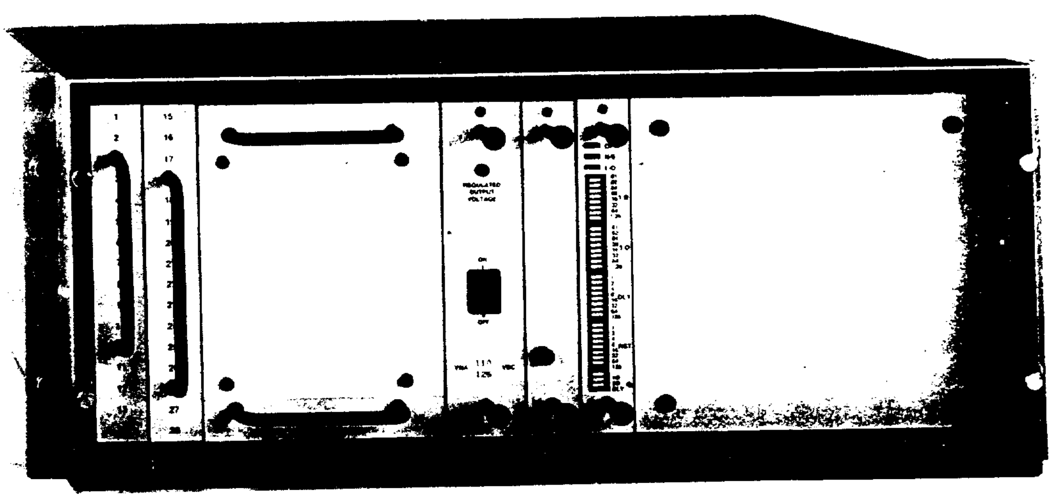
INSTRUCTIONS

GEK-90569

TRANSMISSION LINE RECLOSING SYSTEM

MRS2000



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INTRODUCTION

The MRS2000 is a single/three phase reclosing system with the capability of incorporating a synchronism check module as an option.

Optionally, the system can include a five digit reclose counter.

The MRS 2000 is a static design and incorporates a dc-dc converter as power supply, fed from the substation battery. It is of modular construction based on a set of plug-in modules and a magnetic module, also removable, which contains the main magnetic elements (transformers, telephone relays, etc.). Printed circuit boards and the magnetic module are contained in a 19" case.

Basic Characteristics

MRS2000 relays include the following basic characteristics:

* Single/three phase reclosing.
* Two shot reclosing, independently programmable.
* DC-DC converter as power supply.
* Test module.

Optional Characteristics

* Synchronism Check for Reclose Supervision.

  Line and bus voltage monitoring.
  Angle measurement.
  Slip measurement circuit.

* Electromechanical reclose counter (five digit).

Model List

Table I gives the Nomenclature Selection Guide based on the desired characteristics.

TABLE I

```
MRS 2 0 0 * A * * 0 * 0 0 B
          0   : : : :     :   WITHOUT SYNCHRONISM CHECK
          1   : : : :     :   WITH SYNCHRONISM CHECK
            0 : : :     :   WITHOUT RECLOSURE COUNTER
            1 : : :     :   WITH RECLOSURE COUNTER
              0 : :     :   50 Hz
              1 : :     :   60 Hz
                  A     :   48 VOLT DC
                  B     :   110/125 VOLT DC
                  C     :   220/250 VOLT DC
                        B   REVISION LEVEL
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PRINCIPLES OF OPERATION

Basic Automatic Reclosing

Automatic reclosing is initiated when the protection associated with the recloser gives a trip output and sends a single or three phase trip to the reclosing relay.

Let's consider the case of a single phase to ground fault. The protection relay gives an output that trips one of the poles of the breaker and sends a single phase trip signal (IR1) to the recloser. This initiates the single phase reclose timer. When the timer has elapsed, it gives a reclose output.

If the fault persists, the protection will trip the breaker again. In this case the trip will be three phase because at the beginning of its cycle the recloser will have sent a three phase trip signal to the protection relay.

The reclosure initiate signal will correspond to a three phase trip (IR3), which will activate a second timer (timed reclosure timer). When the recloser finishes timing, it will give a new reclosure output.

If the fault is still present, the protection will trip the breaker a third time (three pole).

The recloser will remain in a blocked state, prohibiting further reclose attempts.

The recloser functions initially in a three phase mode for polyphase faults. A separate three phase reclose timer exists for this case. The second shot is always three phase and therefore there is only one setting for the second reclose timer.

The logic diagram and associated description for the recloser (See the Section titled Logic Description) provides a detailed description of the operation of the recloser. A Synchronism Check module can be included to supervise reclosing, as an option.

Manual Reclosure

When a manual close order is given, operation of the recloser is inhibited for the period of time corresponding to the setting of the reset timer.

LOGIC DESCRIPTION

The MRS2000 recloser operates in accordance with the block diagram of Figure 1. The diagram is a functional representation, not directly related to the actual circuitry.

The recloser can function in one of the following modes:

1. One shot reclose, single or three phase, depending on the trip.
2. One shot reclosure, single phase only.
3. One shot reclosure, three phase only.
4. Two shot reclosure, single or three phase for the first, and three phase for the second.
5. Two shot reclosure, both three phase.
6. Two shot reclosure for a single phase initiation and one shot reclosure for a three phase inititiation.

Table III shows the reclose programs that can be performed with the MRS 2000 (eight altogether).

We will begin the discussion with the fourth mode because it involves all the recloser circuitry. Following this, the other modes will be described.

The reclosure cycle begins automatically when the protection associated with the recloser produces a trip and generates a reclose initiate signal: IR1 if the trip has been single phase and IR3 if the trip has been three phase.

First Reclosure Attempt Following a Single Phase Trip

Let's consider the case of a phase A to ground fault resulting in a single phase trip. The recloser receives a signal IR1 that provides the third input to AND1. The first input will be satisfied since the selector switch MONO (Single Phase Reclosure Selected) is closed. The second input will also be satisfied, through NOT1, since the signal BR (Block Reclose) will be inactive. The signal BR will be activated whenever the reclosure initiate cycle is not wanted; for example whenever the trip corresponds to a fault in a protection zone where a reclosure is unwanted. Finally, the lower input to AND1 will be satisfied, through NOT5, because the flip-flop L6 (recloser not blocked) will be at zero.

The output of AND1 is transformed to a pulse P1 (Edge Detector) and activates the flip-flop L1, providing the upper input to AND8 and since we're dealing with the first trip and the sequencer is found in state "1", the output to AND8 is activated.

Activation of L1, through OR3, causes LED OPN to light, indicating that the breaker is open and initiating the timer TL5 (40 milliseconds). At the end of the count, the output for timer TL5 activates flip-flop L4 which, through OR22, activates the signal 3PT (three pole trip enable).

This signal is sent to the protection which caused the trip with the objective that from this point on, all trips will be three pole. The function of timer TL5 is to delay the activation of signal 3PT sufficient time for the breaker to open and to reset the trip which initiated the cycle. The activation of signal 3PT before the trip resets would transform the trip into three pole.

The output of AND8 initiates a single pole reclosure timer TL1a which, after the set time, provides an output pulse which, through OR6, activates the lower input to AND5. Let's suppose that the HOLD link, whose function is described later, is in the OUT position and, therefore, activates the upper input to AND5. The output of AND5, through OR8, is applied over the upper input to AND11.

The output of AND9 will be inactive, since the trip has not been three phase, and therefore the output of AND3 will also be inactive, activating NOT9 and through it, the lower input of AND11. The output of AND11 activates timer TL4 and through it, the output of reclosure

RCL. This output is maintained active for the time setting of the maintain timer TL4. In the same way, the output of AND11, through OR21, initiates a reset timer TL3 and a timer TL6, that produces a pulse of 128 milliseconds in the output COFD to activate the reclosure counter (optional).

The final reclosure time pulse, originating in the output of OR6, puts the flip-flop L9 to "one" which, through OR13, activates output PBZ1X. This output is sent to the protection relay with the objective that, after the first reclosure attempt, to return the zone one extension to its normal reach for subsequent trips (if the protection relay is operating in a zone one extension protection scheme). If the protection relay is operating in a logic scheme different than zone one extension, the signal PBZ1X will have no effect on the relay.

Reclosure output RCL resets flip-flop L1 through input R, leaving the system prepared to receive a new initiate input. In the same manner, the input CL of the sequencer can cause the sequencer to advance a state.

Second Reclose Attempt Following a Single Phase Fault

If before a new trip occurs, the timer TL3 completes its count, the sequencer is reset through OR4, as is signal 3PT through OR9 and OR10 and signal PBZ1X through OR9, such that the recloser remains in a reset state.

Let's suppose that after the first reclosure attempt, the fault persists and the protection trips again before the reset timer TL3 completes its count. The new trip will be three phase because the recloser will have sent signal 3PT to the protection relay as a consequence of the first reclosure initiate.

We suppose that the three pole reclosure selector switch (selector TRI) is found activated and therefore the upper input to AND2 will be active. If the trip is a new one in the first zone, signal BR will be inactive and, through NOT1, the second input to AND2 is activated. Since the recloser is not blocked by the activation of L6, the fourth input of AND2 will be present. Therefore, activation of the three phase initiate signal, IR3, causes an output of AND2 which, converted to a pulse in P2, activates the flip-flop L2, and through OR3, lights LED OPN again. The sequencer will be in state 2 and will therefore activate the output of AND10, and the reclosure timer TL1c will be initiated. The sequence of events that follows is the same as for the case of the first reclosure. Upon activation of output RCL, the sequencer advances to state 3 activating the upper input to AND4.

If the fault persists, the protection will trip again three phase. This time, since the sequencer is in state 3, output OR3 will activate the output of AND4, which, through OR5 and OR17, activates flip-flop L6, lighting the LED L/O indication of a blocked recloser due to permanent fault. Output L6 activates the exterior output LOCKOUT to close an alarm contact and contacts to maintain OR22 and OR13, and 3PT and PBZ1X respectively.

The reclosure blocked output resets the following flip-flops and timers:

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

Moreover, through NOT5, gates AND1 and AND2 are disabled, blocking the reactivation of the recloser by new initiate inputs.

First Reclosure Attempt Following a Multiphase Fault

Let's consider the case of a two phase or a three phase fault. The distance relay will trip three phase and will send the signal IR3 to the recloser which, through AND2, P2 and L2, will activate the upper input of AND9. Since this is the first trip, the sequencer is in state 1, AND9 will give an output that will initiate the three phase recloser timer TL1b. The sequence of events that follows in series is the same as that for first single phase reclose attempt described above; equal to that case which activates the outputs 3PT and PBZ1X.

Second Reclose Attempt Following a Multiphase Fault

The second reclosure attempt following a two phase or three phase fault will be identical to the second reclosure attempt following a single phase fault. Again, the recloser will be in the blocked state after the third trip.

Single Shot Reclosure Attempt

The second reclosure attempt can be eliminated by closing the selector switch named NO-TEMP. In this case when the first reclose attempt is produced, the sequencer passes to state 2. The activation of this state will produce, through the selector NO-TEMP and OR19 a new clock pulse on the sequencer which will take it to state 3, thereby leading the recloser to a blocked state with the following trip.

Single Phase Reclose only

The recloser can be placed in this mode by opening the switch TR1 and closing the switch MONO. With the switches in these positions, reclosings can only be initiated by activating the input IR1 (single phase trip) since the AND2 gate will be blocked because the switch TR1 is open.

It should be noted that in this mode a single reclosure attempt will only be produced because the second trip, as we have seen, will always be three phase and the corresponding reclosure attempt will be blocked in AND2.

Three Phase Reclose only

For the recloser to function in this mode, switch TR1 has to be closed, and switch MONO has to be open. With the switches in these positions, output 3PT will be activated through NOT2 and OR22, so all trips will be three phase; and therefore only signal IR3 will be activated by a three phase reclose initiate. In this case, the recloser will perform the two reclose attempts, assuming the switch NO-TEMP is open.

One or Two Shot Reclosing Depending On The Reclose Initiation.

This feature was added for B revision level of MRS, and thus, is not available in A revision models. It allows, using a new setting SW-9 in the recloser module RLM, the selection of new reclosing scheme number 9 (table III, page 33).

When SW-9 is in IN position, and there is a three phase reclose initiation through IR3, flip-flop L11 is activated through OR25, producing a logic "0" in the output of L11 (and middle input of AND10), that eliminates the possibility of second reclose for a three phase initiation.

For a single phase initiation (IR1), the output of L11 is set to a logic "1", and the relay will permit one or two shot reclosing depending on the position of NO-DLY switch.

Manual Close

Activation of the contact converter CC5 activates the flip-flop L10 through AND13, and initiates the reset timer through AND13 and OR21. In the same way it resets the flip-flops:

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

The output of flip-flop L10 activates the lower input of AND14. If a trip is produced before the reset timer completes its count, the output of OR3 is activated and block the recloser , through AND4, OR5, and OR17.

If the reset timer completes its count before a trip is produced, the output of flip-flop L10 will respond and the recloser will remain in the reset position.

Behaviour of the MRS2000 Relay For Evolving Faults

Evolving faults constitute a frequent problem for transmission lines, that is, a single phase fault which evolves to a multi-phase fault in an interval of time during which one pole of the breaker is open, awaiting the signal to reclose. The relay will permit the reclosure, depending on whether a three pole reclosure is or is not programmed.

a) Three Pole Reclosure Not Programmed

In these conditions, upon the occurrence of a single phase fault, the distance relay sends the recloser a signal of single pole reclosure initiate. In the MRS2000, the single pole recloser timer is activated through AND1, L1, and AND8. In this situation, if the fault evolves and affects one of the other phases, the trip will be transformed to a three pole trip and the recloser will be sent a new reclosure initiate, this time three pole. This new Reclosure Initiate, through OR25 and OR30, will reset flip-flop L1, interrupting the count of the single pole reclosure timer.

b) Three Phase Reclosure Programmed

In this case, like the previous, if the fault evolves to a multiphase fault, the trip from the distance relay will transform into a three pole trip, and a new initiate will reset flip-flop L1 through OR25 and OR30, interrupting the count of the single pole reclosure timer. However, in this case, with the upper input to AND2 activated by being programmed for three phase reclosure, actuation of P2 and L2 is produced and the three phase reclosure timer is activated via AND9.

Synchronism Check Supervision

MRS systems have synchronism check as an option. When the voltages on the two sides of the breaker are out of synchronism, the supervision circuit gives an output which is applied to the input SYNC of the recloser activating the lower input of AND3. The upper input of AND3 is only activated when the reclosure initiate has been three phase (output of AND9 active). Assuming that the trip has been three phase, the output of AND3 will activate, blocking AND11 through NOT9, and inhibiting reclosure.

The link HOLD is utilized when a reclosure is desired if the blocking disappears during the time set for TL2 (the same time as that set for the reset timer). The timer TL2 is initiated when OR6 is activated at the end of the reclosure time. The output of OR6 activates flip-flop L5, which keeps the upper input of AND7 active.

If the link HOLD is in the OUT position, the center input of AND7 will be active. If synchronism doesn't exist, the lower input of AND7 will be active and whenever the output of OR6 activates flip-flop L5, the output of AND7 and flip-flop L8 will be activated, through OR11. Flip-flop L5 lights LED N/S, indicating that a reclosure attempt has existed, blocked by lack of synchronism, and activating reclosure blocked flip-flop L6.

If the link HOLD were IN, the center input of AND7 would be missing, and flip-flops L8 and L6 would not be activated. Nonetheless, if timer TL2 were to finish its count before the lack of synchronism condition disappeared, it would give an output that would activate L8 through OR11. If before TL2 finished, the SYNC input deactivates, indicating the presence of synchronism, a reclosure order would be generated through AND6 (L5 is activated and the link HOLD is IN), OR8 and AND11 (whose lower input would remain unblocked upon the deactivation of the input SYNC). The reclosure output resets timer TL2 through OR28.

External Blocking of the Recloser

The recloser can be externally blocked through the contact converter CC4. When this contact is active, both gates AND1 and AND2 are blocked, through NOT1 and no initiate input signal is permitted.

Contact CC4 also blocks the input of manual close signals, through OR23, NOT1 and AND15.

The purpose of the block input is to coordinate the recloser with the protection, such that reclosures are only permitted for first zone faults.

If one wishes to use this input as an external recloser blocking, the corresponding protection relay inputs, "THREE POLE TRIP" and "RETRACTION OF ZONE ONE EXTENSION", which correspond to a blocked recloser, should be applied simultaneously.

Recloser Out of Service

The recloser can be taken out of service by opening switches MONO and TR1. When this occurs, gates AND1 and AND2, as well as AND13, are blocked, in exactly the same way as if they were blocked externally. In the out of service state, a series of indications are activated which are not active with an external block:

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

INPUTS AND OUTPUTS

Recloser Inputs

The signals that control the reclosure cycle access the logic through contact converters which serve the dual purpose of galvanically insulating the internal logic from the external system and of adjusting the voltage levels of the external signals to that appropriate for electronic circuitry.

The details of the input signals are as follows:

-IR1.-	Corresponds to contact converter CC1. It is the single pole reclose initiate signal.
-IR3.-	Corresponds to contact converter CC2. It is the three pole reclose initiate signal.
-BR .-	Corresponds to contact converter CC4. It is the block recloser signal.

-CM .- Corresponds to contact converter CC5. It is the manual close information signal.

-RR .- Corresponds to contact converter CC6. It is the remote recloser reset signal.

Recloser Outputs

The output contacts of the MRS2000 correspond to the following functions:

Reclosure Command:

Three normally open contacts which are activated during the programmed Close Time at the moment the reclosure command is given.

Three Pole Trip Protection Enable:

A normally open contact which is activated when the state of the recloser is such that the following trip is not going to be reclosed, or it will be three phase reclosed. Activation of this signal is used to force the associated protection to trip three phase for all fault types.

Recloser Out of Service:

A contact which is active when all reclosures have been deprogrammed.

Recloser Blocked (Lock Out):

A normally open contact which is active either because the recloser has performed a complete cycle and has remained in a blocked state (lock out) due to a permanent fault, or due to a lack of synchronism conditions.

Retraction of Zone One Extension

A normally open contact which is active after the recloser has given its first reclosure command within a cycle. This signal is used to retract the zone 1 extension of the associated protection, after the first trip, in the case where the protection is operating in a zone 1 extension scheme.

Power Supply in Service

A form "C" contact which changes state when the power supply is turned on.

Visual Indications

The MRS2000 has the following front view, visual indicators available:

Power Supply In Service:

Green LED diode, located on the front of the PSM module.

OPN:

Amber LED diode, located on the front of the RLM module, lights the moment a trip signal is received from the protection and goes out when the recloser activates the reclosure output.

N/S:

Red LED diode, located on the front of the RLM module, lights when the recloser remains blocked (Lock Out) due to lack of synchronism.

L/O:

Red LED diode, located on the front of the RLM module, lights when the recloser reaches the blocked state (Lock Out), either because the fault is permanent, or due to lack of synchronism.

SYNCHRONISM CHECK OPERATION
(Optional)

General

Figure 2 is a combination of logic and block diagram of the synchronism function assembly. Bus and line voltages are reduced to voltage levels compatible with the electronic circuitry through voltage transformers located on the relay's magnetic module. The rest of the circuitry represented in Figure 2 is found on the SVM module.

Line voltage is applied to two detectors: one of presence and one of absence of voltage respectively; each one of these compares the voltage to a preset value. The presence of voltage detector gives an output when the input exceeds the threshold and the absence of voltage detector gives an output when the level is below the threshold. In other words, these circuits produce outputs when conditions are desirable for reclosure. Bus voltage is sent to another two detectors of presence and absence of voltage in the same manner.

In addition to being sent to the voltage detectors, bus and line voltages are also sent to:

1) A combined fast detector of phase angle and slip.

2) A slow slip detector.

These detectors, in contrast with those of voltage, give an output when conditions are not appropriate for reclosure, for example when:

1) The phase angle is outside the limits or the slip frequency exceeds the setting of the fast slip detector.

2) The slip frequency is above the setting of the slow slip detector.

The mode of supervision is selected by closing the appropriate microswitches. More than one microswitch can be closed simultaneously in order to obtain a combination of functions.

Let's consider the case of a reclosure under conditions of absence of line and bus voltage. Closing the microswitch DLDB, we enable AND1 while AND2, 3, and 4 remain disabled. In order for AND1 to produce an output, both bus and line voltage detectors need to give an output, indicating that both bus and line voltages are registered as absent.

In this mode, an output of AND1 constitutes the "Permission to Reclose" signal through OR2. Its absence gives rise to block reclosure . Modes DLLB and LLDB operate in a similar form through AND2 and AND3 respectively. In the synchronism check mode (microswitch SYNC CK closed), an output of AND4 is required to permit a reclosure. This occurs only when:

1) There is voltage at the bus and the line, and

2) There is no output coming from the fast phase angle and slip detector nor from the slow slip detector. An output from either one of these detectors blocks reclosure and disables AND4 in its input NOT (via OR1).

fast Phase Angle and Slip Detectors

The fast phase angle and slip detectors are shown in Figure 3. Bus and line voltages are applied to a non-coincidence logic circuit which gives a positive output only when the instantaneous voltages are of the opposite polarity. The output of this circuit, (in the form of waveform A) which can be considered as a pulse train whose width is equal to the angular separation ø (phase angle) between bus and line voltages.

Afterwards the output of the non-coincidence circuit is applied to the angle timer, which gives an output only when the width of the pulses is greater than the set value, θ. The output of the timer consists of a pulse (in the form of waveform B) each time the time set for the timer transpires.

$$\text{Angle Time Setting} = \frac{\theta}{360\text{deg}} \times \frac{1}{f} \text{ seconds}$$

where f is the rated frequency of the system (50 or 60 Hz)

The pulse output of the timer sets flip-flop FF1 to a "1", giving rise to continuous "Block Reclosure" signal (of the form of waveform D).The pulse initiates the fast slip timer; this timer gives an output only when the time THS is over before the next pulse arrives, since the succession of pulses resets and reinitiates the timer continuously.

$$THS = \frac{1}{FHS} \times \frac{2x\theta}{360deg}$$

Where FHS is the threshold setting of the fast slip detector.

Due to the coupling between the angle setting and fast slip timer, the angle setting can be varied without modifying the setting FHS.

The output of the fast slip timer (in the form of waveform C) resets FF1 and permits reclosure.

Let's consider the example where bus and line voltages have exactly the same frequency (no slip exists) and an angular separation ∅ between them is greater than the setting θ. The waveforms which result are shown in Figure 3-1. The point to the left of each waveform indicates the time reference.

The output of the fast slip timer (in the form of waveform C) is continuously inactive since the pulse train output of the angle timer (in the form of waveform B) continuously resets and reinitializes the slip timer, not allowing it to time out and issue an output. Therefore FF1 is set to "1" and never resets, giving rise to a "Block Reclosing" output as is shown in the form of waveform D.

If ∅ is less than θ, the forms of waveforms B, C, and D will be at value "0" continuously.

Let's now consider the case in which the frequency difference between the two voltages is less than the setting of the fast slip detector, FHS. The waveforms are illustrated in Figure 3-2. Eleven cycles of VL are shown in the same time interval (one complete slip cycle), as 12 cycles of VB (90 degrees to 90 degrees). The labels over the VB waveform and around the circle indicate the degrees of slip. If one assumes that waveform VB is 50 Hz, waveform VL is 11/12 times 50, or 45.8 Hz and the slip velocity is 50 - 45.8 = 4.2 Hz.

Initially the voltages have been drawn as 90 degrees displaced (VL lagging with respect to VB). The width of the output blocks of the non-coincidence circuit varies as the angular separation between the two voltages vary during the slip cycle.

The angle timer measures the width of the blocks and gives a pulse when the width is greater than the set value. As the angular separation increases, the width of the blocks can be two or more times the set angle, in which case the circuit will issue two or more pulses. For example, if the angle is set at 35 degrees, the maximum width of the non-coincidence pulse during the slip cycle (180 degrees) is 180/35 = 5.14 times the setting, and thus, the timer will give five consecutive pulses (only the integer part).

The part of the cycle in which the angular separation between the voltages is less than the setting θ is an interval denominated "slip measurement interval", which represents a reclosure window with the dimension of 2xθ degrees of slip. The duration (tSMI) decreases as the slip increases and vice versa, providing a means of measuring the slip.

$$tSMI = \frac{1}{fS} \times \frac{2\times\theta}{360\ deg}$$

Where: fS is the actual slip frequency.

The absence of pulses at the output of the phase angle timer during the slip measurement interval gives the slip timer a chance to complete its count because it is not reset and reinitiated. After the time THS following the last pulse before the slip measurement interval, the fast slip timer gives an output (waveform C) that resets FF1 and eliminates the signal "Block Reclose". This signal reappears with the first pulse produced by the phase angle timer. Its momentary absence, however, gives a reclosure opportunity (waveform D).

If the slip is greater than the threshold setting (fS > FHS), tSMI will be less than THS, and the slip timer will not produce an output and the recloser will be continuously blocked.

Slow Slip Detector

This detector determines the slip velocity by measuring the time required for line voltage VL to traverse 90 degrees in a slip cycle (one quadrant). This time, T90, is compared with the time limit set in the slow slip detector, TLS.

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

Where: FLS is the threshold of the slow slip detector and the factor 1/4 signifies that the measurement is made in one quadrant.

If T90 is less than TLS, the slip velocity is greater than the setting FLS and the recloser is blocked. If T90 is greater than TLS, the slip velocity is less than the setting and, therefore, reclosure is permitted.

HARDWARE DESCRIPTION

The MRS system is comprised of plug-in modules housed in a steel case.

STEEL CASE ASSEMBLY

Construction

The case is fabricated from sheet metal. The rear is made of thicker gauge so that, together with the front border, the case is given greater rigidity. The external dimensions of the assembly are indicated in the Specifications Section.

The front cover is transparent methacrylate and it fits inside a molded aluminum border. It is fastened with four screws which are embedded in the cover to avoid being misplaced. Resetting the relay indicators, as well as the reclose operation, can be performed through buttons which pass through the cover.

Rubber gaskets have been provided for the rear plate and around the inside of the border where the methacrylate cover is supported, to avoid dust infiltration into the system.

Modules are vertically mounted and the sockets serve as both mechanical support and as the means of electrical connection. Module alignment is maintained through the use of two plastic guides per module, one above and one below, inserted in specific supports within the case. The magnetic module, MGM, is supported with four guides, two above and two below.

Electrical Connections and Internal Wiring

External connection is made through three, fourteen point, screw connection terminal boards. These terminal boards are mounted on the rear case plate.

The connection of the printed circuit boards is made through 60 pin circuit card edge connectors. The connection of the magnetic module is made with two connectors; one with eight contacts for the connection of the current circuits and another of 104 circuits for the connection of the rest of the signals.

The sockets of the card connectors and the magnetic module are mounted in the same plane, approximately 23 centimeters from the front. On the other hand, the sockets for the connection and test plugs are mounted only four centimeters from the front. This assembly will be discussed in a later section. The internal wiring between the modules, to the test plug and terminal boards, is wound. The wiring between modules is arranged randomly, except for those signal sensitive to coupling, which are arranged in bundles with 90 degree angle crossings to minimize the effect of electromagnetic coupling. All wires which connect to test plugs, to the terminal boards, and to the interconnection cables, are also arranged in bundles.

Identification

The correct placement of the modules in the relay case is indicated by two location strips with the name and the position for each one situated on the upper and lower parts of the front border.

Terminal boards are identified by tags with a two letter code located on the lower left.

Each terminal strip appears with the numbers 1 to 14 stamped on each terminal to indicate position.

PRINTED CIRCUIT MODULES

Basic Construction

Each module is comprised of a printed circuit board and a front plate mounted perpendicular to the board. Two handles are mounted on the front to insert and extract the boards. Electrical connection is made through connectors at the edge of the board.

Identification

Each module has its own model number consisting of three letters followed by three digits. Each module number appears in the lower part of the front plate.

Settings

The modules which comprise the MRS relay system have settings divided between the front plate and the inside of the module. There are six types of settings:

(1) Microswitches.

(2) Jumpers, or links.

(3) Push-buttons.

(4) Potentiometers.

(5) Switches.

(6) Rotating double digit switches.

RLM - Reclosure Module

This module contains the circuitry related to the logic and the timers for the reclosing functions.

Switches on the Front Panel

The following settings are found on the front panel:

Identification	Type	Function and Description
1Ø	(1)	Sets the time in seconds until the first reclosure following a single pole trip.
3Ø	(1)	Sets the time in seconds until the first reclosure following a three pole trip.
DLY	(1)	Sets the time in seconds until the second reclosure. The second reclosure, if it occurs, is always three phase.

RST	(1)	Sets the time in seconds before the recloser moves to the reset state after a reclose attempt. When the HOLD setting is IN, this setting also determines the maintain time of a reclosure command waiting for a validation signal coming from the synchronism check circuits.
1ø	(1)	When this setting is found in the left position, single pole reclosures will not be attempted.
3ø	(1)	When this setting is found in the left position, three pole reclosures will not be attempted.
DLY	(1)	When this switch is found toward the left, second reclose attempts will not be made.

On-Board Switches

Identification	Type	Function and Description
HOLD	(2)	When this setting is in the IN position, it maintains the three pole reclose command for a time equal to the reset time waiting for the arrival of the reclose validation command by the synchronism check circuits. In the OUT position, the reclose command is not maintained and if not validated at the moment of being produced, the recloser becames blocked.
SW-9	(2)	When this setting is in the IN position, and with a correct position of 1ø, 3ø, and DLY switches, reclosing scheme number 9 (see table III), can be achieved. For the rest of reclosing schemes, SW-9 must be in the OUT position.

DWELL TIME	(2)	The setting determines the maintain time of the reclose command once produced. 0.2 and 0.8 second times can be selected.

Front Panel LED Diode Indicators

Identification	Color	Function and Description
OPN	Yellow	Is activated while the recloser is counting the reclose times.
N/S	Red	Is activated when the recloser has reached an internal blocked state due to the lack of validation of the reclose command from the synchronism check circuits.
L/O	Red	Is activated when the recloser has reached the internal blocked state due to a permanent fault.

IOM - Input and Output Module

The input and output module contains four auxiliary relays with "a" type contacts corresponding to the following functions:

Three phase trip preparation for the Protection Relay associated with the recloser.

Retraction Signal of the Zone 1 Extension of the Protection Relay associated with the Recloser.

Blocked Recloser.

Recloser Out of Service

In addition to the relays indicated, the module contains five contact converters which are shown below:

Block Reclose

Manual Close

Remote Reset

Initiate Single Pole Reclosure

Initiate Three Pole Reclosure

Front Panel Switches

The only switch located on the front panel of the IOM module is that corresponding to the recloser reset operation:

Identification	Type	Function and Description
RST	(3)	Reset Button. Activation causes the recloser to be reset.

Input and Output Module On-Board Switches

Identification	Type	Function and Description
48/110-125/220-250	(2)	These links set the interface circuits to the appropriate control voltage. There is a separate link for each contact converter.

PSM - Power Supply

The power supply consists of a DC-DC converter with three different rated input voltages.

Vaux = 48 Vdc.

Vaux = 110-125 Vdc.

Vaux = 220-250 Vdc.

The power supply module provides three regulated outputs:

1) +/-12 Vdc with respect to a common and with a capacity of one ampere. This output is used to supply the analog circuitry of the system, necessary when the optional synchronism check function is used.

2) 25 Vdc with respect to the same common reference as in 1) and with a one ampere capacity. It is used to energize the auxiliary relays mounted on the IOM and recloser modules.

   In the same manner, it supplies half the operating voltage of the telephone relays located on the magnetic module, MGM, and finally, it supplies the 5 Vdc supply which provides voltage for all the logic.

3) A second output of 25 Vdc and 0.2 amperes capacity, independent from the previous, supplies the other half of the operating voltage of the telephone relays.

This module contains a relay with a type "c" contact which is operated under normal operating conditions, and drops out when the output from the power supply ceases to regulate for whatever reason, including loss of substation battery voltage.

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

Identification	Color	Function and Description
Output Voltage	Green	This LED is lit continuously when the power supply output is maintained within regulation. It provides a visual indication of the correct operation of the power supply.

Front Panel Switches

Identification	Type	Function and Description
ON/OFF	(5)	In the OFF position, this switch maintains the converter master oscillator inactive, disabling voltage conversion and the generation of regulated voltages, but keeping the primary circuit of the power supply energized. It provides an alternative means of removing power from the electronic circuitry without disconnecting the power supply connections from the terminal boards.

SVM - Synchro Check Module (Optional)

This module contains the synchronism check circuitry utilized to supervise reclosure. It includes the following:

- Voltage detectors to determine if there is voltage on the line and busses. Reclosure can be allowed or permitted for all combinations of presence or absence of bus and line voltage.

- An angle measuring circuit to determine whether the phase angle between the two voltages is between the set limits. When the voltages are outside the set limits, reclosing is blocked.

- A slow slip measuring circuit to determine if the difference in frequencies between the two voltages is within the set limits. If the slip is greater than the setting, reclosing is blocked.

- A special fast slip measuring circuit that allows quick verification of synchronism in the interval in which the slow slip detector has still not had time to perform its measurement, assuming that the angle between bus and line voltage at no time exceeds the set angle.

- A "dead time" timer to coordinate with the reclose time of the remote terminal recloser. If the remote terminal did not reclose in the allowed time, the fast slip detector would give an erroneous output. This danger is eliminated by disabling the detector once the "dead time" has elapsed; in this case the slip measurement is performed solely by the slow slip detector.

Front Panel Switches

Identification	Type	Function and Description
ANGLE	(6)	Determines the maximum allowable out of phase limit between bus and line voltages.
SYNC CK	(1)	Sets the SVM in a Synchronism Check mode so the reclosure can be supervised by the phase angle and slip detectors. Moreover, both voltages, bus and line, should be above their respective thresholds to allow reclosure.
LLDB	(1)	Live line, dead bus mode. In this mode a reclosure is permitted only when the line voltage is above, and the bus voltage is below, the voltage present and voltage absent thresholds (adjustable) respectively.
DLLB	(1)	Live bus, dead line mode. In this mode a reclosure is permitted only when the bus voltage is above, and the line voltage is below (respectively), the voltage present thresholds.

DLDB	(1)	Dead line, dead bus mode. In this mode, reclosure is permitted only when both voltages are below their voltage present thresholds.

On-Board Switches

Identification	Type	Function and Description
PT Voltage	(1)	Rated secondary voltage of the potential transformers. This switch determines the rated phase to ground voltage from which the presence and absence of voltage thresholds are established.
BUS LIVE	(1)	Presence of bus voltage threshold.
BUS DEAD	(1)	Absence of bus voltage threshold. This switch determines the voltage level, in percent of rated, below which bus voltage is considered not to exist.
LINE LIVE	(1)	Same as the switch, BUS LIVE (separately adjustable).
LINE DEAD	(1)	Same as the switch BUS DEAD (separately adjustable).

LOW SET SLIP	(1)	Slow slip detector setting. This switch determines the slip value (FLS), above which reclosure is blocked (except for the instantaneous reclosure).
HIGH SET SLIP	(1)	Fast slip detector setting. This switch establishes the threshold (FHS) for the special slip detector used to supervise instantaneous reclosures.
DEAD TIME	(1)	This switch determines the time following a trip, after which the rapid slip detector is disabled.
50 Hz / 60Hz	(1)	This switch sets the synchronism check circuits to the system frequency.
1	(1)	Slow slip detector multiplier setting. When placed in the right position (lower part of the board) multiplies the setting by ten.
2	(1)	Slow slip detector control for a second breaker. This switch is not used on the MRS. It should be placed in the left position (upper part of the board).
LOW SET ONLY	(1)	This switch cancels synchronism check through the fast slip detector, disabling a reclosure until the measurement can be performed by the slow slip detector.

LED Indicators Inside the Module

This set of diodes is used to facilitate verification of the proper operation of the synchronism check function.

Identification	Colour	Function and Description
TL1	Red	Angle outside the limits. This indicator is lit when the phase between bus and line voltages exceeds the angle set on the front of the module.
TL2	Red	Slip greater than the slow slip detector setting. This indicator is lit when the described condition exists, but only once the slip measurement has been performed.
TL3	Red	Reclosure permit. This indicator is lit when the SVM module is sending a reclosure permit signal to the recloser. It functions in conjunction with both the voltage supervision modes and the synch check mode.

MAGNETIC MODULE

Basic Construction

The magnetic module, designated MGM, consists of a steel structure which houses the electromagnetic components of the relay; including the voltage transformers and the reclose telephone relay. It also contains the reclose counter, in those options where it is required. Finally, it contains a printed circuit board with the following circuits:

- 5 Vdc power supply which supplies power to the logic circuits. This supply is fed from the 25 Vdc, one ampere source.
- Output relay circuit supervision, with the relay on and off.
- Actuating circuits to the telephone output relays.

Electrical connection is made with a 104 pin signal connector.

The module is provided with two handles, one on the lower and one in the upper part, to facilitate insertion and removal.

Identification

The model number of the MGM appears in the lower part of the front plate. Rated value data for the magnitudes which affect the magnetic module are given in the center of the front plate.

SETTING PROCEDURES

Except where indicated otherwise, the switches referred to in this section are located on the front of the relay. Access to the on-board switches, where indicated, can be accomplished by extracting the appropriate module. Figures 4 to 8 are included purposely to illustrate the location and setting of the switches and internal selectors.

CONTROL VOLTAGE SETTING

Control voltage should be set in modules indicated in Table II.

TABLE II

MODULE	NUMBER OF SWITCHES	FUNCTION
IOM	4 Switches	Contact Converters

RECLOSER SETTINGS

Operating Modes:

Eight distinct reclosing programs can be selected through micro switches 1ø, 3ø and DLY, located in the front of the RLM Module and jumper SW-9, located also in the RLM module, as exhibited in Table III.

TABLE III

Reclosing Program	TYPE OF FAULT: Single Phase Reclosure #1	Single Phase Reclosure #2	Poly Phase Reclosure #1	Poly Phase Reclosure #2	Front Plate of RLM Module: 1ø	3ø	DLY
1 (**)	NR	NR	NR	NR	OFF	OFF	OFF
2	HS1	--	--	--	X	OFF	OFF
3 (*)	HS3	L/O	HS3	L/O	OFF	X	OFF
4	HS1	L/O	HS3	L/O	X	X	OFF
5 (**)	NR	NR	NR	NR	OFF	OFF	X
6	HS1	TD	--	--	X	OFF	X
7 (*)	HS3	TD	HS3	TD	OFF	X	X
8	HS1	TD	HS3	TD	X	X	X
9 (***)	HS1	TD	HS3	L/O	X	X	X

(*) In these modes of operation it is assumed that the protection trip and reclose initiate are always three phase, regardless of the type of fault.

(**) These programs are equal.

(***) For programs 1 to 8, SW-9 in the RLM module, must be in the OUT position, for program 9 in the IN position.

NOTES TO TABLE III:

1. NR: No recloser action.
2. HS1: Fast reclosure with the time delay equal to the "1ø" setting on the front of the RLM module.
3. HS3: Fast reclosure with the time delay equal to the "3ø" setting on the front of the RLM module.
4. L/O: Blocked.
5. TD: Timed reclosure with the time delay equal to the DLY setting on the front of the RLM module.
6. OFF: Function not selected.
7. X: Function selected.

The recloser can be left out of service by placing the three programming switches in the left position (program #1).

Time Setting

First Reclosure Attempt - Single Phase

The time between the trip and the first reclosure attempt is set through a set of eight micro switches labeled 1ø and located on the front of the RLM module. Each switch has a number index, and the resultant setting time is the sum of the indices of all the switches set to the right hand position.

First Reclosure Attempt - Three Phase

If the first reclosure attempt is three phase, then the reclosure time is set by a group of eight microswitches labeled 3ø and located on the front of the RLM module. The setting time is determined in the same manner as that for the first reclosure attempt - single phase, namely by summing all the switches set to the right hand position.

Second Reclose Attempt - Always Three Phase

The time between the second reclosure initiation (first attempt failed) and the corresponding reclosure (delayed reclosure) can be determined by a group of eight microswitches designated DLY and located on the front of the RLM module. The setting time is determined in the same manner as for the First Reclosure Attempt - Single Phase, by summing the switches in the right hand position. The setting time should always be greater than the maintain time of the reclosure command(Dwell time).

Reset Time

The reset time is determined by a group of microswitches labeled RST, located in the front of the module and should always be greater than the maintain time of the reclosure command(Dwell time).

Maintain Time of the Reclose Command(Dwell Time)

This time is set by an on-board switch on the RLM module and has two possible positions: 0.2 and 0.8 seconds.

Auxiliary Functions

Synchronism Check Reclose Supervision

If the MRS includes the Synchronism Check option (SVM module), all three phase reclosure attempts will be supervised by a signal from the SVM module. If the internal HOLD link is in the IN position, once the reclosure time delay is completed, it will wait the reset time until a permission to reclose signal; if this signal doesn't arrive within the set time, the recloser will be blocked due to a lack of synchronism.

If the link is set in the OUT position, the blocking will be produced without time delay if at the moment the reclose time delay is completed, there is no reclose attempt permission signal.

SYNCHRONISM CHECK MODULE

Operating Mode

There are four modes of reclosure supervision:

1) SYNC CK - Supervision using slip and angle detectors. This mode requires presence of both bus and line voltage.

2) LLDB - Presence of line voltage and absence of bus voltage.

3) DLLB - Absence of line voltage and presence of bus voltage.

4) DLDB - Absence of bus and line voltage.

The mode of operation is selected by placing the appropriate switch in the right hand position on the SVM module. The functions can be combined by closing more than one switch simultaneously. If none of the modes is selected, the recloser will permanently be blocked.

Synchronism Check Settings

Angle

The maximum angle between bus and line voltage for which reclosure will be allowed is selected by a double digit dial switch on the SVM module. The digits are advanced by depressing the lower push buttons labeled with a (+) and are reduced through the upper push buttons (-). The value presented is in degrees.

Slow Slip Detector Threshold

This threshold is selected by positioning four microswitches inside the SVM module. The setting is equal to the sum of the indices of those microswitches that are in the closed position. The corresponding indices (in Hz) are written above the printed circuit.

The setting can be multiplied by ten by moving the microswitch found below the frequency setting to the right.

Threshold of the Fast Slip Detector

This threshold is selected by positioning four microswitches inside the SVM module. The setting is equal to the sum of the indices of those microswitches that are in the closed position. The corresponding indices (in Hz) are written on the printed circuit.

Slow Slip Detector Only

The possibility that the synchronism check circuit might permit a high speed reclosure by measuring slip with the fast slip detector can be eliminated by positioning the microswitch labeled LOW SET ONLY, on the SVM module, to the right (toward the lower part of the card). This requires the slip measurement to be made through the slow slip detector for a reclosure to be permitted.

Dead Time Timer Setting

This setting is made through six microswitches inside the SVM module. The setting is a result of the sum of the indices of those microswitches which are in the closed position. The indices (in seconds) are written on the printed circuit.

Voltage Threshold Settings

Transformer Rated Voltage

The verification of synchronism circuit has to be set according to the rated value of the transformer secondaries to which the MRS is connected. This setting is accomplished with four microswitches located on the SVM module, designated PT VOLTAGE.

The microswitch which corresponds to the rated value of the transformer secondary should be closed (phase to neutral voltage).

Presence of Bus Voltage

The voltage threshold that determines if bus voltage is considered to be present is adjusted using four switches inside the SVM module, designated as BUS LIVE. The setting is made in percent of rated voltage as set in the previous section and is equal to 70% plus the sum of the indices corresponding to the closed microswitches. The values of the indices are given on the plate on the printed circuit.

Presence of Line Voltage

Similar to the Presence of Bus Voltage. The value as set with the four microswitches designated as LINE LIVE.

Absence of Bus Voltage

Set the threshold below that which no voltage is considered to be present at the bus. The setting is made with the group of four switches designated as BUS DEAD and is ten percent above the sum of the microswitches in the closed position.

Absence of Line Voltage

Similar to the Absence of Bus Voltage. The value is set with the four microswitches designated as LINE DEAD.

Frequency Setting

The synch check circuit is set to the system frequency by a microswitch designated as 50 Hz / 60 Hz and located inside the SVM module.

Synchronism Check Setting Criteria

The synchronism check function compares the angle between line and bus voltage on both sides of the breaker and gives an output if the angle is within the set limits during a certain period of time. The combination of angle and time establishes the slip frequency limit; the slip frequency above which reclosure is not permitted.

For a given angle, a low slip limit results in a greater time delay. Because this time delay is introduced in all the measurements, a conflict between the requirements of fast reclosure and the low slip limit can result.

The synchronism function utilized in MRS 2000 relays (SVM module) has been designed to allow for rapid reclose with a reasonable setting for the lower slip limit. To accomplish this, the relay has two slip measurement circuits available, one for slow slip and the other for rapid slip. The first is based on the maximum slip tolerable allowing for a reclose. The second is a function of the angle setting and the time that the line has remained deenergized.

The following assumptions are made to explain the synchronism check function:

1. A fault has been produced on the line which has been cleared by opening both the local and remote breakers. The remote breaker is closed without synchronism check, reestablishing the voltage VL at the local breaker.

2. Bus voltage is taken for angle reference.

3. The line voltage VL can appear at any moment, and can be rotating in any direction with respect to VB, 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 ϕ.

A. If the angle between VL and VB is greater than the set closing angle, θ, the synchronism check function will not operate and will not allow a reclosure.

B. If the angle between VL and VB is less than the set closing angle, the synchronism check function operates and allows reclosure, but only after the time associated with the fast slip detector, FHS, and the closing angle setting.

This time is expressed as:

$$THS = \frac{1}{FHS} \times \frac{2 \times 0}{360} \times 100$$

Where: THS is the time in milliseconds.
FHS is the setting of the fast slip detector, in hertz.
θ is the set closing angle.

Typically, the setting of the fast slip detector should be equal to the required slip to traverse $(270-\theta)$ during the time in which the line is deenergized; that is:

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

Where: TLD is the time, in seconds, that the line remains deenergized. It is equal to the reclosing time of the remote breaker.

The setting of the fast slip detector, FHS, is based on $(270 - \theta)$ to ensure that, if the slip is less than FHS, VL has had time to traverse less than three quadrants during the interval in which both breakers are open (dead time). If the slip is slightly less than FHS, VL will be in quadrant III for clockwise rotation, or in quadrant II for counterclockwise rotation (see Figure 9). In either case, the slow slip detector will be activated and the actual slip must be less than the setting of this detector to permit reclosure.

There are three conditions which can cause VL to appear in quadrants I or IV when the line is energized. One condition is when the slip is greater than FHS. In this case, the fast slip detector will inhibit reclose. The second condition is an extremely slow slip. For this condition, reclosure will be permitted if VL remains within the closing angle during the time associated with the fast slip measurement (THS). If VL has not gone outside the closing angle during the time in which the line is deenergized, there is a small risk of allowing reclosure without making the slow slip measurement.

The third condition which can cause VL to appear in quadrants I or IV is a reclose attempt at the remote end which has delayed beyond the normal reclose time. An example would be a manual breaker close. The

SVM module includes a timer whose output enables the slow slip detector, disallowing the reclose until the detector gives a permit output. The input of this timer is active when VL is less than the voltage present threshold setting. This setting should be made equal to the time which the line is deenergized plus an adequate margin.

The setting is:

TD = (time that the line is deenergized) +
(channel time) x 1.1

Channel time is included to take into account possible differences in trip time between the two terminals due to a channel related trip on one end and a direct trip on the other.

CASE 2:

The systems are out of synchronism, and VL is rotating with respect to VB.

A. If the voltage VL is in quadrants I or IV when the voltage is reestablished, if it enters the close angle without entering quadrants II or III, and if it remains in the close angle for a time greater than the time associated with the fast slip detector, a reclosure permit output will be given after time THS.

B. If VL returns in quadrants II or III, or enters while rotating from quadrants I or IV, the slow slip detector is enabled and used to supervise the angle and fast slip detector measurement circuits. In this way, reclosure is not permitted unless the slip is less than the setting of the slow slip detector, and VL remains within the closing angle during the time THS.

The slow slip measuring circuit determines the slip comparing the time that VL remains in a quadrant with the reference time established by the slow slip setting. This reference time is the time that VL would take to rotate 90 degrees (one quadrant) at a frequency equal to the slow slip detector setting:

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

Where: FLS is the setting of the slow slip detector.
TLS is the time necessary to rotate 90 degrees.

If VL remains in a quadrant for a time greater than the reference time, it is because the slip is less than the setting of the slow slip detector. In this case, the circuit will give a permit output to enable the angle and fast measurement circuits. The slow slip detector circuit is activated each time VL changes quadrant; therefore, if a permissive signal has been generated in the previous quadrant, it will remain, unless it is determined that the slip is greater than the slow slip detector setting, at which moment the permissive signal is removed.

If VL returns to quadrant II (Figure 9) and rotates in a counterclockwise direction, the slow slip detector will enable the angle and fast slip detector measurement circuits only if VL remains in quadrant II for a time greater than TLS. After VL enters quadrant I, the reclose will be permitted only after VL enters within the closing angle and remains there for a time greater than THS. If, on the other hand, VL returns to quadrant II but does not remain there for a time greater than TLS, the slow slip circuit will block the reclose. Nonetheless, when VL enters quadrant I it will initiate a new measurement, and if VL remains in this quadrant for a time greater than TLS, the angle and fast slip measurement circuits will be enabled. Under these conditions, reclosure will be permitted if VL is within the closing angle and the time THS.

The same thing would occur if VL were to return to quadrant III, rotating in a clockwise direction.

It should be noted that if VL returns to quadrant III and is rotating in a counterclockwise direction, the slow slip measurement is inconsequential because reclosure cannot occur until VL enters within the closing angle, within quadrant I. Therefore, the slip measurement made in quadrant I determines operation.

There is an option with the SVM module that reclosure will not be permitted unless the slow slip measurement has been performed. In this mode of operation, after determining that the slip is less than the setting of the slow slip detector, VL should still be within the closing angle for the time THS. This is so even if the fast slip detector is not in service. In this mode of operation, the minimum time delay is obtained by setting FHS to the maximum value possible.

TESTS

NOTE:

When the insulation test is performed, it is necessary to remove the jumper between terminals AB13 and AB14. Upon doing this, the connection between the common of the transient suppression capacitors and the case is eliminated. To not do so in this manner could cause damage to the filter capacitors in the PSM module when the supply terminals are tested as described below.

INSULATION TEST

The insulation test can be performed:

1) Between all the terminals short circuited and the case, and

2) Between groups of independent circuits (see the external connection diagram in Figure 15). The recommended test voltage is 2200 volts effective (rms) for the initial test and 1600 volts for the following periodic tests. The test voltage should be applied for one second.

ACCEPTANCE TESTS

It is recommended that the functional tests described below should be performed prior to installing the relay.

Initial Settings

The modules should be set as indicated in tables IV and V to begin the acceptance tests. It is necessary to remove the modules in order to access the on-board switches described in Table IV.

Test Equipment

The Acceptance Tests can be performed in a conventional manner using the following test equipment:

- A three phase voltage source of rated frequency.
- A control voltage source (48, 110-125 or 220-250 Vdc).
- A phase shifter.
- A phase angle meter.
- Two variable autotransformers rated 1 amp or better.

- Two ac voltmeters.
- Five contact monitors.

Breakers: One single pole, single circuit.
Four normally open push-buttons.

One card extender (GE #0138B7406G1).

The specific requirements of this equipment are given in the text of this section and in the attached diagrams.

It is essential that the voltage source be a balanced three phase, sine wave, without distortion.

Test Connections

The test circuit diagrams indicate the terminal board numbers on the rear of the MRS 2000 relay and the corresponding points on the XTM test plug. For the acceptance tests, it is recommended that the tests be performed through the rear terminal boards. The purpose of the test plugs is to provide a simple means for the test connections after the equipment is installed and as described in the separate subsection called PERIODIC TESTS.

TABLE IV

Set the on-board switches for the Acceptance Tests.

Module	Switch	Initial Position
RLM	HOLD	OUT
"	DWELL TIME	.2 SECONDS
	SW-9	OUT
IOM	48/110-125/220-250V	SET TO AVAILABLE CONTROL VOLTAGE

TABLE V

Set the Front Plate Switches for the Acceptance Tests.

Module	Switch	Initial Position
RLM	1ø TIME	5 SECONDS
"	3ø TIME	9 SECONDS
"	DLY TIME	15 SECONDS
"	RST TIME	60 SECONDS
"	1ø	ON
"	3ø	ON
RLM	DLY	ON

A. Recloser Verification

Connect the MRS 2000 relay as indicated in Figure 10.

The RLM module should be set as indicated in Tables IV and V.

Reset the recloser by pushing the RST push-buttons on the front of the IOM module.

The recommended time settings for these tests are sufficiently long so as not to need a chronometer. A watch with second is adequate to perform the tests.

Each time the recloser gives a reclose command, in the reclosers with a counter option, the counter advances one count.

A1. Automatic Reclosure: Two Shots

Momentarily push SW1. The rest of the test circuit switches should be left open. Verify that the reclose cycle is in process, as indicated by the lit LED OPN on the front of the RLM module and the closure of the contact between terminals AB3 and AB4.

Verify that the reclose contacts close between terminals AB7 and AB8, AB9 and AB10, AB11 and AB12, five seconds after the initiate command. The five seconds corresponds to setting 1 on the front of the RLM module. Verify that the reclose contacts open 0.8 seconds after they close. The LED OPN will go out when the reclose contacts open. The contact between terminals AB3 and AB4 will continue to be closed. In summary:

1) Momentarily push SW1: OPN indication and contact closes between AB3 and AB4.

|
| 5 seconds
V

2) Verify the contacts close between AB7 and AB8, AB9 and AB10, AB11 and AB12.

|
| 0.8 seconds
V

3) Verify that the closed contacts mentioned under point 2 above open. LED OPN goes out. The contact between AB3 and AB4 remains closed.

Before the reset time (60 seconds - setting RST, on the front of module RLM), momentarily depress the push-button SW2. LED OPN will light up again (the contact between AB3 and AB4 will remain closed).

Verify that 15 seconds later the three reclose contacts close. The 15 seconds correspond to the DLY setting on the front of the DLM module. Verify that the reclosure contacts open 0.8 seconds after closing and that at that moment the LED OPN goes out. The contact between AB3 and AB4 will remain closed. In summary:

1) Momentarily depress SW2: OPN indication.

|
| 15 seconds
V

2) Verify the contacts close between: AB7 and AB8, AB9 and AB10, AB11 and AB12.

|
| 0.8 seconds
V

3) Verify that the closed contacts mentioned in point 2 above open. LED OPN will go out. The contact between AB3 and AB4 will remain closed.

Before the reset time passes, push SW2 again. You should note that the reset time reinitiates with the second reclosure and isn't completed until 60 seconds later. Verify that the recloser is blocked immediately, as indicated by the illumination of the L/O LED on the front of the RLM module and by the closure of the contact between terminals AB5 and AB6. The contact between AB3 and AB4 will open. In summary:

1) Momentarily depress the push-buttons SW2. LED L/O will light, the contact between AB5 and AB6 will close and the contact between AB3 and AB4 will open.

Reset the recloser. Upon resetting the recloser, L/O will go out and the contact between AB5 and AB6 will open.

A2. <u>Automatic Reclose: Single Pole Only</u>

Move the 3ø and DLY switches on the front of the RLM module to the left. Momentarily push SW1. Verify that five seconds later, a reclose is produced.

Momentarily push SW2 before the reset time passes. Verify that a reclose is not initiated. LED OPN will not light and the reclose contacts will not close.

Reset the recloser. Place the 3ø and DLY switches on the front of the RLM module to the right again.

A3. <u>Automatic Reclosure: Three Phase Only</u>

Move the 1ø switch on the front of the RLM module to the left. Momentarily push SW2. Verify that, nine seconds later, a reclosure is produced. The nine seconds correspond to the setting of the group of eight microswitches labeled 3ø on the front of the RLM module.

Momentarily push SW2 again before the reset time passes. Verify that a reclosure is produced fifteen seconds later. These fifteen seconds correspond to the setting of a group of microswitches labeled DLY on the front of the RLM module.

Push SW2 again before the reset time is completed. Verify that the recloser immediately blocks. Reset the recloser. Place the 1ø switch on the front of the RLM module to the right again.

A4. <u>Automatic Reclosure: Single Shot</u>

Move the microswitch DLY on the front of the RLM module to the left. Push SW1 and verify that five seconds later a reclosure is produced.

Push SW2; a reclosure block will be produced immediately. Reset the DLY switch to the right.

A5. Manual Reclosure

Depress push-buttons SW5, which simulates a manual close command, and before the reset time completes, push SW2. An immediate block of the recloser will be produced.

Depress push-buttons SW5 again, the recloser will reset. Before the reset time finishes, push SW2. An immediate reclose block will be produced. Reset the recloser.

A6. Recloser Out of Service

Place the 1ø, 3ø, and DLY switches on the front of the RLM module to the left.

The open contacts between terminals AA13 and AA14 should close. Also. push SW1 and verify that a reclose cycle is not initiated.

A7. Test of reclosing program number 9

Set on-board jumper SW-9 to IN position, and switches 1ø, 3ø and DLY to the right. Try to make a two shot automatic reclosure with single phase initiate, as indicated in point A1. Verify that the relay recloses twice before blocking.

Reset the recloser. Try to repeat the test, but with a three phase initiate (SW2 instead of SW1). Verify that this time there is only one reclose before the relay blocks. Reset SW-9 jumper to the OUT position.

B. Synchronism Check (Optional)

Verification of Recloser Supervision

Connect the system as shown in Figure 10.

On the front of the RLM module, place 1ø and DLY to the left and 3ø to the right. Momentarily push SW2. Verify that reclosure is produced in nine seconds. The recloser functions in the manner described, because without line and bus voltages connected, they are registered as not present, and the SVM module has been set to allow reclosure under conditions of absence of line and bus voltage.

Reset the recloser. Move the DLDB switch on the front of the SVM module to the left and SYNC CK to the right.

Push SW2 again and verify that a reclosure is not produced (the reclosure contacts do not close at any moment). After nine seconds, the red N/S LED, on the front of the RLM module, lights, indicating that the reclose attempt has been blocked by the synchronism check module. In the SYNC CK mode, line and bus voltage must be present and since they have not been connected, they register as absent, and the recloser is blocked.

NOTE

The previous checks verify that the reclose and synchronism modules operate correctly together. Once this is established, it is recommended that the rest of the tests be performed verifying only the SVM module to avoid the initiation of reclosure cycles. This is taken into account in the descriptions of the tests which follow.

Voltage Level Checks

Connect the system as shown in Figure 12. The SVM module should be mounted on a card extender to be able to see the state of the three LED's mounted on the interior. Extract the RLM module to avoid operation.

Apply bus and line voltage and adjust them, examining the status of the TL3 LED (the LED closest to the bottom edge of the card). When this LED lights, reclose is permitted; when it goes out, reclose is blocked.

Verify the thresholds for each mode of operation. To check the thresholds at distinct points of 20% and 80% (absence and presence of voltage respectively) the positions of the setting switches on the inside of the module should be modified.

TL3 should light only when:

1. LLDB a) Line voltage is greater than 55 volts, and
   b) Bus voltage is less than 14 volts.

2. DLLB a) Line voltage is less than 14 volts, and
   b) Bus voltage is greater than 55 volts.

3. DLDB a) Line voltage is less than 14 volts, and
   b) Bus voltage is less than 14 volts.

Angle Verification

Connect the MRS 2000 per Figure 13. The SVM module should remain mounted in the card extender, and the RLM module should remain extracted.

Place the SVM module in the SYNC CK mode. With SW1 closed, set the bus and line voltages to 69 volts. Wait approximately 20 seconds for the circuit to stabilize, and vary the angle (test angle) between the voltages. When the angle is less than the setting (more or less 30 degrees), TL3 should be lit and TL1 should be out. When the angle is greater than the setting, TL3 should be out and TL1 should be lit. Other settings can be checked if desired. To avoid activation of the slow slip detector, the test angle should never be made greater than 90 degrees.

Verification of the Dead Time Timer

With the angle set at 30 degrees, set the test angle to 20 degrees, and wait 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 opened and that they invert, almost immediately, when SW1 is closed (actually 167 milliseconds later; the time delay of the fast slip detector). TL2 should not light throughout this test.

Repeat the previous test, but wait three seconds longer to close SW1.

Verify that when SW1 closes, TL1 goes out and TL2 lights immediately, but TL3 remains out. Approximately 13 seconds later, TL2 will go out and TL3 will light, the time corresponding to the delay of the slow slip detector. This test verifies that the dead time timer has placed the synchronism check circuit in the high speed mode.

Operation in the Slow Slip Mode Only

Move the LOW SET ONLY microswitch, on the inside of the SVM module, toward the lower part of the card. Leave the angle set at 30 degrees and use a test angle of 20 degrees. Open SW1 and close it in less than 3 seconds. Verify that TL1 and TL2 are lit when SW1 is open (TL3 goes out), and that only TL1 goes out when SW1 is closed (TL3 remains out). Approximately 13 seconds later, TL2 goes out and TL3 lights simultaneously. Reset the LOW SET ONLY switch to its normal position (towards the upper part of the card).

Slip Verification

With the angle set at 30 degrees and SW1 closed, the test angle at 20 degrees and SW1 closed, let the circuit stabilize for 20 seconds. The only LED lit should be TL3. Vary the phase angle from 20 to 200 degrees in less than 10 seconds to simulate a slip condition. When the angle passes 30 degrees, TL1 will light and TL3 will go out. When the angle reaches 180 degrees, TL2 will light because the test angle, sweeping, has traversed a complete quadrant (90 to 180 degrees) in a time less than that permitted by the slow slip detector, TLS:

$$TLS = \frac{1}{4} \times \frac{1}{FLS} = \frac{1}{4} \times \frac{1}{.02} = 12.5 \text{ seconds}$$

That is to say, that the synchronism check circuit interprets this test as a slip condition greater than the threshold of the slow slip detector (.02 Hz), and acts accordingly (lighting TL2).

If an angle of 200 degrees is maintained, TL2 will go out 12.5 seconds after 180 degrees is passed, but TL1 will remain lit and TL3 will remain out.

Set the test angle to 20 degrees again and allow 20 seconds for stabilization, TL3 will be the only LED lit. Perform the same sweep as before (from 20 to 200 degrees), slowly, so the time it takes to go from 90 to 180 degrees is greater than 12.5 seconds. TL1 will light and TL3 will go out again when the angle passes 30 degrees. However, this time, since the slip simulated is less than the threshold of the slow slip detector, TL2 will not light at any time.

PERIODIC TESTS
(After Installation)

It is recommended that a program of periodic testing be developed which verifies all those functions of the MRS 2000 involved in the application. It is left to the discretion of the user to select those tests from the Acceptance Tests which are applicable for the particular installation.

Additional Test Equipment

In addition to the equipment described at the beginning of the Acceptance Tests section, the following additional equipment is needed to test the equipment once installed:

A DC Voltmeter (30 Volts or greater)

An Extender (GE #148B7406G1)

A set of test plugs (XTM28L1 and XTM28R1) - described below.

XTM Test Plugs

Description

XTM test plugs are specifically designed for testing installed equipment. There are two plugs: XTM28L1 (left) and XTM28R1 (right); each one allows access to fourteen points on the relay side and fourteen points on the system side. The points corresponding to the system are located on the outside part of the plug. The plugs are coded in a such a way that they cannot accidentally be interchanged.

The plugs have a sloping handle to permit wiring to the terminals. The terminals are screws placed on flat contact plates. The handle has an excellent design which allows the connected cables to be guided to the terminals.

For the relay external connections, those which have been wired through test blocks for access through the test plugs are:

- AC Voltage Inputs.
- Contact Converter Inputs.
- Auxiliary Voltage Inputs.
- Reclose Contacts.
- Auxiliary Contacts.

Terminal Designations

The test block and test plug connections are located to the left of the test block. The terminals are labelled from 1 to 28, with 1 to 14 on the left side and 15 to 28 on the right side. These points are designated on the external connection diagram and on the test schematics as TP1 to TP28.

The terminals for the left test plug (XTM28L1) are labelled 1R to 14R and 1S to 14S for the relay side and system side respectively; with the system side in red color. In the same manner, the right plug terminals are labelled 15R to 28R and 15S to 28S.

Connection through the Test Plugs

Connections designated on the diagrams as TP should be made on the relay side of the test plugs. When magnitudes corresponding to system values are desired in the test, for example for auxiliary voltage, a bridge is made between the relay and system sides corresponding to the point in question. When one is working with the substation battery, special precautions should be taken.

Connection to the test plugs should be made before inserting them into the relay.

Test Plug Insertion

The connection plug must be removed before the test plugs can be inserted. This disconnects those circuits which are wired through the test block.

The two test plugs can be connected simultaneously. If only one test plug is in use, the connection plug can be left inserted in the other side.

When the test plugs are connected, the exterior system remains isolated from the MRS 2000 as far as the test signals are concerned.

Auxiliary Voltage Disconnection

The auxiliary DC voltage can be disconnected by removing either connection plug, or by extracting the magnetic module.

Test Procedures and Connections After Installation

The same procedure used for Acceptance Tests can be employed once measures have been taken to isolate inputs and outputs from the system. The XTM plugs serve this purpose in the case of the basic functions, but in the case of certain auxiliary and alarm functions, special precautions should be taken such as the disconnection of certain modules and the utilization of extenders.

The following subsections, together with the corresponding subsections in the Acceptance Tests section, constitute the periodic testing instructions. If these instructions are followed, it is not necessary to modify or remove the external connections of the relay.

Bridges, push-buttons, and switches are used through extenders to simulate external contacts. Combinations of resistance and voltmeters are used to observe the signals which act on the auxiliary relays in the manner indicated:

Acceptance Tests	Installed Equipment Tests
Relay Deenergized Contact Open	Voltage in the Resistance: 0 V dc
Relay Energized Contact Closed	Voltage in the Resistance: 5 Vdc or 12 Vdc

IMPORTANT

WHEN AN EXTENDER IS INSERTED IN POSITIONS CORRESPONDING TO THE IOM OR PSM MODULES, PROCEED WITH CAUTION BECAUSE BATTERY VOLTAGE CAN BE PRESENT AT SOME POINTS. LACK OF PRECAUTION CAN BE HARMFUL TO PERSONNEL OR TO CONNECTED EQUIPMENT.

A. <u>Verification of The Recloser</u>

Acceptance tests: Figure 10
Installed equipment tests: Figure 11

Function	Contact Fig. 11	Voltmeter On RLM Fig. 11-a
Reclosure	AB7-AB8 AB9-BO10 AB11-AB12	Pin 12
Three Phase Trip Permit	AB1-AB2	Pin 11
Retraction of Zone 1 Extension	AB3-AB4	Pin 39
Recloser Out of Service	AA13-AA14	Pin 7

Notes:

1) Extract IOM Module.
2) Place RLM module on an extender.

SPECIFICATIONS

GENERAL

Rated Frequency	50 or 60 Hz
Rated Voltage	VN = 110 V at 50 Hz VN = 120 V at 60 Hz
Auxiliary Voltage	48 V (34 V - 60 V) 110/125 V (88 - 156 V) 220/250 V (176 - 300 V)
Maximum Voltage Admissible	
Continuous	2.0 x VN
One Minute	3.5 x VN
Ambient Temperature	
Storage	-40C to +65C
Operation	The MRS relay has been designed to function continuously between -20 degrees C and +55 degrees C, per the ANSI C37.90 standard. However, the MRS relay will not misoperate or suffer damage at temperatures up to +65 degrees C.
Insulation Test Voltage	2 KV 50/60 Hz, one minute.
Impulse Voltage Withstand	5 KV peak, 1.2/50 ms, 0.5 joules.
High Frequency Interference	1 MHz, 2.5 KV longitudinal peak, 1 KV transversal peak, mid value decay time of 3 to 6 cycles, repetition frequency of 500 times per second.

Burdens

Voltage Circuits		0.024 VA / 48 deg., 50 Hz 0.2 VA / 49 deg., 60 Hz
	Normal	Maximum
Auxiliary Voltage Power Supply and Telephone Relays		
48 Vdc	9.5 Watts	12 Watts
110/125 Vdc	11.0 Watts	14 Watts
220/250 Vdc	13.5 Watts	17 watts
Auxiliary Voltage Contact Converters		
48 Vdc		1.6 mA each.
110/125 Vdc		1.5 - 1.7 mA each.
220/250 Vdc		1.9 - 2.1 mA each.

Contacts

Reclose Contacts	3 Amps Continuous. 30 A Closing (ANSI C37.90). 180 VA Resistive, Opening, at 125/250 Vdc. 60 VA Inductive, Opening, at 125/250 Vdc.
Auxiliary Outputs	3 Amps Continuous. 5 A for 30 Seconds, Closing. 25 Watts Inductive, Opening, at 125/250 Vdc. 20 Watts Continuous Closing. 250 V maximum, or 0.5 A.

Operating Mode Selection	1.	One shot recloser, single or three pole, depending on trip.
	2.	One shot recloser, single pole only.
	3.	One shot recloser, three pole only.
	4.	Two shot recloser, single or three pole for the first, three pole for the second.
	5.	Two shot recloser, three pole only. The recloser can be taken out of service.
	6.	Two or one shot recloser depending on reclose initiation.

Initiation with only operation of the protection relay.

Recloser blocking during the reset time following a manual close.

The reclosure attempts initially blocked by the synchronism unit, can be maintained. Reclosure will take place if the block condition disappears before the reset time. (This characteristic can be disabled.)

Supervision of all three pole reclosure attempts by the synchronism unit.

Reclosure Times

First Reclosure Single or Three Pole (Independently Adjustable)	0.01 to 2.55 seconds in .01 second steps.
Second Reclosure	1 to 255 seconds in one second steps.

Dwell Time of the Reclosure Command	0.2 or 0.8 seconds.
Reset Time	1 to 255 seconds in one second steps.

SYNCHRONISM CHECK CIRCUIT (Optional)

Angle Setting	1 Deg. to 99 Deg. in One Degree Steps.
Fast Slip Detector	0.25 to 2.5 Hz in 0.25 Hz steps.
Slow Slip Detector	0.01 to 0.1 Hz in 0.01 Hz steps. 0.1 to 1 Hz in 0.1 Hz steps.
Voltage Present Detector	65% to 110 % of nominal voltage in 5% steps.
Voltage Absent Detector	10% to 70% of nominal voltage in 5% steps.
Dead Time Timer	0.05 to 3.15 seconds in 0.05 second steps.
Rated Secondary Voltage of the Potential Transformers (Phase-Ground).	57.7, 63.5, 66.4 and 69 Volts; Adjustable.

ACCURACY

Reclosure Timers	+/- 3% of the setting.

DIMENSIONS

- Height: 177 millimeters
- Width: 484 millimeters
- Depth: 359 millimeters (including the terminal boards).

WEIGHT

The approximate weight is 9 kilograms.

RECEIVING, STORAGE AND HANDLING

PRECAUTION

This relay contains electronic components which can be damaged by electrostatic discharge currents if these flow across certain terminals of the components. The most significant source of these currents is the human body. Conditions of low humidity, carpeted floors, and insulated shoes, exacerbate the problem of generation of this type of discharge current. When these conditions exist, special care should be taken at the time of extracting and manipulating the boards to access the internal settings. The person who will be performing these operations should ensure that his body has discharged by touching any surface tied to ground before touching the components or modules.

The MRS 2000 system is supplied to the user in a special packing that is designed to protect it during transport, provided transport is accomplished in a normal manner.

Immediately after receiving the relay, the equipment should be unpacked and examined to check if there is any sign of damage suffered during transit. If it is evident that damage has been done to the relay due to poor treatment, the transportation company should be notified in writing immediately, with a copy to the factory.

Normal care should be taken while unpacking the relay so as not to lose the screws which are provided in the box.

If the relay is not going to be installed immediately, it is convenient to store it in the original package, in a dry, dust free place.

It is important to check that the nameplate characteristics coincide with those requested on the order.

INSTALLATION

ENVIRONMENT

The location of the relay should be clean and dry, free from dust and excessive vibration and well illuminated to facilitate inspection and testing.

MOUNTING

MRS systems have been designed for mounting in standard racks. Each case measures four rack units in height. The relay should be mounted on a vertical surface. Figure 14 shows the outline dimensions and drilling plan of the panel.

External connections to the relay are shown in Figure 15. The figure assumes a general scheme with all the options included. It is not necessary to connect those terminals associated with options not utilized or included with the equipment.

SURGE SUPPRESSION GROUND CONNECTION

Relay terminal AB14 should be connected to ground so the surge suppression circuits included in the relay function correctly. In the same manner a jumper should be made between terminals AB13 and AB14. The ground connection should be as short as possible to ensure maximum protection (preferably 25 cm or less).

LIST OF FIGURES

Figure 15 (226B7249, Sheet 1):	External Connection Diagram for the MRS 2000 without the Synchronism Check Option.
Figure 16 (226B7349):	External Connection Diagram for the MRS 200 with the Synchronism Check Option.

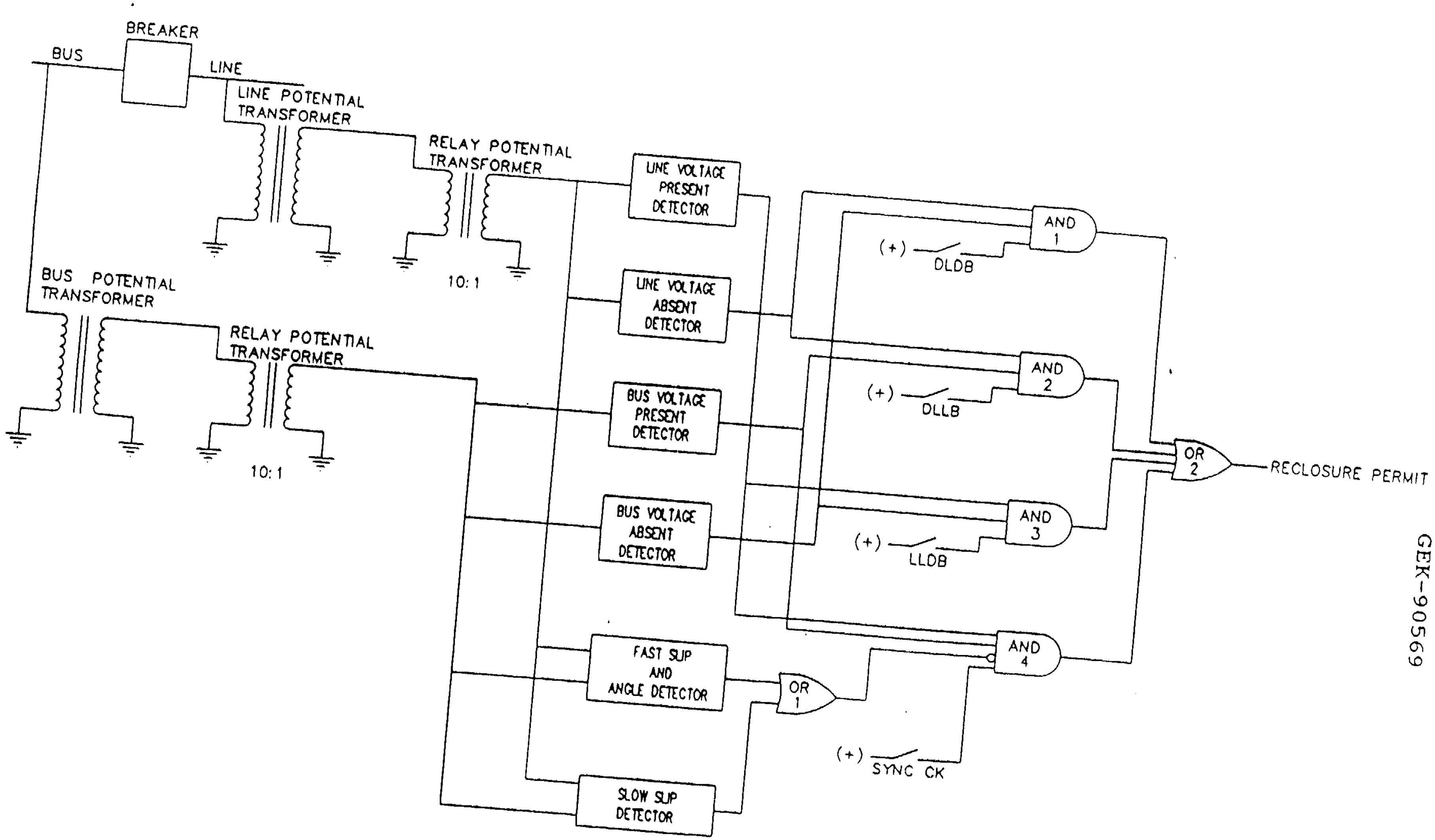


Figure 2 (226B7406, Sheet 1): Synchronism Function Block Diagram

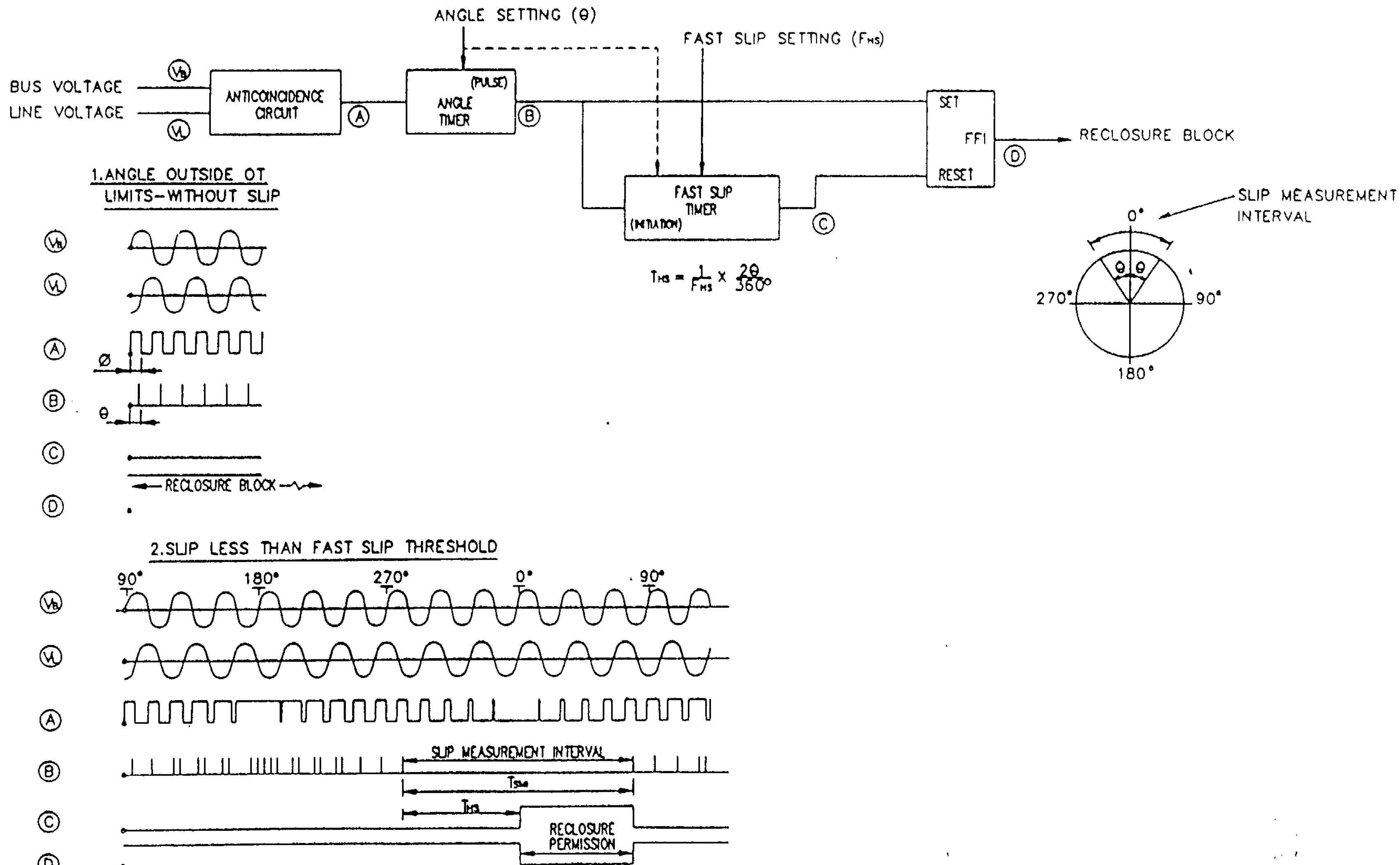


Figure 3 (226B7406, Sheet 2): Fast Slip and Angle Detectors

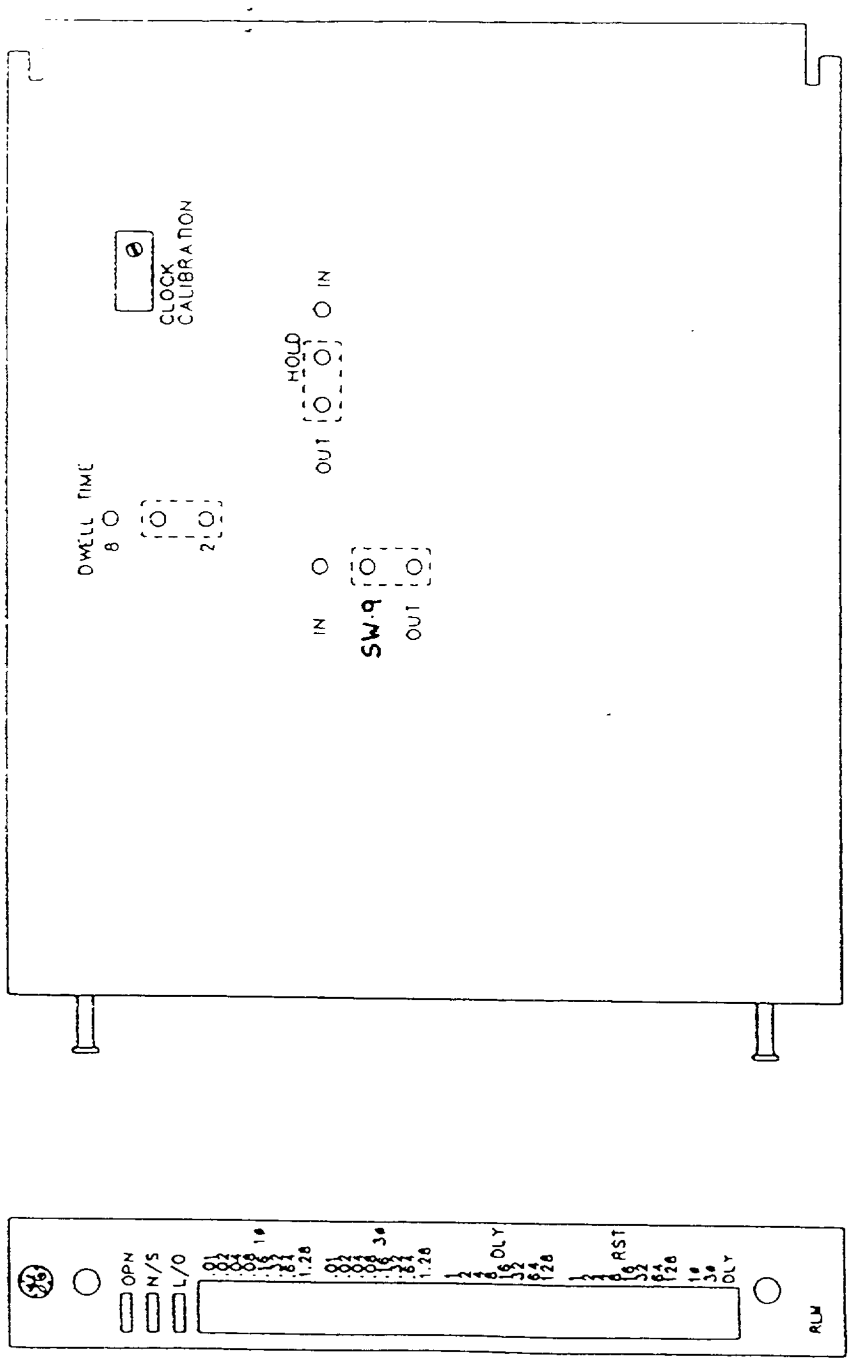


Figure 4 (226B7449, Sheet 1) : Recloser module - RLM

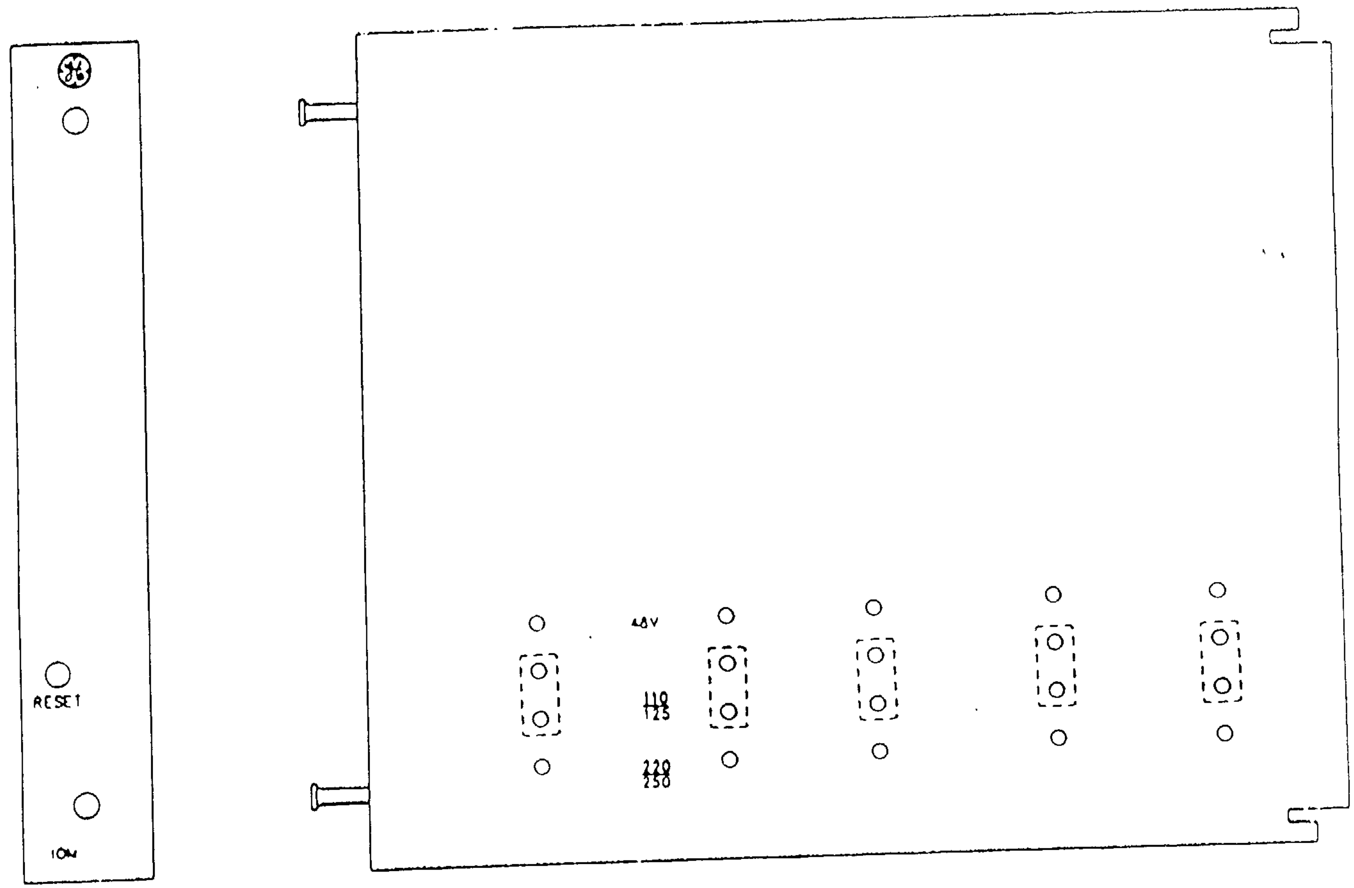


Figure 5 (226B7449, Sheet 2) : Auxiliary imputs and Outputs module - IOM

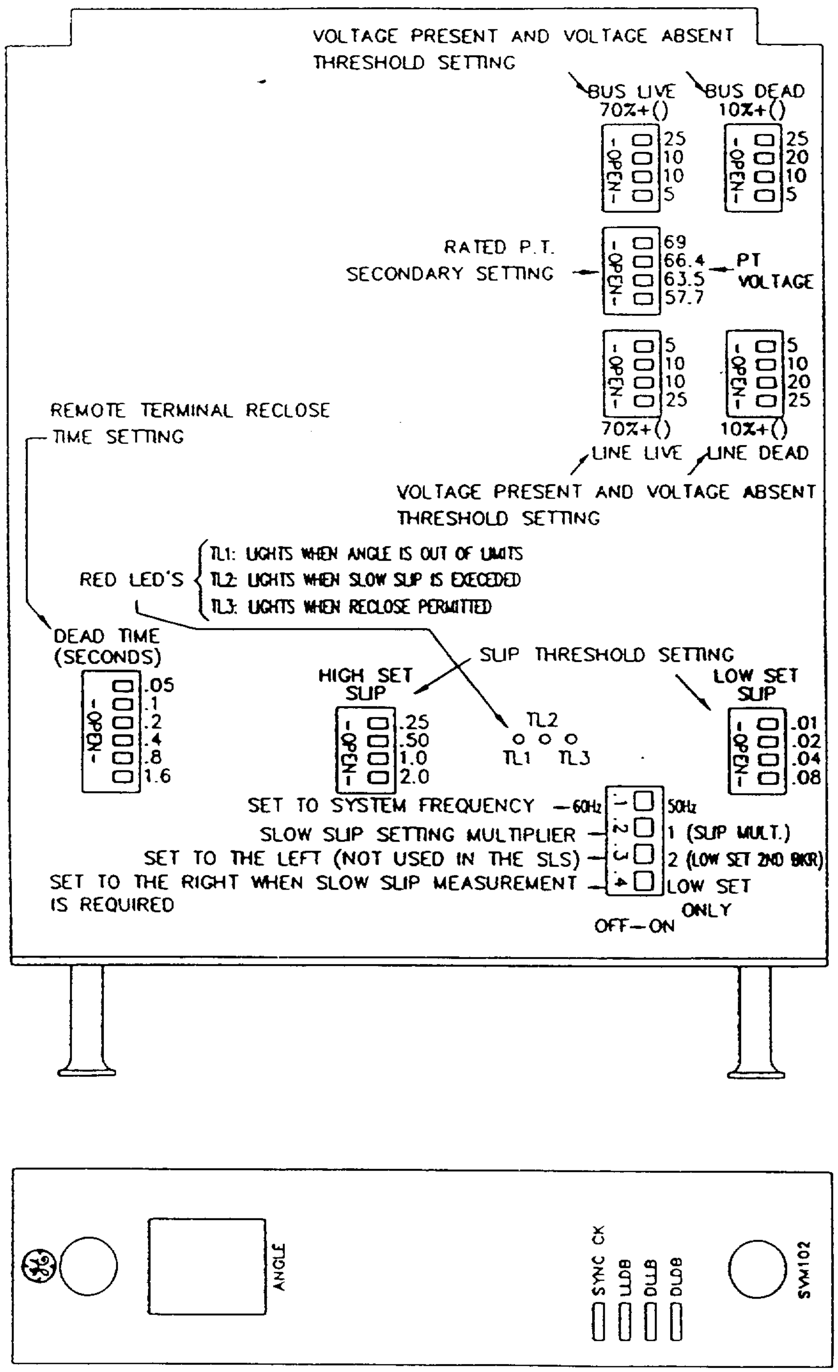


Figure 6 (226B7406, Sheet 5): Synchronism Check Module - SVM

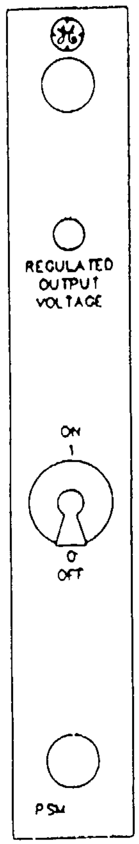


Figure 7 (226B7440, Sheet 18) :
Power supply module - PSM

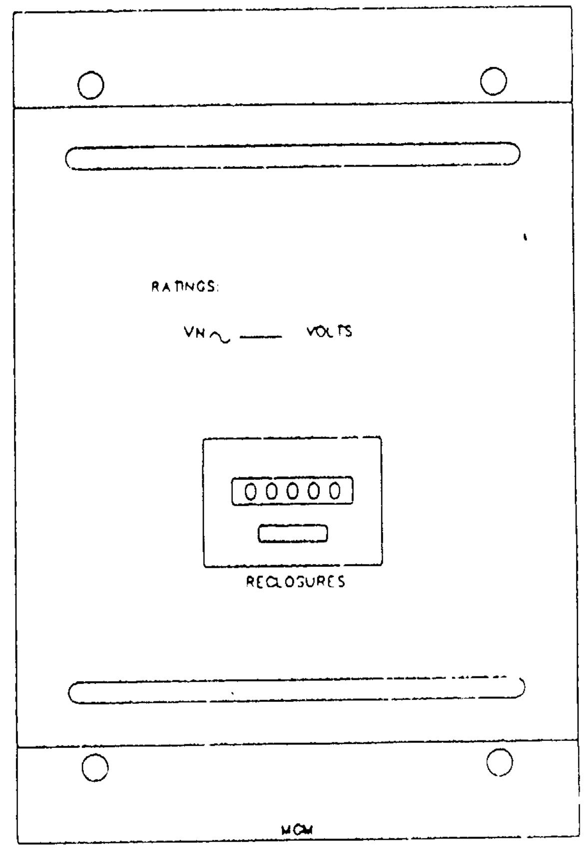
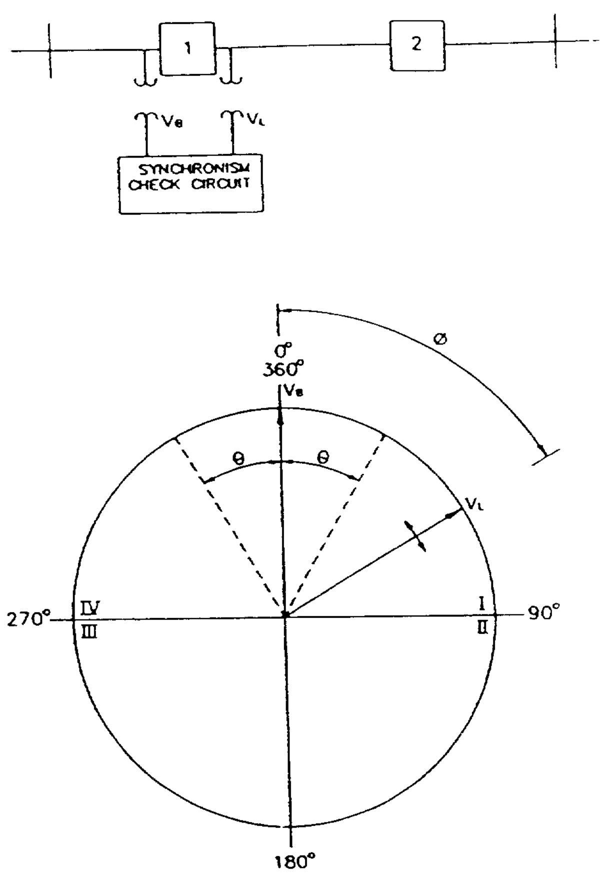


Figure 8 (226B7441, Sheet 34) :
Magnetic Module - MGM



WHERE θ = ANGLE SETTING

Figure 9 (226B7406, Sheet 8): Phasors Diagram for the Synchronism Check Discusion.

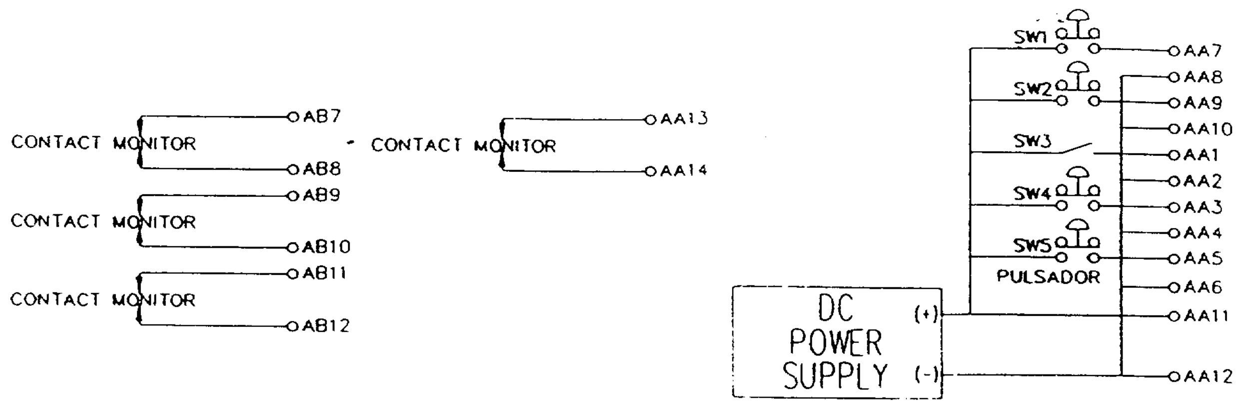


Figure 10 (226B7406, Sheet 9): Recloser Test Circuit

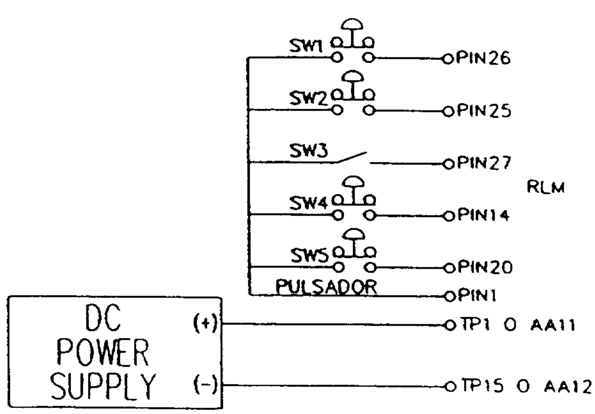


Figure 11 (226B7406, Sheet 10): Recloser Test Circuit

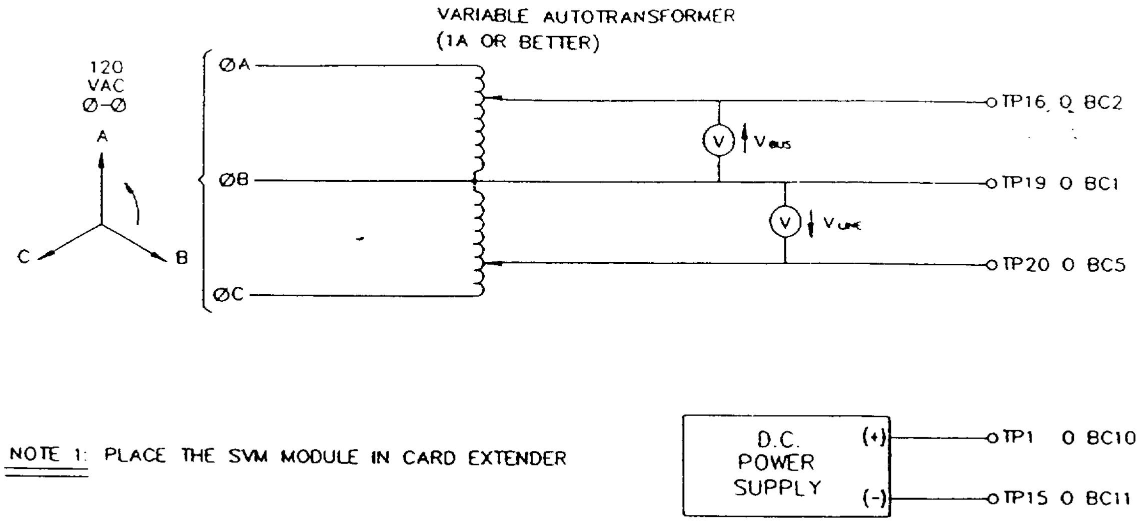


Figure 12 (226B7406, Sheet 11): Synchronism Check Voltage Levels Test Circuit

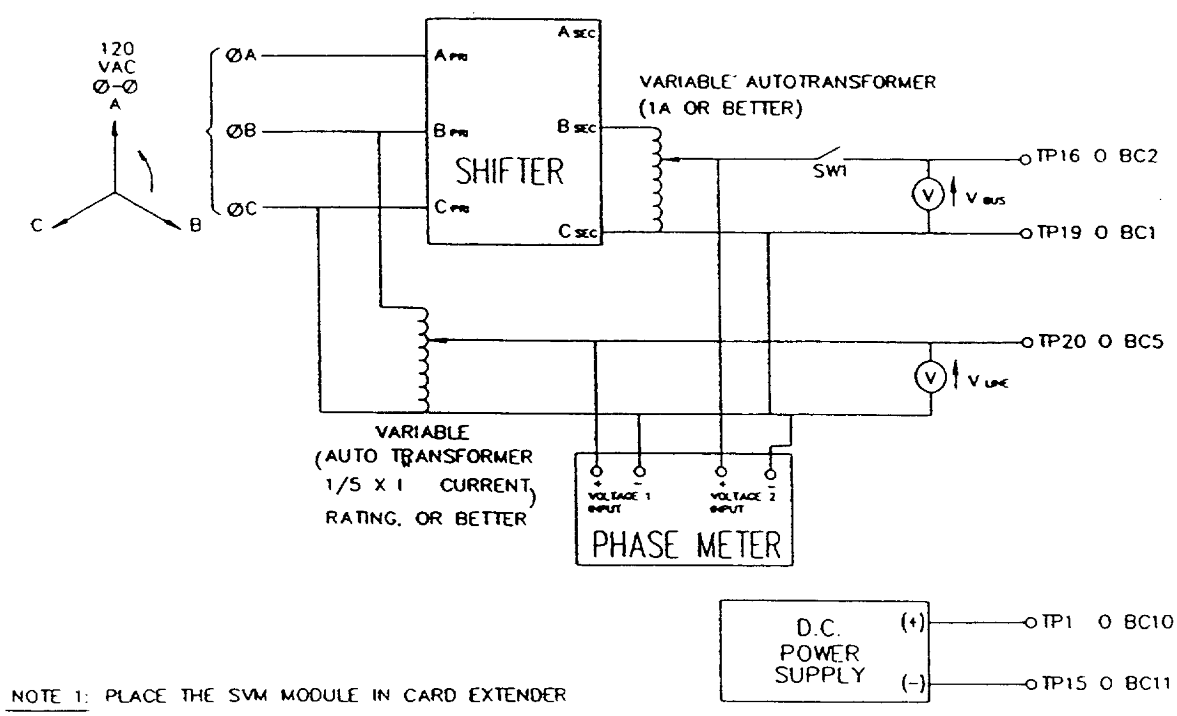


Figure 13 (226B7406, Sheet 12): Synchrocheck unit angle and slip test circuits.

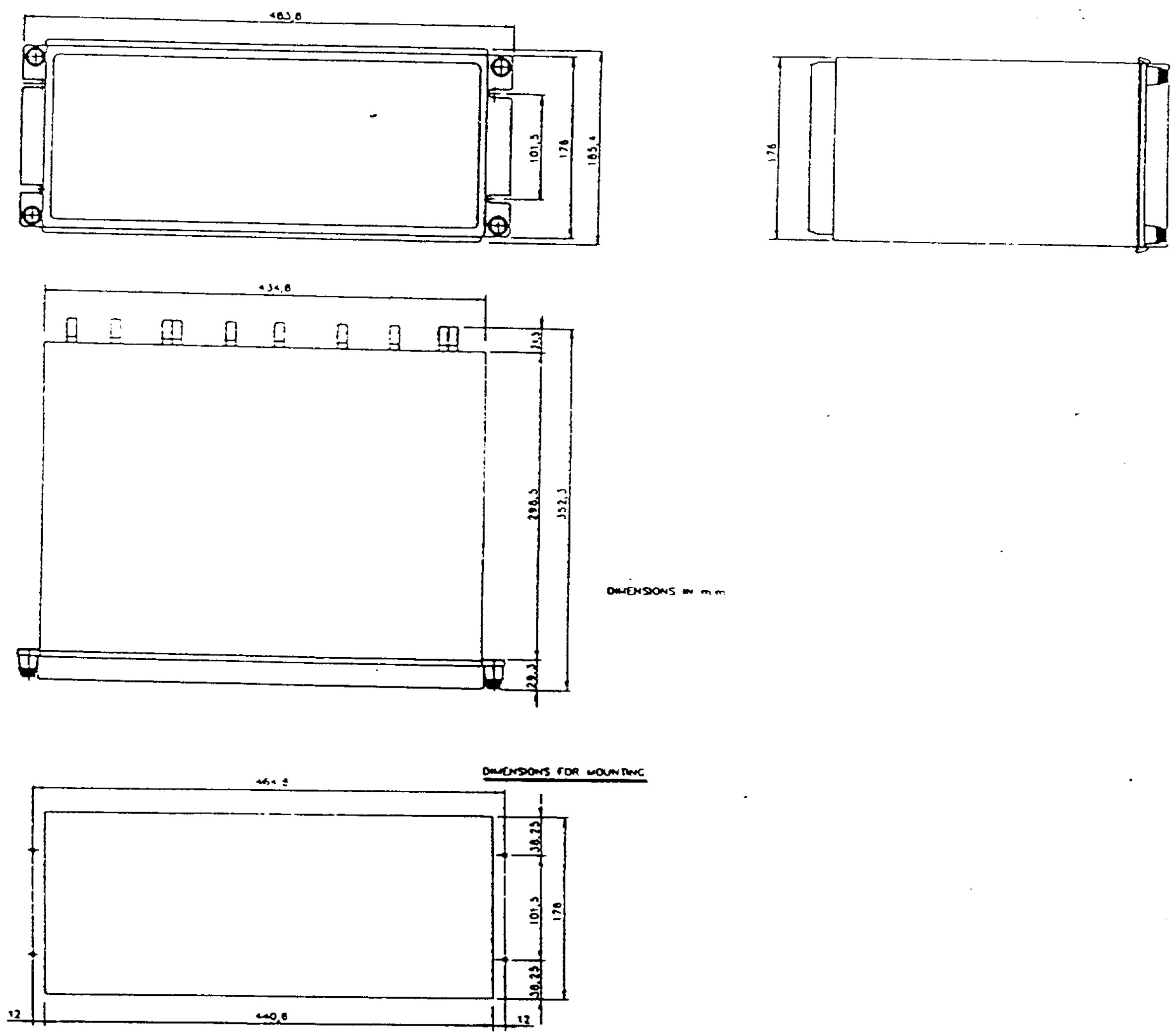


Figure 14 (226B6086, Sheet 6): Outline dimensions and drilling draw. for the MRS2000 system.

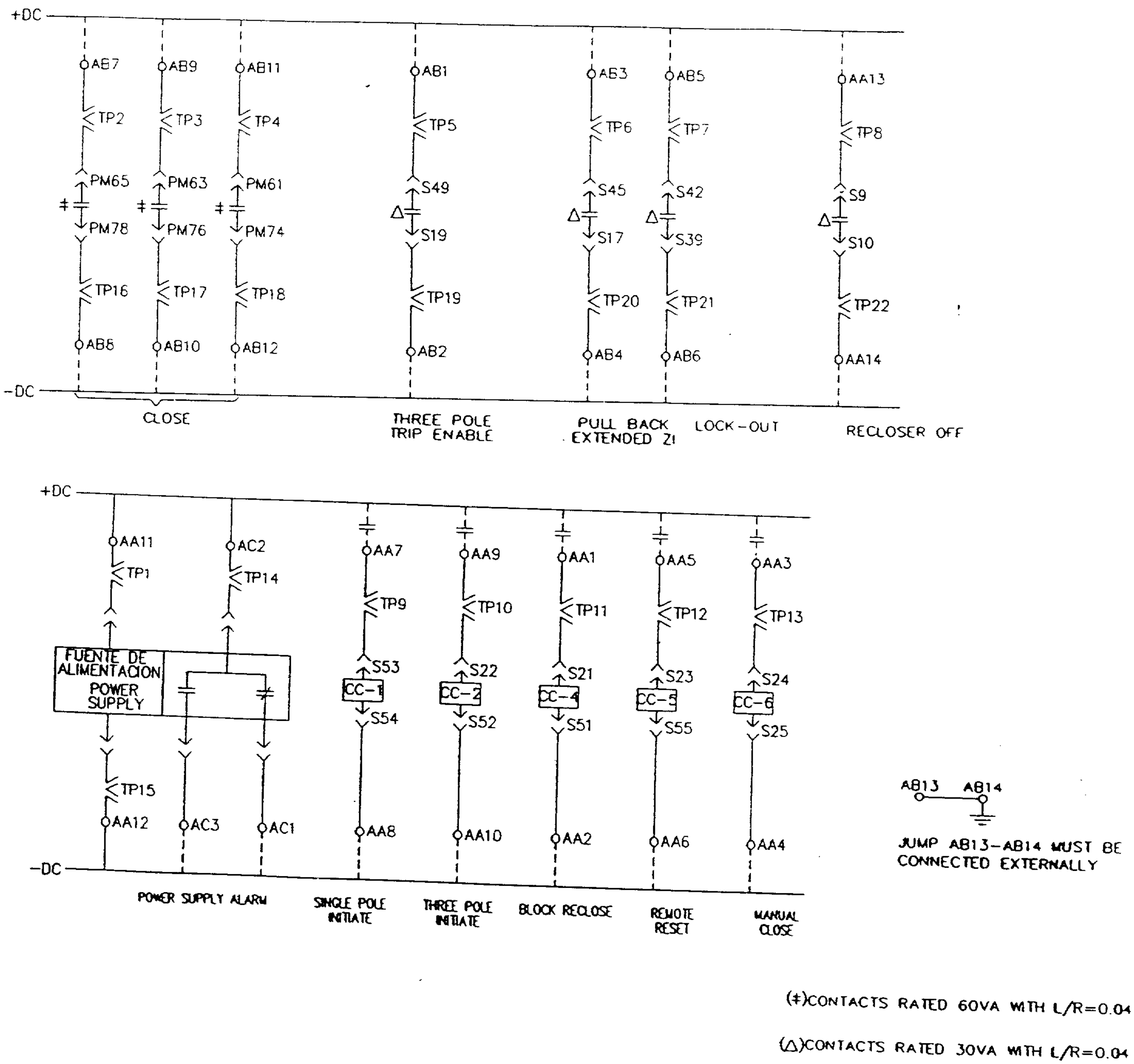


Figure 15 (226B7206, Sheet 13):

MRS2000 External Connections, Diagram without Synchronism Check Option.

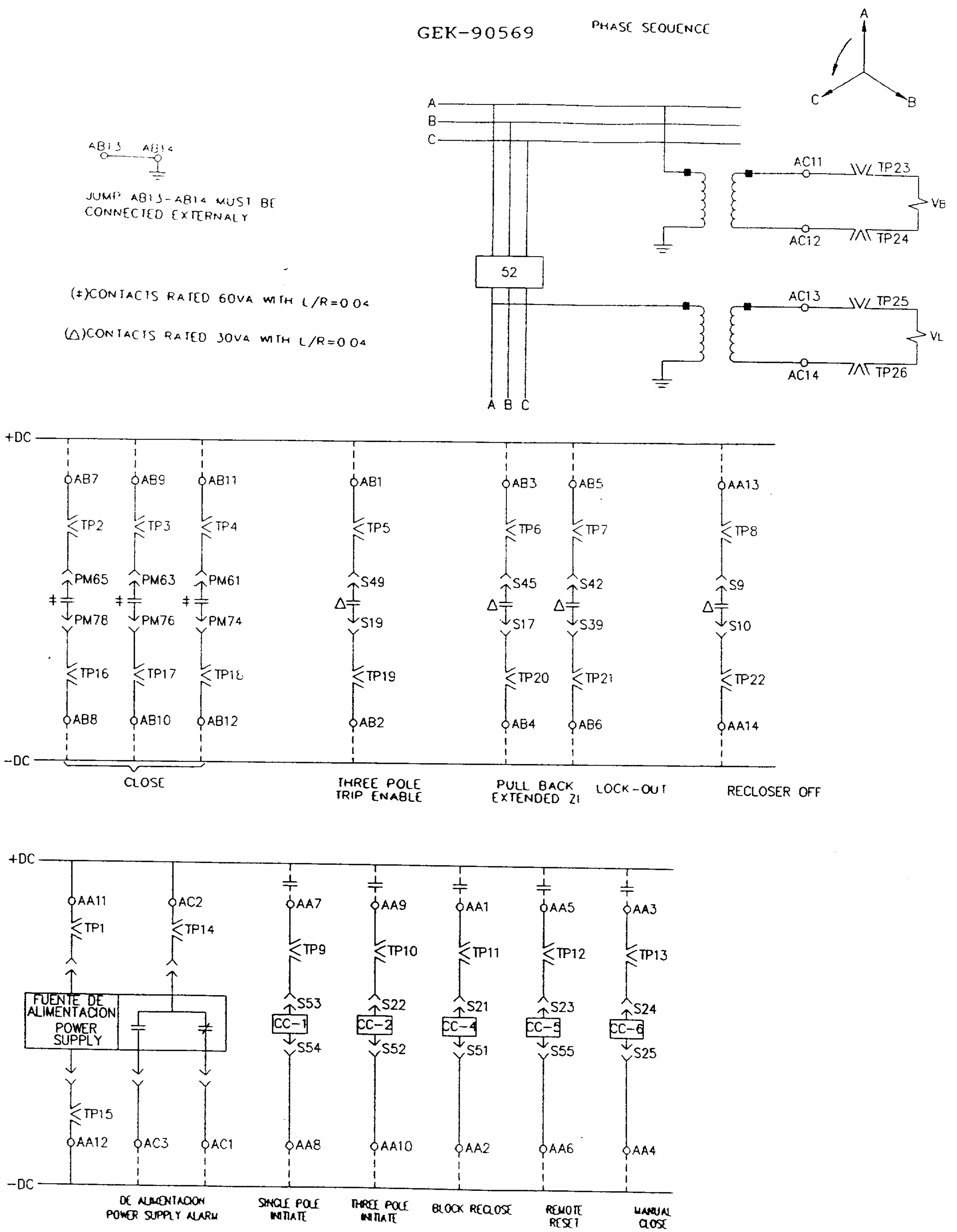


Figure 16 (226B7406, Sheet 14)

MRS2000 External Connections, Diagram with Synchrocheck.