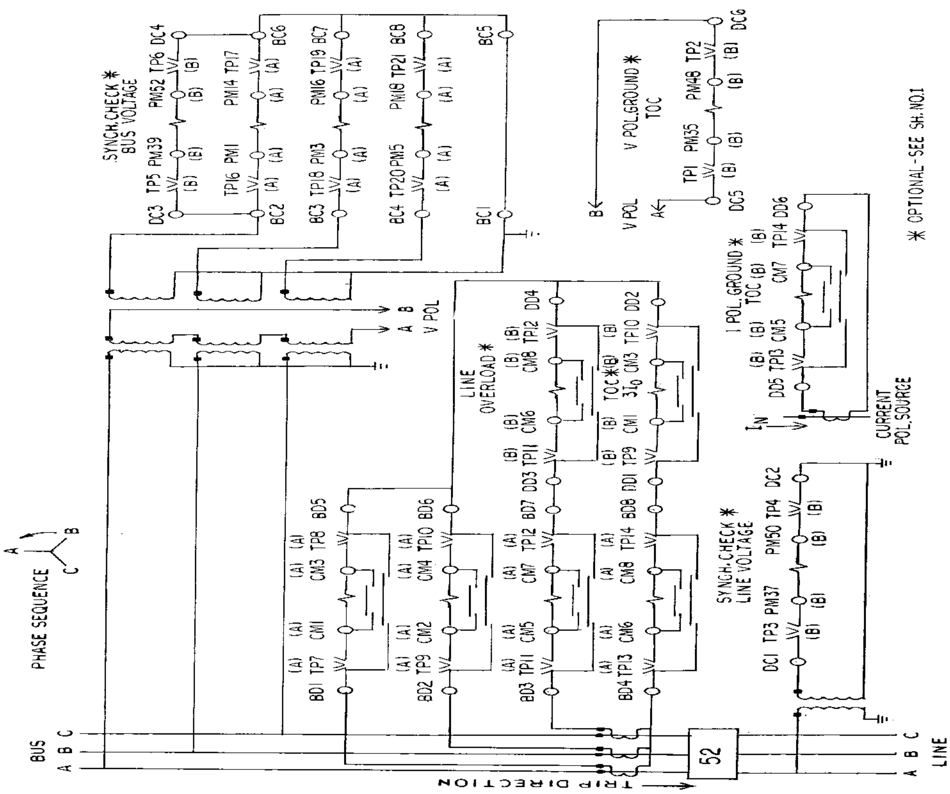


Figure 82B (0138B7593, Sh. 2, Rev. 6) Elementary Diagram - AC Connections

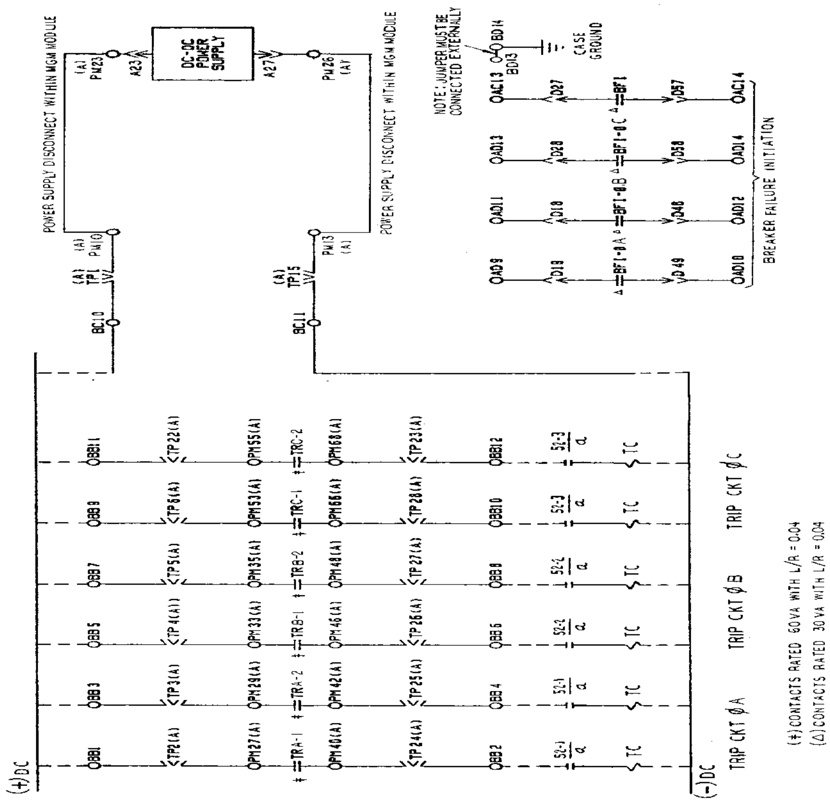


Figure 82C (0138B7593, Sh. 3, Rev. 5) Elementary Diagram - DC Connections

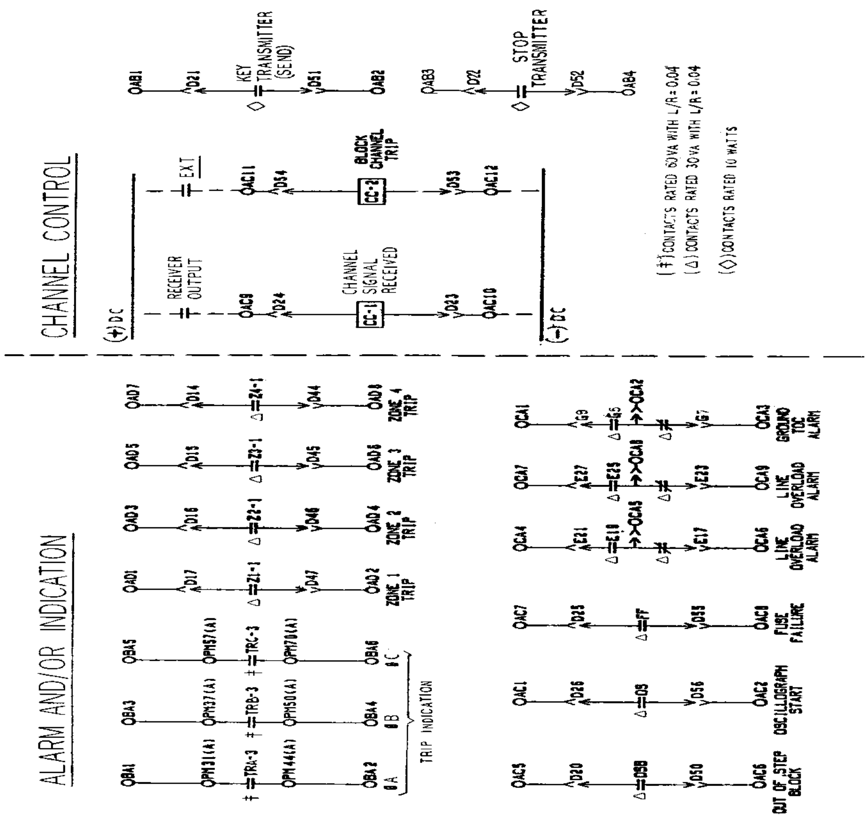


Figure 82D (0138B7593, Sh. 4, Rev. 4) Elementary Diagram - Alarm Indication and Channel Connections

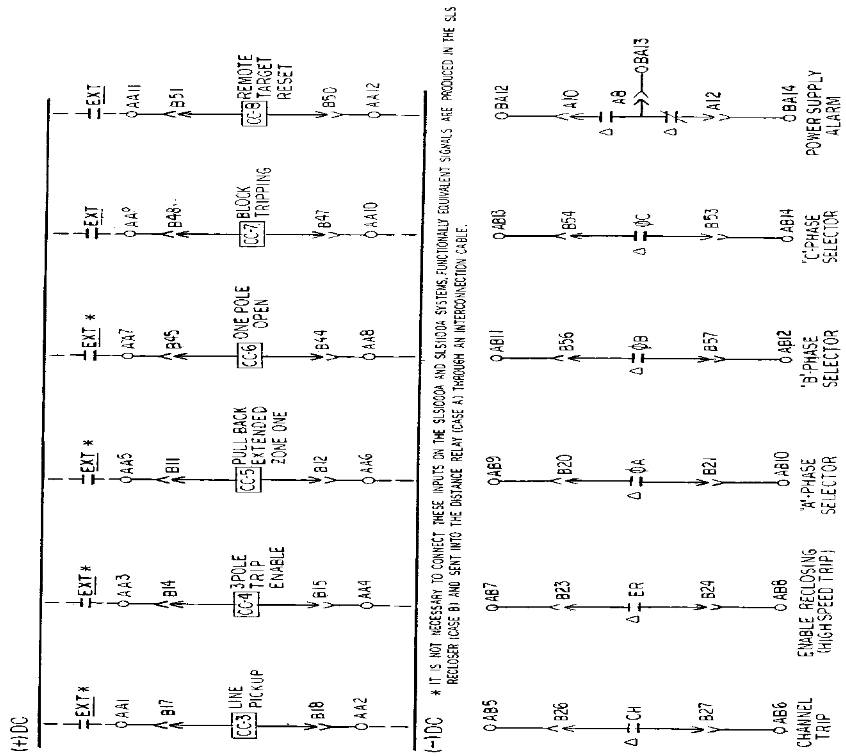


Figure 82E (0138B7593, Sh. 4A, Rev. 3) Elementary Diagram - Contact Converters and Auxiliary Contacts

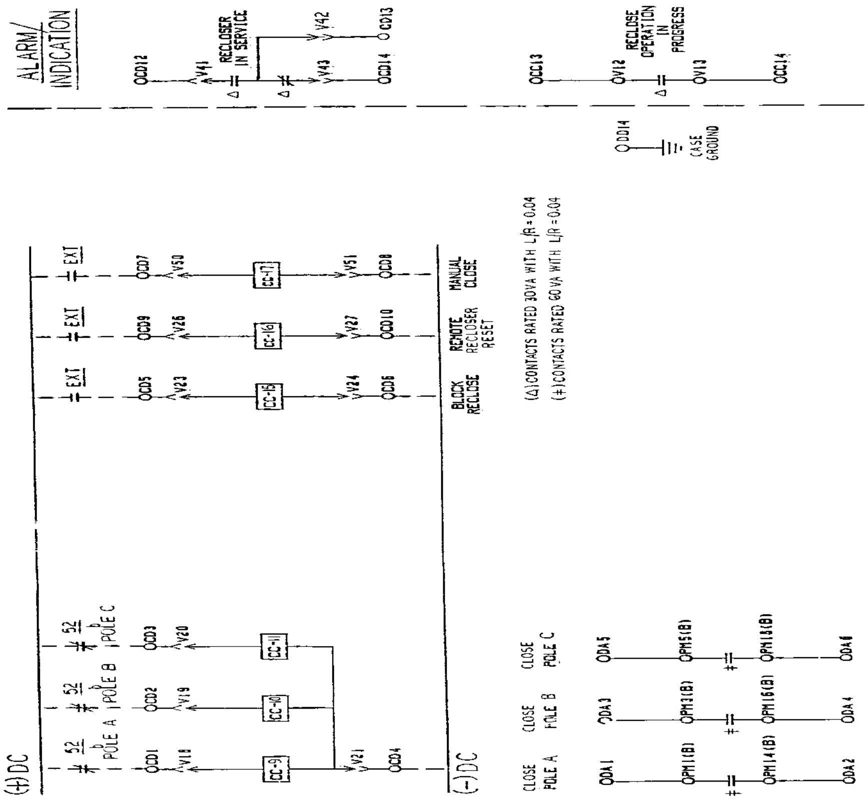


Figure 82F (0138B7593, Sh. 5, Rev. 6) Elementary Diagram - Recloser Connections

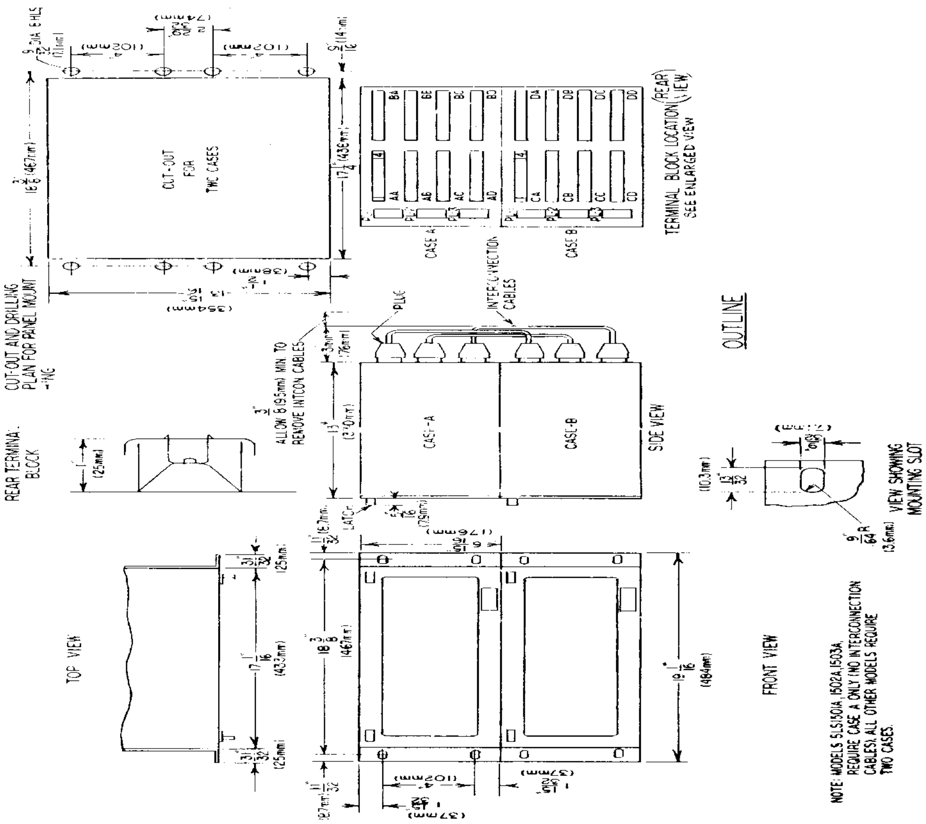


Figure 83 (0138B7600-3, Sh. 2) Outline and Mounting Dimensions for the Modular Relay System

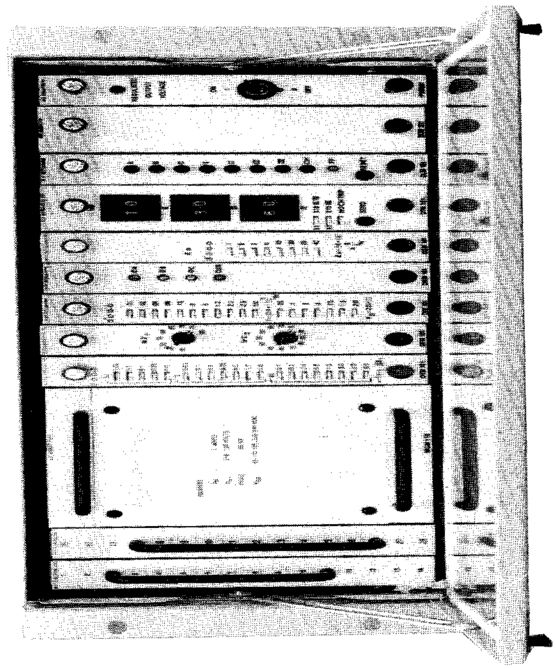


Figure 84A (8043764) Photograph - Distance Relay, Front View

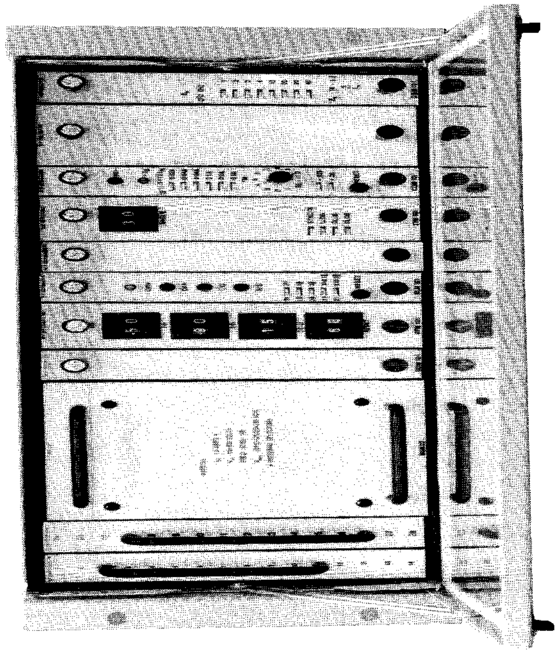


Figure 84B (8043765) Photograph - Recloser Relay, Front View

Meter and Control
Business Department

(9/89)

General Electric Company
205 Great Valley Parkway
Malvern, Pennsylvania 19355-071