SEL-121F
SEL-121F-1
SEL-121F-8

PHASE AND GROUND DISTANCE RELAY
GROUND DIRECTIONAL OVERCURRENT RELAY
SYNCHRONISM CHECKING RELAY
RECLOSING RELAY
FAULT LOCATOR

INSTRUCTION MANUAL

JUNE 4, 1992

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE HOPKINS COURT
PULLMAN, WA 99163-5603
TEL: (509) 332-1890 FAX: (509) 332-7990

Customer: ______________________________

P.O.#: ______________________

Book Assembled and Checked by: ____________________

Date Assembled and Checked: ____________________

Warning

This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

ATTENTION!

Cet équipement est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accès non-autorisé à l'équipement pourrait être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé.

20001120

Standard Product Warranty – Ten Years

Definition of Terms

Product:	All items manufactured by SEL that are sold to a customer.
New Product:	A product manufactured by SEL that is sold for the first time.
Customer:	An end-user of the product.

New Product Warranty

All new products sold to customers are warranted against defects in design, materials, and workmanship for a period of ten (10) years from the date of first retail delivery to a customer. If it is determined that the new product defect is covered under this warranty, SEL will repair, replace, or substitute an identical unit at its own discretion to the customer at no charge.

SEL may, at its own discretion, require the customer to ship the unit back to the factory for diagnosis before making a determination as to whether it is covered by this warranty. In such event, SEL may, at its own discretion, decide to provide the customer with a substitute unit which may be sent to the customer either from the SEL factory or from an authorized representative or distributor from their inventory.

All expenses related to the shipment of defective units back to SEL or the provision of a substitute unit to the customer are the responsibility of the customer. This expense may include, but is not limited to, freight, insurance, Customs clearance, and duties. All expenses related to the shipment of repaired units back to customers (or the provision of a new unit to the customer) will be borne by SEL.

Product Upgrade Policy

From time to time, SEL makes product upgrades to add to or enhance the performance of the products. Customers of a particular product being issued an upgrade will be notified either by SEL directly or through its authorized representatives or distributors.

Customers who have purchased an annual upgrade policy will receive all upgrades during the calendar year free of charge. Customers who did not purchase the annual upgrade policy may purchase each unit upgrade individually. The annual upgrade policy can be purchased at any time. Regardless of whether the upgrade policy is purchased, SEL will make reasonable efforts to notify all customers of all available upgrades.

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Equipment Repair and Warranty

Repair costs of products not covered under this warranty are paid for by customers. Customers are responsible for the cost of shipping the products to SEL located at: 2350 NE Hopkins Court, Pullman, Washington 99163 USA.

All products repaired by SEL will be warranted against defects in material and workmanship for a period of one year from the date the equipment is returned to the customer or the remainder of the new product warranty, whichever is longer.

Limitations

SEL's warranty does not extend to (A) SEL's products subject to (i) improper installation, connection, operation, maintenance, or storage; (ii) accident, damage, abuse, or misuse; (iii) abnormal or unusual operating conditions or applications outside the specifications for the product; (iv) a purpose or application in any way different from that for which the products were designed; or (v) repairs conducted by persons other than SEL employees or an authorized representative or distributor; (B) Equipment and products not manufactured by SEL. Such equipment and products may be covered by a warranty issued by the respective manufacturer.

This warranty is in lieu of any other warranties, express or implied, including without limitation, any warranty of merchantability or fitness for a particular purpose, and is in lieu of any and all other obligations or liability of SEL. Under no circumstances shall SEL be liable for any accidential or consequential damages or for any other loss, injury, damage, or expense of any kind including loss of profits arising hereunder.

To the extent any court, arbitration panel, or other governmental body of competent jurisdiction shall declare any provision of this warranty invalid or unenforceable by reason of a rule of law or public policy, all the other provisions hereof shall remain in full force and effect.

SEL-121F INSTRUCTION MANUAL ADDENDUM

Kilometer/50 Hz Options

The SEL-121F instruction manual is written for fault locations in terms of miles. If your SEL-121F relay is ordered with the kilometer line length option, references made in the instruction manual to miles should be substituted with kilometers.

One exception to the straight substitution of kilometers for miles is the reference in the instruction manual to the effect of shunt capacitance on the fault location calculation. The line length equation and associated paragraphs, corrected for a 100-kilometer line, should read:

Shunt capacitance of the transmission line is not taken into account. The capacitance causes the fault location to appear less remote by, approximately, a factor of 1/cos(bL), where bL is the line length in radians at 50 Hz. One wavelength at 50 Hz is 5996 kilometers. For example, the line length of a 100-kilometer line in radians, is:

$$(100/5996) \times 2 \times 3.14159 = 0.1048 \text{ radians}$$

The indication neglecting capacitance is about cos(0.1048) = 0.9945 times the actual fault location, or about 0.55 kilometers short for a fault at the remote end of a 100-kilometer line.

References made to a sampling time of 1/240 seconds should be replaced with a time of 1/200 seconds.

1 Amp Per Phase Option

For this version of the SEL-121F relay, the nominal current is 1 ampere per phase, instead of 5 amperes per phase stated in the specifications section. Secondary quantities should be divided by five in all calculations of current. The default settings are the same as the 5 ampere relays.

IEC Time-Overcurrent Characteristics Option

The time-overcurrent curves, and their associated equations, in this manual have been modified to conform to IEC specifications.

SEL RELAY INSTRUCTION MANUAL ADDENDUM

ACB PHASE ROTATION OPTION

The SEL relay instruction manuals are written for standard ABC phase rotation applications. If your SEL relay is ordered with the ACB phase rotation option, references made in the instruction manual to voltage and current phase angle should be noted accordingly. The firmware identification number (FID) may be used to verify whether your relay was ordered with ABC or ACB rotation.

All current and voltage inputs are connected to the SEL relay rear panel as shown in the instruction manual.

SEL-121F-1 RELAY ADDENDUM

This addendum details SEL-121F-1 relay protection and security logic which differs from that described in the SEL-121F Instruction Manual. The first section summarizes revisions to the SEL-121F relay. A detailed description of each revision follows the summary.

SEL-121F Relay Logic Revisions

Revision 1: TRIP unlatch logic has been modified to coincide with the loss of current following a trip instead of 52A input deassertion.

Revision 2: The minimum duration which TRIP contacts remain closed is now settable. This time was previously fixed at 60 msec.

Revision 3: The REJO logic can use either 3P50 or 3G50 as a qualifier instead of only 3G50.

Revision 4: If a trip condition exists, front panel targets do not clear when you press the TARGET RESET button.

Revision 5: The recloser reset timer (79RS) in the SEL-121F-1 relay has been modified to begin timing after the relay 52A input is energized following a reclose. Previous SEL-121F relay logic instructed the 79RS timer to begin timing upon closure of the CLOSE contacts.

Revision 1: TRIP Unlatch Logic Modification
Revision 2: Minimum Trip Duration Logic Modification

Unlatching the TRIP output contacts previously depended on three criteria: 1) 60 msec. minimum trip duration timer expiration, 2) 52A input deasserted when 60 msec. timer expired, and 3) trip conditions no longer existed.

The new open TRIP contact logic replaces the fixed 60 msec. timer and 52A status criteria with two new criteria: 1) dropout of all elements masked to cause a trip, 2) expiration of a settable trip duration timer (TDUR), and 3) dropout of both 50NG and 46QL elements. This new logic is as follows:

Open TRIP contact: NOT(TRIP) * [NOT(50NG+46QL) + TARGET RESET button pushed] *
(Minimum Trip Duration timer expired (TDUR))

Where:

TRIP ≡ Any condition resulting in TRIP output contact closure (determined by relay and logic settings)
TDUR ≡ Minimum Trip Duration timer (settable)

The Revision 1 logic change removed TRIP unlatch dependence on 52A input status. Once the line breaker is open (as judged by the loss of current flowing in the poles), it is acceptable to open the high speed TRIP output contacts without interrupting full trip coil current.

The Revision 2 logic modification allows you to set a minimum duration for TRIP output contact closure with the TDUR setting. This function was previously performed by a fixed 60 msec. timer. TDUR is an edge triggered timer initiated from the rising edge of the TRIP output. To maintain the 60 msec. minimum TRIP duration time, set the TDUR timer to 3.5 cycles (3.5 cycles = 58.3 msec.).

The OPEN command now asserts output contacts for the TDUR duration. Setting TDUR to 0 prevents the OPEN command from causing a trip.

Benefit:

The TRIP output contact unlatching operation is not dependent upon the 52A input state. This logic prevents possible timing mismatch between the 52A input to the relay and the 52A contact in series with the line breaker trip coil. Such a mismatch can result in TRIP output contacts interrupting full trip coil current.

Revision 3: REJO Qualifier Change

The REJO setting was expanded to encompass the settings "P," "G," or "N" instead of "Y" or "N." The value of "G" corresponds to the former "Y" value: the 3G50 element is used as a qualifier for the REJO logic. Setting REJO to "P" uses the 3P50 element as the REJO qualifier.

Benefit:

For applications with a tapped line, the pickup threshold for the 3G50 element should be set low enough for high impedance faults, but above the maximum tapped load. On very short lines with heavy fault duty, allowing 3P50 as the REJO qualifier decouples the 3G50 setting from REJO. The 3P50 element can then be set above the tapped load but below the minimum fault duty. For existing applications, the "G" setting can be used to duplicate the former "Y" setting exactly.

Revision 4: Front Panel Target Update Logic

Previous SEL-121F relay logic cleared front panel targets whenever a user pressed the TARGET RESET button regardless of TRIP output status. Pressing TARGET RESET also unlatched the TRIP output contact. When you press TARGET RESET, the new logic assures that no trip condition is present before clearing the targets. Pressing TARGET RESET still unlatches TRIP output contacts when no trip condition exists.

Benefit:

When restoring the SEL-121F relay to service following testing, always press the TARGET RESET button to ensure that TRIP output contacts are open. The new logic allows technicians to determine whether a trip condition persists prior to closing in the trip cutout switch. If relay targets do not clear after you press the TARGET RESET button, a trip condition is present and the trip cutout switch should not be closed.

Revision 5: 79RS Timer Initiation

Previous SEL-121F relay logic allowed the 79RS timer to begin when the CLOSE output contact closed. The recloser reset timer (79RS) in the SEL-121F-1 relay begins timing after the 52A input to the relay is energized following a reclose.

To illustrate the benefits of this modification, please refer to the system in Figure 1. For the system shown, consider a permanent fault on the transformer side of the motor operated disconnect at Station C. The SEL-121F-1 relay at Bus C is being used for line protection. Backup protection energizing the IN1 input permits use of relay reclosing functions for trips generated by backup protection for the transformer bank. Breaker 1 is set up to test the line with a hot bus/dead line in five seconds with the 79RS timer set for 20 seconds. Breaker 2 is set up for synchronized closure with the 79RS timer also set for 20 seconds. Assume the synch check timer is set for five seconds. The MOD is setup for hot line/dead bus reclosure in 50 seconds (25 seconds after Breaker 2 closes).

Breaker 1, Breaker 2, and the MOD should trip for this fault as the MOD is blocked from tripping by an overstress scheme. Five seconds after tripping, Breaker 1 recloses successfully. Five seconds after Breaker 1 energizes the line, Breaker 2 closes. Twenty five seconds later the MOD at Bus C recloses into the fault, which trips Breaker 1, Breaker 2, and the MOD again. Since the trips at Breakers 1 and 2 occurred after their respective 79RS timers had expired, these breakers are permitted to reclose. However, the MOD trip occurred while its 79RS timer was decrementing, which locks out the MOD.

Caution: The 79RS timer in the SEL-121F-1 relay no longer blocks a standing close from the relay if the 52A input is never energized following a reclose.

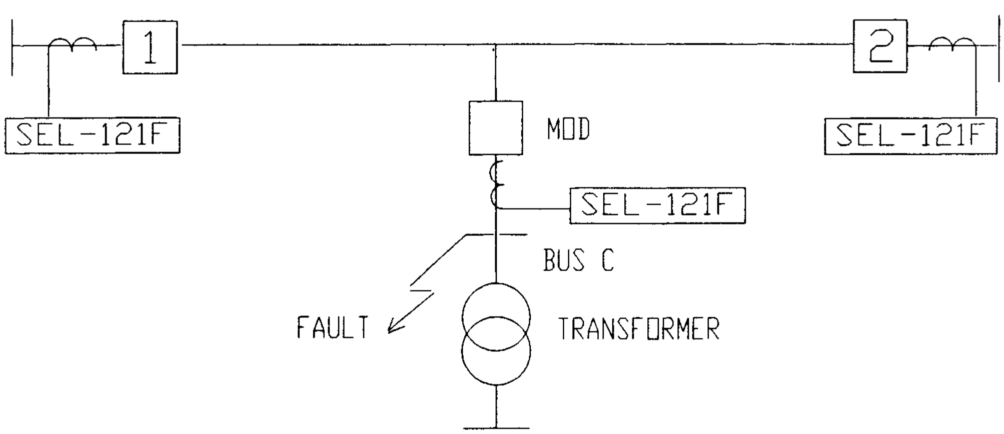

Figure 1: System Single Line Diagram for Revision 5 Explanation

SECTION 1: SEL-100 SERIES ADDENDUM

The SEL-100 series relay logic inputs have been improved to prevent operation of the logic input due to the conditions described in SELUPDATE 94.10. If you would like a copy of SELUPDATE 94.10, please contact the SEL factory.

The new interface board also provides field selectable input voltage selection. The operating voltages and jumper selection for each logic input are shown in the table below.

Control Voltage	Relay Terminals											
	39/40		41/42		43/44		45/46		47/48		49/50	
	JMP11	JMP12	JMP9	JMP10	JMP7	JMP8	JMP5	JMP6	JMP3	JMP4	JMP1	JMP2
250 V												
125 V		•—•		•—•		•—•		•—•		•—•		•—•
48 V	•—•	•—•	•—•	•—•	•—•	•—•	•—•	•—•	•—•	•—•	•—•	•—•

CONTROL INPUT OPERATING RANGES

Control Voltage	Operating Range
250 Vdc	150 - 300 Vdc
125 Vdc	80 - 150 Vdc
48 Vdc	30 - 60 Vdc

Changing the input voltage jumpers requires that you disassemble the relay. The following information describes the procedure for changing the input voltage selection jumpers:

1. Remove power from relay.
2. Place relay in a static-safe work area.
3. Remove top and bottom chassis covers (eight screws total).
4. Remove the four screws securing the front panel.
5. Carefully allow the top edge of the front panel to come forward and down (exposing relay main board/power supply/interface tray assembly).
6. From the bottom of the relay, locate and remove the two 4-40 hex jack screws that secure the tray assembly to the chassis. These jack screws are located at the front corners of the draw-out tray and require a long 3/16-inch nut driver or extended socket.

7. Carefully remove the ribbon cable from the front panel LED display. The power switch/fuse assembly will remain attached to the relay and front panel.

8. Carefully remove the ribbon cable from the main board P104 connector.

9. Pull forward on the draw-out tray using the two standoffs located on the bottom of the tray. Removing the draw-out tray will require a good amount of force.

10. With the main board facing up, rotate the draw-out tray so that the back is facing you. The input jumpers are now exposed on the inside of the interface board (board below draw-out tray).

11. Make the correct jumper selection for the desired input voltages per the jumper selection table.

12. Turn board so that the main board is facing up and reinstall into relay chassis. Note guide hole alignment at the back of the draw-out tray and make sure interface pins located on the back plane board are aligned with the draw-out tray before "seating" the draw-out assembly. Inserting the draw-out tray will require a good amount of force.

13. Reattach ribbon cable to main board P104 connector.

14. Reattach ribbon cable to front panel LED assembly.

15. Replace the 4-40 hex jack screws (two only) so that the draw-out tray is secure.

16. Lift the edge of the front panel up into normal position and replace the four front panel screws. (Make sure switch/fuse cable and ribbon cables are free from any "pinch" points.)

17. Make sure power switch/fuse cable assembly is seated on the back panel connector. (During the normal removal process, it is possible to have partially or completely disconnected this cable.)

18. Carefully replace top and bottom chassis covers and screws (eight screws total).

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INTRODUCTION

GETTING STARTED

This instruction manual applies to SEL-121F, SEL-121F-1, and SEL-121F-8 relays. Please remember that the hardware is identical for all SEL-121F relays. Firmware changes to the logic controlling reclosing and command access level differentiate SEL-121F relay model variations.

If you are not familiar with the SEL-121F, SEL-121F-1, or SEL-121F-8 relay, we suggest that you read this introduction, then perform the Initial Checkout Procedure in Section 7: MAINTENANCE & TESTING.

RELAY OVERVIEW

The SEL-121F family of relays are designed to protect transmission, subtransmission, and distribution lines for all fault types. The following list outlines protective features, performance, and versatility gained when applying any SEL-121F relay to your installations.

- Three zones of instantaneous/definite-time phase and ground distance protection
- Residual time-overcurrent element with selectable curves
- Instantaneous residual overcurrent element
- Negative-sequence polarization of ground directional elements
- Versatile user programmable logic for outputs and tripping
- Programmable switch-onto-fault logic
- Loss-of-potential detection logic
- Programmable single-shot reclosing
- Synch-check and voltage checking to supervise breaker closure
- Fault locating
- Metering
- EIA RS-232-C Communication ports for local and remote access
- Automatic self testing
- Demodulated IRIG-B time code input
- Target indicators for faults and testing
- Compact and economical

MODEL VARIATIONS COVERED BY THIS INSTRUCTION MANUAL

SEL offers several optional variations of the SEL-121F relay logic. While this introduction includes a short description of each model variation, the remainder of the instruction manual pertains only to the standard SEL-121F relay and the -1 variation. Please consult the information sticker on the relay rear panel if you are unsure of the relay model number.

SEL-121F Relay

The basic SEL-121F relay employs each feature outlined in the preceding Relay Overview.

SEL-121F-1 Relay

SEL-121F-1 relay 79RS timer begins timing after the 52A input to the relay is energized following a close. This is different from the SEL-121F relay which starts the 79RS timer when the relay CLOSE output contact asserts.

To illustrate the benefits of this modification, please refer to the system in Figure 1.1, on the following page. The SEL-121F-1 relay at Bus C is being used for line protection. Backup protection energizing the IN1 input permits use of relay reclosing functions for trips generated by transformer bank backup protection. Breaker 1 is set up to test the line after 5 seconds with hot bus/dead line supervision with the 79RS timer set for 20 seconds. Breaker 2 is set up for synch-check supervised closure with the 79RS timer also set for 20 seconds. Assume the synch check timer is set for five seconds. The MOD is setup for hot line/dead bus reclosure in 35 seconds (25 seconds after Breaker 2 closes).

For the system shown, consider a permanent fault on the transformer side of the motor operated disconnect at Station C. Breaker 1, Breaker 2, and the MOD should trip for this fault. The MOD is blocked from immediate tripping by an overstress scheme and trips when the line is dead. Five seconds after the MOD opens, Breaker 1 recloses successfully. Five seconds after Breaker 1 energizes the line, Breaker 2 closes. Twenty-five seconds later, the MOD at Bus C recloses into the fault, which causes Breaker 1, Breaker 2, and the MOD to trip again. Since the trips at Breakers 1 and 2 occurred after their respective 79RS timers had expired, these breakers are permitted to reclose. However, the MOD trip occurred before the 79RS timer reset, which locks out the MOD.

Caution: **The 79RS timer in the SEL-121F-1 relay no longer blocks a standing close from the relay if the 52A input is never energized following a reclose.**

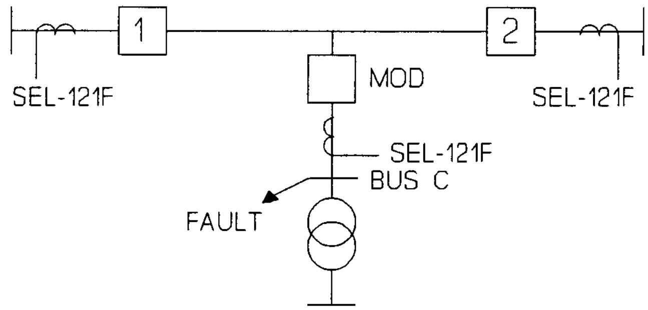

Figure 1.1: System Single-Line Diagram for the SEL-121F-1 Relay Modification Explanation

SEL-121F-8 Relay

The SEL-121F-8 relay has several differences from the basic SEL-121F relay model. A Level 2 access attempt does not pulse the ALARM contacts as in the SEL-121F relay. Instead, the ALARM contact pulses for four seconds after three unsuccessful Level 1 or 2 access attempts. DATE, TIME, TRIGGER, and IRIG command execution requires Level 2 access. In contrast, the basic SEL-121F relay requires only Level 1 access for these commands. TARGET command execution from Level 1 only displays targets. TARGET command execution from Level 2 displays targets and allows the operator to change front panel LED assignments. Excluding these differences, the SEL-121F-8 relay is identical to the SEL-121F relay.

GENERAL DESCRIPTION

Because the -1 and -8 relay variations are derived from the SEL-121F relay, this manual refers to all three variations (standard, -1, and -8) as the SEL-121F relay.

The SEL-121F Phase and Ground Distance Relay with fault locator simultaneously provides high-speed and time delayed protection for transmission, subtransmission, and distribution lines. A 24-bit Relay Word combines mho distance elements, overcurrent elements, directional element, timers, and data and control bits. You can program the tripping, output, and reclosing logic through Relay Word bit combinations to control the relay outputs.

Because of its many relay elements, large setting ranges, programmability, and low cost, the relay meets the requirements of a broad spectrum of applications. Flexible yet simple programmability provides access to relay elements (before and after time delays) and logic results. The relay features include three zones of phase-to-phase distance and phase-ground distance elements, time delayed backup for Zones 2 and 3 phase and ground elements, residual instantaneous and time-overcurrent elements, single shot reclosing with programmable initiate and reclose conditions, synch-check and voltage checking logic, and loss-of-potential logic.

Without requiring an external initiating contact input, the relay provides time-stepped protection in parallel with communication-aided protection. The relay supports:

- Permissive Overreach Transfer Trip (POTT) schemes
- Permissive Underreaching Transfer Trip (PUTT) schemes
- Direct Underreaching Transfer Trip (DUTT) schemes
- Direct Transfer Trip (DTT) schemes

Analog inputs from current and voltage transformers are delivered to the protective relaying elements and saved for additional features such as metering and fault locating.

Relay elements process the analog data. Some intermediate logic is performed, such as overcurrent supervision of the mho elements, directional supervision of the residual overcurrent elements, and grouping of certain elements into zones.

The relay generates an eleven-cycle event report starting with information captured four cycles before fault detection through seven cycles afterward. Each event report resembles a sequence-of-events report; each includes the following information every quarter-cycle for eleven cycles:

- Voltages (VA, VB, VC, and VS)
- Currents (IA, IB, and IC)
- Fault type and involved phases
- Fault location
- Secondary ohms to the fault location
- Maximum phase current measured near the middle of the fault
- Date and time of the event
- Relay element status
- External inputs (breaker status, block trip, etc.)
- Relay contact output status

The information in each event report simplifies analysis of the most complex system operations.

The relay stores the latest twelve event reports, allowing retrieval and examination after the event. You may retrieve any or all records remotely or locally through either of the two serial communications ports.

The metering function permits interrogation of the relay to obtain power system voltage, current, real power, and reactive power readings. The function also includes per-phase measurements of voltage and current. Metering is very valuable for unmanned or remote substations.

The CLOSE, A1, A2, A3, A4, and ALARM outputs may be specified as "a" or "b" type contacts. TRIP outputs are always an "a" type contact.

The relay is compatible with the SEL-PRTU protective relay terminal unit, the SEL-DTA Display/Transducer Adapter, SEL-RD Relay Display, and the SEL-PROFILE Transmission Line Fault Analysis Program.

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SPECIFICATIONS

This section is divided into three subsections. The first describes input parameters, mechanical specifications, and applicable standards. The second provides a functional specification, while the third details the technical features of each relay function.

RELAY STANDARDS AND INPUT PARAMETERS

Rated AC Input Voltage	115 volt nominal phase-to-phase, three-phase four-wire connection
Rated AC Input Current	5 amps per phase nominal 15 amps per phase continuous 500 amps for one second thermal rating
Output Contact Current Ratings	30 amp make per IEEE C37.90 para 6.7.2 6 amp carry continuously MOV protection provided
Optical Isolator Logic Input Ratings	48 Vdc: 25 - 60 Vdc 125 Vdc: 60 - 200 Vdc 250 Vdc: 200 - 280 Vdc Current = 6 mA at nominal voltage
Time Code Input	Relay accepts demodulated IRIG-B time code.
Communications	Two EIA RS-232-C serial communications ports
Power Supply Ratings	48 Volt: 30 - 60 Vdc; 12 watts 125/250 Volt: 85 - 280 Vdc or 85 - 200 Vac; 12 watts
Relay Dimensions	5¼" x 19" x 13" (13.3 cm x 48.2 cm x 33.0 cm) (H x W x D)
Mounting	Mounts in standard EIA 19" (48.2 cm) relay rack or panel cutout. Available in horizontal or vertical mounting configurations.
Operating Temperature	-40°F to 158°F (-40°C to 70°C)
Dielectric Strength Routine Tested	V, I inputs: 2500 Vac for 10 seconds Other: 3000 Vdc for 10 seconds (excludes EIA RS-232-C)
Interference Tests	IEEE C37.90 SWC Test (type tested) IEC 255-6 Interference Test (type tested)

Impulse Tests IEC 255-5 0.5 Joule, 5000 Volt Test (type tested)

RFI Tests Type-tested in field from a ¼-wave antenna driven by 20 watts at 150 MHz and 450 MHz randomly keyed on and off one meter from relay.

Electrostatic Discharge Tests IEC 801-2 (type tested)

Unit Weight 21 pounds (9.1 kg)

Shipping Weight 32 pounds (14.5 kg), including two instruction manuals.

Burn-in Temperature 140°F (60°C) for 100 hours.

Environmental Test IEC 68-2-30 Temp/Humidity Cycle Test - six day (type tested)

FUNCTIONAL SPECIFICATIONS

Expanded Mho Characteristics for Phase-Ground, Phase-Phase, and Three-Phase Faults

- Three zones of phase and ground distance protection
- Distance elements polarized from positive-sequence memory voltage
- Polarization method provides distance element expansion for improved resistive fault coverage
- Independent timers for Zone 2 phase, Zone 2 ground, and Zone 3 distance elements (time-step backup protection)
- Fault detectors and negative-sequence directional elements supervise distance elements
- Loss-of-potential logic supervises all distance elements, when enabled

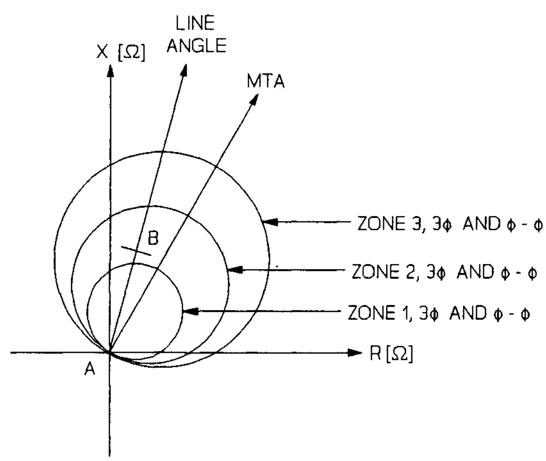


Figure 2.1: Three Zones of Phase and Ground Mho Distance Protection

Residual Overcurrent Backup Protection for Ground Faults

- Time-overcurrent element detects highly resistive ground faults
  - Four curve families (moderate, inverse, very inverse, and extremely inverse)
  - Nondirectional or forward-reaching, as enabled in relay settings
- Instantaneous residual overcurrent element
  - Nondirectional or forward-reaching, as enabled
- Negative-sequence directional polarization

Negative-Sequence Directional Element

- Directional polarization is based upon negative-sequence voltage and current
- Adds security to phase and ground distance elements
- May polarize ground directional overcurrent protection, if enabled

Loss-of-Potential (LOP) Detection

- Detects blown secondary potential fuse(s) condition
- Enabled or disabled with a simple setting
- When enabled, an LOP condition blocks all mho distance elements
- LOP detection may be selected to close programmable output relay or the ALARM contact for indication purposes

Nondirectional Phase Overcurrent Elements

- Low-set phase overcurrent elements supervise phase distance elements and release the TRIP output contacts in conjunction with the low-set residual overcurrent element
- Low-set phase overcurrent elements help detect blown potential fuses in Loss-of-Potential logic
- Low-set three-phase overcurrent elements may be used in Remote-End-Just-Opened (REJO) logic to detect remote breaker clearance of in-section faults
- High-set phase overcurrent element provides switch-onto-fault protection for close-in three-phase faults

Remote-End-Just-Opened (REJO) Protection

- User selected elements enabled to trip if remote breaker clears fault contribution
- Provides pilotless accelerated tripping in many applications

Switch-Onto-Fault Protection

- User selected elements enabled to trip for 52BT time after the line breaker closes
- Functions independently from communications channel equipment

Reclosing

- Single reclosing shot with settable open interval timer
- Selectable reclose initiate and cancel conditions
- Settable reclose reset timer
- Selectable voltage checking and synchronism checking can supervise reclosing

Voltage Checking

- Closing may be supervised by Live-line/Dead-Bus conditions, Live-bus/Dead-line conditions, or either condition
- Supervision may be applied to closures initiated by external equipment
- Supervision is independent of polarizing potential transformer location; you may use either supervision scheme with line-side or bus-side polarizing potentials

Synchronism Checking

- Closing may be supervised by a synchronism checking function
- Supervision may be applied to closures initiated by external equipment
- Relay setting allows synch-check potential to be taken from any phase

IRIG-B Input

The relay accepts demodulated IRIG-B from an external clock source to set the internal clock automatically.

Relay Word

The Relay Word consists of three rows of eight bit groups which represent the state of the relay elements (both instantaneous and timed), timer and logic outputs, and relay inputs. Each bit in the Relay Word has two states: logical 1 when the element is asserted, logical 0 when the element is deasserted.

Each quarter-cycle, the relay samples voltage and current data, performs intermediate logic to determine if elements are asserted, and sets appropriate bits in the Relay Word.

Each TRIP, programmable output relay, and reclose initiate and cancel condition has a corresponding logic mask (see Programmable Logic Masks). These masks determine the state of the output relay and reclosing sequence, depending on which elements are asserted in the Relay Word.

Table 2.1 shows the SEL-121F Relay Word.

Table 2.1: Relay Word

Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q
67N	51NP	51NT	50NG	50P	50H	IN1	REJO
LOP	52BT	27S	27P	59S	59P	SSC	VSC

Logic Inputs

The relay has six opto-isolator inputs to sense external conditions: a programmable input, received permissive trip and block trip signals, breaker status, direct close, and external event report trigger. Assert these logic inputs by applying control voltage to the corresponding rear panel input terminals.

Output Contacts

The relay has seven output contacts: TRIP, CLOSE, ALARM, and four programmable outputs (A1, A2, A3, and A4). Any output contact except TRIP may be configured as either "a" or "b."

Event Reporting

The relay retains eleven cycle data records for each of the last twelve events. The long form of each event record includes the following:

1.* Date and time of disturbance
2.* Terminal identifier
3. Input voltages and currents every quarter-cycle
4. Relay element status every quarter-cycle
5. Input and output contact status every quarter-cycle
6.* Fault location
7.* Event type
8.* Maximum phase current magnitude near the middle of the fault
9.* Fault duration in cycles
10. Relay and logic settings

* Included in the summary event report and event history listing.

An event report is triggered when certain relay elements pick up, the TRIP output contacts close, the Programmable Input, Permissive Trip, Block Trip, External Trigger input contacts are asserted, or by execution of the TRIGGER or OPEN commands.

If tripping occurs after the end of the event report, the trip triggers a second report. For details on the contents and analysis of relay event reports, see Section 4: EVENT REPORTING.

Fault Location

The relay computes fault location using event report data stored for each fault or disturbance. The primary fault locating algorithm compensates for prefault current to improve fault locating accuracy for high-resistance faults. The relay uses two fault locating methods: the Takagi method where sound prefault data are available, or a simple reactance method when sound prefault data are not available.

Metering

The meter function shows the line-neutral and line-line ac voltage and current values, residual current and synchronism checking voltage input values, megawatts (P to represent real power), and megavars (Q to represent reactive power) in primary values. You can display these values locally or remotely with the METER command.

Targeting

Under normal operating conditions, the enable (EN) LED is illuminated. If the relay trips, it illuminates the LED(s) for the highest priority zone and fault type at the time of trip. Target LEDs are latching, so the targets remain illuminated until you press the Target Reset button, execute the TARGET R command, or a trip with a different zone and fault type occurs. When a new trip occurs, targets clear and display the new tripping target.

The TARGET command and front panel LED display allow assignment of front panel LEDs to show the state of relay inputs, outputs, and Relay Word elements. See the TARGET command in Section 3: COMMUNICATIONS for more details.

Self Testing

The relay runs exhaustive self tests which ensure reliable operation. If a test fails, the relay enters a warning or failure state, closes the ALARM output relay, and issues a status report to the port designated automatic. The duration of ALARM output contact closure depends on which self test warns or fails.

Self tests check the following items:

- Analog Channel Offset (IR, IA, IB, IC, VA, VB, VC, and VS)
- +5 V Power Supply
- ±15 V Power Supplies
- Random Access Memory (RAM)
- Read Only Memory (ROM)
- Analog-to-Digital Conversion Time
- Master Offset
- Settings

See Detailed Specifications in this section for a complete description of self tests.

DETAILED SPECIFICATIONS

Distance Elements

Phase-Phase Distance (Secondary Quantities)

21AB1, 21BC1, 21CA1 : 0.125 to 64 ohms
21AB2, 21BC2, 21CA2 : 0.125 to 64 ohms
21AB3, 21BC3, 21CA3 : 0.125 to 64 ohms
Zone 1 < Zone 2 < Zone 3

Ground Distance (Secondary Quantities)

21AG1, 21BG1, 21CG1 : 0.125 to 64 ohms
21AG2, 21BG2, 21CG2 : 0.125 to 64 ohms
21AG3, 21BG3, 21CG3 : 0.125 to 64 ohms
Zone 1 < Zone 2 < Zone 3

Minimum Sensitivity

0.5 Amps secondary, defined by the fault detector minimum setting.

Maximum Torque Angle (MTA)

Adjustable from 47° - 90°.

Residual Current Compensation (K) Factor Range

Magnitude limits: $0.0833 < |K| < 2.0$
Range limits: $47° < MTA + \angle K < 113°$
Where: $K = \frac{Z0 - Z1}{3 \times Z1}$

$Z0 = R0 + jX0$
$Z1 = R1 + jX1$
R0, X0, R1, X1 Relay Impedance Settings

Accuracy

Steady-state Error:

- ±5% of set reach ±0.01 ohm at MTA for $V > 5$ V and $I > 2$ A.
- ±10% of set reach ±0.01 ohm at MTA for $1 < V < 5$ V and $0.5 < I < 2$ A.

Transient Overreach:

- ±5% of set reach, plus steady-state error.

Operating Speed

See Figure 2.10 for operating time curves.

Memory Polarization

Phase and ground distance elements are positive-sequence memory voltage polarized from an infinite impulse-response filter with a four-cycle time constant, yielding polarization for at least six cycles.

Zone 2 and 3 Distance Element Timers

Zone 2 ground distance element timer (Z2DG) range:	3 - 2000 cycles in quarter-cycle steps
Zone 2 phase distance element timer (Z2DP) range:	3 - 2000 cycles in quarter-cycle steps
Zone 3 timer (Z3DP) range:	3 - 2000 cycles in quarter-cycle steps

Note: The instantaneous and time delayed outputs of the Zone 3 distance elements are separate in the Relay Word, permitting access to both. This allows use of a time delay for time-stepped backup functions while maintaining the required instantaneous outputs for communication-based protection schemes.

Overcurrent Elements

Nondirectional Phase Overcurrent Elements (Secondary Quantities)

- 50AG, 50BG, 50CG (low-set ground fault detectors)
  Pickup: 0.5A to 25 times 51NP, but less than 40 A, ±0.1 A ±2% of setting
  Transient overreach: ±5% of set pickup
- 50AP, 50BP, 50CP (phase fault detectors)
  Pickup: 0.5 to 40 A, ±0.1 A ±2% of setting
  Transient overreach: ±5% of set pickup
- 50AH, 50BH, 50CH (high-set phase overcurrent elements)
  Pickup: 0.5 to 80 A, ±0.1 A ±2% of setting
  Transient overreach: ±5% of set pickup

Ground Overcurrent Elements (Secondary Quantities)

- 50N residual overcurrent element
  Nondirectional element supervises ground distance elements
  Pickup: 0.5 A to 25 times 51N pickup, but less than 40 A
  Transient overreach: ±5% of set pickup

- 51N residual time-overcurrent element
  Selectable curve shape (four curve families)
  - Moderately Inverse (curve family 1)
  - Inverse (curve family 2)
  - Very Inverse (curve family 3)
  - Extremely Inverse (curve family 4)

  Time dial: 0.50 to 15.00 in 0.01 steps
  Pickup: 0.5 to 8.0 A, ±0.05 A ±3% of setting
  Timing: ±4% and ±1 cycle for residual current magnitude between 2 and 20 multiples of pickup
  May be directionally controlled (51NTC setting)

- 67N residual overcurrent element
  Pickup: 0.5 A to 50 times 51N pickup
  Transient overreach: ±5% of set pickup
  May be directionally controlled (67NTC enables)

Negative-Sequence Directional Elements

- The angle between the measured negative-sequence voltage and current adjusted by the MTA setting determines fault direction (see Figure 2.2)
- Angle: MTA setting
- Sensitivity: 0.32 VA (V2 x I2) at MTA

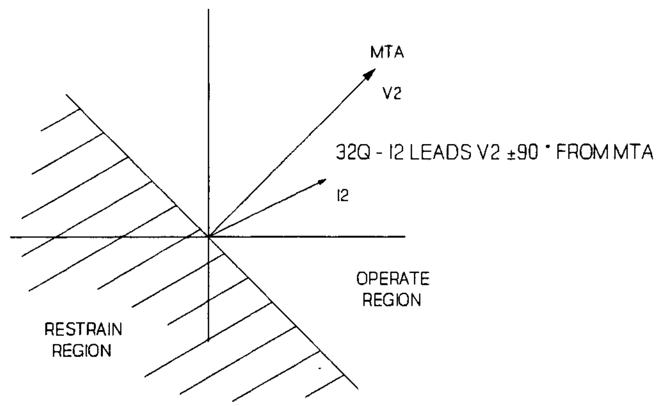


Figure 2.2: 32Q Polarization Criteria

Please refer to the Functional Description portion of this section for equations to determine directional element sensitivities at fault angles other than maximum torque angle.

Sequence-Component Elements (Secondary Quantities)

The following elements are used in the recloser supervision logic and loss-of-potential detection logic.

- Negative-sequence overvoltage element (47QL)
  Pickup: V2 = 14 V (fixed)
- Negative-sequence overcurrent element (46QL)
  Pickup: I2 = 0.083 A (fixed)
- Positive-sequence overvoltage element (59P)
  Pickup: User settable, 0 - 80 $V_{l\text{-}n}$
- Positive-sequence undervoltage element (27P)
  Pickup: User settable, 0 - 80 $V_{l\text{-}n}$
- VS input overvoltage element (59S)
  Pickup: User settable, 0 - 125 $V_{l\text{-}n}$
- VS input undervoltage element (27S)
  Pickup: User settable, 0 - 125 $V_{l\text{-}n}$

Synchronism Checking Element

The synchronism checking voltage element determines the magnitude of the phasor difference between the correct single-phase voltage and the voltage applied to the VS input.

- Phasor difference voltage element (25 DV)
  Pickup: User settable in volts primary, setting range limited 0 - 150 V secondary

Miscellaneous Timers

All timers are set in cycles with quarter-cycle resolution.

• 790I	- Reclose Relay Open Interval	: 0.0 - 8,000	
• 79RS	- Reclose Relay Reset Time	: 60.0 - 8,000	
• 25T	- Synchronism Checking Timer	: 0.0 - 8,000	
• VCT	- Voltage Condition Timer	: 0.0 - 8,000	
• A1TP	- A1 Output Contact TDPU Timer	: 0.0 - 8,000	
• A1TD	- A1 Output Contact TDDO Timer	: 0.0 - 8,000	
• 52BT	- Switch-Onto-Fault Timer	: 0.5 - 10,000	
• TDUR	- Minimum Trip Duration Timer	: 0.0 - 2,000	0 Disables the OPEN Command

TDPU ≡ Time delayed Pickup
TDDO ≡ Time delayed Dropout

Potential Inputs

Polarizing potential inputs VA, VB, and VC should be driven from a set of three line potential transformers with their primaries connected in a grounded-wye configuration and secondaries connected in a four-wire wye. The relay is equipped with three input transformers connected in a four-wire wye.

The nominal input voltage rating is 115 volts line-to-line or 67 volts line-to-neutral.

The relay is also equipped with a synchronism-checking/voltage-checking input, VS. To perform synchronism checking or voltage checking, connect the VS input to the secondary of a potential transformer on the opposite side of the breaker from where polarizing potential transformers are connected. You may select any phase for a synchronism checking source. The VS input voltage rating is 0 - 120 volts line-to-neutral.

Current Inputs

Each current input is independent; the current transformers are not interconnected inside the relay. The rating of the input transformers in the relay is 5 amperes nominal, 15 amperes continuous, and 500 amperes for one second.

Logic Inputs

The relay has six opto-isolator inputs to control relay functions and sense external conditions: received permissive trip and block trip signals, breaker status, direct close, a programmable input, and external event report trigger. Assert these logic inputs by applying control voltage to the corresponding rear panel input terminals. Control voltage polarity is not important.

Table 2.2 lists the inputs and their functions.

Table 2.2: Logic Input Functions

Input	Function
IN1	Programmable Input
PT	Permissive Trip Input
BT	Block Trip Input
DC	Direct Close Input
52A	52 Auxiliary Contact Input
ET	External Trigger Input

Programmable Input (IN1)

Asserting the IN1 input immediately and unconditionally sets Relay Word bit IN1. The IN1 bit remains set until the IN1 input deasserts, dropping out about one-half cycle after IN1 deasserts. IN1 input assertion generates an event report. You can use the IN1 input to trip the relay or to initiate or cancel reclosing.

Permissive Trip (PT)

The PT input is normally used in Permissive Overreaching Transfer Tripping (POTT) schemes. When the PT input is asserted, elements set in the MPT logic mask are enabled for tripping (see the LOGIC MPT command). Asserting this input triggers an event report.

Block Trip (BT)

The BT input is normally used in blocking schemes. Assert the BT input to block tripping by elements set in the MTB logic mask. Assertions of this input trigger event report generation.

Direct Close (DC)

When you assert the DC input, the relay shuts the CLOSE output if no fault is detected, a trip condition is not present, and the 52A input is not asserted. Assertions of this input do not trigger event reports.

Circuit Breaker Status (52A)

Connect the 52A input such that when the line circuit breaker is closed, the 52A input is asserted. The CLOSE command, recloser, and switch-onto-fault logic use the status of this input. Assertions of this input do not trigger event reports.

External Trigger for Event Report (ET)

Assertion of the external trigger input triggers an event report. Assertion does not influence the protective functions in any way. Applications include monitoring trips initiated by external protective relays, backup protection, breaker failure relaying, bus differential relaying, etc.

Output Contacts

The relay has seven output contacts: TRIP, CLOSE, ALARM, and four programmable outputs (A1, A2, A3, and A4). You can program all outputs except the CLOSE and ALARM outputs using the LOGIC command. Any output contacts except TRIP may be factory configured as "a" or "b" type.

All relay contacts are rated for circuit breaker tripping duty.

TRIP Output

This output closes for a number of conditions you select. Conditions are grouped as follows: unconditional (MTU logic mask), subject to REJO condition or PT input assertion (MPT logic mask), subject to the absence of BT input assertion (MTB logic mask), or subject to the breaker being open or just closed (MTO logic mask).

The TRIP output never closes for less than the TRIP Duration (TDUR) timer interval. After this, it opens when the fault condition is gone, and both the low-set phase and residual (50NG) and negative-sequence overcurrent (46QL) elements have dropped out.

CLOSE Output

This output closes for reclose operations, DC input assertion, and CLOSE command execution. The CLOSE output remains closed until the 52A input asserts, the 79RS timer expires, or a TRIP occurs. The 79RS timer starts when the CLOSE output relay asserts. Operation of this contact does not trigger an event report.

ALARM Output

The ALARM output closes for the following conditions:

- Three unsuccessful Level 1 access attempts: 1 second pulse
- Any Level 2 access attempt: 1 second pulse
- Self test failure: permanent contact closure or 1 second pulse depending on which test fails (see Table 2.6)
- The ALARM output closes momentarily when you change relay settings, logic settings, or passwords. It also closes when a date is entered if the year stored in EEPROM differs from the year entered (see DATE command).

- The ALARM output closes while the relay detects a loss-of-potential condition if you select LOPE = 2, 3, or 4.

Programmable Outputs (A1, A2, A3, A4)

These four outputs may be assigned to any combination of bits in the Relay Word.

Logic Description

Relay logic includes relay elements, timers, and combinations of conditions. Many of these are recorded in the Relay Word (R), which is the basis of programmable mask logic. Elements and other quantities available in the Relay Word appear in boldface type.

Relay Elements

Single-phase overcurrent relays	50AG 50BG 50CG	(**50NG** setting)
	50AP 50BP 50CP	(**50P** setting)
High-set single-phase OC relays	50AH 50BH 50CH	(**50H** setting)
Zone 3 ground mho distance	21AG3, 21BG3, 21CG3	(Z3% setting)
Zone 3 phase mho distance	21AB3, 21BC3, 21CA3	
Zone 2 ground mho distance	21AG2, 21BG2, 21CG2	(Z2% setting)
Zone 2 phase mho distance	21AB2, 21BC2, 21CA2	
Zone 1 ground mho distance	21AG1, 21BG1, 21CG1	(Z1% setting)
Zone 1 phase mho distance	21AB1, 21BC1, 21CA1	

Residual time-overcurrent pickup	**51NP**	(**51NP**, 51NTC settings)
Residual time-overcurrent trip	**51NT**	(**51NP**, 51NTD, 51NC, 51NTC settings)
Residual inst overcurrent	**67N**	(67NP, 67NTC settings)
Residual inst overcurrent	50N	(**50NG** setting)
Negative-sequence directional	**32Q**	forward direction
Negative-sequence overvoltage	47QL	loss-of-potential logic
Negative-sequence overcurrent	46QL	loss-of-potential logic, trip unlatch logic
Positive-sequence overvoltage	47P	loss-of-potential logic
Dead polarizing voltage check	**27P**	V1 < 27VLO
Dead synchronizing voltage check	**27S**	VS < 27VLO
Live polarizing voltage check	**59P**	V1 > 59VHI
Live synchronizing voltage check	**59S**	VS > 59VHI
Synchronism check element	25	VPOL - VS < 25DV

Optically Coupled Logic Inputs

Programmable Input	IN1
Permissive trip	PT
Block trip	BT
Direct close	DC
Circuit breaker monitor	52A
External trigger for event report	ET

Contact Outputs

Circuit breaker trip (two contacts)	TRIP
Circuit breaker close	CLOSE
Programmable output 1	A1
Programmable output 2	A2
Programmable output 3	A3
Programmable output 4	A4
System alarm	ALARM

Timers

Zone 2 delay for phase faults	Z2DP
Zone 2 delay for ground faults	Z2DG
Zone 3 delay	Z3D
Time delayed inverse of 52A	**52BT**
Minimum Trip Duration	TDUR

Enables from Setting Procedure

Select torque control for 51N	51NTC
Select torque control of 67N	67NTC
Remote-End-Open Perm. Trip Enable	REJOE
Loss-of-potential enable	LOPE

Intermediate Logic

The logic equations developed below represent combinations of the relay elements and other conditions. In the following equations, "*" indicates a logical "and," while "+" indicates a logical "or."

Loss-of-Potential (LOP) Logic

Set **LOP**	= 47QL * NOT (46QL) + NOT (47P) * NOT (**50P**)	Set LOP includes a three-cycle pickup delay.
Clear **LOP**	= NOT (47QL) * 47P	

The different set and clear conditions ensure that LOP stays latched during subsequent faults, but is cleared when balanced voltages return. Loss of three-phase potentials due to potential fuse operation may cause the relay to trip if phase current is above the 50P setting.

You determine how the relay uses loss-of-potential detection by selecting the LOPE setting. The LOPE setting choices and their associated results are:

- N Relay sets LOP bit when loss-of-potential condition is detected.
  Distance and directional elements are not blocked.
  Set the LOP bit in a programmable logic mask to indicate condition, if desired.

- Y Relay sets LOP bit when loss-of-potential condition is detected.
  Distance elements are blocked and directional elements default forward.
  Set the LOP bit in a programmable logic mask to indicate condition, if desired.

- 1 Relay blocks distance elements and directional elements default forward when LOP condition is detected.
  If the 52A input is asserted while LOP is detected, the Relay Word LOP bit is asserted.
  If the 52A input is not asserted while LOP is detected, the Relay Word LOP bit is not asserted.
  Set the LOP bit in a programmable logic mask to indicate that a loss-of-potential has occurred while the breaker is closed, if desired.

- 2 Relay sets LOP bit when loss-of-potential condition is detected.
  Distance elements are blocked and directional elements default forward.
  Relay asserts ALARM contact to indicate the LOP condition.

- 3 Relay blocks distance elements and directional elements default forward when LOP condition is detected.
  If the 52A input is asserted while LOP is detected, the Relay Word LOP bit is asserted.
  If the 52A input is not asserted while LOP is detected, the Relay Word LOP bit is not asserted.
  Relay asserts ALARM contact while the Relay Word LOP bit is asserted.

- 4 Relay sets LOP bit when loss-of-potential condition is detected.
  Distance and directional elements are not blocked.
  Relay asserts ALARM contact to indicate the LOP condition.

The following table summarizes the available LOPE settings and their results.

Table 2.3: LOPE Settings

LOPE Setting	Block 21 on LOP	52A Supervises LOP Relay Word Bit	Close ALARM Contact on LOP Bit Assertion
N	No	No	No
Y	Yes	No	No
1	Yes	Yes	No
2	Yes	No	Yes
3	Yes	Yes	Yes
4	No	No	Yes

Phase Overcurrent Conditions

50G	= 50AG + 50BG + 50CG	sensitive phase overcurrent condition
3G50	= 50AG * 50BG * 50CG	sensitive three-phase o/c condition
50NG	= 50N + 50G	sensitive ground or phase o/c condition
50P	= 50AP + 50BP + 50CP	phase overcurrent condition
3P50	= 50AP * 50BP * 50CP	three-phase overcurrent condition
50H	= 50AH + 50BH + 50CH	high-level overcurrent condition

Ground Overcurrent Conditions

67N	= 67NP * [32Q + (**LOP** * LOPE=Y, 1, 2, OR 3) + NOT(67NTC)]	directionally supervised residual inst. overcurrent element
51NP	= 51N pickup * [32Q + (**LOP** * LOPE=Y, 1, 2, OR 3) + NOT(51NTC)]	directionally supervised residual time-overcurrent element

Distance Relay Logic

3P21	= (21AB3*21BC3*21CA3) * 3P50	three-phase fault condition
FDS	= **3P21** + **32Q**	forward-direction supervision
Z1P	= (21AB1*50AP*50BP + 21BC1*50BP*50CP + 21CA1*50CP*50AP) * FDS * NOT(**LOP** * LOPE=Y, 1, 2, OR 3)	
Z2P	= (21AB2*50AP*50BP + 21BC2*50BP*50CP + 21CA2*50CP*50AP) * FDS * NOT(**LOP** * LOPE=Y, 1, 2, OR 3)	
Z3P	= (21AB3*50AP*50BP + 21BC3*50BP*50CP + 21CA3*50CP*50AP) * FDS * NOT(**LOP** * LOPE=Y, 1, 2, OR 3)	
Z1G	= (21AG1*50AG + 21BG1*50BG + 21CG1*50CG) * 50N * FDS * NOT(**LOP** * LOPE=Y, 1, 2, OR 3)	
Z2G	= (21AG2*50AG + 21BG2*50BG + 21CG2*50CG) * 50N * FDS * NOT(**LOP** * LOPE=Y, 1, 2, OR 3)	
Z3G	= (21AG3*50AG + 21BG3*50BG + 21CG3*50CG) * 50N * FDS * NOT(**LOP** * LOPE=Y, 1, 2, OR 3)	
Z3	= Z3P + Z3G	Zone 3 phase or ground fault
Z2PT	= Z2P * Z2PD	Zone 2 phase timeout
Z2GT	= Z2G * Z2GD	Zone 2 ground timeout
Z3T	= Z3 * Z3D	Zone 3 timeout

Synchronism and Voltage Checking Logic

SSCI	= **59S** * **59P** * 25 * NOT(52A) * NOT(**50NG**)	synchronism check initiate
SSC	= SSCI for 25T; 0 dropout delay	sync check timer output
LSDP	= **59S** * **27P** * NOT(**50NG**)	live sync/dead polarizing
LPDS	= **59P** * **27S** * NOT(**50NG**)	live polarizing/dead sync
VCTI	= LSDP * (PSVC=S,E) + LPDS * (PSVC=P,E)	voltage condition timer initiate
VSC	= VCTI for VCT; 0 dropout delay	voltage condition timer output

Remote-End-Just-Opened Logic

When REJOE = G:

3G50D	=	3G50 * (inst pickup/2 cyc dropout)	three-phase current lost
REJO	=	NOT(3G50) * 3G50D * 50G * (½ cyc pu/inst do)	remote end just opened

When REJOE = P:

3P50D	=	3P50 * (inst pickup/2 cyc dropout)	three-phase current lost
REJO	=	NOT(3P50) * 3P50D * 50G * (½ cyc pu/inst do)	remote end just opened

Circuit-Breaker Auxiliary Contact Delay

52BT = NOT(52A), delayed by 52BT at pickup and dropout

Output Equations and Logic

The relay has programmable logic for controlling the TRIP, A1, A2, A3, and A4 output relays for flexibility and testing. The relay has two separate masks for reclose initiation and cancellation. Program logic by setting masks for various conditions. These masks are applied to the general Relay Word. The form for each output equation follows:

Let R = Relay Word

MTU	=	mask for trip	(unconditional)
MPT	=	mask for trip	(permissive trip)
MTB	=	mask for trip	(with no blocking)
MTO	=	mask for trip	(with breaker just opened or closed)

Then:

TRIP	=	[R * MTU	(unconditional tripping)
		+ R * MPT * {PT +(**REJO** * REJOE=P OR G)}	(permissive tripping)
		+ R * MTB * NOT (BT)	(tripping with BT input deasserted)
		+ R * MTO * **52BT**]	(breaker open/just closed tripping)
		+ TC	(Open Command Executed)

Close TRIP contact = TRIP

Open TRIP contact = NOT (TRIP) * [NOT(**50NG** + 46QL) + TARGET RESET button pushed] * (Minimum Trip Duration timer (TDUR) expired)

Close CLOSE contact = (DC + [Reclose Operation] + CLOSE COMMAND) * NOT (52A) * NOT (TRIP)

Open CLOSE contact = NOT (CLOSE) + 79RS + TRIP

A1 = R * MA1
A2 = R * MA2
A3 = R * MA3
A4 = R * MA4

The "*" indicates a logical "and," while the "+" indicates a logical "or."

Relay Word

The Relay Word consists of three eight-bit rows containing relay elements, intermediate logic results, logic inputs, and relay outputs. Each bit in the Relay Word is either a logical 1 or logical 0.

- 1 indicates a picked up element or true logic condition
- 0 indicates a dropped out element or false logic condition

The Logic Description defines logic conditions in the Relay Word.

RELAY WORD

Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q
67N	51NP	51NT	50NG	50P	50H	IN1	REJO
LOP	52BT	27S	27P	59S	59P	SSC	VSC

The meaning of each bit of the Relay Word is explained in the Relay Word Bit Summary Table.

Table 2.4: Relay Word Bit Summary	
Z1P	Zone 1 phase fault, instantaneous output (set by Z1%)
Z1G	Zone 1 ground fault, instantaneous output (set by Z1%)
Z2PT	Zone 2 phase fault, time delayed (set by Z2% and Z2DP)
Z2GT	Zone 2 ground fault, time delayed (set by Z2% and Z2DG)
Z3	Zone 3 phase or ground fault, instantaneous output (set by Z3%)
Z3T	Zone 3 phase or ground fault, time delayed (set by Z3% and Z3D)
3P21	Three-phase fault condition detected by phase distance relays
32Q	Negative-sequence directional element
67N	Residual instantaneous overcurrent (set by 67NP and 67NTC)
51NP	Pickup of residual time-O/C (set by 51NP and 51NTC)
51NT	Timeout of residual time-overcurrent element
50NG	Sensitive residual or phase overcurrent condition (set by 50NG)
50P	Phase overcurrent condition (set by 50P)
50H	High-set phase overcurrent condition (set by 50H)
IN1	Logic Input 1 (use for direct trip, reclose initiate/cancel, etc.)
REJO	Remote-end-just-opened condition
LOP	Loss-of-potential condition
52BT	Inverted 52A input, delayed by 52BT setting at pickup and dropout
27S	Synchronizing undervoltage condition (Tests VS against VLO setting)
27P	Polarizing undervoltage condition (Tests VP1* against VLO setting)
59S	Synchronizing overvoltage condition (Tests VS against VHI setting)
59P	Polarizing overvoltage condition (Tests VP1* against VHI setting)
SSC	Synchronization-supervised condition (set by 25DV, 25T, SYNCP)
VSC	Voltage-supervised condition (set by PSVC for disable/LSDP/LPDS/either)

*VP1 = Positive-sequence voltage applied to the polarizing voltage inputs.

The use of the Relay Word and programmable masks provides the user great flexibility in applying the SEL-121F relay without the need for rewiring panels or changing jumpers on circuit boards.

Remote-End-Just-Opened (REJO) Logic

Remote-end-just-opened detection logic can speed up clearing of internal faults, beyond the reach of Zone 1. A three-phase current condition (e.g., load) must first be established, as detected by the 3G50 or 3P50 logic condition. If, during a short time period after its disappearance (signifying the other end tripped), current still remains in at least one phase (signifying that the fault is still present), then the **REJO** (remote-end-just opened) bit is asserted.

The REJO enable setting, REJOE, allows three settings: N to disable the REJO function, G to enable the function to operate using 3G50 as the three-phase overcurrent qualifier, or P to set the function to use 3P50 as the three-phase overcurrent qualifier. When REJOE = G, the relay sets or clears the elements based on the conditions described below.

1. The 3G50 element is set by three-phase load current.

2. The 3G50D element indicates that load current was present up until at least two cycles ago.

3. If the 50G element is picked up, current is still flowing in at least one phase.

4. The REJO element of the SEL-121F relay is defined by the following logic equation:

   If REJOE = G: REJO = NOT(3G50) * 3G50D * 50G * (½ cyc pu/inst do)
   If REJOE = P: REJO = NOT(3P50) * 3P50D * 50G * (½ cyc pu/inst do)

Three-phase load is no longer present, but was at least two cycles ago, current is still flowing in at least one phase, and these conditions are maintained for at least one-half cycle.

When REJOE = P, the 3P50 and 3P50D elements qualify the REJO condition. Section 5: APPLICATIONS discusses the uses of the REJO function settings.

The relay uses the REJO bit in two places: as a qualifier for permissive tripping and as an indicator in the Relay Word.

If the REJO function is enabled (REJOE = G or P in the relay settings), then the REJO condition is used as a qualifier for permissive tripping.

Used in this way, the REJO condition permits tripping for the relay elements set in the logic mask for Permissive Tripping (MPT) in the same manner as asserting the Permissive Trip input of the relay. You may set the MPT mask as if the relay were being used in a permissive tripping scheme, including instantaneous Zone 3 phase and ground distance elements (Z3 bit).

The REJO bit does not need to be set in any of the tripping logic masks to enable this function.

Targets

Figure 2.3 shows the front panel targets.

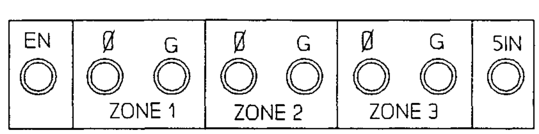


Figure 2.3: Relay Targets

The enable light (EN) indicates normal operation.

The next six indicators show the phase and ground element status for all three zones. The last light shows the status of the residual time-overcurrent element. The targets illuminate to indicate which elements caused the relay to initiate a trip.

Front panel targets illuminate for the following conditions:

Target LED	Conditions for Illumination
EN	Normal Operation
Ø1	Z1P + 50H
G1	Z1G + 67N
Ø2	Z2PT
G2	Z2GT
Ø3	Z3P
G3	Z3G
51N	51NT

The LEDs for the relay elements illuminate on the rising edge of the TRIP output with the following priority:

51N	:	For 51N timeout (51NT)
G1, Ø1	:	For Z1G + 67N + Z1P + 50H, but no 51NT
G2, Ø2	:	For Z2GT + Z2PT, but no Zone 1 or 51NT
G3, Ø3	:	For Z3G + Z3P, but no Zone 2, Zone 1, or 51NT

The relay normally displays the targets identified on the front panel. Under normal operating conditions, the enable (EN) target lamp is lit. If the relay trips, it illuminates the LED corresponding to the element asserted at the time of trip. The target LEDs latch. The target LEDs which illuminated during the last trip remain lit until one of the following occurs:

- Next trip
- Operator presses front panel TARGET RESET button
- Operator executes TARGET R command

When a new trip occurs, the targets clear and the LEDs display the most recent tripping target.

When you press the TARGET RESET button, all eight indicators illuminate for a one-second lamp test. If no trip condition is present, the relay targets clear and the Enable light (EN) illuminates to indicate that the relay is operational.

Use the TARGET command and display to examine the state of the relay inputs, outputs, and Relay Word elements.

Pressing TARGET RESET also unlatches the TRIP output if no trip condition is present. This feature is useful during testing and reduces the possibility of relay installation with the TRIP output asserted.

Reclosing Relay

The reclosing relay provides one shot of automatic reclosing for selectable fault types. The open interval and reset timers are individually programmable. You may use voltage conditions to externally supervise the reclosing function.

In order for the SEL-121F relay reclosing unit to operate, four conditions must be met:

- The relay must trip
- The 52A signal must deassert, indicating that the line breaker opened
- Reclosure must be initiated by operation of an element set in the MRI logic mask
- Reclosure must not be cancelled by operation of an element set in the MRC logic mask

Section 5: APPLICATIONS provides discussion of the reclosing relay timing and setting selection.

Reclose Cancellation

While the TRIP output is asserted, the reclosing shot is cancelled if a bit set in the MRC logic mask asserts in the Relay Word. Once the TRIP contacts open, assertion of Relay Word bits set in the MRC logic mask does not cancel reclosing.

Reclosing is cancelled when the relay trips during the open interval.

Recloser Reset Time, 79RS

The relay includes a 79RS reclosing reset timer setting. The relay uses this timer in several ways:

- To limit the CLOSE contact operation time;
- To reset the recloser after a successful closing sequence;
- To block the recloser for a short time after any close.

The relay operates the CLOSE output in response to command execution, Direct Close input assertions, and reclosing relay operations. The relay CLOSE contacts remain closed until the 52A input asserts (indicating that the breaker has closed), the 79RS timer expires, or a trip condition occurs. This logic prevents a standing close signal.

After the close operation during a reclosing sequence, the 79RS timer runs. If a fault occurs before the 79RS timer expires, the reclosing relay goes to lockout. If the 79RS timer expires, the reclosing relay is reset and the full reclosing sequence is enabled.

When the breaker is closed, the reclosing relay is not reenabled until the 52A input has been asserted for 79RS time. This prevents the recloser from operating if an operator closes into a fault.

Synchronism Checking

The synchronism-checking element (25) monitors the phasor difference voltage between voltage applied to the VS input and the polarizing voltage selected via the SYNCP setting, from either VA, VB, or VC inputs. The element asserts when the magnitude of the difference voltage is less than the 25DV voltage setting.

The synchronism checking timer (25T) begins timing when four conditions are met:

1. The breaker appears open, as judged by an unasserted 52A input and dropped out 50NG overcurrent element.

2. The 25 element asserts indicating that the phasor difference voltage across the selected pole of the circuit breaker is less than the 25DV setting. When 25 asserts, the polarizing and synchronizing sides of the system are within the synchronizing voltage range.

3. The **59P** element indicates that the polarizing voltage is present and normal. The 59P element operates on positive-sequence voltage applied to VA, VB, and VC.

4. The **59S** element indicates that the monitored phase of the synchronizing voltage is present and normal.

When the timer expires at the end of its 25T setting, the **SSC** bit in the Relay Word is set. It remains set until any one of the four conditions listed above is violated.

Section 5: APPLICATIONS provides a discussion of the applications and setting selections for this logic.

Voltage Checking (VSC)

Four voltage elements monitor high/low voltage conditions on both sides of the circuit breaker:

Undervoltage elements: **27P**, **27S**
Overvoltage elements: **59P**, **59S**

The **27P** and **59P** elements monitor the polarizing positive-sequence voltage magnitude determined from VA, VB, and VC inputs. The **27S** and **59S** elements monitor the phase-to-neutral voltage magnitude presented to the VS input. All four voltage elements are in the Relay Word. They are processed by polarizing/synchronizing voltage logic, which is selectable by the PSVC Polarizing/Synchronizing Voltage Check setting, to select voltage conditions as follows:

PSVC Setting	Voltage Relationship	VSC Logic Condition
N	Disable voltage checking scheme	0 (FALSE)
S	Live Sync/Dead Pol (LSDP) condition	**59S * 27P**
P	Live Pol/Dead Sync (LPDS) condition	**59P * 27S**
E	Either LSDP or LPDS	**59S * 27P + 59P * 27S**

A valid voltage condition starts the voltage-condition timer (VCT). When it times out, the **VSC** bit is set in the Relay Word. It remains set until the voltage condition is no longer valid.

Section 5: APPLICATIONS provides a discussion of the applications and setting selections for this logic.

Signal Processing

The relay low-pass filters all analog input channels to remove high frequency components. Next it samples each channel four times per power system cycle. After low-pass filtering, the relay digitally filters each sample with the CAL digital filter method. The CAL filter eliminates dc offset and reduces the decaying exponential offset that may be present on the input signal following a fault.

The digital filter has the properties of a double differentiator smoother and requires only addition and subtraction of data samples. Let the latest four samples of one channel be X1, X2, X3, and X4. Then the digital filter is defined:

$$P = X1 - X2 - X3 + X4.$$

This filter eliminates dc offsets. When all samples are set to the same value, the filter output is zero. It also eliminates ramps, which you may verify by setting the samples equal to 1, 2, 3, and 4. Again, the output is zero.

Every quarter-cycle, the relay computes a new value of P for each input. The current value of P combines with the previous value (renamed Q) to form a Cartesian coordinate pair. This pair represents the input signal as a phasor (P, Q). The relay processes these phasor representations of the input signals.

Event Reporting

The relay retains an eleven cycle data record for each of the last twelve events. The record includes input currents and voltages, element states, input contacts, and output contacts. The relay saves a report when any of the following occur:

- The relay trips
- Certain protective elements, inputs, or outputs assert
- User executes the TRIGGER command

Protective elements which trigger event reports when they pick up are:

- Zones 1, 2, and 3 phase and ground distance elements
- Ground overcurrent elements
- High-set nondirectional phase overcurrent element

The relay stores the last twelve event reports in a buffer. You can examine any full length report stored in the relay using the EVENT command. The relay clears the event buffer when relay power is interrupted or when you make a setting or logic change.

The relay stores event summaries corresponding to each of the twelve events. Summaries contain operation data such as event type, event date and time, fault type and location, maximum phase current near the middle of the fault, and fault duration. Use the HISTORY command to view summaries for events reports stored in the relay history buffer.

Section 4: EVENT REPORTING has further information regarding the generation, content, and analysis of event reports and summaries saved by the relay.

Fault Locator

The relay calculates a fault location from data stored in the event report. The fault location is determined for event records in which any triggering relay elements listed above are picked up, unless they are picked up in the first seven rows of prefault data or picked up only in the last five rows of the event report.

The actual fault location algorithm is composed of two steps. First the fault type must be determined, then the location can be calculated.

For the event reports, the fault type is determined independently from the relay element operations. The involved phases are determined by fault current comparison.

Once fault type is determined, the fault locator employs the Takagi algorithm to locate the fault. Using prefault and fault data, it compensates for errors introduced by fault resistance or the presence of load flow. If the event record does not provide prefault data, the relay gives a location based on a simple reactance measurement.

Although the fault location computation takes several seconds, the relay can handle faults in quick succession, such as those occurring in a reclosing sequence. This is because the fault data are stored, then processed later. For example, suppose three faults occur within a few seconds. The data from each is stored as it occurs. Fault location computations begin with the first (oldest) fault and proceed until all three faults are processed.

Metering

The meter function shows the values of ac current, voltage, and real and reactive power measured by the relay (see Section 3: COMMUNICATIONS, METER command). You can execute the METER command locally or remotely to check breaker conditions.

Serial Interfaces

Relay rear panel connectors labelled PORT 1 and PORT 2 are EIA RS-232-C serial data interfaces. Generally, PORT 1 is used for remote communications via a modem, while PORT 2 is used for local communications via a terminal or SEL-PRTU protective relay terminal unit. PORT 2 may also be connected to the SEL-DTA, which serves as a local operator interface and transducer output.

The baud rate for each port is set by jumpers near the front of the main board. You can access these jumpers by removing either the top cover or front panel. Available baud rates are 300, 600, 1200, 2400, 4800, or 9600.

The serial data format is:

Eight data bits
Two stop bits (-E2 model) or One stop bit (-E1 model)
No parity

This format may not be changed. The serial communications protocol appears in Section 3: COMMUNICATIONS.

IRIG-B Input Description

The port labelled J201/AUX INPUT accepts demodulated IRIG-B input.

The IRIG-B serial format consists of a one second long, 100 pulse code divided into fields. The relay decodes the second, minute, hour, and day fields.

When IRIG-B data acquisition is activated, either manually with the IRIG command or automatically, two consecutive frames are taken. The older frame is updated by one second, then the frames are compared. If the frames do not agree, the data are considered erroneous and discarded.

Automatic execution is invoked about once every five minutes. The relay stops IRIG-B data acquisition ten minutes before midnight on New Year's Eve and restarts acquisition twenty minutes later. IRIG-B data acquisition is halted so the system clock may implement the year change without interference from the IRIG-B clock.

Self Tests

The relay runs a variety of self tests. Some tests have warning and failure states; others only have failure states. The relay generates a report after any change in self test status.

The relay closes the ALARM contacts after any self test fails. When it detects certain failures, the relay disables the breaker control functions and places the relay output driver port in an input mode. No outputs may be asserted when the instrument is in this configuration. The relay runs all self tests on power up and before enabling new settings. During normal operation, it performs self tests at least every few minutes.

Offset

The relay measures the offset voltage of each analog input channel and compares the value against fixed limits. It issues a warning when offset is greater than 50 millivolts in any channel and declares a failure when offset exceeds 75 millivolts. Offset levels for all channels appear in the STATUS command format.

Power Supply

Power supply voltages are limit-checked. The table below summarizes voltage limits.

Table 2.5: Power Supply Self Test Limits

Supply	Warning Thresholds		Failure Thresholds	
+5 V	+5.3 V	+4.7 V	+5.4 V	+4.6 V
+15 V	+15.8 V	+14.2 V	+16.2 V	+13.8 V
-15 V	-15.8 V	-14.2 V	-16.2 V	-13.8 V

The relay transmits a STATUS command response for any self test failure or warning. A +5 volt supply failure deenergizes all output relays and blocks their operation. A ±15 volt supply failure disables protective relay functions while control functions remain intact. The ALARM relay remains closed after a power supply failure.

Random Access Memory

The relay checks random access memory (RAM) to ensure that each byte can be written to and read from. There is no warning state for this test. If the relay detects a problem, it transmits a STATUS command message with the socket designation of the affected RAM IC. A RAM failure disables protective and control functions and closes the ALARM output relay contacts.

Read Only Memory

The relay checks read only memory (ROM) by computing a checksum. If the computed value does not agree with the stored value, the relay declares a ROM failure. It transmits a STATUS command response with the socket designation of the affected ROM IC. A ROM failure disables protective and control functions and closes the ALARM output relay contacts.

Analog-to-Digital Converter

The analog-to-digital converter (A/D) changes voltage signals derived from power system voltages and currents into numbers for processing by the microcomputer. The A/D test verifies converter function by checking conversion time. The test fails if conversion time is excessive or a conversion starts and never finishes. There is no warning state for this test.

Though an A/D failure disables protective functions, control functions remain intact. The relay transmits a STATUS command response and closes the ALARM relay contacts.

Master Offset

The master offset (MOF) test checks offset in the multiplexer/analog to digital converter circuit. A grounded input is selected and sampled for dc offset. The warning threshold is 50 mV; failure threshold is 75 mV. A failure pulses the ALARM contact closed for one second.

Settings

The relay stores two images of the system settings in nonvolatile memory. These are compared when the relay is initially set and periodically thereafter. If the images disagree, the setting test fails and the relay disables all protective and control functions. It transmits the STATUS message to indicate a failed test. The ALARM relay remains closed after a setting failure.

Table 2.6 shows relay actions for any self test condition: warning (W) or failure (F).

Table 2.6: Self Test Summary

Self Test	Limits	Status Message	Protection Disabled	Control Disabled	Alarm Output
RAM	—	F	YES	YES	permanent contact assertion
ROM	—	F	YES	YES	permanent contact assertion
SETTINGS	—	F	YES	YES	permanent contact assertion
A/D	—	F	YES	NO	permanent contact assertion
+5 V	±0.3 V	W	NO	NO	no ALARM contact assertion
	±0.4 V	F	YES	YES	permanent contact assertion
±15 V	±0.8 V	W	NO	NO	no ALARM contact assertion
	±1.2 V	F	YES	NO	permanent contact assertion
CHANNEL	50 mV	W	NO	NO	no ALARM contact assertion
OFFSETS	75 mV	F	NO	NO	one second contact pulse
MASTER	50 mV	W	NO	NO	no ALARM contact assertion
OFFSET	75 mV	F	NO	NO	one second contact pulse

FUNCTIONAL DESCRIPTION

Self-polarized Mho Elements

The following settings affect mho circles: positive-sequence line impedances (R1, X1), maximum torque angle (MTA), set reach (Z1%, Z2%, and Z3%), and positive-sequence transmission line angle (arctan (X1/R1)). Self-polarized mho circles pass through the impedance-plane origin. The diameter passing through the origin is at an angle of MTA (maximum torque angle) with respect to the resistance axis. The chord passing through the origin at the positive-sequence impedance (Z1) angle of the transmission line has a length equal to the set relay reach. Therefore, the self-polarized mho circle diameter is calculated:

$$\text{DIAMETER} = \frac{\text{SET REACH}}{\cos(\text{T. L. ANGLE} - \text{MTA})}$$

where T. L. is defined as the positive-sequence transmission line angle.

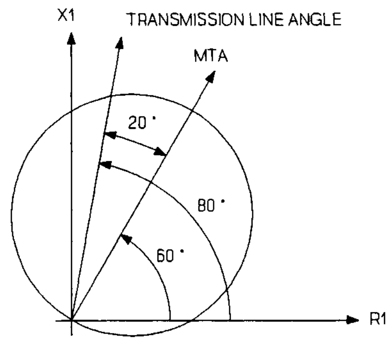


Figure 2.4: Self-Polarized Mho Element Reach at Maximum Torque Angle

Relay Characteristics and Equations

The phase and ground distance elements in the SEL-121F relay are supervised by three relay elements or functions:

- A negative-sequence directional element
- Non-directional phase and ground overcurrent fault detecting elements
- A loss-of-potential, if enabled.

The negative-sequence directional element operates when negative-sequence voltage and current indicate that the fault is in the forward direction. The element is sensitive and secure. Check your fault study to verify that sufficient negative-sequence polarizing quantities are available for all phase and ground faults within the desired protection characteristic.

The phase distance elements are supervised by single-phase 50P non-directional phase overcurrent elements. Set the 50P element to assert during the most remote Zone 3 fault that the relay must detect. If possible, set the 50P element above maximum load current to improve security of the loss-of-potential logic.

Ground distance elements are supervised by single-phase 50G phase overcurrent elements and the 50N residual overcurrent element. Both elements are set using the 50NG relay setting, and both elements must pick up to enable the ground distance elements.

Loss-of-potential logic blocks distance element operation during blown potential fuse periods if you enable the function by setting LOPE = Y, 1, 2, or 3.

The SEL-121F relay uses positive-sequence memory voltage polarized mho distance elements for phase and ground distance protection. These elements expand in proportion to the source impedance to provide more resistive fault coverage than self-polarized mho elements.

When we use positive-sequence memory voltage polarization, the mho characteristics expand all the way back to the source. The relay impedance setting Z_r defines the maximum reach point. Figures 2.5, 2.6, and 2.7 show the impedance plane characteristics for several fault types. The forward-reaching mho circles extend from the source impedance ZS, forward to the relay impedance setting Z_r.

Table 2.7 shows the voltage and current combinations used to operate and polarize the six mho elements.

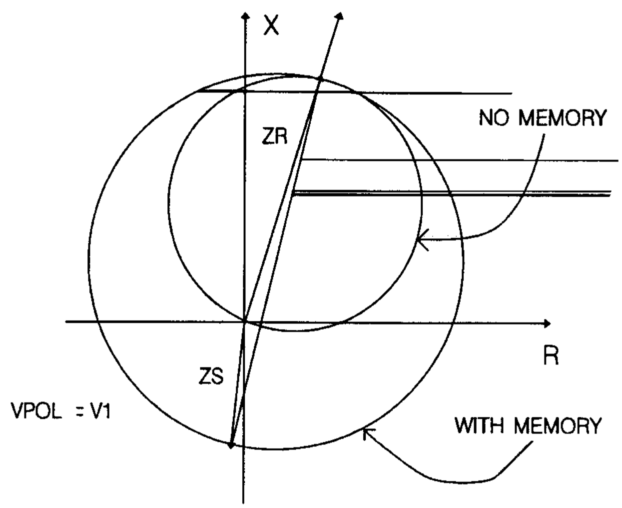


Figure 2.5: Phase-Phase Element Response for a Three-Phase Forward Fault

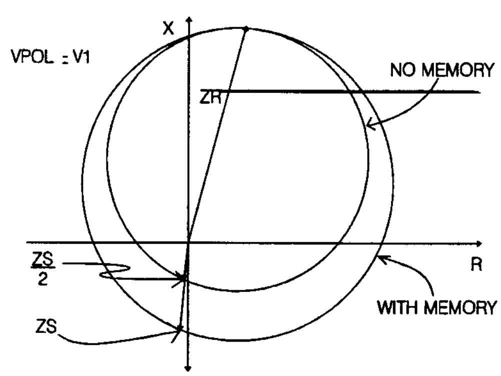


Figure 2.6: Phase-Phase Element Response for a Phase-Phase Forward Fault

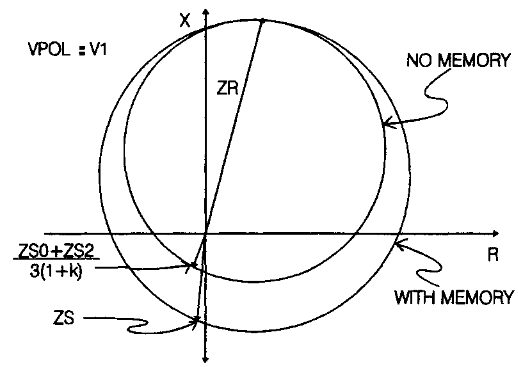


Figure 2.7: Phase-Ground Element Response for a Phase-Ground Forward Fault

Table 2.7: Voltages and Currents for Mho Elements AG, BG, CG, AB, BC, CA

Element	Voltage V	Current I	Polarization VP	Torque T
AG	VA	IA + K x IR	VA1m	Tag
BG	VB	IB + K x IR	VB1m	Tbg
CG	VC	IC + K x IR	VC1m	Tcg
AB	VA - VB	IA - IB	-j x VC1m	Tab
BC	VB - VC	IB - IC	-j x VA1m	Tbc
CA	VC - VA	IC - IA	-j x VB1m	Tca

m: denotes memory voltage
K = 1/3 (ZO/ZL - 1) ... residual current compensation factor

Each torque is a product with the following form:

$$T = Re\ [(Z_r xI - V)\ x\ VP^*]$$

In a microprocessor implementation, the computer calculates the six torque-like products and tests their signs. Positive products indicate impedances inside the expanded mho circle characteristics.

Positive-sequence memory voltage polarization provides expansion which maximizes coverage for high-resistance faults. Memory ensures that all elements operate reliably and securely for at least as long as the memory quantity lasts.

Forming the Positive-Sequence Polarizing Voltage with Memory

The block diagram in Figure 2.8 shows how a relay can determine positive-sequence memory voltage polarizing quantities from the three-phase voltages. The following description assumes a digital implementation.

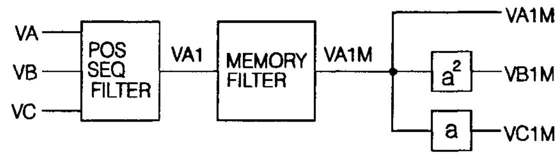


Figure 2.8: Positive-Sequence Polarizing Voltage Block Diagram

The relay filters and samples each of the voltages VA, VB, and VC every 90° (or four times per power cycle). A digital filter removes dc offset. The result is a phasor for each of the three voltages.

Next, the computer calculates the positive-sequence voltage, referred to phase A, from the voltage phasors.

The block diagram in Figure 2.8 completes the set of polarizing voltages by rotating VA1M by ±60° and inverting the two results to obtain VB1 and VC1. As our table for the mho elements showed earlier, VA1M, VB1M, and VC1M polarize the AG, BG, and CG elements. The polarization voltages for the BC, CA, and AB elements are the same as those for the AG, BG, and CG elements rotated -90°. Rotations back 90° are simple:

(x,y) ---> (y,-x).

For example, if (x,y) is the phasor for polarizing the AG element, then (y,-x) is the phasor for polarizing the BC element.

Time-Overcurrent Elements and Curves

The 51N time-overcurrent element provides directional forward or nondirectional ground fault protection as enabled. You can program its pickup (51NP) and trip (51NT) states into any mask. The 51NP bit appears in the Relay Word to provide a means of determining residual overcurrent element pickup.

The setting procedure includes time dial and curve shape selections. Four curve shapes are available: moderately inverse, inverse, very inverse, and extremely inverse. The curves and their equations are shown near the end of this section.

The relay forms the time-overcurrent characteristics by calculating a recursive sum of the magnitude or magnitude-squared of the phase or residual current adjusted by the appropriate pickup setting.

The time dial setting determines the limit the recursive sum must reach for a trip.

Negative-Sequence Directional Element

You can enable the negative-sequence directional element to provide directional supervision of the residual overcurrent elements. The negative-sequence directional elements always supervises the distance elements.

The negative-sequence directional elements are phasor-product derived. The product is negative-sequence voltage times negative-sequence current adjusted by the maximum torque angle setting. The relay declares a fault forward when I2 leads V2 ±90° from the maximum torque angle.

Table 2.9 shows the equation the relay uses to express the sensitivity of the directional element in units of torque. These equations are useful in determining directional element sensitivities for fault angles which may differ from the MTA.

Table 2.8: Directional Element Torque Equations

$$32Q: \; T \equiv |V2| x |I2| x[\cos(\angle -V2 - (\angle I2 + MTA))]$$

Where:

T ≡ Torque, positive for a forward fault
V2 ≡ Negative-sequence secondary voltage
I2 ≡ Negative-sequence secondary current

Programmable Logic Mask Concept

Figure 2.9 illustrates the concept of the programmable logic mask by comparing it to the connections of discrete relay elements. At the top, the figure shows relay element contacts X, Y, and Z connected to a common reference, such as the positive pole of a battery. The other ends of these contacts pass through knife switches, while the other side of the switches are connected to drive an auxiliary relay labelled A1. The knife switch positions select relay elements which can pick up the auxiliary relay.

In the figure, switches SX and SY are closed, so closure of either contact X or Y causes A1 to pick up. The figure expresses this process in Boolean terms next to the A1 output contact with the notation X + Y. The "+" indicates a logical "OR" operation.

The A1 contact control logic scheme may be modified by setting switches SX, SY, and SZ to other positions. If an application requires combinations of contacts X, Y, and Z to control other auxiliary relays, diodes must be used in each contact path. This ensures that the logic settings for this scheme do not affect other auxiliary relays. Since each output contact has a separate logic mask, this step is unnecessary in the microprocessor based relay.

In the programmable mask logic, the states of all relay elements are collected into a single group of binary digits called the Relay Word. Each bit position reports the state of one relay element. 0 indicates the element is not picked up; 1 indicates the element is picked up.

Figure 2.9 shows a three-bit Relay Word with elements X, Y, and Z. Each bit corresponds to one relay element contact in the contact logic equivalent. The operator sets or clears bits in the mask for the A1 output rather than using switches to select relay elements which control the A1 output (see Section 3: LOGIC command). In the figure, the operator sets the logic mask to bits (1,1,0), selecting only assertion of the X and Y elements.

The Z element is not selected, so its assertion cannot close the A1 output contact due to an open path from the positive to negative bus. The computer ANDs each bit in the Relay Word with the corresponding bit the operator set in the mask. Next it ORs all three outputs together, forming the condition which drives the output relay A1. A convenient shorthand expression for this bitwise AND followed by an OR operation is:

$$A1 = R * MA1$$

where R is the Relay Word (X,Y,Z), MA1 is the mask (1,1,0), "*" indicates the bitwise AND, and "+" indicates the OR operation.

While the mask elements are fixed, the Relay Word is updated each quarter-cycle. In this example, if the X or Y element is set to (1) in the Relay Word, the A1 contact closes. The A1 contact state is independent of the Z element state in the Relay Word because the corresponding Z element in the mask equals zero.

The user programmable logic masks in this relay control the TRIP and programmable output contacts. The logic masks are saved in nonvolatile memory with the other settings and retained through loss of control power.

The masking concept provides more flexibility than switch selectable logic, is more convenient than making wiring changes to hard wired discrete relay systems, and provides noticeable benefits during commissioning and routine testing.

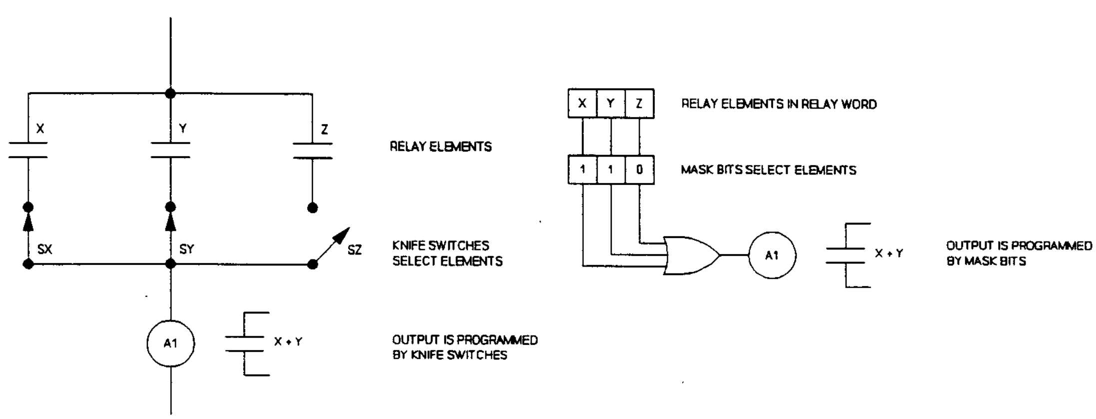


Figure 2.9: Programmable Logic Mask Analogy

RELAY ELEMENT OPERATING TIME CURVES

Figure 2.10 shows operating times for the relay phase and ground distance elements. For the distance element tests, a fault was applied at a location representing a percentage of the Zone 1 relay reach setting. At each reach percentage five tests were run. Tests were performed for source impedance ratios (SIR) of 0.1, and 1.0. The diagrams show maximum, average, and minimum operating times at each test point. Operating times include output contact closure time. No prefault load current was included. System frequency is 60 Hz.

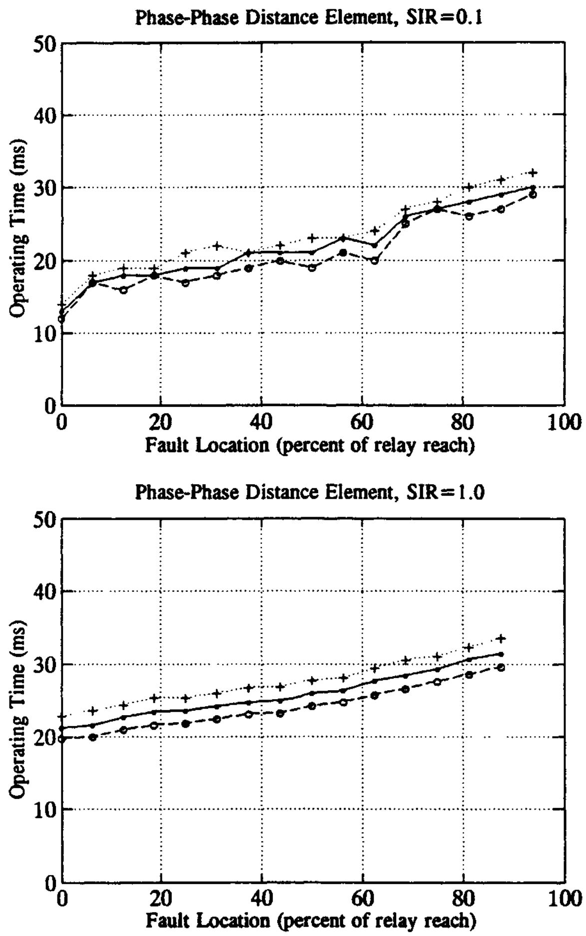


Figure 2.10: Phase and Ground Distance Element Speed Curves

TIME-OVERCURRENT CURVE EQUATIONS

These time curve equations are valid for the phase and residual time-overcurrent elements. Plots showing operating time versus multiples of pickup current are shown on the following pages.

Let t = operating time in seconds,
TD = time dial setting,
M = multiples of pickup.

Curve 1 -- Moderately Inverse

$$t_M = TD \left[0.157 + \frac{0.668}{M-1}\right]$$

Curve 2 -- Inverse

$$t_M = TD \left[0.180 + \frac{5.95}{M^2-1}\right]$$

Curve 3 -- Very Inverse

$$t_M = TD \left[0.0963 + \frac{3.88}{M^2-1}\right]$$

Curve 4 -- Extremely Inverse

$$t_M = TD \left[0.0352 + \frac{5.67}{M^2-1}\right]$$

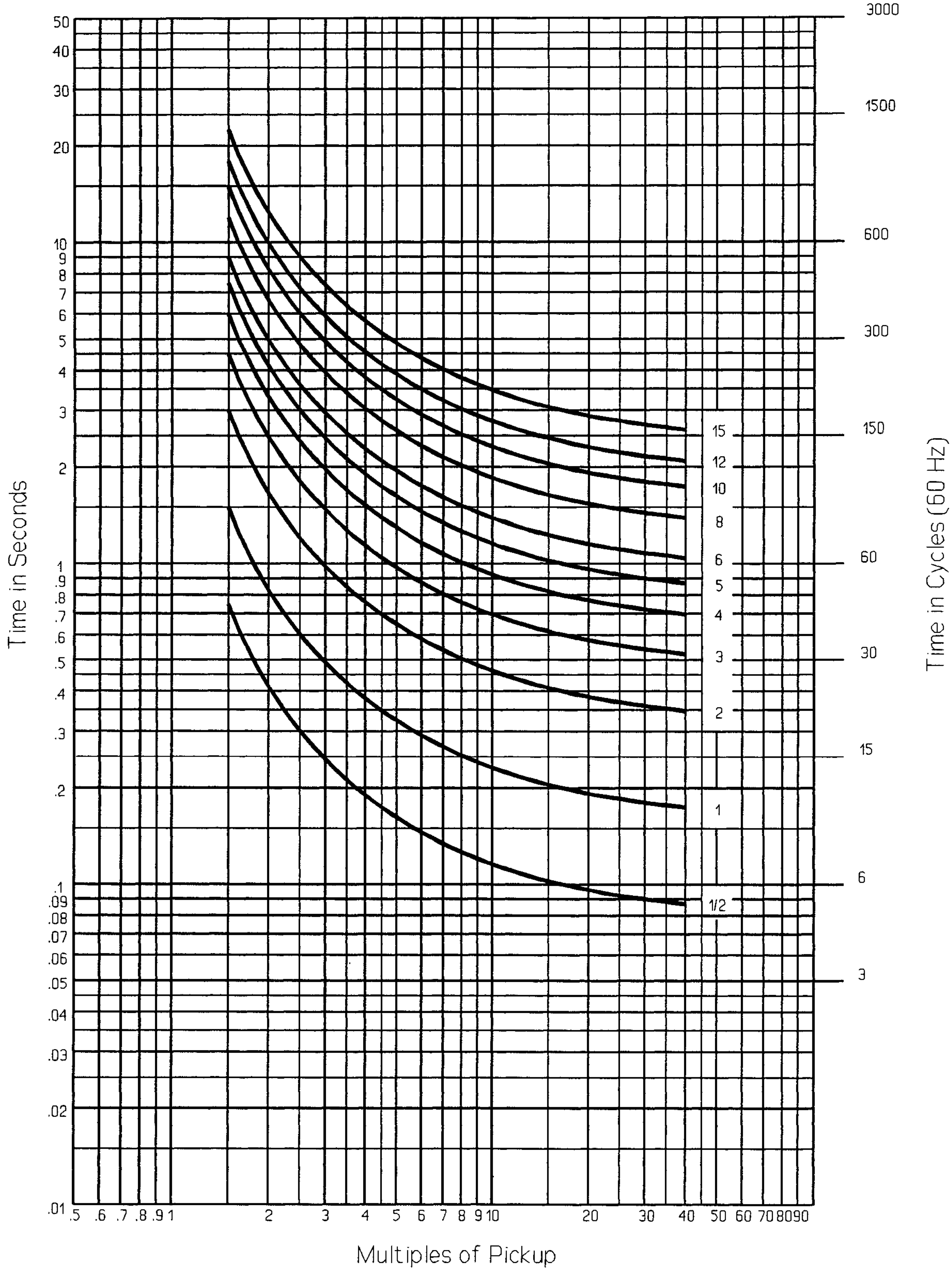


Figure 2.11: Residual Time-Overcurrent Element Moderately Inverse Time Characteristic (Curve 1)

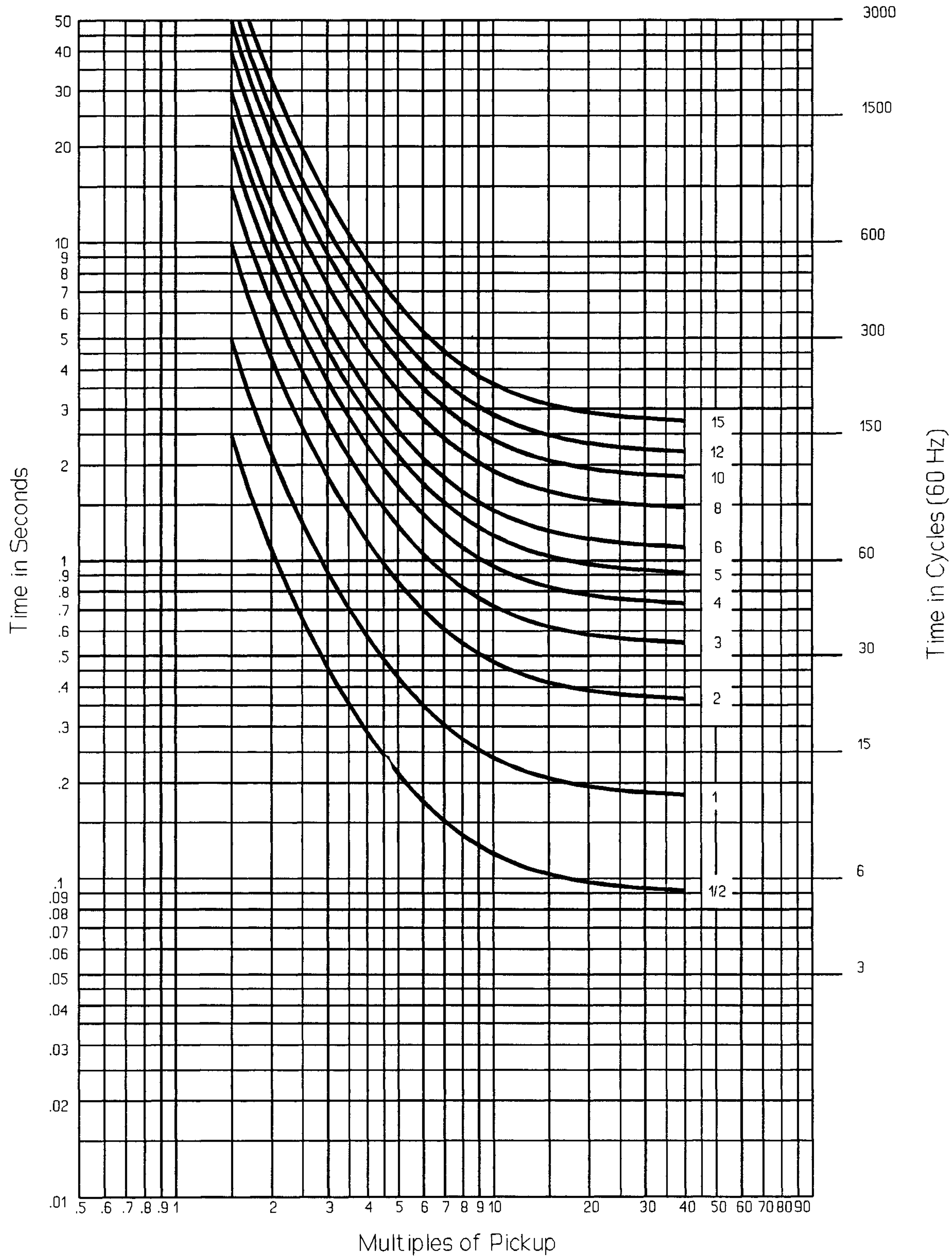


Figure 2.12: Residual Time-Overcurrent Element Inverse Time Characteristic (Curve 2)

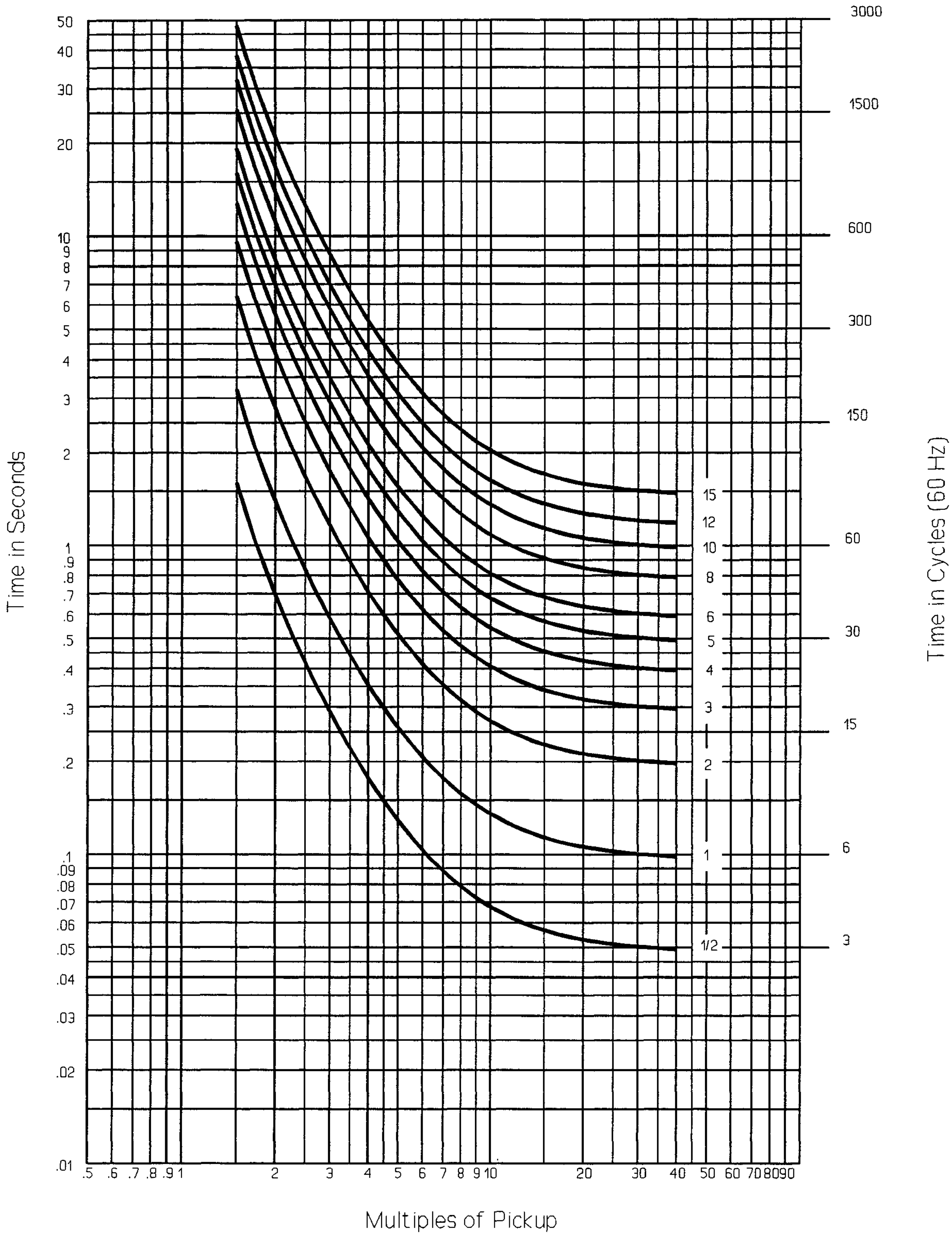


Figure 2.13: Residual Time-Overcurrent Element Very Inverse Time Characteristic (Curve 3)

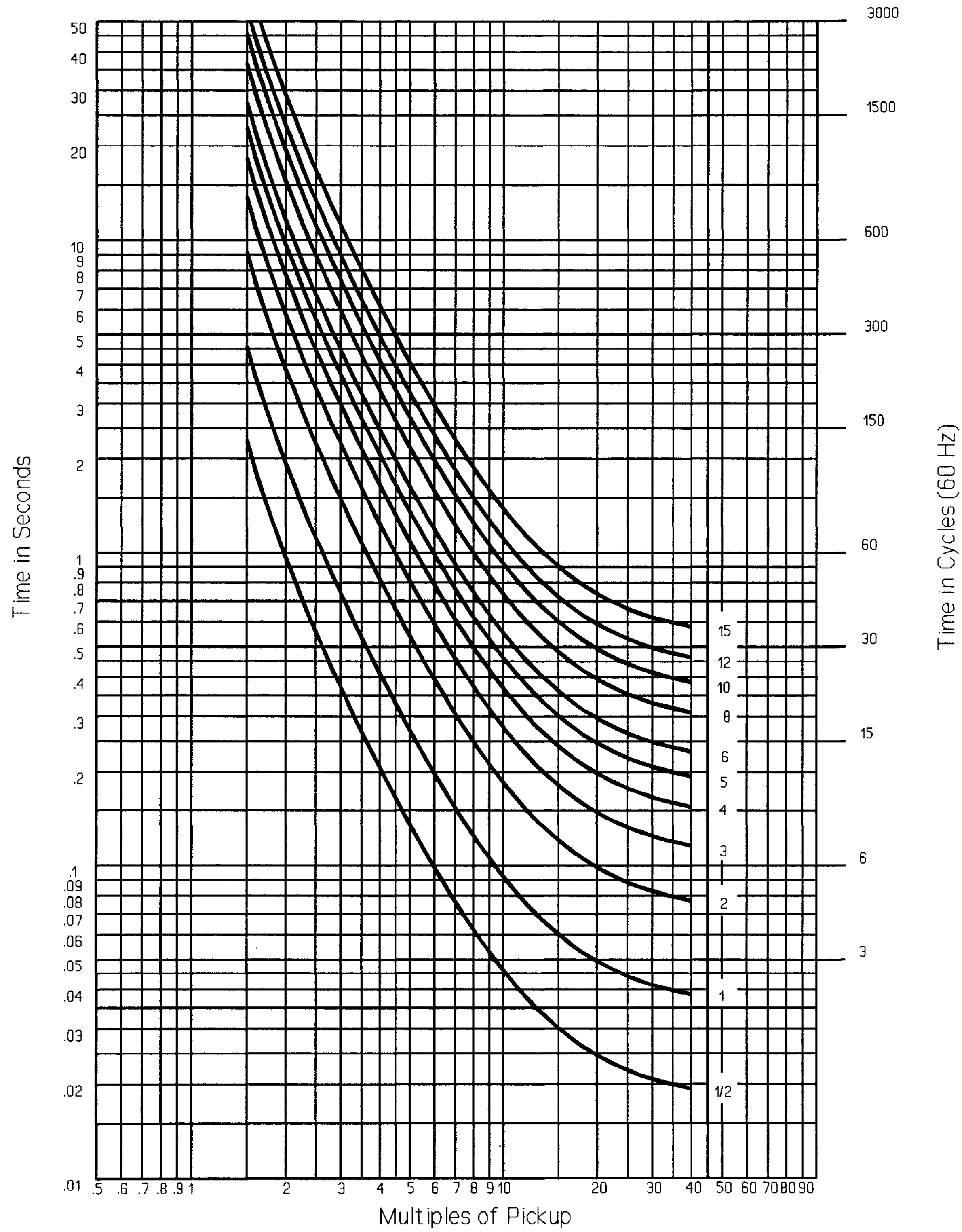
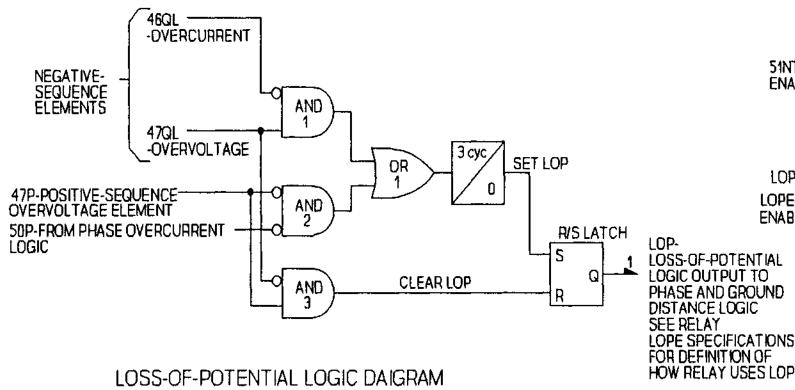
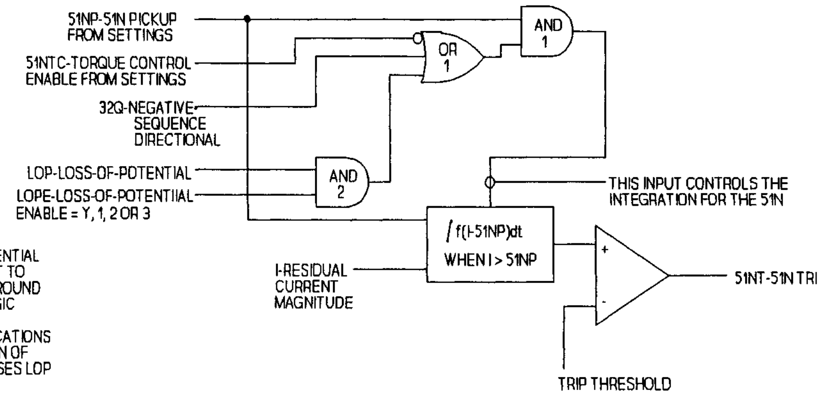


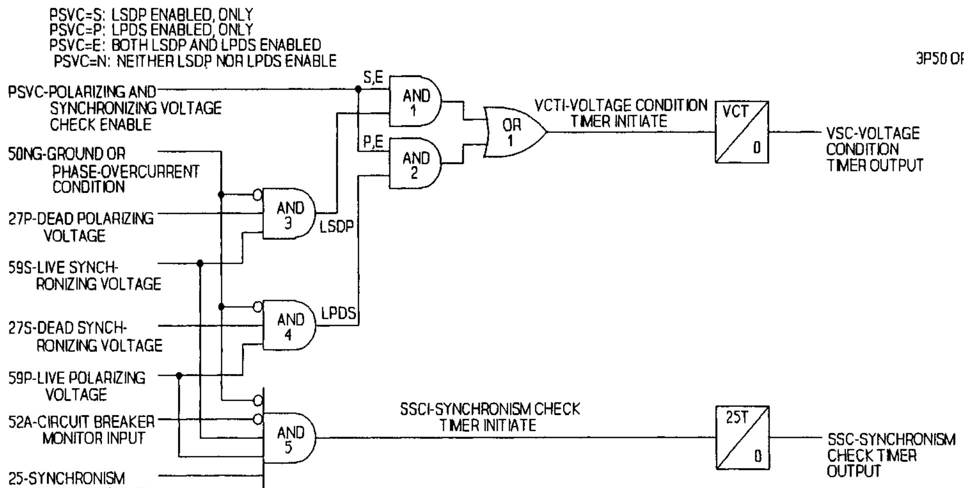
Figure 2.14: Residual Time-Overcurrent Element Extremely Inverse Time Characteristic (Curve 4)



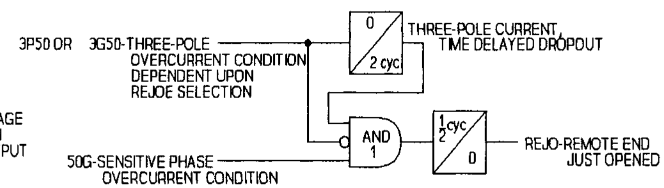
LOSS-OF-POTENTIAL LOGIC DAIGRAM



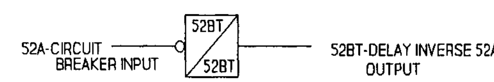
RESIDUAL TIME-OVERCURRENT (51N) LOGIC DIAGRAM



SYNCHRONISM AND VOLTAGE CHECKING LOGIC DIAGRAM

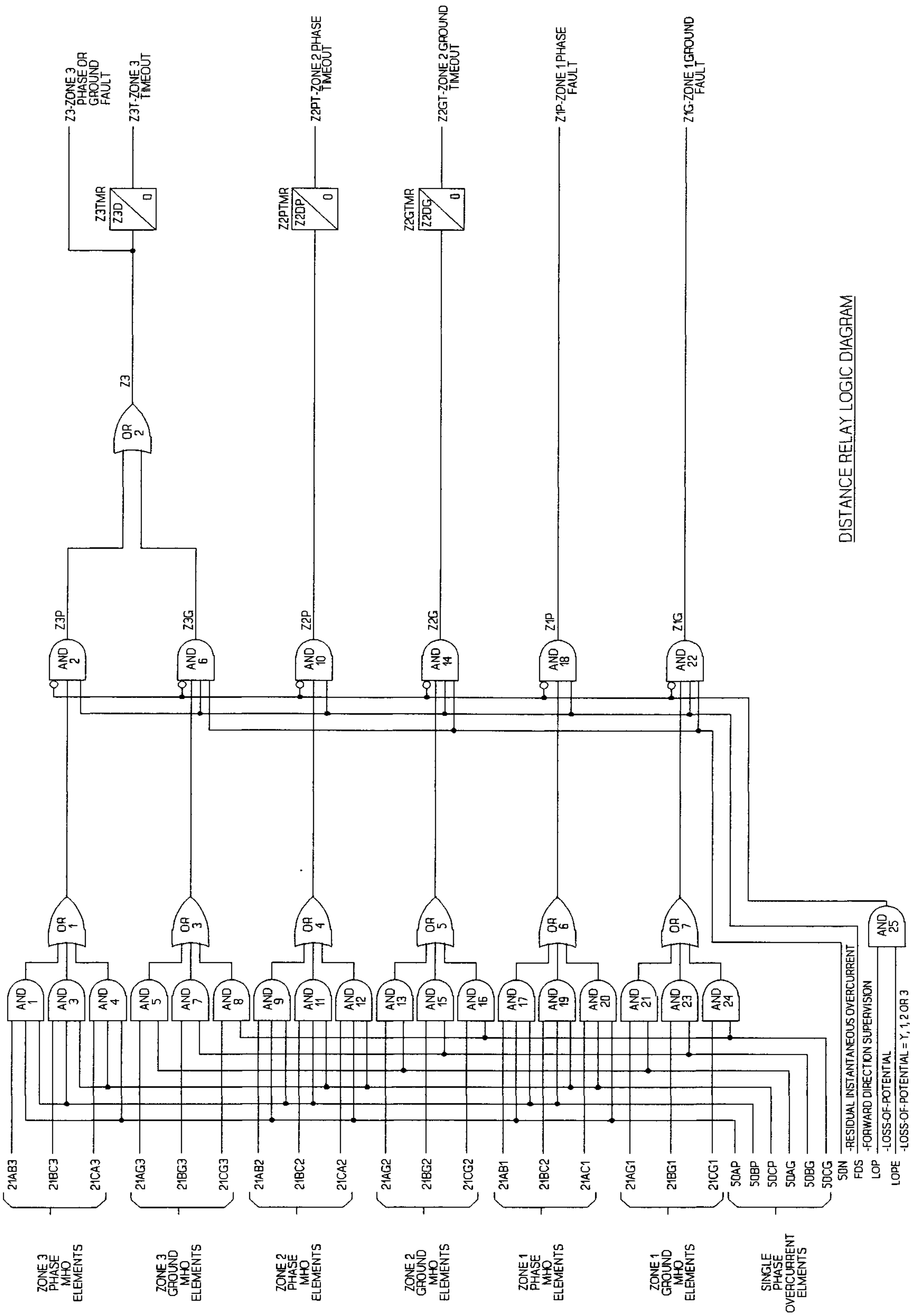


REMOTE-END-JUST-OPENED LOGIC DIAGRAM

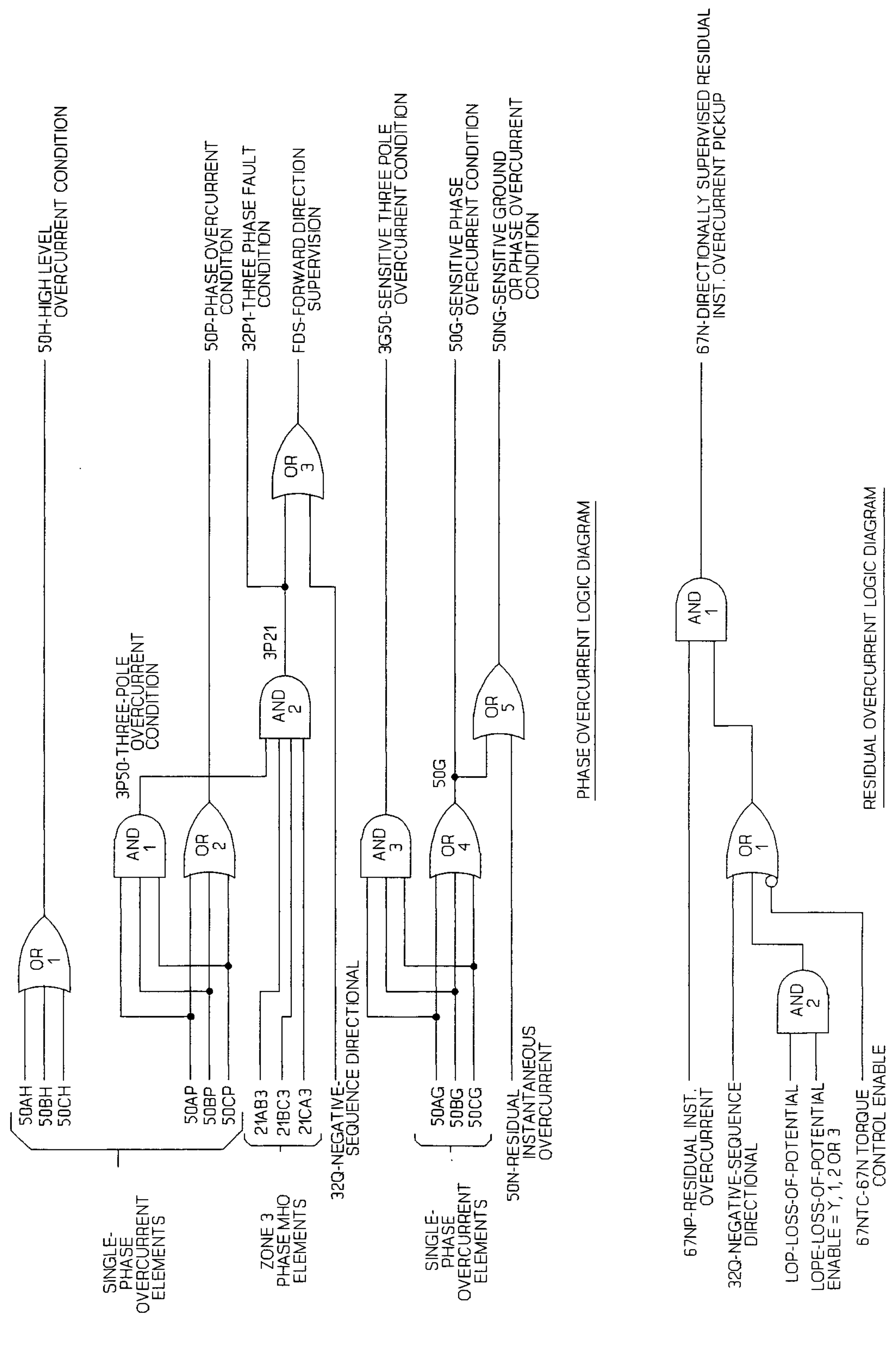


CIRCUIT BREAKER AUXILIARY CONTACT DELAY

LOGIC DIAGRAM

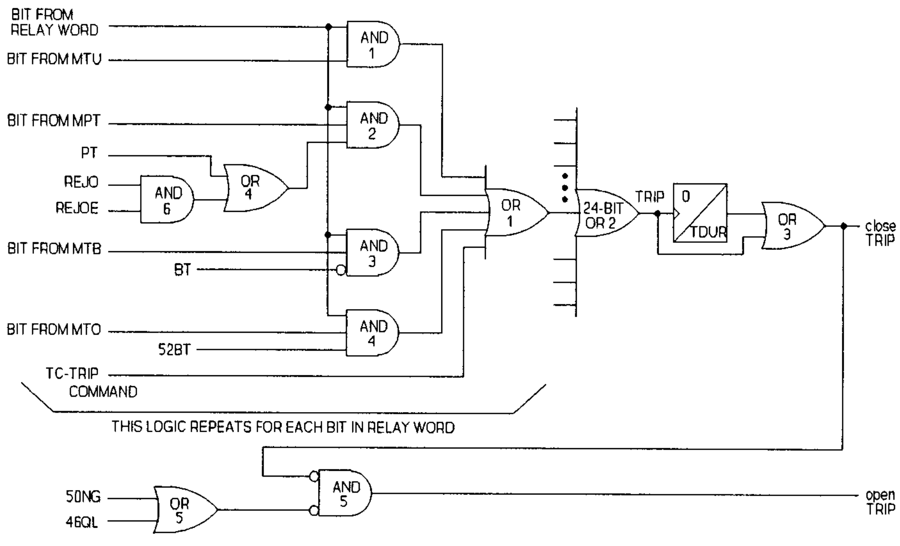


DISTANCE RELAY LOGIC DIAGRAM

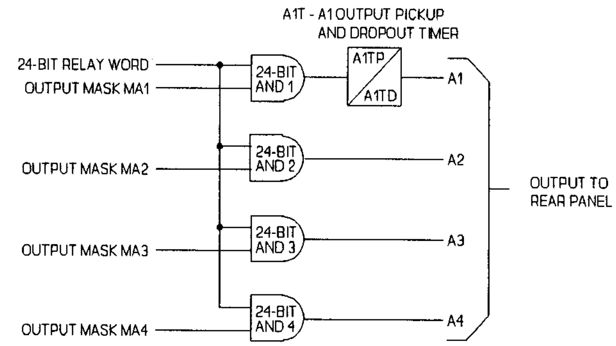


PHASE OVERCURRENT LOGIC DIAGRAM

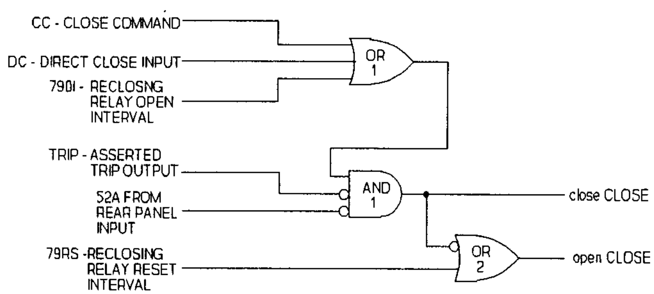
RESIDUAL OVERCURRENT LOGIC DIAGRAM



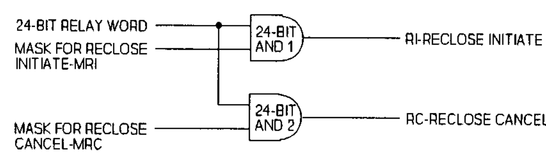
PROGRAMMABLE TRIP LOGIC DIAGRAM



PROGRAMMABLE OUTPUT LOGIC DIAGRAM



CLOSE LOGIC DIAGRAM



PROGRAMMABLE RECLOSE INITIATE

AND CANCEL LOGIC DIAGRAM

MTU - MASK FOR UNCONDITIONAL TRIP
MPT - MASK FOR TRIP WITH PERMISSIVE-TRIP UNASSERTED
MTB - MASK FOR TRIP WITH BLOCK-TRIP UNASSERTED
MTO - MASK FOR TRIP WITH BREAKER OPEN
PT - PERMISSIVE TRANSFER TRIP
BT - BLOCK TRIP
52BT - 52A INPUT TIMER INVERTED OUTPUT
REJO - REMOTE-END-JUST-OPENED CONDITION
REJOE - REMOTE-END-OPEN PERMISSIVE TRIP ENABLE

COMMUNICATIONS
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COMMUNICATIONS

INTRODUCTION

The relay is set and operated via serial communications interfaces connected to a computer terminal and/or modem or the SEL-PRTU. Communication serves these purposes:

1. The relay responds to commands spanning all functions, such as setting, metering, and control operations.

2. The relay generates an event record for TRIP output assertions, for an event triggering command, or for pickup of any relay element that triggers an event record.

3. The relay transmits messages in response to changes in system status, such as self test warnings.

It is impossible to disable any relaying or control functions via communications, unless a user enters erroneous or improper settings with the SET or LOGIC commands.

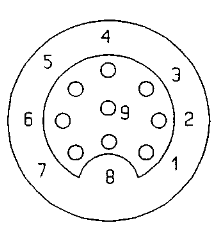
Note: In this manual, commands to type appear in bold/uppercase: **OTTER**. Keys to press appear in bold/uppercase/brackets: **<ENTER>**.

Relay output appears boxed and in the following format:

```
Example 230 kV Line                Date: 6/2/92    Time: 01:01:01
```

SERIAL PORT CONNECTIONS AND CONFIGURATIONS

The rear panel of the relay has two serial port connectors, marked PORT 1 and PORT 2. Both ports adhere to EIA RS-232-C data communications standards. Figure 3.1 shows the pin number convention for the EIA RS-232-C data ports.



(female chassis connector, as viewed from outside rear panel)

Figure 3.1: Nine-Pin Connector Pin Number Convention

Table 3.1 lists port pin assignments and signal definitions.

Table 3.1: Serial Port Connector Pin Assignments

Pin	Name	Description
2	TXD	Transmit data output.
3	RTS	The relay asserts this line under normal conditions. When its received-data buffer is full, the line deasserts until the buffer has room to receive more data. Connected devices should monitor RTS (usually with their CTS input) and stop transmitting characters whenever the line deasserts. If transmission continues, data may be lost.
4	RXD	Receive data input.
5	CTS	The relay monitors CTS and transmits characters only when CTS is asserted.
6	+5 volts	
7	+12 volts	
8	-12 volts	
1, 9	GND	Ground for ground wires and shields.

COMMUNICATIONS PROTOCOL

Communications protocol consists of hardware and software features. Hardware protocol includes the control line functions described above. The following software protocol is designed for manual and automatic communications.

1. All commands received by the relay must be of the form:

   <command><ENTER> or <command><CRLF>

   Thus, a command transmitted to the relay should consist of the command followed by either a carriage return or a carriage return and line feed. You may truncate commands to the first three characters. Thus, **EVENT 1 <ENTER>** would become **EVE 1 <ENTER>**. Upper and lower case characters may be used without distinction, except in passwords.

Note: The ENTER key on most keyboards is configured to send the ASCII character 13 (^M) for a carriage return. This manual instructs you to press the ENTER key after commands, which should send the proper ASCII code to the relay.

2. The relay transmits all messages in the following format:

```
<STX> <MESSAGE LINE 1> <CRLF>
      <MESSAGE LINE 2> <CRLF>
      .
      .
      <LAST MESSAGE LINE> <CRLF> <PROMPT> <ETX>
```

   Each message begins with the start-of-transmission character (ASCII 02) and ends with the end-of-transmission character (ASCII 03). Each line of the message ends with a carriage return and line feed.

3. The relay indicates the volume of data in its received data buffer through an XON/XOFF protocol.

   The relay transmits XON (ASCII hex 11) and asserts the RTS output when the buffer drops below one-quarter full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is over three-quarters full. The relay deasserts the RTS output when the buffer is approximately 95% full. Automatic transmission sources should monitor for the XOFF character so they do not overwrite the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and may resume when the relay sends XON.

4. You can use an XON/XOFF procedure to control the relay during data transmission. When the relay receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the relay receives XON.

   The CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating an unwanted transmission.

5. Control characters can be sent from most keyboards with the following keystrokes:

   XON: **<CTRL>Q** (hold down the Control key and press Q)
   XOFF: **<CTRL>S** (hold down the Control key and press S)
   CAN: **<CTRL>X** (hold down the Control key and press X)

COMMAND CHARACTERISTICS

The relay responds to commands sent to either serial communications interface. A two level password system provides security against unauthorized access.

When the power is first turned on, the relay is in Access Level 0 and honors only the ACCESS command. It responds "Invalid command" or "Invalid access level" to any other entry.

You may enter Access Level 1 with the ACCESS command and first password. The Level 1 password is factory-set to OTTER and may be changed with the PASSWORD command in Access Level 2. Most commands may be used in Access Level 1.

Critical commands such as SET operate only in Access Level 2. You may enter Access Level 2 with the 2ACCESS command and second password. The Level 2 password is factory-set to TAIL and may be changed with the PASSWORD command.

Startup

Immediately after power is applied, the relay transmits the following message to the port(s) designated automatic:

```
Example 230 kV Line                    Date: 6/2/92      Time: 01:01:01

SEL-121F
=
```

The ALARM contacts should open.

The = represents the Access Level 0 prompt.

The relays are shipped with PORT 2 designated automatic; you may use the SET command to change this designation (see SET command, AUTO setting). This allows you to select PORT 1, PORT 2, or both ports to transmit automatic responses from the relay.

To enter Level 1, type the following on a terminal connected to PORT 2:

```
=ACCESS <ENTER>
```

The response is:

```
Password: ? @@@@@@
```

Respond by entering the Level 1 password, **OTTER**, followed by a carriage return. The response is:

```
Example 230 kV Line                Date: 6/2/92       Time: 01:01:44

Level 1
=>
```

The Access Level 1 prompt is =>. Now you can execute any Level 1 command.

Use a similar procedure to enter Access Level 2:

Type **2ACCESS <ENTER>**. The relay pulses the ALARM relay contact closed for approximately one second, indicating an attempt to enter Access Level 2. Enter the proper password, **TAIL**, when prompted. After you enter the second password, the relay opens access to Level 2, as indicated by the following message and Level 2 prompt (=>>):

```
=>2ACCESS <ENTER>
Password:   TAIL <ENTER>


Example 230 kV Line                 Date: 6/2/92      Time: 01:03:32

Level 2
=>>
```

Any Level 2 or Level 1 command can now be executed.

Command Format

Commands consist of three or more characters; only the first three characters of any command are required. You may use upper or lower case characters without distinction, except in passwords.

You must separate arguments from the command by spaces, commas, semicolons, colons, or slashes.

You can enter commands any time after the terminal displays an appropriate prompt.

COMMAND DESCRIPTIONS

Access Level 0 Command

ACCESS

ACCESS allows you to enter Access Level 1. The password is required unless you install jumper JMP103. The first password is set to OTTER at the factory; use the Level 2 command PASSWORD to change passwords.

The following display indicates successful access:

```
=>ACCESS <ENTER>
Password:   OTTER <ENTER>


Example 230 kV Line                      Date: 6/2/92      Time: 14:12:01

Level 1
=>
```

The => prompt indicates Access Level 1.

If you enter incorrect passwords during three consecutive attempts, the relay pulses the ALARM contact closed for one second. This feature can alert personnel to an unauthorized access attempt if the ALARM contact is connected to a monitoring system.

Access Level 1 Commands

2ACCESS

2ACCESS allows you to enter Access Level 2. The password is required unless you install jumper JMP103. The second password is set to TAIL at the factory; use the Level 2 command PASSWORD to change passwords.

The following display indicates successful access:

```
=>2ACCESS <ENTER>
Password:   TAIL <ENTER>


Example 230 kV Line                    Date: 6/2/92      Time: 14:12:01

Level 2
=>>
```

You may use any command from the =>> prompt. The relay pulses the ALARM contact closed for one second after any Level 2 access attempt (unless an alarm condition exists).

DATE mm/dd/yy

DATE displays the date stored by the internal calendar/clock. To set the date, type **DATE mm/dd/yy <ENTER>**.

For example, to set the date to January 17, 1992, enter:

```
=>DATE 1/17/92 <ENTER>
1/17/92
=>
```

The relay sets the date, pulses the ALARM relay closed as it stores the year in EEPROM (if the year input differs from the year stored), and displays the new date.

EVENT n

EVENT displays an event report. Type **EVENT n <ENTER>** to display an event report for the nth event. The parameter n ranges from 1 for the newest event through 12 for the oldest event stored in the relay memory. If n is not specified, the default value is 1 and the relay displays the newest event report.

You can control transmissions from the relay with the following keystrokes:

- **<CTRL>S** Pause transmission
- **<CTRL>Q** Continue transmission
- **<CTRL>X** Terminate transmission

The following incidents clear the event buffers:

- Interruption of control power
- Changing any relay setting
- Changing any logic mask setting

All event data are lost when event buffers are cleared. If an event buffer is empty when you request an event, the relay returns an error message:

```
=>EVENT 12 <ENTER>
Invalid event
=>
```

Section 4: EVENT REPORTING explains the generation and analysis of event reports.

HISTORY

HISTORY displays the date, time, and type of event for each of the last twelve events. If the event is a fault, the distance, duration, and maximum phase current appear in the History readout.

```
=>HISTORY <ENTER>


Example 230 kV Line                Date: 6/2/92      Time: 07:38:12

#  DATE        TIME         TYPE  DIST   DUR   CURR

1  1/01/91   07:36:52.150  1AG   74.93  5.00  1070.1
2  1/01/91   07:36:18.400  1BC   74.53  4.75  1567.2
3  1/01/91   07:35:42.970  3BC   84.68  4.25  1411.8
4  1/01/91   07:35:23.783  EXT
5  1/01/91   07:35:07.958  TRIP
6
7
8
9
10
11
12

=>
```

Note that only five events have occurred since the relay was set or powered on.

The time is saved to the nearest quarter-cycle (4.17 ms) and referenced to the 16th row of data in the report. All reports trigger at row 16. If a long fault triggers two event reports, you can still determine its duration. Simply calculate the time difference between the first report generated at fault inception and the second report generated at the TRIP.

The TYPE column provides an abbreviated indication of the event type. This is the same data presented for EVENT in the event summary automatically generated for each fault.

For faults, the indication includes zone and phase involvement information. The zone is determined from the relay elements asserted at the middle of the first contiguous sequence of relay elements picked up in the report. For example, if relay elements are contiguously picked up from the 15th to the 24th rows, the zone will be determined from the 20th row. The zone is indicated by the left-most character of the TYPE string, and is one of the following:

1 : For faults in which a Zone 1 element picked up
2 : For Zone 2 time out, but not Zone 1 pickup
3 : For Zone 3, but not Zone 2 or 1
6 : For 67N pickup, but not Zone 3, 2, or 1
5 : For 51N pickup, but not 67N, Zone 3, 2, or 1
H : For 50H pickup, but not 51N, 67N, Zone 3, 2, or 1
? : For none of the above picked up at midfault

Phase involvement is shown by the characters subsequent to the zone indication and is determined independently from relay elements. Phase involvement is determined solely from uncompensated and load compensated current magnitudes. These magnitudes are measured at the midpoint of the first contiguous relay pickup sequence in the event report (see the Event Type description in Section 4: Event Reporting for algorithmic details). The phase involvement is indicated as one of the list below.

AG : For A-phase to ground faults
BG : For B-phase to ground faults
CG : For C-phase to ground faults
AB : For A-B two-phase faults
BC : For B-C two-phase faults
CA : For C-A two-phase faults
ABG : For A-B two-phase to ground faults
BCG : For B-C two-phase to ground faults
CAG : For C-A two-phase to ground faults
ABC : For three-phase faults

The zone and phase involvement data are concatenated into a single string, completing the TYPE designation, as in "3BG", for a Zone 3 B-to-ground fault, for example. For event reports triggered by the assertion of the TRIP output, the TYPE designation is further appended with a "T". This aids the determination of clearing times for faults which persist beyond the end of the first event report. For example, if the SEL-121F relay trips for a 3BG fault after the initial report was completed, the second report shows "3BGT" for TYPE.

For events other than faults, TYPE indication is either "TRIP" or "EXT." The TYPE is "TRIP" when the relay generates an event report in response to TRIP output assertion. This can occur after OPEN command execution during a no-fault condition. For all other events, TYPE shows "EXT", indicating the report was generated in response to some external stimulus, such as the assertion of the ET (External Trigger), PT (Permissive Trip), BT (Block Trip), or IN1 (Programmable Input 1) inputs, or by execution of the TRIGGER command.

The DIST column presents the equivalent distance to a fault in miles or kilometers. This is calculated using the Takagi algorithm or a reactance measurement, depending on whether prefault data are available in the event report. For some boundary faults of long duration, the fault locator may not be able to locate the fault for every report generated when relay operation is sporadic. The DIST column may contain "999999" in such cases. While this behavior can be contrived under test conditions, it is extremely rare in actual practice.

The column headed DUR gives a measure of the fault duration. This is measured from the first pickup of a Zone 1, 2, or 3, 51N, 67N or 50H relay element, until the first dropout of all said relay elements. In other words, it is the duration of the first contiguous pickup of relay elements found in the long event report, converted to units of cycles.

The CURR column shows the magnitude of the maximum phase-current measured at the middle of the fault, in primary amperes. This information is useful for determining the row pair used by the relay for fault location calculations.

IRIG

IRIG directs the relay to read the demodulated IRIG-B time code input at J201 on the rear panel if a time code signal is input.

If the relay reads the time code successfully, it updates the internal clock/calendar time and date to the time code reading and the relay transmits a message with relay ID string, date, and time.

```
=>IRIG <ENTER>

Example 230 kV Line              Date: 6/2/92        Time: 01:45:40

=>
```

If no IRIG-B signal is present or the code cannot be read successfully, the relay sends the error message "IRIGB DATA ERROR."

Note: Normally, it is not necessary to synchronize using this command because the relay automatically synchronizes every few minutes. The command is provided to prevent delays during testing and installation.

METER displays the phase-to-neutral and phase-to-phase voltages and currents in primary kilovolts and amperes. METER also displays real and reactive power in megawatts and megavars.

```
=>METER <ENTER>

Example 230 kV Line               Date: 6/2/92        Time: 07:56:36

                  A       B       C       AB      BC      CA     IR/VS
I (A)            994     995     994     1723    1724    1724       0
V (kV)         134.4   134.3   134.2    233.1   232.8   232.9   134.3

P (MW)        401.12
Q (MVAR)        1.00

=>
```

P and Q are positive when the power flow is in the direction of the reach of the relay, i.e., out from the bus and into the line.

The optional command parameter n selects the number of times the meter data are displayed. For example, to see a series of eight meter readings, type METER 8.

QUIT

QUIT returns control to Access Level 0 from Level 1 or 2 and resets targets to the Relay Targets (TAR 0). The command displays the relay I.D., date, and time of QUIT command execution.

Use this command when you finish communicating with the relay to prevent unauthorized access. Control returns to Access Level 0 automatically after a settable interval of no activity (see the TIME1 and TIME2 settings of the SET command).

```
=>QUIT <ENTER>

Example 230 kV Line                 Date: 6/2/92      Time: 01:45:40

=
```

SHOWSET

SHOWSET displays the current relay and logic settings. Settings cannot be entered or modified with this command. The SET command description provides complete information about changing settings.

```
=>SHOWSET <ENTER>

Settings for: Example 230 kV Line

R1   =13.90  X1   =79.96   R0   =41.50   X0   =248.57 LL   =100.00
CTR  =200.00 PTR  =2000.00 SPTR =2000.00 MTA  =80.10
79OI =40.00  79RS =240.00
PSVC =S      27VLO=26.60   59VHI=106.20  25DV =53.12  SYNCP=A
25T  =300.00 VCT  =30.00
A1TP =0.00   A1TD =0.00
Z1%  =80.00  Z2%  =120.00  Z3%  =150.00
Z2DP =30.00  Z2DG =30.00   Z3D  =40.00   TDUR =9.00
50NG =250.00 50P  =370.00  50H  =1500.00
51NP =270.00 51NTD=3.00    51NC =2       51NTC=Y
67NP =650.00 67NTC=Y       52BT =30.00   REJOE=N      LOPE =Y
TIME1=5      TIME2=0       AUTO =2       RINGS=7


Logic settings:

MTU  MPT  MTB  MTO  MA1  MA2  MA3  MA4  MRI  MRC
F4   08   00   FC   00   00   F0   04   F0   04
A2   00   00   A4   00   00   80   20   80   20
00   00   00   00   02   01   00   00   00   00

=>
```

A detailed explanation of the relay and logic settings is given in the description of the SET and LOGIC commands. Each column in the logic settings display shows the masks for the Relay Word as follows:

Row 1, of any column:	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q
Row 2, of any column:	67N	51NP	51NT	50NG	50P	50H	IN1	REJO
Row 3, of any column:	LOP	52BT	27S	27P	59S	59P	SSC	VSC

The logic settings are shown in hexadecimal format. Table 3.2 shows the equivalencies between hexadecimal (hex) and binary numbers to assist you in examining the logic settings display in event reports and the SHOWSET display.

Table 3.2: Hexadecimal/Binary Conversion

Hexadecimal	Binary	Hexadecimal	Binary
0	0000	8	1000
1	0001	9	1001
2	0010	A	1010
3	0011	B	1011
4	0100	C	1100
5	0101	D	1101
6	0110	E	1110
7	0111	F	1111

For example, consider row 2 of mask MTO, which is set to A4 hex format. Using the table to convert A4 to binary gives:

A4 -> 1010 0100

Now, build the Relay Word for row 2 of mask MTO as follows:

```
67N    51NP   51NT   50NG   50P    50H   IN1   REJO
 1      0      1      0      0      1     0     0
_______   A   _______       _______   4  _______
```

STATUS

STATUS allows inspection of self test status. The relay automatically executes the STATUS command whenever a self test enters a warning or failure state. If this occurs, the relay transmits a STATUS report from the port(s) designated automatic (see SET command, AUTO setting).

```
=>STATUS <ENTER>

Example 230 kV Line                 Date: 6/2/92     Time: 01:08:44

SELF TESTS

W=Warn F=Fail
      IR   IA   IB   IC   VA   VB   VC   VS
OS    0    0    0    0    0    2    0    0
PS     5.11      15.15    -14.91
RAM    ROM    A/D    MOF    SET
OK     OK     OK     OK     OK

=>
```

The OS row indicates measured dc offset voltages in millivolts for the eight analog channels. An out-of-tolerance offset is indicated by a W (warning) or F (failure) following the displayed offset value.

The PS row indicates power supply voltages in volts for the three power supply outputs.

If a RAM or ROM test fails, the IC socket number of the defective part replaces OK.

The A/D self test checks the analog-to-digital conversion time.

The MOF test checks dc offset in the MUX-PGA-A/D circuit when a grounded input is selected.

The SET self test calculates a checksum of the settings stored in nonvolatile memory and compares it to the checksum calculated when settings were last changed.

Section 2: SPECIFICATIONS provides full definitions of the self tests, their warning and failure limits, and the results of test warnings and failures.

TARGET n k

This command selects the information to be displayed on the front-panel target LEDs, and also communicates the state of the selected LEDs.

When the relay power is turned on, the LED display indicates the functions marked on the front panel. That is, the LEDs default to displaying fault information shown in the row labelled RELAY TARGETS in the table on the next page.

Using the TARGET command, you may select any one of seven sets of data, as listed on the following page, to be printed and to be displayed on the LEDs.

Table 3.3: Target LED Assignment

LED: N	1	2	3	4	5	6	7	8	
O	EN	PH1	G1	PH2	G2	PH3	G3	51N	RELAY TARGETS
1	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	RELAY WORD ROW #1
2	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	RELAY WORD ROW #2
3	LOP	52BT	27S	27P	59S	59P	SSC	VSC	RELAY WORD ROW #3
4	50G	50N	59PH	25	Z3G	Z3P	RC	RI	INTERNAL ELEMENTS
5		ET	52A	DC	BT	PT	DT	IN1	CONTACT INPUTS
6		TRIP	CLOS	A1	A2	A3	A4	ALRM	CONTACT OUTPUTS

These selections are useful in testing, in checking contact states, and in remotely reading the targets. A "1" indicates an asserted element; a "0" indicates an unasserted element.

The optional command parameter k selects the number of times the target data are repeatedly displayed for a certain choice of parameter n. For example, to see a series of ten target readings of target number four, execute the following:

```
=>TARGET 4 10 <ENTER>

 50G  50N  59PH 25   Z3G  Z3P  RC   RI
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0

 50G  50N  59PH 25   Z3G  Z3P  RC   RI
 0    0    0    1    0    0    1    0
 0    0    0    1    0    0    1    0

=>
```

When finished, type **TAR 0 <ENTER>** to return to fault targets so field personnel do not misinterpret displayed data. Also, if the relay sends an automatic message to a timed out port, it clears the target display and displays the TAR 0 data.

Press the front panel TARGET RESET button to clear the TAR 0 data and illuminate all target LEDs for a one second lamp test.

You can reset front panel targets to TAR 0 and clear them remotely or locally with the TARGET command. Type **TARGET R <ENTER>** to reset and clear the targets as shown below.

```
=>TARGET R <ENTER>
Targets reset

 EN   PH1  G1   PH2  G2   PH3  G3   51N
 1    0    0    0    0    0    0    0

=>
```

TIME hh:mm:ss

TIME checks the internal clock. To set the clock, type **TIME** and the desired setting, then press **<ENTER>**. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes. To set the clock to 23:30:00, enter:

```
=>TIME  23:30:00 <ENTER>
23:30:00
=>
```

A quartz crystal oscillator provides the time base for the internal clock. You can set the time clock automatically with the relay time code input and a source of demodulated IRIG-B time code.

TRIGGER

TRIGGER generates an event record. After command entry, the relay responds "Triggered," and displays a record summary.

```
=>TRIGGER <ENTER>
Triggered

=>

Example 230 kV Line                Date: 6/2/92     Time:01:11:17.304

Event    : EXT    Location    :       mi        ohms sec
Duration:         Flt Current:


=>
```

Use TRIGGER to inspect the input voltages. For example, when the relay is first installed, execute the TRIGGER command, draw the phasors (Section 4: EVENT REPORTING gives an example of how to do this), and check for the proper polarity and phase-sequence of the inputs.

Access Level 2 Commands

While all commands are available from Access Level 2, the commands below are available only from Access Level 2. Remember, the relay pulses the ALARM contact closed for one second after any Level 2 access attempt.

CLOSE

The CLOSE command asserts the CLOSE output relay. You can also accomplish this by asserting the DIRECT CLOSE input as long as the 52A input or TRIP outputs are not asserted. The CLOSE output relay then remains closed until the 52A input is asserted (indicating that the circuit breaker is closed) or until the reclose reset timer (79RS) expires.

To close the circuit breaker with this command, type **CLOSE <ENTER>**. The prompting message "Close BREAKER (Y/N) ?" is displayed. **Y <ENTER>** yields a second prompting string: "Are you sure (Y/N) ?" Type **Y <ENTER>** to assert the CLOSE output relay, as long as the TRIP output and 52A input are not asserted. The relay transmits the message "Breaker CLOSED" once the breaker closes, or if it is already closed (as determined by the state of the 52A input). Typing **N <ENTER>** after either of the above prompts aborts the closing operation with the message "Aborted."

```
=>>CLOSE <ENTER>
Close BREAKER (Y/N) ? Y <ENTER>
Are you sure (Y/N) ? Y <ENTER>
Breaker CLOSED
=>>
```

LOGIC n

The LOGIC command programs the masks which control outputs and event report triggering.

The parameter n specifies a mask to program.

MTU - Mask for trip unconditional
MPT - Mask for trip with permissive-trip asserted
MTB - Mask for trip with block-trip unasserted
MTO - Mask for trip with breaker open
MA1 - Mask for A1 relay control
MA2 - Mask for A2 relay control
MA3 - Mask for A3 relay control
MA4 - Mask for A4 relay control
MRI - Mask for reclose initiate
MRC - Mask for reclose cancel

The logic programming procedure requires you to enter changes to the mask or press **<ENTER>** to indicate no change. Each mask listed above is split into sections which correspond to the three rows of the Relay Word as follows:

Relay Word 1:	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q
Relay Word 2:	67N	51NP	51NT	50NG	50P	50H	IN1	REJO
Relay Word 3:	LOP	52BT	27S	27P	59S	59P	SSC	VSC

The LOGIC command displays a header and settings for each row of the logic mask. Next it displays a question mark prompt and waits for input. Enter only ones and zeros with no separating spaces as input; one selects and zero deselects a member of the mask. Press **<ENTER>** when a group is satisfactory. If you wish to change any member of a group, you must re-enter all eight members, even if some remain the same. The relay repeats logic settings and the question mark prompt after entry of each row to allow corrections.

When all data are entered for each row, the relay displays the new settings and prompts for approval to enable the relay with them. **Y <ENTER>** enters the new data, pulses the ALARM contacts closed momentarily, and clears the event buffers. **N <ENTER>** retains the old settings.

LOGIC command example for the MTU mask:

```
=>>LOGIC MTU <ENTER>

1 selects, 0 deselects.

Z1P  Z1G  Z2PT Z2GT Z3   Z3T  3P21 32Q
 0    0    0    0    0    0    0    0
 ? 11110100 <ENTER>
 1    1    1    1    0    1    0    0
 ? <ENTER>
67N  51NP 51NT 50NG 50P  50H  IN1  REJO
 0    0    0    0    0    0    0    0
 ? 10100110 <ENTER>
 1    0    1    0    0    1    1    0
 ? <ENTER>
LOP  52BT 27S  27P  59S  59P  SSC  VSC
 0    0    0    0    0    0    0    0
 ? <ENTER>


New MTU :

Z1P  Z1G  Z2PT Z2GT Z3  Z3T  3P21  32Q
 1    1    1    1    0   1    0     0
67N  51NP 51NT 50NG 50P 50H  IN1   REJO
 1    0    1    0    0   1    1     0
LOP  52BT 27S  27P  59S 59P  SSC   VSC
 0    0    0    0    0   0    0     0

OK (Y/N) ? Y <ENTER>
Enabled

Example 230 kV Line                Date: 6/2/92      Time: 02:12:28

=>>
```

The example above selects unconditional tripping for assertion of the Zone 1 phase and ground distance elements, Zone 2 and Zone 3 time delayed phase and ground distance elements, instantaneous and inverse-time residual overcurrent elements, high-set nondirectional phase overcurrent element, or the IN1 programmable input.

Note: The masks must be properly configured for your application.

The programmable masks enable the outputs to be used for any desired function. Examples include separating outputs for phase and ground, or by direction or by zone.

OPEN

The TRIP output relay closes in response to the OPEN command. The TRIP relay remains closed until the 50NG and 46QL overcurrent elements have dropped out. In all cases the TRIP output remains asserted at least TDUR cycles. If TDUR=0, the OPEN command is aborted.

To open the power circuit breaker by command, type **OPEN <ENTER>**. The prompt "Open BREAKER (Y/N) ?" is transmitted. Answering **Y <ENTER>** yields a second prompt: "Are you sure (Y/N) ?" Answering **Y <ENTER>** again closes the TRIP output relay as described above. The OPEN command aborts unless the remote open/close jumper (JMP104) is in place on the main board.

```
=>>OPEN <ENTER>
Open BREAKER (Y/N) ? Y<ENTER>
Are you sure (Y/N) ? Y<ENTER>
Breaker OPEN
=>>

Example 230 kV Line                Date: 6/2/92     Time: 23:36:10.887

Event   : TRIP  Location   :      mi        ohms sec
Duration:       Flt Current:


=>>
```

PASSWORD (1 or 2) password

PASSWORD allows you to inspect or change existing passwords. To inspect passwords, type **PASSWORD <ENTER>** as the following example shows:

```
=>>PASSWORD <ENTER>
1: OTTER
2: TAIL
=>>
```

To change the password for Access Level 1 to BIKE enter the following:

```
=>>PASSWORD 1 BIKE <ENTER>
Set
=>>
```

The relay responds by setting the password, pulsing closed the alarm relay, and transmitting the response "Set."

After entering new passwords, type **PASSWORD <ENTER>** to inspect them. Make sure they are what you intended and record the new passwords. There is no communications procedure to access the relay without the passwords.

Passwords can be any length up to six numbers, letters, or any other printable characters except delimiters (space, comma, semicolon, colon, slash). Upper and lower case letters are treated as different characters. Examples of valid, distinct passwords include:

OTTER otter Ot3456 +TAIL+ !@#$%^ 123456 12345. 12345

If the passwords are lost or you wish to operate the relay without password protection, install JMP103 on the main board. With no password protection, you may gain access without knowing the passwords and view or change current passwords and settings.

SET

SET allows entry of relay settings. At the setting procedure prompts, enter new data or press **<ENTER>** to indicate no change.

The SET command prompts you for each setting. The relay checks new settings against established limits twice. If the setting is within primary setting range, the relay prompts you for the next setting. Press **<ENTER>** to retain an existing setting.

The first check is a primary setting limit check, the second is a secondary setting limit check. The primary check is intended as a rough guideline for individual settings and ensures that settings fall within a reasonable range. The secondary check compares the entire group of settings against the individual secondary setting limits shown in Section 2: SPECIFICATIONS.

When you finish entering setting changes, it is not necessary to scroll through the remaining settings. Type **END <ENTER>** after your last change to display the new settings and enable prompt. Do not use the END statement at the Relay ID setting. Use **<CTRL>X** to abort the SET procedure from any point.

After you enter all data, the relay displays the new settings and prompts for approval to enable them. Answer **Y <ENTER>** to approve the new settings. Error messages notify you when entry combinations result in an out-of-range secondary setting. If all settings are acceptable, the relay enables them, closes the ALARM contact momentarily, and clears the event buffer.

A list of relay settings and the primary limit checks follow. Please note that each setting must also be within the secondary setting limit of the relay.

R1, X1	Positive-sequence primary impedance of the line (0 - 9999 ohms)
R0, X0	Zero-sequence primary impedance of the line (0 - 9999 ohms)
LL	Line length (0.1 - 999 miles)
CTR	CT ratio (e.g., for 600:5, enter 120) (1 - 6000)
PTR	PT ratio (e.g., 1200:1, enter 1200) (1 - 10,000)
SPTR	Synchronization voltage transformer ratio (1 - 10,000)
MTA	Maximum torque angle for mho elements (47° - 90°)
79OI	Reclosing relay open interval (0 - 8,000 cycles; 0 disables reclosing)
79RS	Reclosing relay reset time (60 - 8,000 cycles)
PSVC	Polarizing and Synchronizing voltage checks (N: none, S: LSDP, P: LPDS, or E: either)
27VLO	Dead voltage threshold (0 - 2000 kV)
59VHI	Live voltage threshold (0 - 2000 kV)
25DV	Difference voltage threshold (0 - 2000 kV)
SYNCP	Do you want to synch-check to phase A, B, or C?
25T	Synch-check timer (0 - 8000 cycles)
VCT	Voltage condition timer (0 - 8000 cycles)
A1TP	A1 contact output pickup delay (0 - 8000 cycles)
A1TD	A1 contact output dropout delay (0 - 8000 cycles)
Z1%	Zone 1 reach (percent of line length: 0 - 2000%)
Z2%	Zone 2 reach (percent of line length: 0 - 3200%)
Z3%	Zone 3 reach (percent of line length: 0 - 3200%)

Z2DP	Zone 2 delay for phase-to-phase faults (3 - 2000 cycles in quarter-cycle steps)
Z2GP	Zone 2 delay for ground faults (3 - 2000 cycles in quarter-cycle steps)
Z3D	Zone 3 delay for both phase-to-phase and ground faults (3 - 2000 cycles in quarter-cycle steps)
TDUR	Minimum TRIP output duration (0 - 2000 cycles in quarter-cycle steps, 0 disables the OPEN Command)
50NG	Sensitive residual or phase overcurrent element pickup (0.25 - 50,000 primary amperes)
50P	Phase overcurrent element pickup (0.25 - 50,000 primary amperes)
50H	Phase overcurrent element high pickup (0.25 - 50,000 primary amperes)
51NP	Residual time-overcurrent pickup (0.25 - 50,000 primary amperes)
51NTD	Residual time-overcurrent time dial (0.5 - 15)
51NC	Residual time-overcurrent curve index. Choices are as follows: Use 1 to select a moderately inverse curve Use 2 to select an inverse curve Use 3 to select a very inverse curve Use 4 to select an extremely inverse curve
51NTC	Do you want residual time-overcurrent torque control? (Y or N)
67NP	Residual instantaneous overcurrent pickup (0.25 - 50,000 primary amperes)
67NTC	Do you want residual instantaneous overcurrent torque control? (Y or N)
52BT	52B time delay (0.5 - 10,000 cycles)
REJOE	Should permissive tripping be allowed when the remote end just opens? (P, G, or N)
LOPE	Loss-of-potential detection function (Y, N, 1, 2, 3, 4)
TIME1	Timeout for PORT 1 (0 - 30 minutes)
TIME2	Timeout for PORT 2 (0 - 30 minutes)
AUTO	Autoport (PORT 1, 2, or 3)
RINGS	The number of rings after which the modem answers (1 - 30 rings)

Refer to the functional description and be sure the settings you choose result in relay performance appropriate to your application.

The AUTO setting selects PORT 1, PORT 2, or both serial ports for automatically transmitted messages. If PORT 2 of the relay is connected to an SEL-DTA or SEL-PRTU, the AUTO setting must direct automatic messages to that port. The following table shows the effect of each possible setting:

Auto Setting	Automatic Message Destination Port
1	1
2	2
3	1 and 2

Event summaries and self test warning and failure reports are automatically transmitted from port(s) designated automatic regardless of access level, if the designated port is not timed out. Enter zero as the timeout setting of the appropriate port if automatic transmissions will be monitored by a dedicated channel, printed on a dedicated printer, or if that port is connected to an SEL-DTA, SEL-RD, or SEL-PRTU.

SEL-121F DISTANCE RELAY/FAULT LOCATOR COMMAND SUMMARY

Access Level 0

ACCESS	Answer password prompt (if password protection enabled) to gain access to Level 1. Three unsuccessful attempts pulses ALARM relay.

Access Level 1

2ACCESS	Answer password prompt (if password protection enabled) to gain access to Level 2. This command always pulses the ALARM relay.
DATE m/d/y	Show or set date. DAT 2/3/92 sets date to Feb. 3, 1992. This setting is overridden when IRIG-B synchronization occurs. Pulses the ALARM relay momentarily when a different year is entered than the previously stored.
EVENT	Show event record. EVE 1 shows long form of most-recent event.
HISTORY	Show DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION, and CURRENT for the twelve latest events.
IRIG	Force immediate execution of time code synchronization task.
METER n	Show primary current, voltage, and real and reactive power. METER runs once. METER n runs n times.
QUIT	Return to Access Level 0 and reset targets to target 0.
SHOWSET	Show the relay settings and logic settings - does not affect the settings. The logic settings are shown in hexadecimal format for each.
STATUS	Show self test status.
TARGET n	Show data and set target lights as follows: TAR 0: Relay Targets — TAR 1: RELAY WORD #1 TAR 2: RELAY WORD #2 — TAR 3: RELAY WORD #3 TAR 4: INTERNAL ELEMENTS — TAR 5: Contact Inputs TAR 6: Contact Outputs — TAR R: Returns to TAR 0 and clears Be sure to return to TAR 0 when done, so LEDs display fault targets.
TIME h/m/s	Show or set time. TIM 13/32/00 sets clock to 13:32:00 PM. This setting is overridden when IRIG-B synchronization occurs.
TRIGGER	Trigger and save an event record. (Type of event is EXT).

Access Level 2

CLOSE	Close circuit breaker, if Jumper JMP104 is installed.
LOGIC n	Show or set logic masks MTU, MPT, MTO, MTB, MRI, MRC, MA1-MA4. ALARM relay closes momentarily while the new settings are stored in EEPROM and event data buffers are cleared.
OPEN	Open circuit breaker, if Jumper JMP104 is installed.
PASSWORD	Show or set passwords. Pulses the ALARM relay momentarily when new passwords are set. PAS 1 OTTER sets Level 1 password to OTTER. PAS 2 TAIL sets Level 2 password to TAIL.
SET	Initiate setting procedure. ALARM relay closes momentarily while the new settings are stored in EEPROM and event data buffers are cleared.

Use the following to separate commands and their parameters: space, comma, semicolon, colon, or slash.

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EVENT REPORTING
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EVENT REPORTING

EVENT REPORT GENERATION

The relay generates a summary and long event report in response to actions listed in Table 4.1. The summary event report allows a quick review of the information necessary to determine the location and type of fault. The long event report displays eleven cycles of information for analyzing system and scheme performance.

Note: The relay need not trip to generate an event report.

Table 4.1: Event Report Triggering Actions

- Fault in any zone
- OPEN command execution (if a trip results)
- TRIGGER command execution
- IN1 input assertion
- PERMISSIVE TRIP input assertion
- BLOCK TRIP input assertion
- EXTERNAL TRIGGER input assertion
- TRIP output contact assertion

The relay generates a second summary and long event report for the same fault if the trip occurs after the end of the first report.

Actions listed in Table 4.2 do not trigger an event report.

Table 4.2: Non-Event Report Triggering Actions

- CLOSE command execution
- DIRECT CLOSE input assertion
- 52A input status changes
- Pickup of the 50P or 50NG overcurrent elements

Relay elements which trigger event reports must drop out for at least four cycles before they can initiate another event report. This helps to eliminate multiple records for boundary faults.

Triggering is recorded to the nearest quarter-cycle (4.17 ms) and referenced to the 16th row of data in the report. All reports trigger at row 16. This system allows you to determine the total duration of a long fault which triggers two event reports. Simply calculate the time difference between the report generated at fault inception and the report generated by the TRIP.

SUMMARY EVENT REPORT

The summary report is automatically transmitted from port(s) designated AUTOMATIC regardless of access level, as long as the designated port has not timed out. If automatic transmissions are monitored by a dedicated channel or printed on a dedicated printer, enter a timeout setting of zero for the appropriate port.

Due to the length of the full report, it is not automatically transmitted. You can display the full report with the EVENT command.

The summary event report includes:

- Relay identifier
- Date and time
- Event type
- Fault location
- Secondary ohms from relay location to fault
- Duration relay elements are picked up
- Maximum phase current measured near the middle of fault

The following shows an example summary event report.

```
Example 230 kV Line         Date: 6/2/92         Time: 10:25:08.841

Event   : 1BC    Location   : 15.07  mi  1.89   ohms sec
Duration: 3.75   Flt Current: 715.9


=>
```

The relay clears the event report and history buffer for the following conditions:

- Loss of control power
- Entry of a new setting via the SET or LOGIC commands

Relay Identifier

The relay identifier is the information entered in the 39 character Relay ID setting. This information can include the identification of the protected line, serial number of the relay, date of last relay maintenance, etc.

Event Time and Date

The event summary date and time are taken from the relay internal clock. The time corresponds to the data in the sixteenth row of the event report.

Event Type

The event type indicates zone and phase involvement of the fault.

The zone is determined from the relay elements picked up at the middle of the first contiguous sequence of picked-up relay elements in the report. For example, if relay elements are continuously picked up from the 16th to the 24th rows, the zone will be determined using the 20th row. The zone is indicated by the left-most character of the TYPE string, and is one of the following:

1 : For faults in which a Zone 1 element picked up
2 : For Zone 2 time delay expired, but not Zone 1 pickup
3 : For Zone 3 pickup, but not Zone 2 time delay expired or Zone 1 picked up
6 : For 67N pickup, but not Zone 3, 2, or 1
5 : For 51N pickup, but not 67N, Zone 3, 2, or 1
H : For 50H pickup, but not 67N, 51N, or Zone 3, 2, or 1
? : For none of the above picked up at mid-fault

The relay determines phase involvement independently of the relay element operations based upon a phase current magnitude comparison.

Compared currents are taken from two rows at the middle of the stored fault data. If the uncompensated current magnitudes are in large ratios between phases (4:1 or more), the fault type becomes immediately apparent as single- or two-phase. If not, the same current is load compensated by the two corresponding prefault current rows in the first cycle of the event report.

If these fault current component magnitudes are in moderate ratios (1.5:1 or more), the relay lists a single- or two-phase fault. If the ratios are all less than 1.5, the relay lists a three-phase fault. Explicit fault classification logic is as follows, where "I" values are uncompensated midfault currents and "If" values are midfault currents compensated for load, yielding true fault current components:

```
     IF ( Imax  >   4 x Imed   ) THEN Single-phase
ELSE IF ( Imed  >   4 x Imin   ) THEN Two-phase
ELSE IF ( Ifmax > 1.5 x Ifmed  ) THEN Single-phase
ELSE IF ( Ifmed > 1.5 x Ifmin  ) THEN Two-phase
ELSE IF (  none of the above   ) THEN Three-phase
```

Where:

Imax = Highest uncompensated phase current
Imed = Second highest uncompensated phase current
Imin = Lowest uncompensated phase current
Ifmax = Highest load compensated phase current
Ifmed = Second highest load compensated phase current
Ifmin = Lowest load compensated phase current

This algorithm is largely immune to load and system grounding variations.

The phase involvement is indicated as one of the following:

AG : For A-Phase to ground faults
BG : For B-Phase to ground faults
CG : For C-Phase to ground faults
AB : For A-B two-phase faults
BC : For B-C two-phase faults
CA : For C-A two-phase faults
ABG : For A-B two-phase to ground faults
BCG : For B-C two-phase to ground faults
CAG : For C-A two-phase to ground faults
ABC : For three-phase faults

The zone and phase involvement data are joined into a single string, completing the TYPE designation, as in "3BG" for a Zone 3 B-phase to ground fault.

For event reports triggered by TRIP output assertion, TYPE designation is appended with a "T." This aids in determining clearing times for faults that continue after the first event report ends. For example, if the relay trips for a 3BG fault after completing the initial report, the second report shows "3BGT" for TYPE.

Event records taken with no triggering relay elements picked up are labeled as follows:

"EXT" for reports triggered externally via input contacts or "TRIGGER" command execution

or

"TRIP" for reports triggered by "TRIP" output contact assertion.

Fault Location

The relay fault locating function is separate from the protective functions. The relay calculates fault location from data stored in the 44 cycle event report. It calculates a fault location for every event report which has fault detecting elements asserted between the 8th and 39th event report rows.

The relay uses the fault type selected above and performs a fault locating calculation based on the Takagi algorithm, if prefault data is available. The Takagi algorithm uses prefault current values to compensate for the effects of fault resistance, load current, and remote infeed. When protective elements are picked up in the first four Event Report rows, the relay uses the simple reactance method calculation for fault locating.

Secondary Ohms

The relay also displays the fault location in secondary ohms. This value corresponds to the distance value calculated above when the protected line has a constant impedance per unit distance characteristic.

Fault Duration

The event summary contains a fault duration calculated from the first pickup of a fault detecting element until the last fault detecting element drops out or the event report ends.

Maximum Phase Current

The relay displays the maximum phase current magnitude calculated in the same event report row where fault data was gathered for the fault locating calculation. This data helps show the severity of the fault.

LONG EVENT REPORT

The long event report contains 44 quarter-cycles of prefault, fault, and post fault voltage and current information. For each quarter-cycle of voltage and current information, the relay also records the states of all fault measuring elements, outputs, and inputs. This information is useful in reviewing fault inception and duration, relay element response, fault evolution, interaction with communications equipment, and breaker reaction time.

The last twelve event records are stored in volatile memory. You can review the stored summary reports quickly with the HISTORY command; use the EVENT command to display the long form of each event report.

Interpretation of Voltage and Current Data

Voltage and current data in the event report are determined using the following steps. The process uses secondary quantities presented to the rear panel of the relay.

1. Input analog signals are filtered by two pole, low pass filters with cutoff frequencies of approximately 85 Hz.

2. Filtered analog signals are sampled four times per power system cycle and converted to numerical values.

3. A digital filter processes the sampled data and removes dc and ramp components. The unit sample response of this filter is:

   1, -1, -1, 1

   The filter has the property of a double differentiator smoother.

4. The latest four samples are processed through the digital filter every quarter-cycle. Successive outputs of the filter arrive every 90 degrees. With respect to the present value of the filter output, the previous value was taken one quarter-cycle earlier and appears to be leading the present value by 90 degrees.

   Filter output values can be used to represent the signals as phasors:

   The previous value of the output is the Y-component.
   The present value of the output is the X-component.

The following example may clarify why we refer to the older data as the leading component of the phasor.

Consider a sinewave having zero phase shift with respect to t=0 and a peak amplitude of 1. Now consider two samples, one taken at t=0, the other taken 90 degrees later. They have values 0 and 1, respectively. By the above rules, the phasor components are (X,Y) = (1,0).

Now consider a cosine function. Its samples taken at t=0 and t+90 degrees are 1 and 0; its phasor representation is (0,1). The phasor (0,1) leads the phasor (1,0) by 90 degrees. This coincides with a 90 degree lead of the cosine function over the sine function.

To construct a phasor diagram of voltages and currents, select a pair of adjacent rows from an area of interest in the event report. On Cartesian coordinates, plot the lower row (newer data) as the X-components and the upper row (older data) as the Y-components. Rotate the completed diagram to any angle of reference. The magnitude of any phasor equals the square root of the sum of its squares.

Note that moving forward one quarter-cycle rotates all phasors 90°. You can verify this by plotting the phasor diagram with rows 1 and 2, then rows 2 and 3 of an event report. Example Event Report 1 shows the process of converting the rectangular format voltages and currents displayed in the event report to polar format.

Relays

The states of all relay elements are indicated in the six columns headed "Relays." Active states of the various relay elements are indicated by designator symbols which correspond with relay element names. The contents of the columns for active relay elements appear below. Sync-check and voltage condition checking elements are shown under the heading "Sync."

21P	: Phase distance units	:	1	= Zone 1 picked up	
			2	= Zone 2 timer expired	
			3	= Zone 2 or 3 picked up	
21G	: Ground distance units	:	1	= Zone 1 picked up	
			2	= Zone 2 timer expired	
			3	= Zone 2 or 3 picked up	
50P	: Phase overcurrent elements	:	H	= 50H	high set picked up
			P	= 50P	picked up
			G	= 50G	picked up
51N	: Residual time-overcurrent	:	P	= 51NP	51N element picked up
			T	= TRIP	51N element time out
50NG	: Sensitive residual or phase overcurrent element	:	P	= 50NG	picked up
67N	: Residual overcurrent units	:	P	= 67N	picked up
27S	: Synchronism checking undervoltage detection	:	S	= 27S	picked up
27P	: Polarizing undervoltage condition detection	:	P	= 27P	picked up
SSC	: Sync-check conditions fulfilled	:	S	= SSC	picked up
VSC	: Voltage-check conditions fulfilled	:	V	= VSC	picked up
LOP	: Loss-of-potential detected	:	L	= LOP	
REJO	: Remote-end-just-open detect	:	R	= REJO	

Contact Outputs and Inputs

The next two columns (headed "Outputs" and "Inputs") show the states of all output and input contacts. The report indicates assertion of an output contact or logic input by a designator symbol which corresponds to the respective output or input; a period indicates deassertion. The following list shows the contents of these columns.

Outputs

TP	:	TRIP output:	T = TRIP contact closed
CL	:	CLOSE output:	C = CLOSE contact closed
A1	:	Programmable output #1:	1 = A1 contact closed
A2	:	Programmable output #2:	2 = A2 contact closed
A3	:	Programmable output #3:	3 = A3 contact closed
A4	:	Programmable output #4:	4 = A4 contact closed
AL	:	ALARM output:	A = ALARM contact closed

Inputs

IN1	:	IN1 Programmable input:	I = IN1 input asserted
PT	:	PERMISSIVE TRIP input:	P = PT input asserted
BT	:	BLOCK TRIP input:	B = BT input asserted
DC	:	DIRECT CLOSE input:	D = DC input asserted
52A	:	BREAKER AUXILIARY 52A SWITCH input:	5 = 52A input asserted
ET	:	EXTERNAL TRIGGER input:	E = ET input asserted

Event Summary

Following the 44 quarter-cycles of fault data, the relay displays the short form event summary. Event summary contents are described in the Summary Event Report Section.

Relay Settings

After the event summary, the relay displays the relay settings and logic mask settings installed when the event occurred.

EXAMPLE EVENT REPORTS

Externally Triggered Event Report

The relay records an eleven cycle event report when you issue the TRIGGER command. This command does not affect the protective functions of the relay. The event type listing EXT signifies an externally triggered event. For events triggered by this command, the report does not include a fault location, fault impedance in secondary ohms, fault duration, or maximum fault current. Use the TRIGGER command to generate an event report for plotting voltage and current phasors during normal load conditions prior to releasing the relay for service.

Example Event Report 1 shows the first cycle of normal operating conditions for Breaker 3 in the system shown in Figure 4.1. The event report was generated with the TRIGGER command. Note that the line breaker is closed, as signified by the 5 in the 52A column.

Event report data for the voltages and currents is displayed in rectangular format. You can easily convert these rectangular values to polar format as described under Interpretation of Voltage and Current Data. Section 6: INSTALLATION includes a blank form for plotting voltage and current phasors. A completed SEL Direction and Polarity Check Form using the first two rows of data from the event report follows Example Event Report 1.

Using the voltage and current phasor diagrams at the end of the SEL Direction and Polarity Check Form, note that the current and voltage phase rotation is ABC in the clockwise direction. This phase rotation must match the rotation of your system. In addition, note that the load is flowing out from Breaker 3 as indicated by each phase current lagging the respective phase voltage by the load flow angle.

Example Event Report 1

```
Example 230 kV Line                              Date:  6/2/92     Time: 11:20:27.212
FID=SEL-121F-R405-V656mps2-D910326-E2

     Currents                Voltages                   Relays Sync    Outputs Inputs
      (amps)                   (kV)
                                                        225556 22SV LR TCAAAAA IPBD5E
                                                        110107 77SS OE PL1234L NTTC2T
    IA      IB      IC     VA      VB      VC       VS  PGPNNN SPCC PJ         1   A
                                                           G         O
  -325     362     -38 -120.1   110.0     9.7      0.0  ..P.P. S... .. ....... ....5.
  -227    -170     390  -58.1   -75.3   132.4      0.1  ..P.P. S... .. ....... ....5.
   325    -359      41  120.2  -110.0    -9.7      0.0  ..P.P. S... .. ....... ....5.
   227     170    -393   58.0    75.3  -132.4     -0.1  ..P.P. S... .. ....... ....5.

Event   : EXT    Location   :        mi         ohms sec
Duration:        Flt Current:
```

SEL DIRECTION AND POLARITY CHECK FORM

STATION ____SEL____ DATE: 6 / 2 / 92 TESTED BY ________

SWITCH NO. ________ EQUIPMENT ____SEL-121F Relay____

INSTALLATION ________ ROUTINE ___X___ OTHER ________

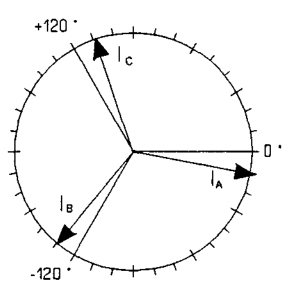
LOAD CONDITIONS:

STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS

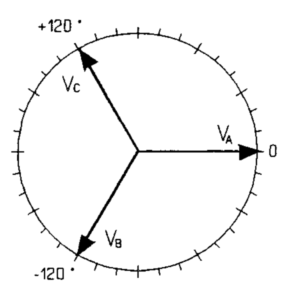
SEL READINGS: ___155___ MW (+)(-) ___27___ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I(a)	I(b)	I(c)	V(a)	V(b)	V(c)	
1st LINE CHOSEN (Y COMPONENT)	-325	362	-38	-120.1	110.0	9.7	
2nd LINE CHOSEN (X COMPONENT)	-227	-170	390	-58.1	-75.3	132.4	
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$	396.4	400.0	391.9	133.4	133.3	132.8	ROW 1
ANGLE IN DEGREES ARCTAN Y/X	-124.9°	115°	-5.6°	-115.8	124.4°	4.2°	
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0	-115.8	-115.8	-115.8	-115.8	-115.8	-115.8	
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM	-9.1°	-129.2°	110.2°	0°	-119.8°	120.0°	ROW 2

USE THE VALUES IN ROWS 1 AND 2 ABOVE TO DRAW PHASOR DIAGRAMS BELOW



CURRENTS



VOLTAGES

Zone 1 AG Fault

Example Event Report 2 shows an in-section fault as viewed from Breaker 3 at Bus B. This report was triggered by pickup of the ground time-overcurrent element in the sixteenth row of data. The date and time tags at the top of the event report are referenced to this row of data.

The relay labelled the event a Zone 1 AG fault and calculated a fault location 75.86 miles from the relay terminal. The relay is expected to trip for this fault. The fault detecting element is the Zone 1 ground distance element set in the MTU logic mask.

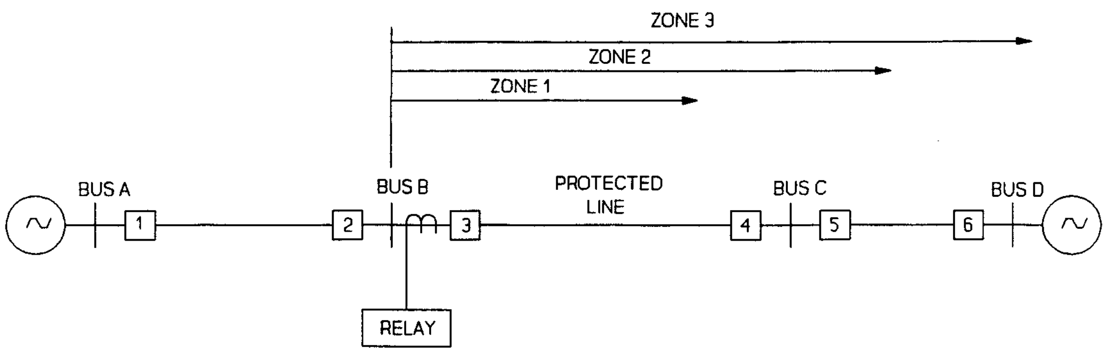


Figure 4.1: Example System Single-Line Diagram

Example Event Report 2

```
Example 230 kV Line                        Date: 6/2/92      Time: 10:48:46.579

FID=SEL-121F-R405-V656mps2-D910326-E2

      Currents                 Voltages          Relays Sync    Outputs Inputs
       (amps)                    (kV)
                                                 225556 22SV LR TCAAAAA IPBD5E
                                                 110107 77SS OE PL1234L NTTC2T
    IA     IB     IC     VA     VB     VC     VS PGPNNN SPCC PJ         1    A
                                                     G         O

   -38     98    -60  -55.5  132.7  -77.1  -55.5 ...... .... .. ....... ....5.
   -94     13     79 -121.3   12.5  108.0 -121.3 ...... .... .. ....... ....5.
    38    -98     60   55.5 -132.7   77.1   55.5 ...... .... .. ....... ....5.
    94     -9    -79  121.3  -12.5 -108.0  121.3 ...... .... .. ....... ....5.

   -38     98    -60  -55.5  132.7  -77.2  -55.5 ...... .... .. ....... ....5.
   -94      9     79 -121.4   12.4  108.2 -121.4 ...... .... .. ....... ....5.
    38    -94     60   55.5 -132.7   77.1   55.5 ...... .... .. ....... ....5.
    94    -13    -79  121.4  -12.4 -108.2  121.4 ...... .... .. ....... ....5.

   -38     94    -60  -55.5  132.7  -77.1  -55.5 ...... .... .. ....... ....5.
   -94     13     79 -121.4   12.4  108.2 -121.4 ...... .... .. ....... ....5.
    38    -98     60   55.5 -132.7   77.1   55.5 ...... .... .. ....... ....5.
    94     -9    -79  120.6  -12.7 -108.5  120.6 ...... .... .. ....... ....5.

    35     98    -60  -54.1  133.4  -76.5  -54.1 ...... .... .. ....... ....5.
  -116      9     79 -102.0   20.3  116.1 -102.0 ...... .... .. ....... ....5.
  -277    -94     60   41.5 -138.5   71.3   41.5 ..G.P. .... .. ....... ....5.
   236    -13    -79   74.1  -31.8 -127.5   74.1 ..GPP. .... .. ....... ....5.

   485     94    -57  -29.3  143.6  -66.2  -29.3 .3PPP. .... .. ....... ....5.
  -346     13     76  -62.6   36.6  132.4  -62.6 .3PPP. .... .. ....... ....5.
  -529    -94     60   28.0 -144.3   65.5   28.0 .1PPP. .... .. T...3.. ....5.
   362    -13    -79   60.9  -37.3 -132.9   60.9 .1PPP. .... .. T...3.. ....5.

   535     94    -63  -27.9  144.4  -65.4  -27.9 .1PPP. .... .. T...3.. ....5.
  -365     13     82  -60.7   37.3  132.9  -60.7 .1PPP. .... .. T...3.. ....5.
  -535    -98     60   27.8 -144.4   65.5   27.8 .1PPP. .... .. T...3.. ....5.
   365     -9    -79   60.7  -37.2 -133.0   60.7 .1PPP. .... .. T...3.. ....5.

   535     98    -60  -27.8  144.4  -65.5  -27.8 .1PPP. .... .. T...3.. ....5.
  -365      9     76  -60.7   37.2  133.1  -60.7 .1PPP. .... .. T...3.. ....5.
  -535    -98     63   27.8 -144.4   65.4   27.8 .1PPP. .... .. T...3.. ....5.
   365     -9    -76   60.7  -37.2 -133.1   60.7 .1PPP. .... .. T...3.. ....5.

   535     98    -63  -27.9  144.4  -65.4  -27.9 .1PPP. .... .. T...3.. ....5.
  -365      9     76  -60.6   37.2  133.1  -60.6 .1PPP. .... .. T...3.. ....5.
  -535    -94     66   27.9 -144.4   65.4   27.9 .1PPP. .... .. T...3.. ....5.
   365    -13    -79   60.6  -37.3 -133.1   60.6 .1PPP. .... .. T...3.. ....5.

   535     94    -66  -27.9  144.4  -65.2  -27.9 .1PPP. .... .. T...3.. ....5.
  -365     13     79  -60.7   37.2  133.1  -60.7 .1PPP. .... .. T...3.. ....5.
  -535    -94     63   27.9 -144.4   65.2   27.9 .1PPP. .... .. T...3.. ....5.
   365    -13    -76   60.0  -33.3 -134.9   60.0 .1PPP. .... .. T...3.. ....5.

   462     82    -53  -26.4  124.1  -49.4  -26.4 .1PPP. .... .. T...3.. ....5.
  -318      3     63  -41.3   11.0  105.0  -41.3 .1PPP. .... .. T...3.. ....5.
  -233    -41     25   14.0  -59.9   20.7   27.9 .1PPP. .... .. T...3.. ......
   151      3    -28   13.2    3.9  -41.5   74.1 .1GPP. .... .. T...3.. ......

    44      6     -3   -1.6    9.0   -4.6  -55.5 ...... .... .. T...... ......
   -16      0      3   -1.7   -0.4    5.5 -121.3 ...... .P.. .. T...... ......
    -9      0      0    0.2   -1.1    0.8   55.5 ...... .P.. .. T...... ......
     0      0      0    0.2   -0.1   -0.6  121.3 ...... .P.. .. T...... ......

Event   : 1AG    Location   : 75.86  mi   6.16   ohms sec
Duration: 6.25   Flt Current: 647.5

R1   =13.90     X1   =79.96     R0   =41.50     X0   =248.57    LL   =100.00
CTR  =200.00    PTR  =2000.00   SPTR =2000.00   MTA  =80.10
79OI =40.00     79RS =240.00
PSVC =S         27VLO=26.60     59VHI=106.20    25DV =53.12     SYNCP=A
25T  =300.00    VCT  =30.00
A1TP =0.00      A1TD =0.00
Z1%  =80.00     Z2%  =120.00    Z3%  =150.00
Z2DP =30.00     Z2DG =30.00     Z3D  =40.00     TDUR =9.00
50NG =250.00    50P  =370.00    50H  =1500.00
51NP =270.00    51NTD=3.00      51NC =2         51NTC=Y
67NP =650.00    67NTC=Y         52BT =30        REJOE=N         LOPE =Y
TIME1=5         TIME2=0         AUTO =2         RINGS=7

Logic settings:

MTU  MPT  MTB  MTO  MA1  MA2  MA3  MA4  MRI  MRC
F4   08   00   FC   00   00   F0   04   F0   04
A2   00   00   A4   00   00   80   20   80   20
00   00   00   00   02   01   00   00   00   00
```

The following is the first four cycles (quarter-cycles 1 - 16) of Example Event Report 2, showing prefault and fault inception conditions.

```
   Currents                        Voltages              Relays Sync    Outputs Inputs
    (amps)                           (kV)
                                                         225556 22SV LR TCAAAAA IPBD5E
                                                         110107 77SS OE PL1234L NTTC2T
  IA      IB       IC      VA      VB      VC       VS   PGPNNN SPCC PJ         1   A         Quarter
                                                              G        0                          Cycle

 -38      98      -60   -55.5   132.7   -77.1    -55.5   ...... .... .. ....... ....5.          1
 -94      13       79  -121.3    12.5   108.0   -121.3   ...... .... .. ....... ....5.          2
  38     -98       60    55.5  -132.7    77.1     55.5   ...... .... .. ....... ....5.          3
  94      -9      -79   121.3   -12.5  -108.0    121.3   ...... .... .. ....... ....5.          4

 -38      98      -60   -55.5   132.7   -77.2    -55.5   ...... .... .. ....... ....5.          5
 -94       9       79  -121.4    12.4   108.2   -121.4   ...... .... .. ....... ....5.          6
  38     -94       60    55.5  -132.7    77.1     55.5   ...... .... .. ....... ....5.          7
  94     -13      -79   121.4   -12.4  -108.2    121.4   ...... .... .. ....... ....5.          8

 -38      94      -60   -55.5   132.7   -77.1    -55.5   ...... .... .. ....... ....5.          9
 -94      13       79  -121.4    12.4   108.2   -121.4   ...... .... .. ....... ....5.         10
  38     -98       60    55.5  -132.7    77.1     55.5   ...... .... .. ....... ....5.         11
  94      -9      -79   120.6   -12.7  -108.5    120.6   ...... .... .. ....... ....5.         12

  35      98      -60   -54.1   133.4   -76.5    -54.1   ...... .... .. ....... ....5.         13
-116       9       79  -102.0    20.3   116.1   -102.0   ...... .... .. ....... ....5.         14
-277     -94       60    41.5  -138.5    71.3     41.5   ..G.P. .... .. ....... ....5.         15
 236     -13      -79    74.1   -31.8  -127.5     74.1   ..GPP. .... .. ....... ....5.         16
```

The event report uses a sequence of event format which allows performance analysis of the system by quarter-cycles. Through this analysis, you can observe the prefault voltage and current conditions prior to the fault, determine whether or not the breaker was closed by the 52A Inputs column and line current magnitudes, and learn when the protective elements assert. The following outline lists observed incidents shown in Example Event Report 2 by quarter-cycle.

Quarter Cycle	Event Report Shows:
1-14	Prefault conditions:
	• No protective relay elements are picked up.
	• 5 in 52A Inputs column verifies breaker closure (as does load current flow).
15	Fault Inception:
	• G in 50P column shows phase current reached 50G element pickup threshold.
	• P in 50NG column shows phase current reached 50N element pickup threshold.
16	• P in 51N column shows that the ground time-overcurrent element picked up.

The ground time-overcurrent element picked up in row 16 because the residual current was above the 51NP setting and the 32Q directional element indicated that the fault was in the forward direction.

Quarter-cycles 17 through 32 are shown below.

```
  Currents                Voltages              Relays Sync    Outputs Inputs
   (amps)                   (kV)
                                                225556 22SV LR TCAAAAA IPBD5E
                                                110107 77SS OE PL1234L NTTC2T
   IA     IB     IC     VA     VB     VC     VS PGPNNN SPCC PJ         1   A      Quarter
                                                   G          0                     Cycle

  485     94    -57  -29.3  143.6  -66.2  -29.3 .3PPP. .... .. ....... ....5.        17
 -346     13     76  -62.6   36.6  132.4  -62.6 .3PPP. .... .. ....... ....5.        18
 -529    -94     60   28.0 -144.3   65.5   28.0 .1PPP. .... .. T...3.. ....5.        19
  362    -13    -79   60.9  -37.3 -132.9   60.9 .1PPP. .... .. T...3.. ....5.        20

  535     94    -63  -27.9  144.4  -65.4  -27.9 .1PPP. .... .. T...3.. ....5.        21
 -365     13     82  -60.7   37.3  132.9  -60.7 .1PPP. .... .. T...3.. ....5.        22
 -535    -98     60   27.8 -144.4   65.5   27.8 .1PPP. .... .. T...3.. ....5.        23
  365     -9    -79   60.7  -37.2 -133.0   60.7 .1PPP. .... .. T...3.. ....5.        24

  535     98    -60  -27.8  144.4  -65.5  -27.8 .1PPP. .... .. T...3.. ....5.        25
 -365      9     76  -60.7   37.2  133.1  -60.7 .1PPP. .... .. T...3.. ....5.        26
 -535    -98     63   27.8 -144.4   65.4   27.8 .1PPP. .... .. T...3.. ....5.        27
  365     -9    -76   60.7  -37.2 -133.1   60.7 .1PPP. .... .. T...3.. ....5.        28

  535     98    -63  -27.9  144.4  -65.4  -27.9 .1PPP. .... .. T...3.. ....5.        29
 -365      9     76  -60.6   37.2  133.1  -60.6 .1PPP. .... .. T...3.. ....5.        30
 -535    -94     66   27.9 -144.4   65.4   27.9 .1PPP. .... .. T...3.. ....5.        31
  365    -13    -79   60.6  -37.3 -133.1   60.6 .1PPP. .... .. T...3.. ....5.        32
```

Quarter Cycle	Event Report Shows:
17-18	• 3 in the 21G column shows that the Zone 3 ground distance element is asserted.
19	Tripping Conditions: • 1 in 21G column indicates that the Zone 1 ground distance element is asserted, causing the trip. • T in the Trip output column indicates that the TRIP output is asserted. • 3 in the A3 output column indicates that the A3 output is asserted, indicating assertion of a reclose initiating condition, in this case Z1G.
20-32	• Fault detecting elements and output contacts remain asserted. • Fault locating, event type, and fault current information is calculated from data in this area of the event report.

The relay tripped in event report row 19 due to assertion of the Zone 1 ground distance element, Z1G. The A3 contact asserted to indicate the pickup of a reclose initiating condition (MA3 is set identically to MRI).

The last three cycles of event data are shown below.

```
  Currents                Voltages              Relays Sync    Outputs Inputs
   (amps)                   (kV)
                                                225556 22SV LR TCAAAAA IPBD5E
                                                110107 77SS OE PL1234L NTTC2T
   IA     IB     IC     VA     VB     VC     VS PGPNNN SPCC PJ         1   A      Quarter
                                                   G          0                     Cycle

  535     94    -66  -27.9  144.4  -65.2  -27.9 .1PPP. .... .. T...3.. ....5.        33
 -365     13     79  -60.7   37.2  133.1  -60.7 .1PPP. .... .. T...3.. ....5.        34
 -535    -94     63   27.9 -144.4   65.2   27.9 .1PPP. .... .. T...3.. ......        35
  365    -13    -76   60.0  -33.3 -134.9   60.0 .1PPP. .... .. T...3.. ......        36

  462     82    -53  -26.4  124.1  -49.4  -26.4 .1PPP. .... .. T...3.. ......        37
 -318      3     63  -41.3   11.0  105.0  -41.3 .1PPP. .... .. T...3.. ......        38
 -233    -41     25   14.0  -59.9   20.7   27.9 .1PPP. .... .. T...3.. ......        39
  151      3    -28   13.2    3.9  -41.5   74.1 .1GPP. .... .. T...3.. ......        40

   44      6     -3   -1.6    9.0   -4.6  -55.5 ...... .... .. T...... ......        41
  -16      0      3   -1.7   -0.4    5.5 -121.3 ...... .P.. .. T...... ......        42
   -9      0      0    0.2   -1.1    0.8   55.5 ...... .P.. .. T...... ......        43
    0      0      0    0.2   -0.1   -0.6  121.3 ...... .P.. .. T...... ......        44
```

Quarter Cycle	Event Report Shows:
33-39	• Fault detecting elements remain asserted. • 5 in 52A column changes to a period indicating deassertion of the 52A input.
40	• G in 50P column indicates that phase current has dropped below the 50P setting in all three phases, but is still above the 50NG setting.
41-44	Postfault conditions: • Period in 21G column indicates that the ground distance elements have dropped out. • 3 in A3 column drops out, indicating that all reclose initiating elements have deasserted. • Voltage and current samples go to zero, indicating that the breaker is open and line deenergized. Potentials in this example are drawn from line-side PTs. • P in the 27P column indicates that the undervoltage elements associated with the polarizing voltage input is picked up. • No protective relay elements are picked up. • T in TP Outputs column shows that trip is still asserted. The 9.0 cycle TDUR setting ensures that the trip contacts remain closed for at least nine cycles.

The event summary shows that the fault was an A-G fault in Zone 1, at approximately 75 miles from the relay location. The fault duration was 6.25 cycles and maximum phase current magnitude at the midpoint of the fault was 647.5 amps primary.

FIRMWARE IDENTIFICATION

The relay provides a Firmware Identification Data (FID) string to identify the relay software version installed. The FID string is included near the top of each full length event report. The string format is as follows:

FID = [PN] - R[RN] - V[VS] - D[RD] - E[ER],

Where:

[PN] = Product Name

[RN] = Revision Number

[VS] = Version Specifications

[RD] = Release Date

[ER] = Version Specifications: EEROM

For the SEL-121F relay, version specifications are interpreted as follows:

V[VS] = V[ABCDEFGHI]

Option	Specifier	Specifier Meaning	Option Description
A	5, 6	50 Hz, 60 Hz	Power System Frequency
B	1, 5	1 amp, 5 amps	Nominal Amps per Phase
C	1, 6	120 volts, 67 volts	Nominal Volts per Phase
D	m, k	miles, kilometers	Fault Locator Distance Units
E	p, n	positive, negative	Phase-Sequence of Power System
F	s, d	std., modified F-1	Recloser Logic
G	1, 2	rev.1, rev. 4	Main Board Configuration
H	s, t	std, 52BT modified F-2	52BT or Trip in Relay Word
I	u, i	US curves, IEC curves	Time-Overcurrent Curves

EEROM version specifications are interpreted as follows:

E[ER] = E[Z]

Option	Specifier	Specifier Meaning	Option Description
Z	1, 2	1 stop bit, 2 stop bits	Communications Protocol Stop Bits

Please contact Schweitzer Engineering Laboratories, Inc. for more information concerning available versions of the relay. Version specifications provided above are not intended for ordering purposes but to help users identify software installed in a relay.

Refer to Appendix A for a list of all firmware versions covered by this manual.

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APPLICATIONS

RELAY APPLICATION OVERVIEW

Relay Features

The SEL-121F relay provides three zones of forward-reaching phase and ground distance protection. Independent, internal, user-settable timers delay the Zone 2 phase elements, Zone 2 ground elements, and Zone 3 elements to provide time-stepped coordination with downstream relays.

The distance elements are supervised by internal fault detecting phase and ground overcurrent elements with a wide range of user settable pickup levels.

The distance elements are polarized by positive-sequence memory voltage. Positive-sequence memory polarization provides expanded resistive coverage for phase and ground faults. The amount of distance element expansion depends upon the strength of the source relative to the set relay reach.

Ground distance protection is complemented by an instantaneous directional ground overcurrent element and a directional ground time-overcurrent element with four selectable curve shapes. Both elements have a wide range of pickup settings. The time-overcurrent element curve shape and time dial settings provide simple coordination with downstream relays. The ground overcurrent elements may be used together or independently.

The SEL-121F relay includes a single-shot recloser with user selectable initiate and cancel conditions. The recloser can be supervised using an independent synchronism checking relay, included in the SEL-121F relay. Also included is a voltage checking function which can be set to supervise reclosing using live-bus/dead-line, dead-bus/live-line conditions, or either. The synchronism checking and voltage checking relays can be used to supervise external closing functions, if necessary.

Relaying potential circuits are typically protected using fuses or molded-case circuit breakers. Occasionally, one or more of these devices may operate, leaving directional and distance relays without proper polarizing voltages. In some applications you may wish to detect this loss-of-potential (LOP) condition and block distance relays or sound an alarm.

The SEL-121F relay includes logic to detect loss of relaying potential, discriminate them from system faults, and use that information to generate an alarm or block distance and directional elements. The logic is settable, so that you can choose how the relay uses the LOP detection.

In addition to the features outlined above, the SEL-121F relay adds the following protection features:

- Flexibility for application in communication-based protection schemes such as POTT, PUTT, DUTT, or DTT. Addition of the communications equipment and a few minor setting changes are all that is required to apply this relay to a communication-based scheme.

- Remote-end-just-opened logic provides accelerated clearing of certain fault types without communications equipment.

- Internal negative-sequence ground directional polarization provides sensitive, secure ground overcurrent element polarization without additional external inputs or connections.

- An event reporting feature is included. The relay stores eleven cycles of fault data including voltages, currents, status of relay elements, inputs, and outputs. The time tagged event reports also include fault type and location data.

- The relay calculates fault location using a method which compensates for fault resistance, load flow, and remote infeed. The accurate fault location may be used to quickly sectionalize and restore a faulted system.

Backup Relaying

Where adequate high-speed primary protection already exists, the SEL-121F relay can be applied as backup protection. Its programmability and remote-access capabilities allow remote adjustment of relay settings to meet virtually any contingency. Its application also offers the benefits of event reporting and fault locating.

Replacement of Outdated Protective Relays

The relay is an ideal replacement for aging or obsolete electromechanical relays. Compact size and simple field wiring make replacing electromechanical relays with this relay especially convenient in crowded substations. Both horizontal and vertical mounting configurations are available. The required panel cutout is equivalent to that of a single electromechanical distance relay, eliminating panel cutting where relays already exist.

Event reporting and fault locating features economically provide valuable engineering and operating information, eliminating the need for event recorders and oscillographs in most applications. A negligible instrument transformer burden makes the relay an attractive alternative for overburdened current and potential transformers.

Other Applications

The SEL-121F relay is cost-effective in applications requiring fault locating, temporary installations, bus-tie breaker relaying (where frequent setting changes may be required), and remote control and monitoring.

230 kV SETTING EXAMPLE

Purpose

This example shows the steps for setting the relay at Breaker 3 to protect Line 2 in Figure 5.1. System impedance data appears in the following table.

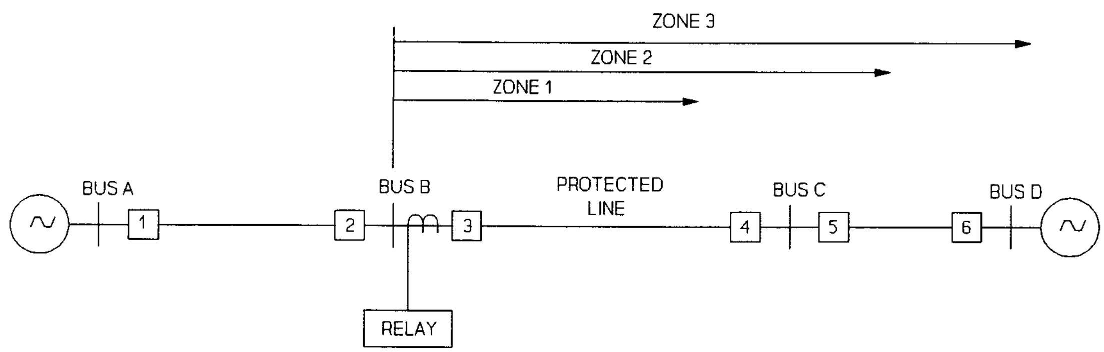

Figure 5.1: 230 kV Setting Example System Single-Line Diagram

System Data

Nominal System Voltage	:	230 kV (132.8 kV line-neutral)		
Line Length	:	100 miles		
Line Impedances:				
Positive-sequence	:	Z1	$= 81.16 \angle 80.1°$	(primary Ω)
			$= 13.90 + j79.96$	(primary Ω)
Zero-sequence	:	Z0	$= 252.01 \angle 80.5°$	(primary Ω)
			$= 41.50 + j248.57$	(primary Ω)
Branch Line Impedances	:			
Positive-sequence	:	$Z1_{AB} = Z1_{CD}$	$= 40.58 \angle 80.1°$	(primary Ω)
			$= 6.95 + j39.98$	(primary Ω)
Zero-sequence	:	$Z0_{AB} = Z1_{CD}$	$= 126.01 \angle 80.5°$	(primary Ω)
			$= 20.75 + j124.29$	(primary Ω)

Source Impedances:

Source S = Source R	:	Z1S = Z1R	= 20.29 ∠80.14	(primary Ω)
	:	Z0S	= Z0R = 3 x Z1S	

Current Transformer Ratio	:	1000:5 (200:1)
Potential Transformer Ratio	:	2000:1

Protection Scheme Overview

The line section under consideration is the section from Bus B to Bus C. The relays at Breakers 3 and 4 are the primary protection for faults on the line. In this example, we select settings for the relay at Breaker 3. Instantaneous phase and ground distance elements operate for faults over 80% of the line. Residual instantaneous and inverse-time overcurrent elements backup the ground distance element. Zone 2 time delayed elements protect for end-section faults. Zone 3 elements provide an additional time-step of forward-reaching backup protection and provide backup for faults in Zone 1 of the next line section.

Following clearance of a fault, a line test is provided by a single reclosing shot at Breaker 3. Reclosing is supervised by live-bus/dead-line condition. Closes initiated by control switch operation are supervised by the relay synch-check function or live-bus/dead-line conditions. Switch-onto-fault protection is provided using the 50H high-set nondirectional instantaneous overcurrent element.

Relay Settings

The following information presents considerations for selecting each relay setting value. Use this information to help improve your understanding of the relay functions. Select relay settings appropriate to your applications.

Fault voltages and currents in this example were derived from a fault study of the system in Figure 5.1.

Values entered during the actual setting procedure appear in bold immediately after the = prompt in the dashed boxes.

Identifier

The relay tags each event report with a label in the identifier string. This allows you to distinguish the event report as one generated for a specific breaker and substation. Typical identifiers include an abbreviation of the substation name and line terminal. The date of the last functional test may also be included for maintenance purposes.

Where an SEL-DTA or SEL-RD is used with the relay, the identifier string is displayed on the device display screen. This feature helps in recognizing the associated line terminal when multiple SEL-DTAs are separated from their respective relays.

For the relay at Breaker 3:

```
ID = Example 230 kV Line
```

- Setting Limit Check

The identifier string is limited to 39 characters. Characters entered after the 39th character are ignored.

- Other Settings Affected

None.

R1, X1, R0, X0, and Line Length (LL)

For optimal performance, the relay requires accurate values of positive- and zero-sequence impedances for the protected transmission line. The relay uses positive-sequence impedance settings to establish phase distance element reaches and calculate fault locations. Similarly, the relay uses zero-sequence impedances with positive-sequence impedances to establish ground distance element reaches and to calculate line-ground fault locations.

You can obtain values for the positive- and zero-sequence line impedances from transmission line modeling programs, existing fault studies, or hand calculations. Only the positive- and zero-sequence impedances for the protected transmission line are entered as relay settings R1, X1, R0, and X0. Values entered for R1 and X1 are the positive-sequence resistance and reactance for the protected transmission line section. The R0 value is transmission line zero-sequence resistance; the X0 value is transmission line zero-sequence reactance. Enter all impedances in primary ohms.

The relay fault locator uses the line length setting to scale the calculated fault location in terms of miles or kilometers. Set the LL setting equal to the transmission line length which corresponds to the value of positive-sequence impedance entered for R1 and X1. Typically, this is the length of the protected transmission line section.

For the relay at Breaker 3:

```
R1 =  13.90
X1 =  79.96
R0 =  41.50
X0 = 248.57
LL = 100.00
```

- Setting Limit Check

The relay allows impedance settings In the range 0 - 9999 ohms and line length settings between 0.1 and 999 miles.

While there are no secondary setting limits for the impedance or line length settings, the magnitude and angle of the residual current compensation factor is range limited.

Where K = (Z0 - Z1)/(3 x Z1)

$$0.0833 < |K| < 2.0$$

and

$$47° < MTA + \angle K < 113°$$

Given the impedance settings selected,

$$K = 0.702 \angle 0.57°$$

You should perform a cursory check to be sure the minimum Zone 1, Zone 2, or Zone 3 secondary reaches at MTA are not below the minimum distance element reach setting of 0.125 Ω secondary or above the maximum setting limit of 64 Ω secondary.

- Other Settings Affected

Z1%, Z2%, Z3%, MTA

Current and Potential Transformer Ratio Selection

Current transformer ratio (CTR) selection for line protection is often based on the transmission line current carrying capability. CTR selections also determine the magnitude of secondary fault current presented to the relay.

Select a current transformer ratio which reduces the likelihood of CT saturation and allows the current transformer to deliver a reliable secondary representation of the primary current during a fault condition.

The potential transformer ratio (PTR) setting should be selected to match the primary voltage ratio (l-n) to approximately 67 V_{l-n}.

The synch-check potential transformer ratio (SPTR) setting should be selected to allow the synch-check voltage input to range between 67 V_{l-n} and 120 V_{l-n}.

The current transformer ratio selected for this example is 1000/5 or 200:1. This ratio allows 1000 A of load to flow without exceeding five amperes of secondary current, while limiting the secondary current to well below 50 A for the maximum available fault duty.

```
CTR = 200.00
```

The system voltage is 230 kV line-line or 132.8 kV line-neutral. The relay requires a nominal phase voltage of approximately 66.4 $V_{l\text{-}n}$ or 115 $V_{l\text{-}l}$. The PTR selected for this example is 2000:1. The synch-check potential transformer uses the same ratio.

$$PTR = \frac{(230\ kV)}{(115\ V)} = 2000:1$$

$$SPTR = \frac{(132.8\ kV)}{(66.4\ V)} = 2000:1$$

```
PTR  = 2000.00
SPTR = 2000.00
```

- Setting Limit Check

The primary limit check for the CTR and PTR settings allows you to enter values from 1 - 5000 and 1 - 10,000 respectively.

There is no secondary setting range check for the CTR setting. The ratio of PTR:SPTR must be between 0.5 and 1.99.

- Other Settings Affected

CTR - All overcurrent pickup settings   Ratio of PTR/CTR: Z1%, Z2%, Z3%
PTR - All voltage element pickup settings

Maximum Torque Angle (MTA)

The maximum torque angle (selected in the setting procedure) is common for all protective elements. A typical maximum torque angle setting is at or less than the positive-sequence transmission line impedance angle. A lower MTA setting extends the amount of resistive coverage provided by the mho elements. MTA selected for this example is 80.1°. Note that this value matches the positive-sequence line impedance angle of 80.1°.

```
MTA = 80.1
```

- Setting Limit Check

The primary setting range check allows MTA settings from 47° - 90°. The secondary check for this setting checks the sum of the MTA setting and the angle of the residual compensation factor, K. The sum must fall within the range:

$47° < MTA° + \angle K° < 113°$

- Other Settings Affected

Zone 1, Zone 2, and Zone 3 distance element reach at MTA degrees if MTA does not equal the positive-sequence transmission line impedance angle.

Reclosing Open Interval and Reset Time (79OI and 79RS)

An open interval timer controls the reclosing shot. The recloser must coordinate with remote reclosing schemes.

For this example, the first reclose attempt at Breaker 3 is 40 cycles after the TRIP condition is gone.

Because 79RS limits the duration of CLOSE output operation, the reset time (79RS) must be at least as long as it takes the breaker to completely close. The 79RS timer also serves to block automatic reclosing for 79RS time period after an operator (or SCADA) closes the line breaker. This feature allows the local operator to retain control of the line breaker. For this example, the 79RS timer is set for 240 cycles or four seconds.

For the relay at Breaker 3:

```
79OI =   40
79RS =  240
```

- Setting Limit Check

79OI timer has a primary limit check of 0 to 8,000 cycles. The 79RS timer has a primary limit check of 60 to 8,000 cycles. There is no secondary limit check for 79OI or 79RS. For this example, each open interval and 79RS reset timer setting lies within the relay setting limits.

- Other Settings Affected

Please note that the 52BT timer should be set less than the open interval timer if you need the switch-onto-fault logic enabled for the line test shot (see 52BT Setting for details).

Close Supervision Settings (PSVC, 27VLO, 59VHI, 25DV, SYNCP, 25T, VCT)

The SEL-121F relay includes two functions which can supervise close operations, including reclosures and external close operations.

The voltage condition checking function supervises closures based upon hot-bus/dead-line, hot-line/dead-bus, or either condition. The synch-check function determines whether an energized line and energized bus are in synchronism. The voltage condition checking function uses the PSVC, 27VLO, 59VHI, SYNCP, and VCT settings. The synch-check function uses the 59VHI, 25DV, SYNCP, and 25T settings. The polarizing inputs are VA, VB, and VC. The relay uses sync voltage input, VS, in the voltage checking and sync checking logic.

Voltage Checking Function

Enable the voltage checking function by selecting a PSVC setting of S, P, or E. Voltage checking is disabled when you select PSVC = N. When PSVC = S, the relay asserts Relay Word bit VSC when VS > 59VHI and VP1 < 27VLO (live sync/dead polarizing) for VCT time. When PSVC = P, the relay asserts Relay Word bit VSC when VP1 > 59VHI and VS < 27VLO (live polarizing/dead sync) for VCT time. When PSVC = E, the relay asserts Relay Word bit VSC when either voltage condition is true for VCT time.

Select 59VHI and 27VLO settings based upon your utility standards. Select standard voltage levels where the line is considered live and dead for reclosing purposes.

You can set the Relay Word bit VSC in a programmable logic mask and connect the programmable output contact for that mask in the close path. With this connection, a close is only allowed if the VSC condition is valid.

In the example, we intend to supervise reclose operations with live-bus/dead-line conditions. The relay uses line-side polarizing potential transformers, thus the sync voltage must be taken from the bus side. Based upon the voltage sources and desired performance, we set the relay to perform live-sync/dead-polarizing supervision; PSVC = S.

We only want to close if the voltage conditions have been valid for at least 30 cycles; VCT = 30 cycles. The voltage VS is taken from a bus-side PT attached to A-phase; SYNCP = A.

Synchronism Checking Function

The relay may perform synchronism checking to supervise breaker closures when the line and bus are energized. The sync-check feature in the SEL-121F relay checks the vector difference between a selected polarizing voltage, VP, and the synchronizing voltage, VS. This difference voltage is then compared against the 25DV setting. When the phasor difference between VP and VS is less than the 25DV setting for 25T time, the relay asserts the SSC bit in the Relay Word.

The relay calculates V1 from the positive-sequence voltage presented to the relay polarizing inputs:

$$V1=1/3(Va + aVb + a^2Vc)$$

The relay checks the magnitudes of V1 and VS to ensure that both voltages are above the 59VHI setting. The relay only performs the sync check if both the bus and line are live. Using the positive-sequence voltage for magnitude comparison adds security to the scheme by ensuring that all three potentials are good on the polarizing side of the breaker.

If both voltages are live, the relay calculates the vector difference between VS and the phase voltage selected by the SYNCP setting. If the vector difference is less than the 25DV setting, the 25T timer starts. If the voltages remain in sync, as determined by the magnitude of the vector difference voltage, for 25T time, the relay asserts the SSC bit in the Relay Word.

If the 25T time is relatively short, the breaker close time may become a factor. For example, if 25T is set for 60 cycles and the breaker close time is 10 cycles, it actually takes 70 cycles to parallel the line. If this time is critical, the breaker close time should be taken into account when the 25T time is set so that, in this case, a 25T setting of 50 cycles might be more appropriate.

Figure 5.2 illustrates the sync-check relay "sync-check window." The cross-hatched area is the region in which the breaker may be closed without fear of damage.

To set the relay, you must know the maximum angle (∅) between VPOL and VS that is allowed for the breaker to close. The slip frequency should be estimated to set the 25T time delay and the breaker close time should also be known.

Referring to Figure 5.2, note that 25DV is determined from the known angle, ∅. The 25DV setting is approximated with the equation:

$$25DV = \sin(\varnothing) \times 59VHI$$

The value of ∅ should be the maximum angle across the breaker to allow closing.

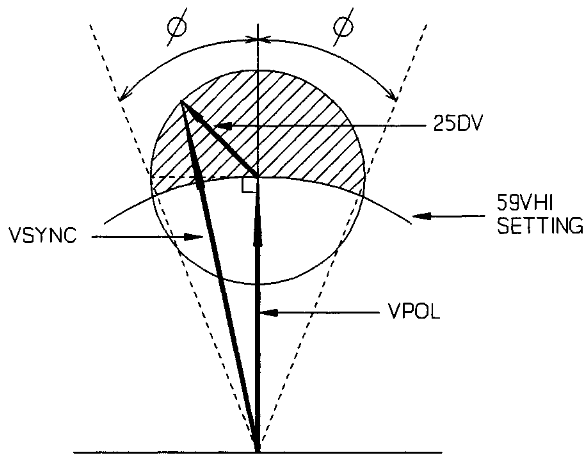

Figure 5.2: Sync-Check Window

For our example, for a maximum angle of 30° and 59VHI equal to 80% of nominal phase-neutral voltage on a 230 kV system:

25DV = sin(30) x (0.8 x 132.8 kv) = 53.12 kv

The slip frequency is the maximum allowed frequency difference between VP and VS. The formula for slip is as follows:

ΔF = (2 x ∅) / (360 x 25T)

Where 25T is the sync-check time delay from the SEL-121F relay setting.

For example, with 25T = 5 seconds and ∅ = 30°:

ΔF = (2 x 30°) / (360° x 5 sec.) = 0.033 HZ

This is to say the frequency of VS with respect to VPOL can vary from 59.967 HZ to 60.033 HZ and the breaker is allowed to close. If the slip frequency is higher, the breaker can not close. Note that this is assuming VPOL is at 60 HZ.

At Breaker 3 we intend to supervise recloses with the VSC live-bus/dead-line voltage conditions. We supervise externally generated close signals using both the VSC and sync-check conditions. If the line is not dead or in synchronism, an external close is not allowed.

For the 27VLO setting, we assume that the line is dead for reclosing purposes if line voltage is below 20% of nominal voltage.

27VLO = 0.20 x 132.8 kV = 26.6 kV

For the 59VHI setting, we assume that the line is live for reclosing purposes if line voltage is above 80% of nominal voltage.

59VHI = 0.80 x 132.8 kV = 106.2 kV

For sync check purposes, we use the 25DV voltage value calculated above:

25DV = 53.12 kV

The VS input is taken from a bus-side PT connected to A-phase.

SYNCP = A

The 25T setting is selected to allow closing under the synchronism conditions outlined above.

25T = 5 sec = 300 cycles

The VCT setting is:

VCT = 30 cycles.

Summarizing for the relay at Breaker 3:

```
PSVC  =   S
27VLO =  26.6
59VHI = 106.2
25DV  =  53.12
SYNCP =   A
25T   = 300
VCT   =  30
```

- Setting Limit Checks

The relay allows PSVC settings of S (for live-sync/dead-pol checking), P (for live-pol/dead-sync checking), E (closing is acceptable if either condition is valid), or N (voltage checking disabled).

The primary setting range check allows 27VLO, 59VHI, and 25DV voltage settings from 0 - 2,000 kV primary. The 27VLO and 59VHI secondary setting range is from 0 - 80.0 V_{l-n} secondary on the polarizing inputs and 0 - 125 V_{l-n} secondary on the synchronism checking input. The 25DV element setting range is 0 - 150 V secondary.

$$\frac{27VLO}{PTR} = \frac{26.6\ kV}{2000} = 13.3\ V_{l-n}\ \text{secondary}$$

$$\frac{59VHI}{PTR} = \frac{106.2\ kV}{2000} = 53.1\ V_{l-n}\ \text{secondary}$$

$$\frac{25DV}{PTR} = \frac{53.12\ kV}{2000} = 26.56\ V\ secondary$$

If SPTR and PTR settings are different, verify that the 27VLO and 59VHI settings fall within specified VS ranges.

The relay allows SYNCP settings of A, B, or C to indicate the phase which the VS input is attached to. If VS is not connected in your application, you may use A, B, or C for a SYNCP setting.

The primary setting range check allows 25T and VCT timer settings of 0 - 8,000 cycles.

- Other Settings Affected

79OI open interval timer.

A1 Programmable Output Time Delayed Pickup and Dropout Settings (A1TP, A1TD)

Pickup and dropout of the A1 programmable output contact can be time delayed using the A1TP and A1TD settings. This example does not require that these time delays be used.

```
A1TP = 0.0
A1TD = 0.0
```

- Setting Limit Checks

The primary setting range check allows A1TP and A1TD settings of 0 - 8,000 cycles.

- Other Settings Affected

None.

Zone 1 Reach Setting (Z1%)

The Zone 1 reach is typically set short of the forward remote terminal. Thus, the Zone 1 elements provide instantaneous protection for phase-phase, three-phase, and phase-ground faults in the first 75-80% of the transmission line. The remainder of the line is protected by the overreaching Zone 2 elements. While the percent error of the impedance element reach is less than 5%, errors in the CT and PT ratios, modeled transmission line data, and fault study data do not permit Zone 1 element settings of 100%.

In this example, the Zone 1 distance elements at Breaker 3 must not reach past Bus C. To prevent overreaching due to the sources of error listed above, the required reach for the Zone 1 three-phase and phase-phase elements is 80% of the positive-sequence impedance of Line 2.

$$\text{Z1 Reach} = 0.80 \times 81.16\ \Omega \text{ primary @ } 80.1° = 64.93\ \Omega \text{ primary @ } 80.1°$$

The reach settings for the phase distance elements are a percentage of the positive-sequence line impedance settings along the line angle. When the MTA setting differs from the positive-sequence line angle, the relay calculates the mho circle diameter with the following equation:

$$\text{Diameter} = \frac{\text{Set Reach}}{\cos(\text{Angle of Z1 - MTA})}$$

For this example, the diameter of the Zone 1 mho circle along the MTA is:

$$\text{Diameter} = \frac{64.93\ \Omega}{\cos(80.1° - 80.1°)}$$

$$= 64.93\ \Omega \text{ primary along the MTA}$$

For the relay at Breaker 3:

```
Z1% = 80.0
```

- Setting Limit Check

The primary limit check allows Zone 1 percent reach settings of 0 - 2000%. The secondary setting check allows secondary reach settings of 0.125 - 64 ohms secondary along the MTA.

Calculations: PTR = 2000:1 PTR/CTR = 10
CTR = 200:1

$$\text{Secondary Ohms} = \frac{64.93\ \Omega \text{ primary}}{10} = 6.493\ \Omega \text{ secondary along the MTA}$$

The Z1% setting of 80 for this example lies within primary and secondary setting limits of the relay.

- Relay Word Bits and Other Settings Affected

Zone 1 must be less than Zone 2 and Zone 3. The Z1P and Z1G bits in the Relay Word depend on the Z1% setting.

Zone 2 Reach Setting (Z2%)

The Zone 2 phase and ground distance elements provide coverage for end-of-section faults. The time delay allows coordination between the Zone 2 element of this relay and the Zone 1 element of the next relay in the forward direction.

Zone 2 elements should never extend past the Zone 1 reach of the next line terminal. This prevents race conditions between Zone 2 time delayed elements of the two line terminals. Typical settings for the Zone 2 distance elements are 120 - 130% of the protected line.

The Zone 2 elements must have adequate reach to detect all phase and ground faults along Line 2, but cannot overreach the Breaker 5 Zone 1 elements for faults on Line 3.

ZL for Line 3 = 40.58 Ω primary

Zone 2 element settings with a reach of 120% of protected line impedance account for the effects of infeed. This point must be verified using a fault study to calculate the apparent ohms at the local terminal for a fault at the remote end of the transmission line. In the example system, 120% is selected for the Zone 2 elements with assurance that all phase faults on Line 2 are detectable, even with infeed from the remote terminals.

Assuming Breaker 5 Zone 1 reach is set for 80% of the line impedance of Line 3, verify that a Zone 2 reach of 120% for Breaker 3 does not overreach the Zone 1 elements at Breaker 5.

$$\text{Line 2 Impedance} + [0.8 \times \text{Line 3 Impedance}] = 81.16\ \Omega + [0.8 \times 40.58\ \Omega] = 113.62\ \Omega \text{ primary}$$

When Zone 2 at Breaker 3 has a set reach of 120%, the effective reach is:

$$\text{Zone 2 @ Bkr. 3} = 1.20 \times 81.16\ \Omega = 97.39\ \Omega \text{ along the line angle}$$

Since 97.39 Ω < 113.62 Ω, the Zone 2 setting of 120% at Breaker 3 does not overreach the Zone 1 protection of Line 3. Any effect of infeed tends to increase the apparent ohms seen at Breaker 3 for faults on Line 3.

The MTA setting applies to all of the distance elements and is the same as the positive-sequence line angle. Calculate the diameter of the Zone 2 mho circle with the following equation:

$$\text{Diameter} = \frac{\text{Set Reach}}{\cos(\text{Angle of Z1 - MTA})}$$

For this example, the Zone 2 mho circle diameter along the MTA becomes:

$$\text{Diameter} = \frac{97.39\ \Omega}{\cos(80.1^\circ - 80.1^\circ)}$$

$$= 97.39\ \Omega \text{ along the MTA}$$

For the relay at Breaker 3:

```
Z2% = 120.00
```

- Setting Limit Check

The primary limit check allows Zone 2 percent reach settings of 0 - 3200% with the requirement that the Zone 2 reach be equal to or greater than the Zone 1 reach. The secondary check allows secondary reach settings of 0.125 - 64 ohms secondary along the MTA.

Calculations: PTR = 2000:1 PTR/CTR = 10
CTR = 200:1

$$\text{Secondary Ohms} = \frac{97.39\ \Omega\ \text{primary}}{10} = 9.739\ \Omega\ \text{secondary along the MTA}$$

The Z2% setting of 120 for this example lies within the secondary setting limits of the relay.

- Relay Word Bits and Other Settings Affected

Zone 2 must be less than Zone 3. The Z2PT and Z2GT bits in the Relay Word depend on the Z2% setting.

Zone 3 Reach Setting (Z3%)

The Zone 3 elements time delayed outputs can serve as remote backup for faults beyond the far bus.

For the relay at Breaker 3:

```
Z3% = 150.00
```

- Setting Limit Check

The primary limit check allows Zone 3 percent reach settings of 0 - 3200%, with the requirement that Zone 3 reach exceed Zone 2 reach. The secondary check allows secondary reach settings of 0.125 - 64 ohms secondary along the MTA.

Calculations: PTR = 2000:1 PTR/CTR = 10
CTR = 200:1

$$\text{Secondary Ohms} = \frac{121.74\ \Omega\ \text{primary}}{10} = 12.174\ \Omega\ \text{secondary along the MTA}$$

The Z3% setting of 150 for this example is within primary and secondary setting limits of the relay.

- Relay Word Bits and Other Settings Affected

The Z3, and Z3T bits in the Relay Word depend on the Z3% setting.

Zone 2 Phase And Ground Distance Time Delays (Z2DP, Z2DG)

The time delay of the Zone 2 phase and ground distance elements is selected by the settings. The Zone 2 elements must coordinate with downstream Zone 1 elements, plus downstream breaker operating time, plus a small safety margin.

For the relay at Breaker 3:

```
Z2DP = 30.00
Z2DG = 30.00
```

- Setting Limit Check

The limit check allows Zone 2 time delays of 3 - 2000 cycles. A Z2DP and Z2DG of 30 cycles each lies within the relay setting limits. There is no secondary limit check for this setting.

- Relay Word Bits and Other Settings Affected

Z2PT and Z2GT bits in the Relay Word.

Zone 3 Phase and Ground Time Delay (Z3D)

The Z3D timer adds a settable delay to the instantaneous outputs of the Zone 3 phase and ground distance elements. The time delayed output of the Zone 3 distance elements is represented by the Z3T bit in the Relay Word. Time delayed Zone 3 elements provide time-step protection. The Zone 3 phase time delay should coordinate with the Zone 2 operating time of the relay and breaker at the remote bus. This allows the remote Zone 1 and Zone 2 elements to pick up and clear the fault.

A typical Zone 3 phase distance time delay setting is 40 cycles.

In the example at Breaker 3, the time selection should coordinate with the Breaker 2 Zone 2 protection to provide time-step backup protection for Line 3. The Zone 3 phase delay selected in this example is 40 cycles.

```
Z3D = 40.00
```

- Setting Limit Check

The limit check allows Zone 3 time delays of 3 - 2000 cycles. A Z3D of 40 cycles lies within the relay setting limits. There is no secondary limit check for this setting.

- Relay Word Bits and Other Settings Affected

Z3T bit in the Relay Word.

Trip Duration Timer (TDUR)

The trip duration timer setting determines the minimum length of time the TRIP output contacts close when the relay trips. The TRIP output contacts close for the greater of the TDUR time or the duration of the trip condition. A typical setting for this timer is 150 msec or nine cycles.

```
TDUR = 9.00
```

- Setting Limit Check

The primary limit check allows TDUR time delay settings of 0 - 2000 cycles. The TDUR setting of 9.00 cycles lies within the relay setting limits. There is no secondary limit check for this setting.

- Relay Word Bits and Other Settings Affected

None.

Phase and Residual Overcurrent Element Setting (50NG)

The 50NG setting selects pickup thresholds for the 50N and 50G ground distance element fault detector overcurrent elements. Before the any zone ground distance element can pickup, the relay must detect phase and residual current greater than the 50NG setting. Calculate the phase and residual current for the most remote ground fault that the Zone 3 ground distance element must detect. Select a 50NG setting to ensure that both the 50N and 50G overcurrent elements pick up for this fault.

The 50N and 50G elements are also used in the trip unlatch logic (see Section 2: SPECIFICATIONS). Before the TRIP output can open, the trip condition must vanish and the phase and residual current must drop below the 50NG element setting. This assures that the TRIP output contact does not open until current has stopped flowing in the breaker.

For the relay at Breaker 3 in the system shown in Figure 5.1, the governing fault condition is a phase-ground fault at Bus D. The fault study revealed that for this fault, IA = 435 A primary and IR = 410 A primary. To ensure that the 50N and 50G elements pick up for the calculated fault current, select some current value below the calculated 410 ampere residual current value for the 50NG setting. This setting accounts for arc resistance and errors in fault study calculations. This value for the 50NG setting may be below load. In this example, the value selected for the 50NG setting is 250 A (approximately 60% of the minimum fault current).

```
50NG = 250.00
```

- Setting Limit Check

The primary limit check allows for 50NG settings of 0.25 - 50,000 A. The secondary check allows for a secondary amp setting of 0.5 - 25 times 51NP, but less than 40 A.

Calculations: CTR = 200:1

$$\text{50NG secondary amps} = \frac{250\text{ A primary}}{200} = 1.25\text{ A secondary}$$

The 50NG setting of 250 A for this example lies within the relay setting limits.

- Relay Word Bits and Other Settings Affected

50NG bit in the Relay Word and all ground distance elements: Relay Word bits Z1G, Z2GT, Z3, and Z3D. REJO bit when REJOE = G.

Low-Set Phase Overcurrent Element Setting (50P)

The 50P element provides fault detector supervision of the phase distance elements and must pick up for all fault conditions where a phase distance element is expected to operate. The ideal setting for the 50P element is above load but below minimum fault duty for the most remote Zone 3 phase fault that the relay must detect.

Although it is not ideal, you can set 50P below load to permit distance element operation for end-of-line faults with magnitudes below load. When 50P is below load current and all three potential fuses operate, the relay three-phase LOP function cannot operate. Refer to the description of LOP logic for more details.

For phase-phase faults, both involved phase current magnitudes must exceed the 50P pickup threshold before the phase-phase distance elements are allowed to operate. For three-phase faults, the current magnitude in all three phases must exceed the 50P pickup threshold before a three-phase fault condition is declared.

For the relay at Breaker 3, the governing fault condition is a phase-phase fault at Bus D. The fault study revealed that the lowest phase fault current equals 620 A primary for this fault. To ensure that the 50P element picks up for the calculated fault current, select some current value below the calculated 620 ampere value for the 50P setting. This setting accounts for arc resistance and errors in fault study calculations. In this example, the value selected for the 50P setting is 370 A (approximately 60% of the minimum fault current).

```
50P = 370.00
```

- Setting Limit Check

The primary limit check allows for 50P settings of 0.25 - 50,000 A. The secondary check allows for a secondary amp setting of 0.5 - 40 A.

Calculations: CTR = 200:1

$$50P \text{ secondary amps} = \frac{370 \text{ A primary}}{200} = 1.85 \text{ A secondary}$$

The 50P setting of 370 A for this example lies within the relay setting limits.

- Relay Word Bits and Other Settings Affected

50P bit in the Relay Word and all phase distance elements: Relay Word bits Z1P, Z2PT, Z3, Z3T, and LOP. REJO bit when REJOE = P.

High-Set Phase Overcurrent Element Setting

The 50H element is intended for use as a high set non-directional phase overcurrent detector in the switch-onto-fault logic. If a line breaker is closed into a close-in three-phase bolted fault where line-side potential transformers are used, polarizing voltage for the three-phase distance elements is never established. In this situation, the distance elements do not operate. The 50H element is provided to help prevent a failure to trip the line breaker in this instance.

The 50H element measures current magnitude in each phase with no dependence on polarizing voltages. This element is non-directional and should be used only in the switch-onto-fault logic mask (MTO) when the line breaker is closed to test the line on a radial basis. If fault duty in front of the line terminal is much greater than behind it, the 50H element can also be used in the unconditional trip logic mask (MTU) to provide rapid clearance of close-in faults.

Typical 50H settings are 50% - 70% of three-phase fault duty at the local bus.

The three-phase fault duty for a fault at Bus B is 2180 A. To assure rapid clearance of this fault, a 50H setting of 1500 A is selected for this example.

```
50H = 1500.00
```

- Setting Limit Check

The primary limit check allows 50H settings of 0.25 - 50,000 A. The secondary check allows a secondary amp setting of 0.5 - 80 A.

Calculations: CTR = 200:1

$$50H \text{ secondary amps} = \frac{1500 \text{ A primary}}{200} = 7.50 \text{ A secondary}$$

The 50H setting of 1500 A for this example lies within the setting limits of the relay.

- Relay Word Bits and Other Settings Affected

50H bit in the Relay Word.

Residual Time-Overcurrent Settings (51NP, 51NC, 51NTD, 51NTC)

Consult a fault study to select the residual time-overcurrent element pickup setting. The residual time-overcurrent element provides current dependent, time delayed clearance of faults along the protected line and provides backup protection for remote terminals. Because the measure of residual current varies with system switching configuration, fault location, and fault resistance, a complete fault study is necessary to determine the minimum pickup setting, appropriate time dial, and curve characteristic. When you enable the element forward-reaching by setting 51NTC=Y, consider only faults in front of the line terminal for coordinating purposes.

For the relay at Breaker 3, a single line to ground fault at Bus C dictates the sensitivity required for the residual time-overcurrent pickup. The residual current magnitude for this fault is 540 A primary. To allow for ground fault resistance, a value of 50% of 540 A is selected as the residual time-overcurrent element pickup. The pickup (51NP), time dial (51NTD), and family of curves (51NC) selections are assumed to coordinate with the remaining residual time-overcurrent elements of the example system.

```
51NP = 270.00
51NTD= 3.00
51NC = 2
51NTC= Y
```

- Setting Limit Check

The primary limit check for the residual time-overcurrent element allows 51NP settings of 0.25 - 50,000 A. The secondary check allows for secondary amp settings of 0.5 - 8.0 A. The 51NC setting check allows settings of 1, 2, 3, or 4 for the family of curves. The 51NTD setting check allows settings from 0.5 to 15 in increments of 0.01. The 51NTC setting allows the residual time-overcurrent element to be torque controlled (Y for forward reaching directional) or non-torque controlled (N for nondirectional).

Calculations: CTR = 200:1

$$\text{51NP secondary amps} = \frac{270 \text{ A primary}}{200} = 1.35 \text{ A secondary}$$

The 51NP, 51NTD, 51NC, and 51NTC settings are all within the setting limits of the relay.

- Relay Word Bits and Other Settings Affected

The 51NP setting affects the 50NG and 67N pickup setting ranges. Relay Word bits 51NT and 51NP depend on the 51NP, 51NTD, 51NC and 51NTC settings.

67NP Residual Overcurrent Settings (67NP, 67NTC)

The relay provides an instantaneous residual overcurrent element, 67N. You can make the overcurrent element forward-looking by setting 67NTC = Y. The relay uses a negative-sequence directional element to torque control the 67N element when 67NTC = Y.

The pickup setting for this element should always be greater than the maximum end-of-line (EOL) ground fault current level. A typical setting for the 67NP element is 120% of this maximum EOL single-line-to-ground (SLG) fault duty. This prevents the instantaneous element from overreaching the forward bus.

The maximum residual current measured at Breaker 3 for a fault at Bus C equals 545 A. To ensure that the instantaneous element does not overreach Bus C, the 67NP setting should be 120% of 545 A. This 120% factor accounts for differences between the modeled and actual system, CT ratio errors, etc. The element should be forward-looking.

```
67NP  = 650.00
67NTC = Y
```

- Setting Limit Check

The primary limit check allows 67NP settings of 0.25 - 50,000 A. The secondary check allows a secondary amp setting of 0.5 A to 50 times the 51NP setting.

Calculations: CTR = 200:1

$$\text{67NP secondary amps} = \frac{650 \text{ A primary}}{200} = 3.25 \text{ A secondary}$$

The 67NP setting of 650 A for this example is greater than 0.5 A secondary and less than 50 times the 51NP setting.

The relay allows 67NTC settings of Y or N.

- Relay Word Bits and Other Settings Affected

67N bit in the Relay Word.

52BT Setting (52BT) And Switch-Onto-Fault Protection

The relay includes switch-onto-fault logic for use during line testing. This logic allows you to enable selected elements for a short duration after line breaker closure. Switch-onto-fault logic permits instantaneous line breaker tripping for end-of-section faults which would normally be cleared in Zone 2 time.

Switch-onto-fault protection is provided through elements selected in the MTO logic mask, typically non-time delay overreaching elements. The 52BT time delay setting dictates the interval during which these elements are enabled for tripping.

The 52BT bit is an inverted time delayed follower of the 52A input. When the 52A input changes from the asserted (breaker closed) to deasserted state (breaker open), the 52BT bit remains low for 52BT time. After the 52BT timer expires, the 52BT bit changes from logic state "0" to "1." When the breaker is closed (from an open state), 52BT remains high for 52BT time, then deasserts. While the 52BT bit is high, elements selected in the MTO logic mask are enabled to trip. Thus, for 52BT time after breaker closure, assertion of any element selected in the MTO logic mask causes the relay to close the TRIP output contacts. This logic provides Switch-Onto-Fault (SOTF) protection.

Figure 5.2 illustrates the timing relationship of the 52A input and 52BT element.

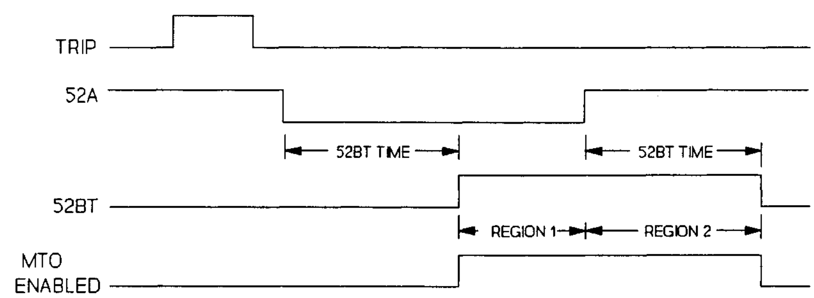

Figure 5.3: 52A Input and 52BT Timing Diagram

MTO logic is enabled during the time period shown for Regions 1 and 2. During Region 1, the MTO logic is enabled to protect the open line breaker. For line breaker tank faults, the relay can issue the trip signal required for breaker failure schemes. Any time delay associated with the circuit breaker auxiliary contact opening occurs during the time shown in Region 1.

Region 2 shows the time period where MTO logic is performing true switch-onto-fault transmission line protection. The 52BT element serves as a permissive signal for elements set in the MTO mask.

For example, the circuit shown in Figure 5.4 has a phase-phase fault close to Breaker 2. Suppose that Breaker 1 is the preferred source for testing the line (Breaker 2 is to remain open until Breaker 1 energizes the line). If standard time-stepped distance protection is employed without SOTF protection, the fault would have to be cleared in Zone 2 time. Using the relay MTO logic, the instantaneous Zone 3 phase elements detect the fault and issue a trip signal without intentional time delay. This reduces the amount of time the system is exposed to the fault energy.

There is no possibility of overreaching the remote terminal with the instantaneous Zone 3 element because Breaker 2 is open while the Breaker 1 MTO logic is enabled. If the fault is not present when Breaker 1 tests the line, the MTO logic of Breaker 1 resets after 52BT time. Then Breaker 2 can synchronize and close. This emphasizes the need to limit the time during which MTO mask elements can trip the breaker. Remember: the 52BT time setting must be long enough for the sensitive elements in the MTO logic mask to assert, yet shorter than the time allowed for Breaker 2 to parallel.

If you require switch-onto-fault protection for the reclose shot, set the 52BT time interval shorter than the recloser open interval. If you want to cancel switch-onto-fault logic for the reclose shot, set the 52BT timer longer than the open interval timer by the maximum expected breaker opening time. If the 52BT timer does not expire before the breaker recloses, switch-onto-fault protection is not enabled for that reclose. If high speed reclosing is not required, typical 52BT settings are 15 - 20 cycles.

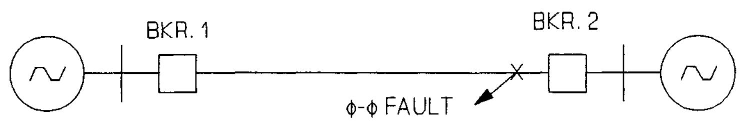

Figure 5.4: Faulted Line With All Sources In

For the relay at Breaker 3 in Figure 5.1, we enable the Zone 3 instantaneous element to trip for end-of-section faults immediately following reclose. Because Breaker 3 is equipped with line-side PTs, we use the 50H element in the MTO logic mask to provide switch-onto-fault protection for close-in bolted faults.

In this example, the first reclose occurs at 40 cycles. A 52BT time of 30 cycles ensures that the 52BT element is asserted before the line breaker recloses.

```
52BT = 30.00
```

- Setting Limit Check

The limit check allows 52BT time delay settings of 0.5 - 10,000 cycles. The 52BT setting of 30.00 cycles lies within the relay setting limits. There is no secondary limit check for this setting.

- Relay Word Bits and Other Settings Affected

None.

Remote-End-Just-Opened (REJO) Enable Setting (REJOE)

When this feature is used, the SEL-121F relay can deliver accelerated trips for Zone 2 faults without the use of a communications channel.

An overview of pilotless accelerated trip schemes is provided below. This description is followed by a detailed description of the scheme implementation in the SEL-121F relay.

Pilotless Accelerated Trip Schemes

In many lower voltage transmission applications, the cost of communication equipment for line protection is not justifiable. In these installations it is still possible to achieve accelerated trip times. We can do this because certain system conditions indicate in-section faults.

In the system shown in the figures below, we know that after Breaker 2 clears its contribution to the fault, the only current that is permitted to flow through Breaker 1 is fault current through the B-phase breaker pole.

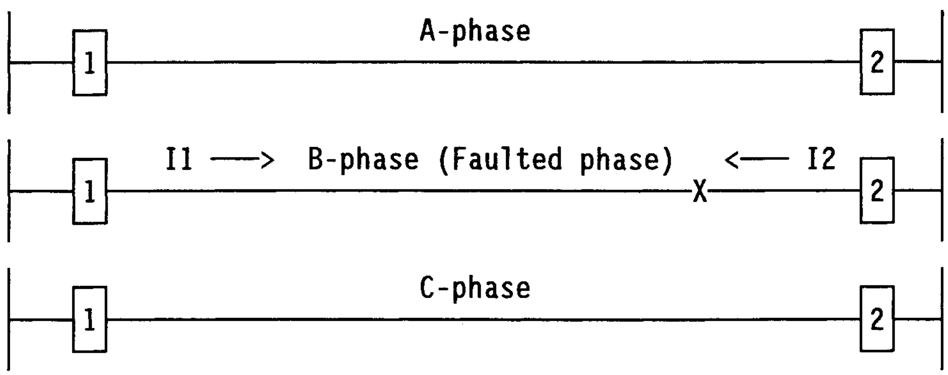

Figure 5.5: Faulted System with Breakers 1 and 2 Closed

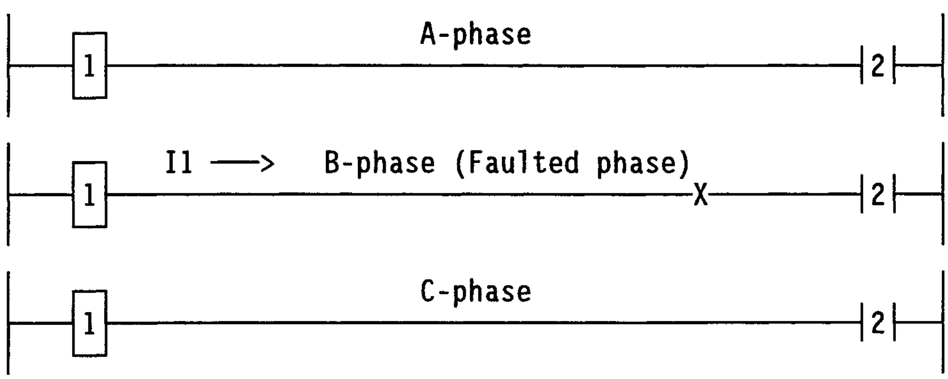

Figure 5.6: Faulted System with Breaker 2 Open

If the following conditions are met, they may be used in the same fashion as receiving a permissive signal from the remote end, without the need for a communications channel:

1. Three-phase load was present before the fault (therefore the remote end of the transmission line was closed).

2. Three-phase current was lost, signifying that the remote end of the transmission line has opened its breaker.

3. Current above a certain threshold is detected in at least one of the three phases, signifying that a fault may be present.

When all of these conditions are met, and an overreaching protective element asserts, the relay can issue an accelerated trip.

Pilotless Tripping with the SEL-121F Relay

The SEL-121F relay includes the overcurrent elements defined below. The elements are defined using "+" as logical OR and "*" as logical AND:

50G = 50AG + 50BG + 50CG	50G asserts when any phase current is above the 50NG setting.
3G50 = 50AG * 50BG * 50CG	3G50 asserts when all three phase currents are above the 50NG setting.
3G50D = 3G50 * (2 cycle TDDO)	3G50D is an instantaneous pickup, two cycle time delayed dropout 3G50 element.
50P = 50AP + 50BP + 50CP	50P asserts when any phase current is above the 50P setting.
3P50 = 50AP * 50BP * 50CP	3P50 asserts when all three phase currents are above the 50P setting.
3P50D = 3P50 * (2 cycle TDDO)	3P50D is an instantaneous pickup, two cycle time delayed dropout 3P50 element.

Referring the new overcurrent elements to the pilotless tripping scheme described above, the relay sets or clears the elements based on the conditions described below.

1. The 3G50 element is set by three-phase load current.
2. The 3G50D element indicates that load current was present up until at least 2 cycles ago.
3. If the 50G element is picked up, current is still flowing in at least one phase.
4. When REJOE = G, the REJO element is defined by the following logic equation:

   REJO = NOT(3G50) * 3G50D * 50G * (½ cyc pu/inst do)

   Three-phase load is no longer present, but was at least 2 cycles ago, current is still flowing in at least one phase, and these conditions are maintained for at least ½ cycle.

5. When REJOE = P, the REJO element is defined by the logic equation:

REJO = NOT(3P50) * 3P50D * 50G * (½ cyc pu/inst do)

By using the 3P50 instead of the 3G50, you may be able to set the relay to reject low-level tapped three-phase load between the relay and the remote breaker.

The relay uses the REJO bit in two places: as a qualifier for permissive tripping and as an indicator in the Relay Word.

If the REJO function is enabled (REJOE = P or G in the relay settings), then the REJO condition is used as a qualifier for permissive tripping.

The permissive tripping/REJO portion of the output equation for the TRIP contact is:

close TRIP = MPT * R * (PT + (REJOE * REJO))

Where:
R = Relay Word
MPT = Mask for Permissive or REJO Tripping

Used in this way, the REJO condition permits tripping for the relay elements set in the logic mask for Permissive Tripping (MPT) in the same manner as asserting the Permissive Trip input of the relay. You may set the MPT mask as if the relay were being used in a permissive tripping scheme, including instantaneous Zone 3 phase and ground distance (Z3) elements.

The REJO bit does not need to be set in any of the tripping logic masks to enable this function.

In the example, for the relay at Breaker 3, we select REJOE = N.

```
REJOE = N
```

- Setting Limit Check

The primary limit check allows REJOE settings of P (enabled, use 3P50), G (enabled, use 3G50), or N (not enabled).

Loss-of-Potential (LOP) Enable Setting, (LOPE)

Fuses or molded case circuit breakers often protect the secondary windings of the power system potential transformers. An operation of one or more fuses or molded case circuit breakers results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly discriminating fault direction.

Because occasional loss-of-potential to the relay is unavoidable, detection of this condition is desirable. Once a true loss-of-potential condition is detected, you may elect to block distance element operation and issue an alarm.

The relay discriminates between faults (which may reduce the voltage magnitude(s) to nearly zero) and loss-of-potential conditions. The following equation shows the loss-of-potential (LOP) detection logic for the relay:

SET LOP = [47QL * NOT(46QL)]:	Detects the presence of negative-sequence voltage in the absence of negative-sequence current
+ [NOT(47P) * NOT(50P)]:	Detects the absence of positive-sequence voltage in the absence of current above the 50P setting

Where:

47QL ≡ Low set negative-sequence overvoltage detector
50QL ≡ Low set negative-sequence overcurrent detector
47P ≡ Low set positive-sequence overvoltage detector
50P ≡ Low set phase overcurrent element

For one or more blown PT fuses, the relay declares a loss-of-potential condition when the measured negative-sequence voltage exceeds 14 V of V2 and measured negative-sequence current is below 0.083 A secondary. For three blown PT fuses, the relay declares an LOP condition when the measured positive-sequence voltage is below 14 V of V1 and the low set phase overcurrent detector (50P) is not picked up.

You determine how the relay uses loss-of-potential detection by selecting the LOPE setting. The LOPE setting choices and their associated results are:

- N Relay sets LOP bit when loss-of-potential condition is detected.
  Distance and directional elements are not blocked.
  Set the LOP bit in a programmable logic mask to indicate condition, if desired.

- Y Relay sets LOP bit when loss-of-potential condition is detected.
  Distance elements are blocked and directional elements default forward.
  Set the LOP bit in a programmable logic mask to indicate condition, if desired.

- 1 Relay blocks distance elements and directional elements default forward when LOP condition is detected.
  If the 52A input is asserted while LOP is detected, the Relay Word LOP bit is asserted.
  If the 52A input is not asserted while LOP is detected, the Relay Word LOP bit is not asserted.
  Set the LOP bit in a programmable logic mask to indicate that a loss-of-potential has occurred while the breaker is closed, if desired.

- 2 Relay sets LOP bit when loss-of-potential condition is detected.
  Distance elements are blocked and directional elements default forward.
  Relay asserts ALARM contact to indicate the LOP condition.

- 3 Relay blocks distance elements and directional elements default forward when LOP condition is detected.
  If the 52A input is asserted while LOP is detected, the Relay Word LOP bit is asserted.
  If the 52A input is not asserted while LOP is detected, the Relay Word LOP bit is not asserted.
  Relay asserts ALARM contact while the Relay Word LOP bit is asserted.

- 4 Relay sets LOP bit when loss-of-potential condition is detected.
  Distance and directional elements are not blocked.
  Relay asserts ALARM contact to indicate the LOP condition.

The following table summarizes the available LOPE settings and their results.

LOPE setting	Block 21 on LOP	52A supervises LOP Relay Word bit	Close ALARM contact on LOP bit assertion
N	No	No	No
Y	Yes	No	No
1	Yes	Yes	No
2	Yes	No	Yes
3	Yes	Yes	Yes
4	No	No	Yes

LOPE selections 1 and 3 are useful when line-side polarizing potentials are applied to the relay. A loss-of-potential condition may be detected while the breaker is open and the line and PTs are deenergized. Supervision of the Relay Word LOP bit prevents a continuous LOP alarm indication while the breaker is open.

LOPE selections 2, 3, and 4 cause the relay to close the ALARM contact while loss-of-potential is detected. This is useful when all four of the relay programmable output contacts are dedicated to other functions.

For the relay at Breaker 3:

```
LOPE = Y
```

- Setting Limit Check

The primary limit check allows LOPE settings of N, Y, 1, 2, 3, or 4.

- Relay Word Bits and Other Settings Affected

If LOPE=N or 4, the mho distance elements are not blocked from operating during an LOP condition.

Serial Port(s) Timeout Settings (TIME1, TIME2)

The TIME1 and TIME2 settings allow their respective ports to time out after the relay detects a period of inactivity for that port. After timing out, access for the port returns to Level 0 and no automatic messages are transmitted to it. In this example, a modem is connected to PORT 1. This requires a definite time setting for the port to prevent accumulation of toll charges if an operator does not hang up. PORT 2 is to be connected to an SEL-DTA and should never time out. This allows the SEL-DTA to receive any automatic message transmitted by the relay.

```
TIME1= 5   TIME2 = 0
```

- Setting Limit Check

The TIME1 and TIME2 limit check allows settings of 0 - 30 minutes. A zero setting signifies that the port never times out. There is no secondary limit check for this setting.

- Other Settings Affected

None.

Autoport Designation Setting (AUTO)

The AUTO setting specifies the port to which the relay directs automatically generated messages. The example has a modem connected to PORT 1 and an SEL-DTA connected to PORT 2. Since only the SEL-DTA is required to receive automatic messages, the AUTO setting is 2.

```
AUTO = 2
```

- Setting Limit Check

The limit check allows messages to be sent to PORT 1 only, (AUTO = 1), PORT 2 only (AUTO = 2), or both ports (AUTO = 3).

- Other Settings Affected

None.

Modem Answer Ring Setting (RINGS)

The RINGS setting specifies the number of rings a modem connected to PORT 1 waits to answer. This permits use of a single substation telephone line by both substation personnel and the relay. In this example, personnel have seven rings to answer the phone before the modem answers.

```
RINGS = 7
```

- Setting Limit Check

The limit check allows for the modem to answer between 1 and 30 rings.

- Other Settings Affected

None.

Full Example Setting Group

The following table shows all relay settings calculated above.

Table 5.1: Settings for Bus B, 230 kV Breaker 3

```
R1   =13.90   X1   =79.96    R0   =41.50    X0   =248.57    LL=100.00
CTR  =200.00  PTR  =2000.00  SPTR =2000.00  MTA  =80.10
79OI =40.00   79RS =240.00
PSVC =S       27VLO=26.60    59VHI=106.2    25DV =53.12  SYNCP=A
25T  =300.00  VCT  =30.00
A1TP =0.00    A1TD =0.00
Z1%  =80.00   Z2%  =120.00   Z3%  =150.00
Z2DP =30.00   Z2DG =30.00    Z3D  =40.00    TDUR =9.00
50NG =250.00  50P  =370.00   50H  =1500.00
51NP =270.00  51NTD=3.00     51NC =2        51NTC=Y
67NP =650.00  67NTC=Y        52BT =30       REJOE=N       LOPE =Y
TIME1=5       TIME2=0        AUTO =2        RINGS=7
```

Programmable Output Contact Mask Settings

The relay uses ten separate logic masks. Four of these masks control the TRIP output contacts (MTU, MPT, MTB, and MTO). The masks labelled MA1, MA2, MA3, and MA4 control the four programmable output contacts. The masks for reclose initiation (MRI) and reclose cancel (MRC) are used as inputs for controlling the reclosing relay.

Communication Scheme Use of Logic Masks

The relay supports a wide variety of protective schemes, some of which are shown below:

- Time-Stepped distance
- Permissive-Overreaching Transfer Trip (POTT) schemes
- Direct Underreaching Transfer Trip (DUTT) schemes
- Permissive Underreaching Transfer Trip (PUTT) schemes
- Direct Transfer Trip (DTT) schemes

The Relay Word and programmable masks provide great flexibility in applying the relay without rewiring panels or changing jumpers on circuit boards.

Operating the relay in each of the various schemes involves three simple steps: 1) connecting the communications equipment to the appropriate rear panel logic input (IN1, PT, or BT), 2) selecting the appropriate mask and bits for the tripping scheme (MTU, MPT, MTB, or MTO), and 3) depending on which scheme is selected, determining the number of programmable output contacts required to interface with the communications equipment. Each mask is independent from the other masks. This allows multiple schemes to function simultaneously.

The following guideline shows typical usage of bits in each mask.

Please note that each application requires a careful study of bits used in each mask. This guideline is included as a reference of typical Relay Word bit uses.

MTU: Mask for Trip Unconditional

Elements selected in this mask do not require that external conditions be met to initiate a trip. If an element masked in the MTU logic mask picks up, the TRIP output contacts close. You must be certain that elements used in this mask coordinate with other system protective devices. Unless your application permits, it is not advisable to set non-directional overcurrent elements in the MTU logic mask.

Typical bits masked in the MTU logic mask include Zone 1 instantaneous elements (Z1P, Z1G, and 67N) if they underreach the remote terminal, the ground time-overcurrent element (51NT), time delayed Zone 2 phase and ground distance elements (Z2PT and Z2GT), time delayed Zone 3 phase and ground distance elements (Z3T), and the IN1 bit if you intend to use the input as a direct trip input. The external tripping source is often a backup protective relay, breaker failure relaying, or a direct trip signal from communications equipment. In each example listed (except breaker failure), energizing the IN1 input allows you to utilize the reclosing functions by forcing the relay to trip.

Mask for Trip Unconditional (MTU)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
1	1	1	1	0	1	0	0	F4
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
1	0	1	0	0	0	1	0	A2
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

Where primary and secondary protection trip output contacts are routed to separate trip coils of the line breaker, you can cross trip the relays by routing the trip output of each set of protection to trip the other. When you need to cross trip the SEL-121F relay, route the trip output from the secondary line protection relays to the IN1 input with the IN1 bit set in the MTU logic mask.

MPT: Mask for Trip with Permissive Trip Input Asserted

The relay closes the TRIP output when the Permissive Trip (PT) input is asserted or the REJO condition is enabled and asserted and elements selected in the MPT mask pick up. As with the MTU logic mask, it is not advisable to mask non-directional elements in the MPT logic mask unless your application permits.

Typical bits masked in the MPT logic mask include Zone 3 instantaneous element (Z3).

Mask for Permissive Trip (MPT)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
0	0	0	0	1	0	0	0	08
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
0	0	0	0	0	0	0	0	00
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

The example mask for permissive tripping contains one additional bit not included in the MTU logic mask, the Zone 3 instantaneous phase and ground distance element. This element would be included if the relay were being used in a permissive overreaching transfer tripping scheme.

MTB: Mask for Trip with Block Trip Input Deasserted

The relay closes the TRIP output when the Block Trip (BT) input is not asserted and elements selected in this mask pick up. BT input assertion serves as an external qualifying condition. As with the MTU logic mask, it is not advisable to mask nondirectional elements in the MTB logic mask unless your application permits.

Mask for Trip Block (MTB)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
0	0	0	0	0	0	0	0	00
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
0	0	0	0	0	0	0	0	00
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

The example mask for block tripping contains all zeros because the relay is not being used in a blocking scheme.

MTO: Mask for Trip with the 52BT Element Asserted

The relay closes the TRIP output when the 52BT bit is asserted and elements selected in this mask pick up. The 52BT bit is a time delayed, inverted follower of the 52A input (see switch-onto-fault logic explanation for a detailed timing explanation of the 52BT bit). This tripping mask differs from the MTU, MPT, and MTB tripping masks because it is acceptable to mask sensitive nondirectional elements into MTO in certain applications. Such masking is advisable except in applications where the line breaker is closed into a line energized from the remote terminal (i.e., synchronized closures).

Typical bits set in the MTO logic mask include Zone 1 instantaneous elements (Z1P, Z1G, and 67N), the non-directional high-set overcurrent element (50H), and Zone 3 instantaneous elements (Z3).

Note: Never mask the 52BT bit into the MTO logic mask. This causes an undesirable seal-in of TRIP output contacts when the 52BT bit is asserted.

Mask for Trip Breaker Open (MTO)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
1	1	1	1	1	1	0	0	FC
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
1	0	1	0	0	1	0	0	A4
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

MA1, MA2, MA3, and MA4 Programmable Output Contact Masks

Any element listed in the Relay Word may be masked into these programmable output contacts. Guidelines to follow when masking elements into each mask depends on equipment connected to the contact outputs. If external equipment is not connected to the contact outputs, you may set elements in these masks to enhance event report analysis. For example, masking the 32Q (negative-sequence direction forward declaration) into one of the programmable output contacts informs you when the relay declares a fault to be in the forward direction.

Mask for the A1 Output Contact (MA1)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
0	0	0	0	0	0	0	0	00
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
0	0	0	0	0	0	0	0	00
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	1	0	02

For the example, the A1 output contact closes when the SSC bit asserts. The SSC bit asserts when the relay detects that the sync check and polarizing voltages are in synchronism. Using this setting, contact A1 may be used to supervise reclosures or external close signals.

Mask for the A2 Output Contact (MA2)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
0	0	0	0	0	0	0	0	00
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
0	0	0	0	0	0	0	0	00
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	1	01

The A2 output contact asserts when the VSC bit asserts, indicating that voltage conditions have fulfilled the voltage checking requirements. Using this setting, the A2 contact can supervise reclosures or external close signals.

Mask for the A3 Output Contact (MA3)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
1	1	1	1	0	0	0	0	F0
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
1	0	0	0	0	0	0	0	80
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

The A3 output contact asserts when any reclose initiate condition set in the MRI logic mask is fulfilled.

Mask for the A4 Output Contact (MA4)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
0	0	0	0	0	1	0	0	04
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
0	0	1	0	0	0	0	0	20
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

The A4 output contact asserts when any reclose cancel condition set in the MRC logic mask is fulfilled.

MRI: Mask for Reclose Initiation

If an element masked in the MRI mask is asserted when the TRIP output contacts close, reclosing is initiated unless a reclose cancel condition occurs. Reclose initiation is subordinate to reclose cancel. See the SPECIFICATION and APPLICATIONS Reclosing Relay descriptions for more details.

Mask for Reclose Initiation (MRI)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
1	1	1	1	0	0	0	0	F0
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
1	0	0	0	0	0	0	0	80
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

The example mask for reclose initiation selects the Zone 1 instantaneous elements (67N, Z1P, Z1G), and the time delayed Zone 2 phase and ground distance elements (Z2PT, Z2GT).

MRC: Mask for Reclose Cancellation

If an element masked in the MRC mask is asserted when the TRIP output contacts close, reclosing is cancelled even if a reclose initiate condition occurs. Reclose initiation is subordinate to reclose cancellation.

Mask for Reclose Cancel (MRC)

								Event Report Hexadecimal Code
Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
0	0	0	0	0	1	0	0	04
67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
0	0	1	0	0	0	0	0	20
LOP	52BT	27S	27P	59S	59P	SSC	VSC	
0	0	0	0	0	0	0	0	00

The example mask for reclose cancel stops reclosing for a timeout of the Zone 3 distance elements (Z3T), or 51NT residual time-overcurrent trips.

Relay Word Bits Intended for Relay Testing

Each bit in the Relay Word has a designated purpose. The following bits are included to assist in relay testing: 3P21, 32Q, 51NP, 50NG, 50P, 27S, 27P, 59S, 59P. This does not exclude the use of these bits in one of four trip or programmable output contacts if required by your application.

Note: Each mask must be properly configured for your application.

RECLOSING RELAY OPERATION EXAMPLES

Overview

The SEL-121F relay includes several voltage supervised reclosing schemes and one unsupervised scheme. The following timing diagrams and text explain how each reclosing scheme operates successfully. Also, there is one example of a cancelled reclosing shot. Section 2: SPECIFICATIONS provides detailed reclosing logic descriptions.

The table below outlines the reclosing examples in this section.

Table 5.2: Reclosing Relay Timing Examples

Example 1:	Single Shot Unsupervised Reclose Sequence
Example 2:	Reclosing Cancelled Due to RC Assertion
Example 3:	Live-Bus/Dead-line Supervised Reclose
Example 4:	Sync-check Supervised Reclose

Examples 1 and 2 provide information on the basic reclosing function. The remaining examples describe the reclosing options in greater detail. Timing diagrams, example settings, and an explanation of the events are provided in each example.

In each of the cases, the 79RS timer starts when the 52A input asserts. If the 79RS timer expires before the next trip, the relay resets the recloser and the available shot is reenabled. Refer to Section 2: SPECIFICATIONS, 79RS Timer for more details.

Example 1: Single Shot Unsupervised Reclose Sequence

This example shows a successful reclosing sequence. Regardless of other recloser settings, four requirements must be fulfilled before the relay can initiate the reclosing sequence. The four requirements are listed below.

- The relay must trip.
- The 52A input must deassert.
- At least one reclose initiate condition must occur.
- No reclose cancel condition can occur.

Table 5.3 shows the recloser settings used for Examples 1 and 2. Settings not shown in Table 5.3 are identical to the example settings calculated earlier in this section. Figure 5.7 shows the timing of Example 1. Settings marked N/A are not applicable to the example.

Table 5.3: Recloser Settings for Examples 1 and 2

PSVC	N/A
27VLO	N/A
59VHI	N/A
25DV	N/A
SYNCP	N/A
25T	N/A
VCT	N/A
79OI	40 cycles
79RS	240 cycles
TDUR	9 cycles

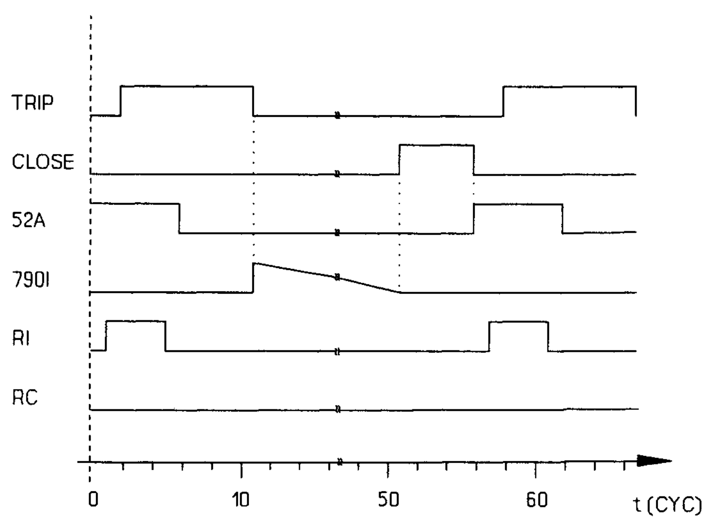

Figure 5.7: Single Shot Unsupervised Reclose Sequence

Referring to Figure 5.7 at t = 0, a permanent phase-phase fault occurs within the relay Zone 1 reach. The relay detects the fault and asserts the TRIP outputs, fulfilling the first requirement to initiate the reclosing sequence. Because the Z1P Zone 1 phase distance element is set in the Mask for Reclose Initiate, reclosure is initiated.

In response to the relay TRIP signal, the line breaker opens. This causes the RI bit to deassert because the Z1P element drops out. When the breaker opens, the breaker auxiliary contact also opens, deasserting the relay 52A input.

The relay TDUR setting of nine cycles causes the TRIP to remain asserted until cycle 11. No reclose cancel condition occurred, and the other three initiating conditions were fulfilled, so the 79OI timer starts when TRIP drops out.

Forty cycles later, the 79OI timer expires. The relay issues the CLOSE signal, the breaker recloses, and the 52A input is asserted by closure of the breaker auxiliary contact.

When the breaker closes, the phase-phase fault is reenergized. The relay Z1P element picks up causing the relay to TRIP and the RI bit to assert. Again, the breaker opens and the 52A input deasserts. Because the available reclosing shot has operated, when the relay trips a second time, the recloser is locked out and the breaker remains open.

Example 2: Reclosing Cancelled Due to RC Assertion

In this example, the fault is a Zone 3 phase-ground fault. The fault was not cleared by the primary protection, so this relay tripped due to assertion of the time delayed Zone 3 distance element, Z3T. Because the Z3T bit is set in the Mask for Reclose Cancel, the reclose cancel condition is fulfilled, cancelling the reclosing shot. Figure 5.8 illustrates the timing of the example.

Because Reclose Cancel has precedence over Reclose Initiate, the reclosing sequence is cancelled any time RC asserts while the TRIP is asserted, regardless of the presence of Reclose Initiating conditions.

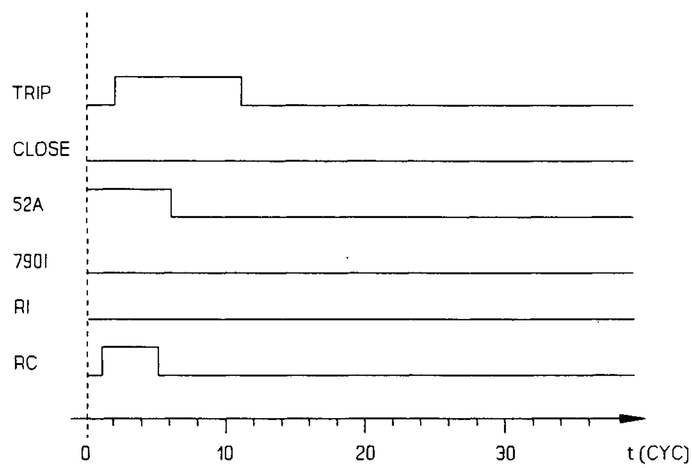

Figure 5.8: Reclosing Cancelled Due to RC Assertion

Example 3: Live-Bus/Dead-line Supervised Reclose

This example shows a successful live-bus/dead-line supervised reclosing sequence. Table 5.3 shows the recloser settings used for Example 3. Settings not shown in Table 5.3 are identical to the example settings calculated earlier in this section. Figure 5.9 shows the timing of Example 3. Settings marked N/A are not applicable to the example.

Table 5.4: Recloser Settings for Example 3

PSVC	**S**
27VLO	**26.6**
59VHI	**106.2**
25DV	N/A
SYNCP	**A**
25T	N/A
VCT	**30** cycles
79OI	**40** cycles
79RS	**240** cycles
TDUR	**9** cycles

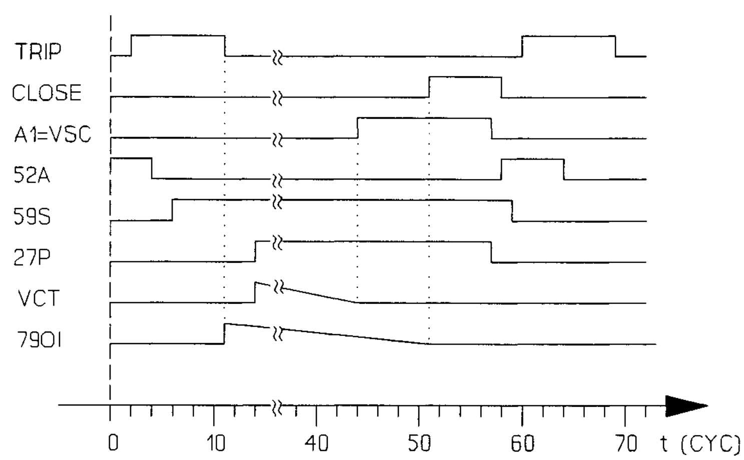

Figure 5.9: Live Bus\Dead-Line Supervised Reclose

Referring to Figure 5.9 at t = 0, a permanent phase-ground fault occurs within the relay Zone 1 reach. The relay detects the fault and asserts the TRIP outputs, fulfilling the first requirement to initiate the reclosing sequence. Because the Z1G Zone 1 ground distance element is set in the Mask for Reclose Initiate, reclosure is initiated.

In response to the relay TRIP signal, the line breaker opens. This causes the RI bit to deassert because the Z1P element drops out. When the breaker opens, the breaker auxiliary contact also opens, deasserting the relay 52A input.

The relay TDUR setting of nine cycles causes the TRIP to remain asserted until cycle 11. No reclose cancel condition occurred, and the other three initiating conditions were fulfilled, so the 79OI timer starts when TRIP drops out.

When the line breaker opens, normal bus voltages are restored. In cycle 6 the 59S element asserts, indicating that VS is above the 59VHI setting. The bus is live for reclosing purposes. In cycle 14 the remote breaker has operated, the line is deenergized, and the 27P element asserts. The line is dead for reclosing purposes. The voltage condition requirements are fulfilled and the VCT timer starts. In cycle 44, the VCT timer expires, the relay asserts the VSC bit, and the relay A1 contact closes.

In cycle 51, the 79OI timer expires. The relay issues the CLOSE signal. Because the A1 contact (wired in series with the CLOSE contact) is also closed, the breaker close coil is energized and the breaker recloses. The 52A input is asserted by closure of the breaker auxiliary contact.

When the breaker closes, the phase-ground fault is reenergized. The relay Z1G element picks up causing the relay to TRIP and the RI bit to assert. Again, the breaker opens and the 52A input deasserts. Because the available reclosing shot has operated, when the relay trips a second time, the recloser is locked out and the breaker remains open.

Example 4: Sync-Check Supervised Reclose

This example shows a successful sync-check supervised reclosing sequence. Table 5.5 shows the recloser settings used for Example 4. Settings not shown in Table 5.5 are identical to the example settings calculated earlier in this section. Figure 5.10 shows the timing of Example 4. Settings marked N/A are not applicable to the example.

Table 5.5: Recloser Settings for Example 4

PSVC	N/A
27VLO	N/A
59VHI	**106.2**
25DV	**53.12**
SYNCP	**A**
25T	**300** cycles
VCT	N/A
79OI	**350** cycles
79RS	**240** cycles
TDUR	**9** cycles

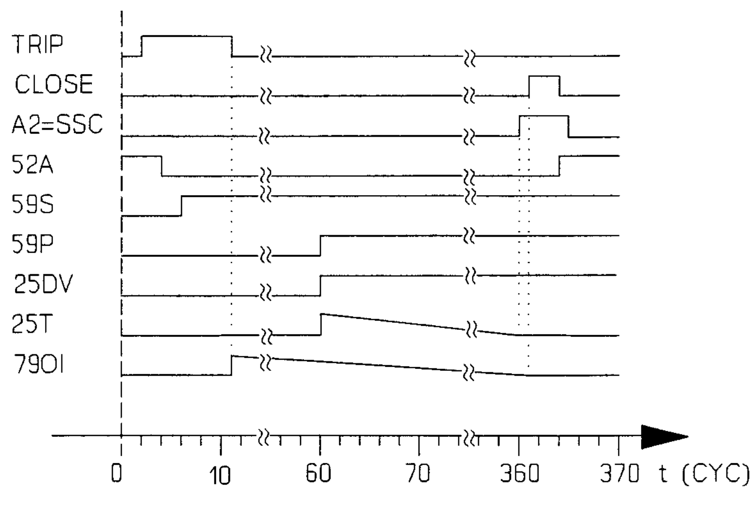

Figure 5.10: Sync-Check Supervised Reclose Sequence

Referring to Figure 5.10 at t = 0, a nonpermanent phase-ground fault occurs within the relay Zone 1 reach. The relay detects the fault and asserts the TRIP outputs, fulfilling the first requirement to initiate the reclosing sequence. Because the Z1G Zone 1 ground distance element is set in the Mask for Reclose Initiate, reclosure is initiated.

In response to the relay TRIP signal, the line breaker opens. This causes the RI bit to deassert because the Z1P element drops out. When the breaker opens, the breaker auxiliary contact also opens, deasserting the relay 52A input.

The relay TDUR setting of nine cycles causes the TRIP to remain asserted until cycle 11. No reclose cancel condition occurred, and the other three initiating conditions were fulfilled, so the 79OI timer starts when TRIP drops out.

When the line breaker opens, normal bus voltages are restored. In cycle 6 the 59S element asserts, indicating that VS is above the 59VHI setting. The bus is live for reclosing purposes. In cycle 60, remote breaker has reclosed, the line is reenergized, and the 59P element asserts. The line is live for reclosing purposes. The magnitude of the difference voltages falls below the relay 25DV setting, fulfilling the voltage condition requirements for the sync-check function. The 25T timer starts. In cycle 360, the 25T timer expires, sync-check conditions have been fulfilled. The relay asserts the SSC bit, and the relay A2 contact closes.

In cycle 361, the 79OI timer expires. The relay issues the CLOSE signal. Because the A2 contact (wired in series with the CLOSE contact) is also closed, the breaker close coil is energized and the breaker recloses. The relay shot counter (not shown) advances to 1 and the 52A input is asserted by closure of the breaker auxiliary contact.

SETTINGS SHEET FOR SEL-121F RELAY

SUBSTATION ______ CIRCUIT ______

BREAKER ______ DEVICE NO. ______

FUNCTION ______

MAKE ______ C.T. SETTING ______

MODEL/STYLE NO. ______ P.T. SETTING ______

PART # ______ SOFTWARE VERSION ______

SERIAL #______ POWER SUPPLY ______ VOLTS ac/dc LOGIC INPUT ____ Vdc

SECONDARY INPUTS: V/φ = 67L-N, NOMINAL AMPS = 5, Hz = 60

MASK: MTU (UNCONDITIONAL TRIP)

									HEXADECIMAL REPRESENTATION SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MPT (PERMISSIVE TRIP)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MTB (BLOCK TRIP)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

DATE ___________

SETTINGS SHEET FOR SEL-121F RELAY

MASK: MTO (SWITCH-ONTO-FAULT)

									HEXADECIMAL REPRESENTATION SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MA1 (A1 CONTACT)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MA2 (A2 CONTACT)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MA3 (A3 CONTACT)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MA4 (A4 CONTACT)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

SETTINGS SHEET
FOR SEL-121F RELAY

MASK: MRI (RECLOSE INITIATE)

									HEXADECIMAL REPRESENTATION SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

MASK: MRC (RECLOSE CANCEL)

									SETTING
ROW #1: RELAY WORD BINARY REPRESENTATION	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q	
ROW #2: RELAY WORD BINARY REPRESENTATION	67N	51NP	51NT	50NG	50P	50H	IN1	REJO	
ROW #3: RELAY WORD BINARY REPRESENTATION	LOP	52BT	27S	27P	59S	59P	SSC	VSC	

BINARY	HEXADECIMAL
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

ACCESS Command passwords: (6 Characters excluding "SPACE, COMMA, SEMI-COLON and SLASH")

LEVEL 0: "=" **ACCESS <ENTER>**
PASSWORD: ________________

LEVEL 1: "=>" **2ACCESS <ENTER>**
PASSWORD: ________________

LEVEL 2: "=>>" ENTER SETTINGS PER MATRIX TABLE

NOTE: FOR NEW RELAYS BEGIN WITH LEVEL 1 PASSWORD = OTTER AND LEVEL 2 PASSWORD = TAIL. WHEN IN LEVEL 2 MODIFY PASSWORDS VIA PASSWORD 1 AND 2 COMMANDS.

SETTINGS SHEET
FOR SEL-121F RELAY

DATE ____________

DESCRIP.	POS SEQ. IMPEDANCE		ZERO SEQ. IMPEDANCE		LINE LENGTH*
RANGE	0-9999 (PRI. OHMS)		0-9999 (PRI. OHMS)		0.1-999 MILES
ABBREV. SETTING	**R1**	**X1**	**R0**	**X0**	**LL**
DESCRIP.	C. T. RATIO	P. T. RATIO	SYNCHRON. VOLTAGE TRANS. RATIO	MAX. TORQUE ANGLE	
RANGE	1-6,000:1	1-10,000:1	1-10,000:1	47°-90°	
ABBREV. SETTING	**CTR**	**PTR**	**SPTR**	**MTA**	
DESCRIP.	RECL. OPEN INTERVAL	RECLOSER RESET TIME			
RANGE	0-8,000 CYCLES (¼ CYCLE STEPS)	60-8,000 CYCLES (¼ CYCLE STEPS)			
ABBREV. SETTING	**79OI**	**79RS**			
DESCRIP.	POL. & SYNC. VOLTAGE CHECKS	DEAD VOLTAGE THRESHOLD	LIVE VOLTAGE THRESHOLD	DIFF. VOLTAGE THRESHOLD	SYNC. PHASE
RANGE	(S, P, E, OR N)	(0-80V_{L-N} SEC) 0-2,000 kV	(0-80V_{L-N} SEC) 0-2,000 kV	(0-125V SEC) 0-2,000 kV	(A, B, OR C)
ABBREV. SETTING	**PSVC**	**27VLO**	**59VHI**	**25DV**	**SYNCP**
DESCRIP.	SYNC. TIMER	VOLTAGE COND. TIMER			
RANGE	(0-8,000 CYC.)	(0-8,000 CYC.)			
ABBREV. SETTING	**25T**	**VCT**			
DESCRIP.	A1 OUTPUT PICKUP DELAY	A1 OUTPUT DROPOUT DELAY			
RANGE	(0-8,000 CYC.)	(0-8,000 CYC.)			
ABBREV. SETTING	**A1TP**	**A1TD**			
DESCRIP.	ZONE 1 REACH	ZONE 2 REACH**	ZONE 3 REACH**		
RANGE	(0.125-64Ω SEC) 0-2,000% OF R1+jX1	(0.125-64Ω SEC) 0-3,200% OF R1+jX1	(0.125-64Ω SEC) 0-3,200% OF R1+jX1		
ABBREV. SETTING	**Z1%**	**Z2%**	**Z3%**		

SETTINGS SHEET
FOR SEL-121F RELAY

DATE ______

DESCRIP. RANGE	ZONE 2 DELAY PHASE-TO-PHASE 3-2,000 CYC. (¼ CYCLE STEPS)	ZONE 2 DELAY GROUND FAULTS 3-2,000 CYC. (¼ CYCLE STEPS)	ZONE 3 DELAY $\phi\phi$ & GND FAULTS 3-2,000 CYC. (¼ CYCLE STEPS)	TRIP DURATION TIMER 0-2,000 CYC. (¼ CYCLE STEPS)	
ABBREV. SETTING	**Z2DP**	**Z2GP**	**Z3D**	**TDUR**	
DESCRIP. RANGE	RESIDUAL & ϕ O/C PICKUP (0.5-25*51NP A) 0.25-50,000 A P	PHASE O/C PICKUP (0.5-40 A SEC) 0.25-50,000 A P	PHASE O/C HIGH PICKUP (0.5-40 A SEC) 0.25-50,000 A P		
ABBREV. SETTING	**50NG**	**50P**	**50H**		
DESCRIP. RANGE	RES. TIME O/C PICKUP (0.5-8.0 A SEC) 0.25-50,000 A P	RES. TIME O/C TIME DIAL 0.5-15	RES. TIME O/C CURVE INDEX (1,2,3, OR 4)	RES. TIME O/C TORQUE CONTROL (Y OR N)	
ABBREV. SETTING	**51NP**	**51NTD**	**51NC**	**51NTC**	
DESCRIP. RANGE	RES. INSTANT. O/C PICKUP (0.5-50*51NP A) 0.25-50,000 A P	RES. INSTANT. O/C TORQUE CON. (Y OR N)	52B TIME DELAY 0.5-10,000 CYCLES	PER. TRIPPING REMOTE END OPEN (N, P, OR G)	BLOCK DIST. ELEMENTS ON LOP (Y,N,1,2,3,4)
ABBREV. SETTING	**67NP**	**67NTC**	**52BT**	**REJOE**	**LOPE**
DESCRIP. RANGE	SEL-121F PORT #1 TIMEOUT (0-30 MINUTES)	SEL-121F PORT #2 TIMEOUT (0-30 MINUTES)	AUTOMATIC MESSAGE TRANS. AUTOPORT (PORT 1,2,3)	# RINGS AFTER WHICH MODEM ANSWERS (1-30)	
ABBREV. SETTING	**TIME1**	**TIME2**	**AUTO**	**RINGS**	

SETTINGS SHEET
FOR SEL-121F RELAY

DATE ___________

*   Line Length = Station #1 (relay location) to Station #2; the full distance in miles or kilometers between stations.

**   Zones 2 and 3 are limited as follows: ohmic range is 0.125 to 64 ohms secondary.

Zone 1 < Zone 2 < Zone 3

Comments: ____

Settings recommended by ______________________________

Settings approved by ______________________________

Settings approved by ______________________________

Settings performed by ______________________________

Test printout required ___ Yes ___ No   Substation ______________

INSTALLATION
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INSTALLATION

Mounting

The relay is designed for mounting by its front vertical flanges in a 19" vertical relay rack. It may also be mounted semi-flush in a switchboard panel. Use four #10 screws for mounting. Front and rear panel drawings are included in this manual.

Frame Ground Connection

Terminal 35 or 36 on the rear panel must be connected to frame ground for safety and performance. These terminals connect directly to the chassis ground of the instrument.

Power Connections

Terminals 37 and 38 on the rear panel must be connected to a source of control voltage. Control power passes through these terminals to the fuse(s) and a toggle switch, if installed. The power continues through a surge filter and connects to the switching power supply. The control power circuitry is isolated from the frame ground.

Secondary Circuits

The relay presents a very low burden to the secondary potential and current circuits. It requires four-wire wye potentials and three currents from the power system current transformer secondaries.

Control Circuits

The control inputs are dry. For example, to assert the 52A input, you must apply control voltage to the 52A input terminals. Each input is individually isolated, and a terminal pair is brought out for each input. There are no internal connections between control inputs.

Control outputs are dry relay contacts rated for tripping duty. A metal-oxide varistor protects each contact.

Each control circuit input and output point is bypassed to chassis ground via a 0.0047 uF, 3000 Vdc disc ceramic capacitor.

Communications Circuits

Connections to the two EIA RS-232-C serial communications ports are made via the two nine-pin connectors labelled PORT 1 and PORT 2 on the rear panel. Pins 1 and 9 connect directly to frame (chassis) ground.

Warning: Do not rely upon pins 1 and 9 for safety grounding, since their current-carrying capacity is less than control-power short circuit current and protection levels.

The communications circuits are protected by low-energy, low-voltage MOVs and passive RC filters. You can minimize communications-circuit difficulties by keeping the length of the EIA RS-232-C cables as short as possible. Lengths of twelve feet or less are recommended, and the cable length should never exceed 100 feet. Use shielded communications cable for lengths greater than ten feet. Modems are required for communications over long distances.

Route the communications cables well away from the secondary and control circuits. Do not bundle the communications wiring with secondary or control circuit wiring. If these wires are bundled, switching spikes and surges can cause noise in the communications wiring. This noise may exceed the communications logic thresholds and introduce errors. The IRIG-B clock cable should also be routed away from the control wiring and secondary circuits.

Jumper Selection

All jumpers are on the front edge of the main board. They are easily accessed by removing the top cover or front panel.

EIA RS-232-C Jumpers

JMP105 provides EIA RS-232-C baud rate selection. Available baud rates are 300, 600, 1200, 2400, 4800, and 9600. To select a baud rate for a particular port, place the jumper so it connects a pin labeled with the desired port to a pin labeled with the desired baud rate.

Caution: Do not select two baud rates for the same port. This can damage the baud rate generator.

Password Protection Jumper

Put JMP103 in place to disable password protection. This feature is useful if passwords are not required or when passwords are forgotten.

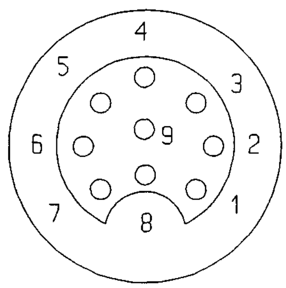
OPEN/CLOSE Command Enable Jumper

With jumper JMP104 in place, the OPEN and CLOSE commands are enabled. If you remove jumper JMP104, executing OPEN and CLOSE commands results in the message: "Aborted."

EIA RS-232-C And IRIG-B Installation

The following information contains specific details regarding communications port pinouts.

A pin definition of the nine-pin port connectors and cabling information for the EIA RS-232-C ports appears in Figure 6.1. The following cable listings show several types of EIA RS-232-C cables. These and other cables are available from SEL. Cable configuration sheets are also available at no charge for a large number of devices. Contact the factory for more information.



(female chassis connector, as viewed from outside rear panel)

Figure 6.1: Nine-Pin Connector Pin Number Convention

EIA RS-232-C Cables

```
SEL Relay            25-Pin *DTE DEVICE

GND  1 ----------------- 7   GND
TXD  2 ----------------- 3   RXD
RTS  3 ----------------- 5   CTS
RXD  4 ----------------- 2   TXD        (SEL  CABLE 123)
CTS  5 ----------------- 4   RTS
+5   6
+12  7
-12  8
GND  9 ----------------- 1   GND
                         6-┐ DSR
                         8-┤ DCD
                        20-┘ DTR
```

```
SEL Relay           25-Pin **DCE DEVICE

GND   1 ---------------- 7   GND
TXD   2 ---------------- 2   RXD
RTS   3 ---------------- 20  DTR        (SEL  CABLE 422)
RXD   4 ---------------- 3   TXD
CTS   5 ---------------- 8   CD
GND   9 ---------------- 1   GND
```

```
SEL Relay                    9-Pin *DTE DEVICE

GND  1 ---------------------- 5  GND
TXD  2 ---------------------- 2  RXD
RTS  3 ---------------------- 8  CTS
RXD  4 ---------------------- 3  TXD        (SEL  CABLE 134)
CTS  5 ---------------------- 7  RTS
                              1-┐ DCD
                              4-┤ DIR
                              6-┘ DSR
                              9  RI
```

```
SEL Relay                       PRTU

GND   1 --------------------- 1  GND
TXD   2 --------------------- 4  RXD
RXD   4 --------------------- 2  TXD        (SEL  CABLE 331A - 338A)
CTS   5 --------------------- 7  +12
+12   7 --------------------- 5  CTS
GND   9 --------------------- 9  GND
```

* DTE = Data Terminal Equipment (terminals, printers, computers, etc.)
** DCE = Data Communications Equipment (modems, etc.)

IRIG-B Input Description

The port labelled J201/AUX INPUT receives demodulated IRIG-B input. Pin definitions appear in Table 6.1.

Table 6.1: AUX INPUT Pin Definition

Pin	Name	Description
2	IRIGIN HI	Positive IRIGB input
3	IRIGIN LOW	Negative IRIGB input
6	+5 *	
7	+12 *	
8	-12 *	
1,5,9	GND	Ground

* Consult the factory before using these power supply outputs

The actual IRIG-B input circuit is a 56 ohm resistor in series with a optocoupler input diode. The input diode has a forward drop of about 1.5 volts. Driver circuits should put approximately 10 mA through the diode when "on."

The IRIG-B serial data format consists of a one second frame containing 100 pulses and divided into fields. The relay decodes the second, minute, hour, and day fields and sets the internal relay clock accordingly.

When IRIG-B data acquisition is activated either manually (with the IRIG command) or automatically, two consecutive frames are taken. The older frame is updated by one second and the two frames are compared. If they do not agree, the relay considers the data erroneous and discards it.

The relay reads the time code automatically about once every five minutes. The relay stops IRIG-B data acquisition ten minutes before midnight on New Year's Eve so the relay clock may implement the year change without interference from the IRIG-B clock. Ten minutes after midnight, the relay restarts IRIG-B data acquisition.

INSTALLATION CHECKOUT

You may follow the suggestions below or combine them with your standard procedures. Never implement recommendations prohibited by the rules of your normal practice.

The following equipment is required for initial checkout:

- Portable terminal or computer
- Control power to the relay power connections
- Source of three-phase voltages and at least one current source
- Ohmmeter or contact opening/closing sensing device

1. Apply control power and make sure the terminal displays the startup message. If not, set AUTO = 2 with the SET command in Access Level 2. Check the settings with the ACCESS and SHOWSET commands. Use the TIME command to set the clock.

2. Apply three-phase voltages in positive-sequence rotation. Execute the METER command and make sure the readings are accurate. If they are not, be sure the correct PT ratio was entered. Remember that displayed values are in primary line-to-neutral and line-to-line kV.

3. Use the TRIGGER command to generate an event record. Type **EVENT 1 <ENTER>** and examine the event record. Refer to the top row of data as the "Y" components and the next row as the "X" components. Plot the three voltage phasors to ensure that they are 120° apart, of reasonable magnitudes, and rotating in the positive-sequence direction. The zero-sequence voltage Y and X components (times a factor of three) are the totals of the three Y components and the three X components.

These sums should be near zero if balanced three-phase potentials are present. See the SEL Direction and Polarity Check Form at the end of this section for this purpose.

4. Use the TARGET command to check the state of all contact inputs and outputs.

5. Proceed to Access Level 2 with the 2ACCESS command and second password. Be sure the ALARM relay contacts close and open when the relay executes 2ACCESS. The ALARM pulse will not be detectable if the ALARM contacts are closed due to an alarm condition.

6. Test the tripping function in any of three ways. First, be sure the circuit breaker can be tripped by OPEN command execution. Second, the circuit breaker may be tripped by IN1 input assertion if the IN1 bit is selected in the MTU mask. Third, the circuit breaker may be tripped by applying voltages and currents representing a fault condition for which the relay should respond. Here, the TRIP relay closes regardless of the 52A contact state, and opens when there are no currents above the 50NG setting, negative-sequence current is below the 46QL threshold, and fault conditions no longer exist. The TRIP output always remains closed for at least the TDUR setting.

7. There are three ways the circuit breaker is closed: by CLOSE command execution, a reclose attempt by the reclosing relay, or DIRECT CLOSE input assertion. The CLOSE output relay closes for all of these conditions if the 52A input is not asserted (indicating the circuit breaker is open) and no trip condition is present. The CLOSE relay opens when the 52A input is asserted or the 79RS timer expires, whichever occurs first.

8. If the Permissive Trip and Block Trip inputs are used, check them for proper operation (see the LOGIC MPT and LOGIC MTB settings in Section 3: COMMUNICATIONS). An event record should be generated after each PT or BT input assertion.

9. Assert the External Trigger input. This should trigger an event record, but does not affect the protective relaying functions in any way.

10. Use the STATUS command to inspect the self test status. You may wish to save the reading as part of an "as-left" record.

When local checkout is complete, check communications with the instrument via a remote interface (if used). Make sure the automatic port is properly assigned and that desired timeout intervals are selected for each port. Also, be sure to record password settings.

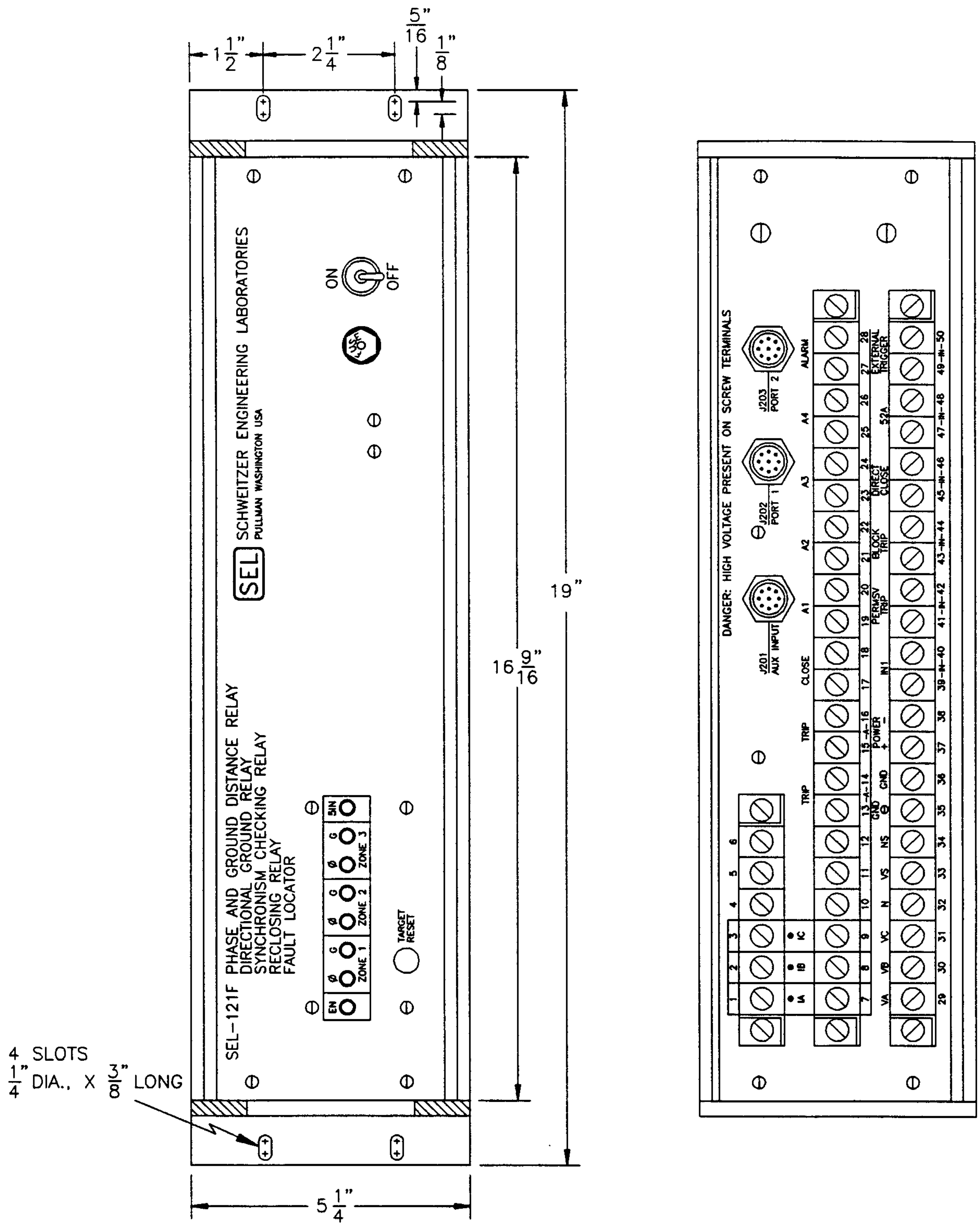


Figure 6.2: Horizontal Front and Rear Panel Drawings

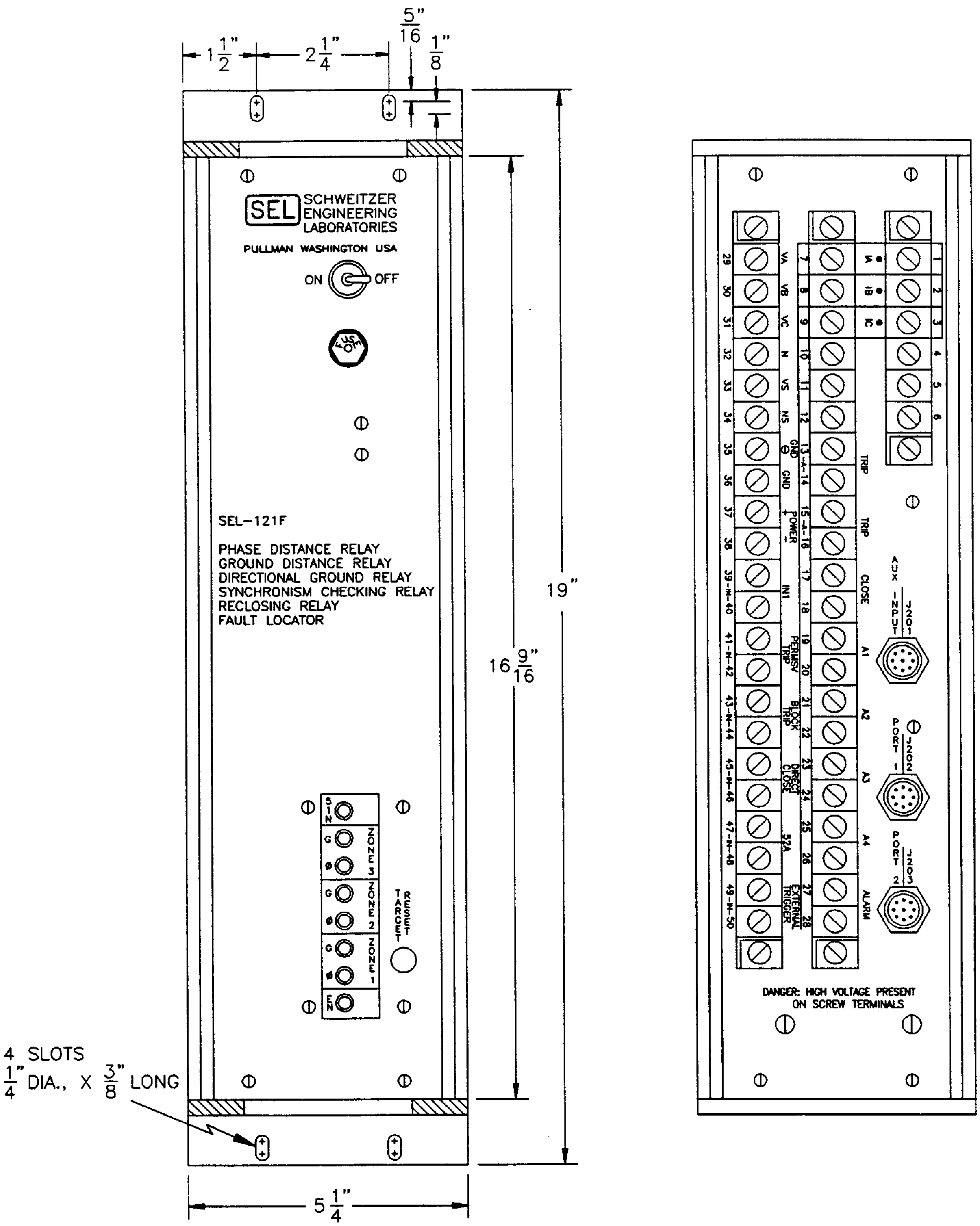
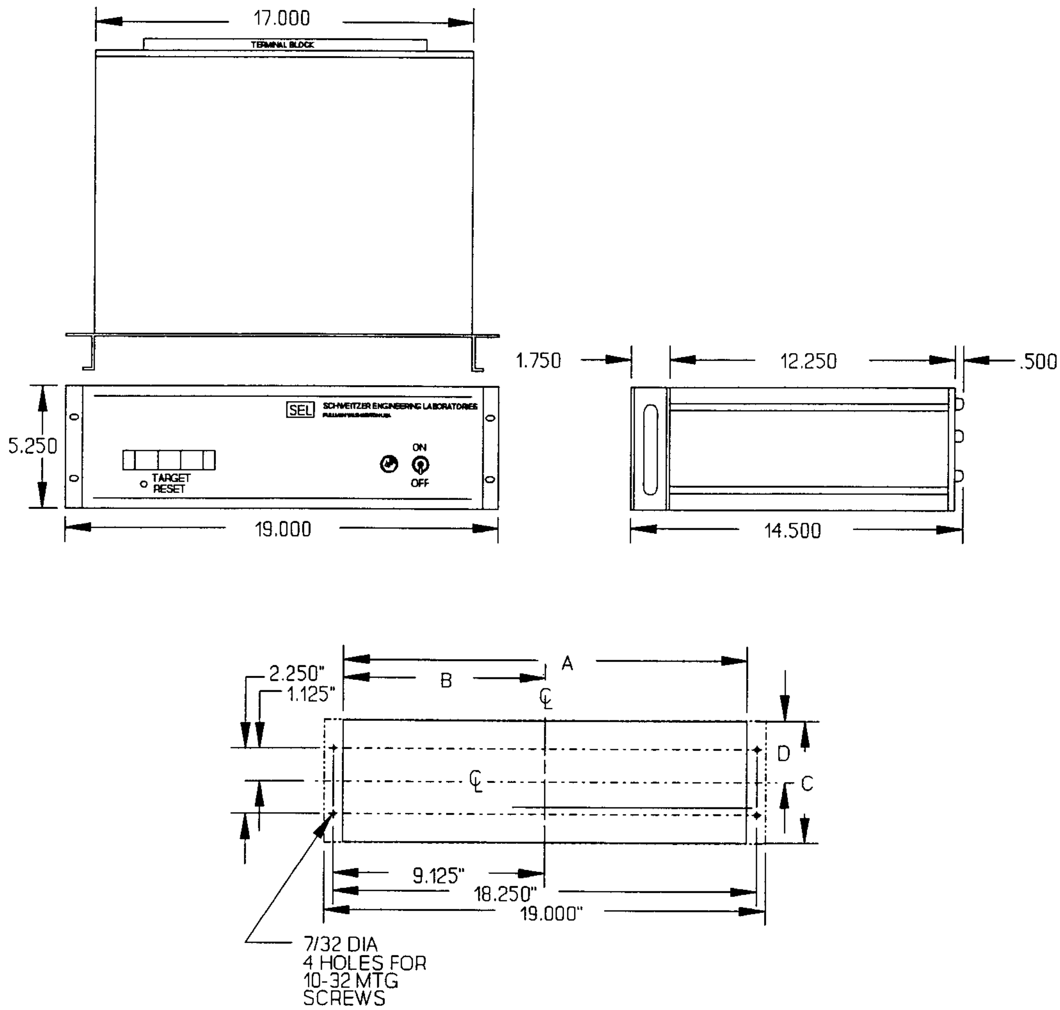


Figure 6.3: Vertical Front and Rear Panel Drawings



DIMENSION A:
CUT OUT: 17.250" - 17.875"
17.375" PREFERRED

DIMENSION B:
CUT OUT: 8.625" - 8.9375"
8.688" PREFERRED

DIMENSION C:
CUT OUT: 5.350" - 5.450"

DIMENSION D:
CUT OUT: 2.675" - 2.725"

NOTE: ALL INSTRUMENTS MAY BE MOUNTED HORIZONTALLY (AS SHOWN) OR VERTICALLY.

PANEL CUTOUT AND DRILL FOR SEMI-FLUSH MOUNTING OF 5.250 INCH HIGH CASE.

Figure 6.4: Relay Dimensions, Panel Cutout, and Drill Plan

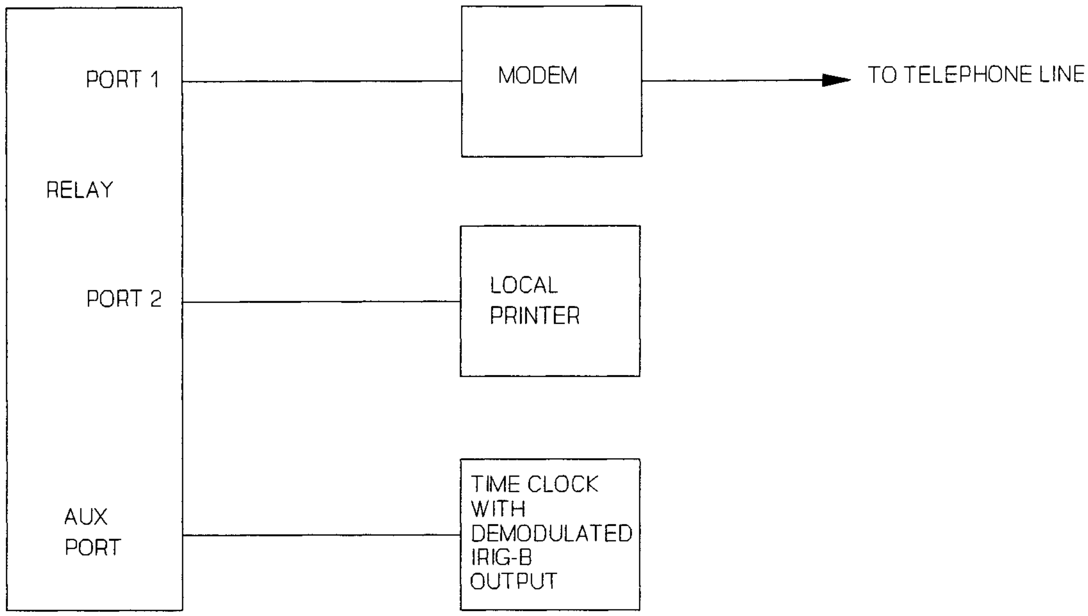


Figure 6.5: Communications and Clock Connections - One Unit at One Location

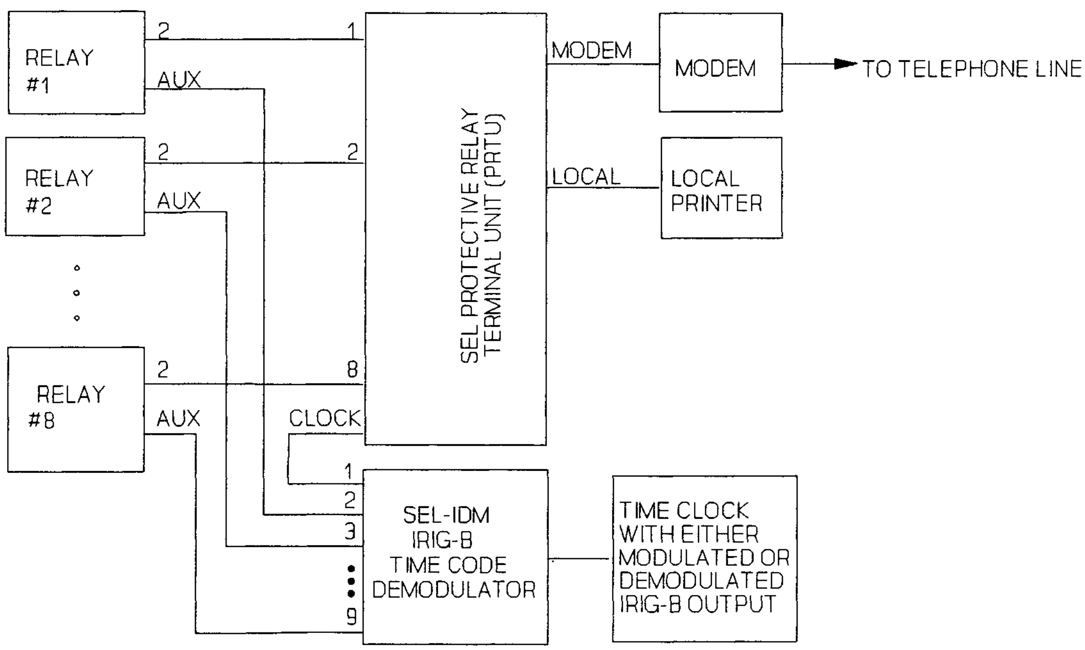


Figure 6.6: Communications and Clock Connections - Multiple Units at One Location

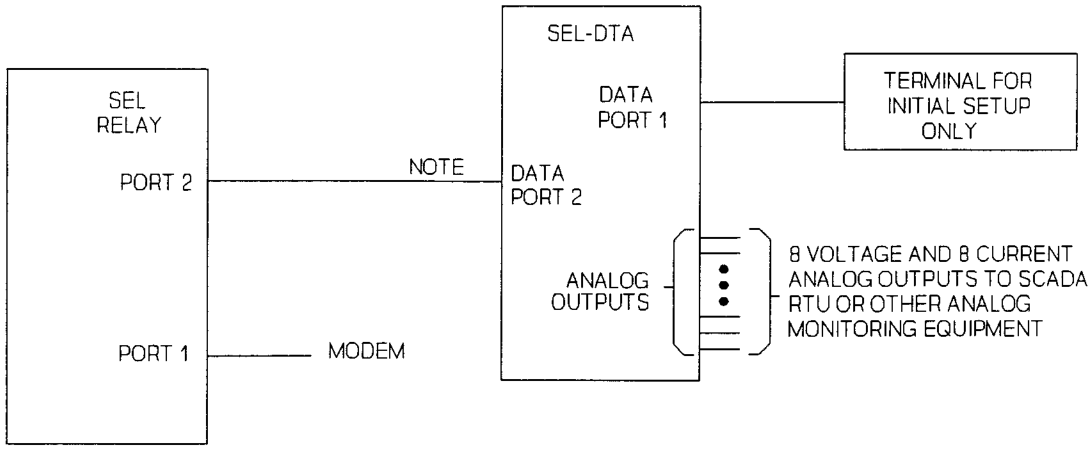


Figure 6.7: SEL Relay Communications Diagram for Connection to the SEL-DTA

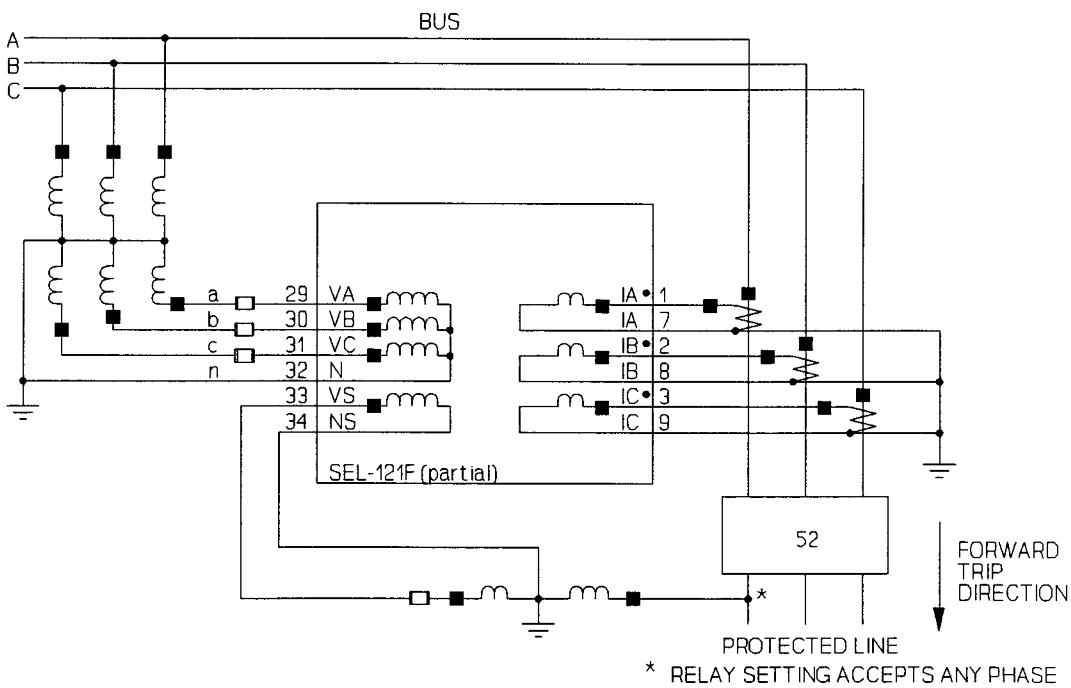


Figure 6.8: External Current and Voltage Connections

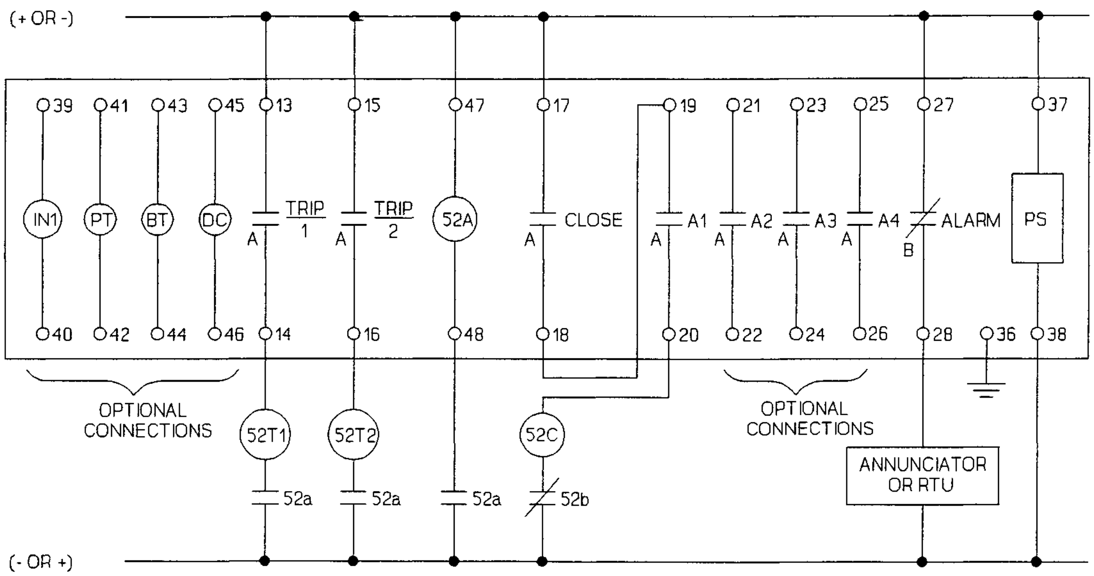


Figure 6.9: DC External Connection Diagram (Typical)

SEL DIRECTION AND POLARITY CHECK FORM

STATION ______________________ DATE: ___/___/___ TESTED BY ______________

SWITCH NO. ______________ EQUIPMENT ______________________

INSTALLATION ________ ROUTINE ________ OTHER ______________________

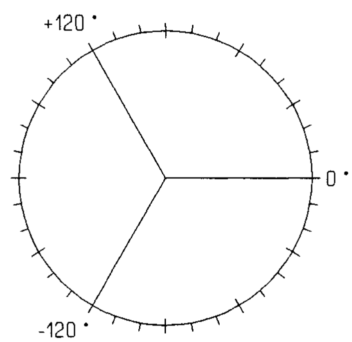
LOAD CONDITIONS:

STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS

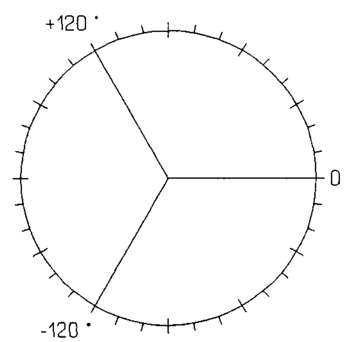
SEL READINGS: ________ MW (+)(-) ________ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I( )	I( )	I( )	V( )	V( )	V( )	
1st LINE CHOSEN (Y COMPONENT)							
2nd LINE CHOSEN (X COMPONENT)							
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$							ROW 1
ANGLE IN DEGREES ARCTAN Y/X							
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0							
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM							ROW 2

USE THE VALUES IN ROWS 1 AND 2 ABOVE TO DRAW PHASOR DIAGRAMS BELOW



CURRENTS



VOLTAGES

SEL DIRECTION AND POLARITY CHECK FORM

STATION ______________________________ DATE: ___/___/___ TESTED BY ____________________

SWITCH NO. ____________________ EQUIPMENT ______________________________

INSTALLATION ________ ROUTINE _______ OTHER ______________________________

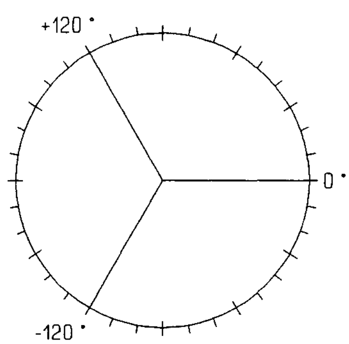
LOAD CONDITIONS:

STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS

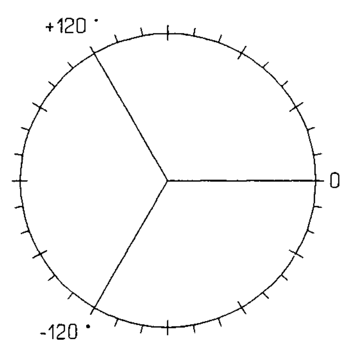
SEL READINGS: ________ MW (+)(-) ________ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I( )	I( )	I( )	V( )	V( )	V( )	
1st LINE CHOSEN (Y COMPONENT)							
2nd LINE CHOSEN (X COMPONENT)							
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$							ROW 1
ANGLE IN DEGREES ARCTAN Y/X							
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0							
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM							ROW 2

USE THE VALUES IN ROWS 1 AND 2 ABOVE TO DRAW PHASOR DIAGRAMS BELOW



CURRENTS



VOLTAGES

MAINTENANCE & TESTING
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FIGURES

MAINTENANCE & TESTING

TEST PROCEDURES

Test Aids Provided by the Relay

The following features assist you during relay testing and calibration:

METER Command

The METER command shows the voltages and currents presented to the relay in primary values. The relay calculates Megawatts (MW) and Megavars (MVAR) from these voltages and currents. These quantities are useful for comparing relay calibration against other meters of known accuracy.

When testing the relay, first verify relay calibration against meters of known accuracy. Each relay is calibrated at the factory prior to shipment and should not require further adjustments. If calibration is necessary, refer to the Calibration portion of this section. Consider all tests invalid if you determine that the relay is out of calibration.

TARGET Command

The relay allows you to reassign front panel targets to indicate elements and intermediate logic results in the Relay Word as well as input and output contact status. Use the TARGET command to reassign the front panel LEDs. Once target LEDs are reassigned from the default targets, the front panel targets are no longer latching. This means the targets follow the pickup and dropout condition in much the same manner as an output contact. See Section 3: COMMUNICATIONS for more information about the TARGET command.

By using the target LEDs for testing, you need not change the relay settings during testing.

Event Reporting

The relay generates an eleven cycle event report in response to faults or disturbances. Each event report contains voltage and current information, relay element states, and input/output contact information in quarter-cycle resolution. If you question the relay response or your test method, use the event report for more information.

Each event report is date and time tagged relative to the sixteenth quarter-cycle. Each report is triggered upon assertion of designated relay elements and/or contact inputs and outputs. If the timeout of a protective element results in TRIP output contact closure, the trip generates a second event report. Thus, the relay generates two event reports: the first when the instantaneous element asserts, the second when the TRIP output contact closes. Where time delayed pickup (TDPU) timers are concerned, the time tag in the event reports may be used to determine the validity of a TDPU timer setting. Simply subtract the latest event report time tag from the previous event report time tag. Section 4: EVENT REPORTING has further details concerning event report generation.

Programmable Logic

Programmable logic allows you to isolate individual relay elements. See the LOGIC command description in Section 3: COMMUNICATIONS for further details.

Test Methods

There are two means of determining the pickup and dropout of relay elements: target lamp illumination and output contact closure.

Testing Via Target LED Illumination

During testing you can use target lamp illumination to determine relay element status. Using the TARGET command, set the front panel targets to display the element under test. For example, the Zone 1 phase distance element appears in Relay Word row 1. When you type the command **TARGET 1 <ENTER>**, the LEDs display the status of the elements in Relay Word row 1. Thus, with Target 1 displayed, if the Zone 1 phase distance element (Z1P) asserts, the left most LED illuminates. Using LED illumination as an indicator, you can measure the element operating characteristics.

When the TARGET command sets the target LED output to a level other than 0 (Relay Targets), the front panel target markings are no longer relative to illuminated LEDs and the LEDs do not latch.

If you place the relay in service with the target level other than Level 0, it automatically reverts to target Level 0 when an automatic message transmits to a timed out port. While this feature prevents confusion among station operators and readers, it can be inconvenient if the relay tester does not want targets to revert to Level 0. Targets remain in the specified level if you set timeout setting equal to 0 for the communications ports selected by the AUTO setting. This prevents automatic message transmission to a port which may be timed out.

Testing Via Output Contact Assertion

To test using this method, set one programmable output contact to assert when the element under test picks up. With the LOGIC command, set a 1 in the mask for the element under test. Set all other elements in that mask to 0.

For an "a" contact, when the condition asserts, the output contact closes. When the condition deasserts, the output contact opens. For a "b" contact, when the condition asserts, the output contact opens. When the condition deasserts, the output contact closes. Programmable contacts can be specified at the factory as either an "a" or "b." Using contact operation as an indicator, you can measure element operating characteristics, stop timers, etc.

Tests in this chapter use the output contact method and assume an "a" output contact.

Using a Breaker Simulator

Because the switch-onto-fault and recloser logic depend on whether the breaker is open (52A deenergized) or closed (52A energized), it is important to use a breaker simulator for these tests. We recommend testing the relay with a latching relay to simulate line breaker auxiliary contact action. This ensures proper assertion and deassertion of the 52A input contact on the back panel. If you do not have a means of simulating breaker action and status, zero out the MTO logic mask and omit the recloser tests.

INITIAL CHECKOUT

The initial checkout procedure should familiarize you with the relay and ensure that all functions are operational. For a complete understanding of the relay capabilities, study Functional Specification and Description in Section 2: SPECIFICATIONS, command descriptions in Section 3: COMMUNICATIONS, and Section 4: EVENT REPORTING.

Minimum Equipment Required

The following equipment is necessary for initial checkout.

1. Terminal with EIA RS-232-C serial communication interface
2. Interconnecting cable between terminal and relay
3. Source of control power
4. Source of three-phase voltages and at least two currents
5. Ohmmeter or contact opening/closing sensing device

Checkout Procedure

In the procedure below, you will use several relay commands. Section 3: COMMUNICATIONS provides a full explanation of all commands. The following information should allow you to complete the checkout without referring to the detailed descriptions in Section 3.

Note: In this manual, commands to type appear in bold/uppercase: **OTTER**. Keys to press appear in bold/uppercase/brackets: **<ENTER>**.

Relay output appears in the following format:

```
Example 230 kV Line        Date: 6/2/92    Time: 01:01:01
```

Step 1

Purpose: Be sure you received the relay in satisfactory condition.

Method: Inspect the instrument for physical damage such as dents or rattles.

Step 2

Purpose: Verify the requirements for the relay logic inputs, control power voltage level, and voltage and current inputs.

Method: Refer to the information sticker on the rear panel of the relay. Figure 7.1 provides an example. It is important that you read the information on this sticker before applying power to the relay or starting tests. Be sure your dc supply is correctly adjusted for the control and logic input requirements.

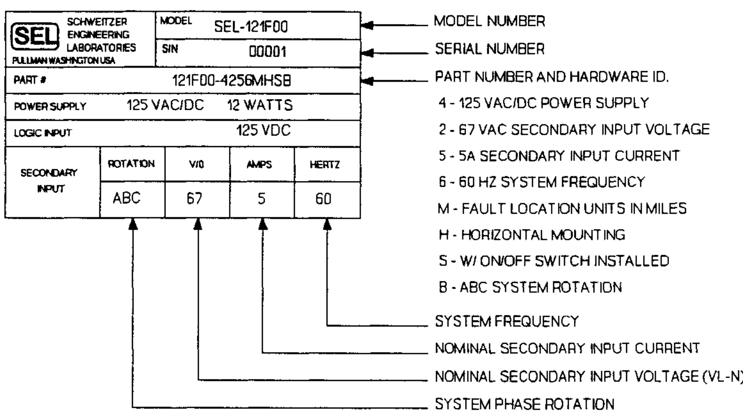


Figure 7.1: Relay Part Number and Hardware Identification Sticker

Step 3

Purpose: Verify the communications interface setup.

Method: Connect a computer terminal to PORT 2 on the relay rear panel. The terminal should be configured to 2400 baud, eight data bits, and no parity. The terminal should be set to two stop bits for standard (-E2) relay versions, or one stop bit for specially ordered (-E1) relays. The relay is shipped from the factory with PORT 2 set to 2400 baud and PORT 1 set to 300 baud. Section 3: COMMUNICATIONS provides additional information about port configurations. Baud rate selection is described under Jumper Selection in Section 6: INSTALLATION. Figure 7.2 shows the typical communication interface setup for testing purposes.

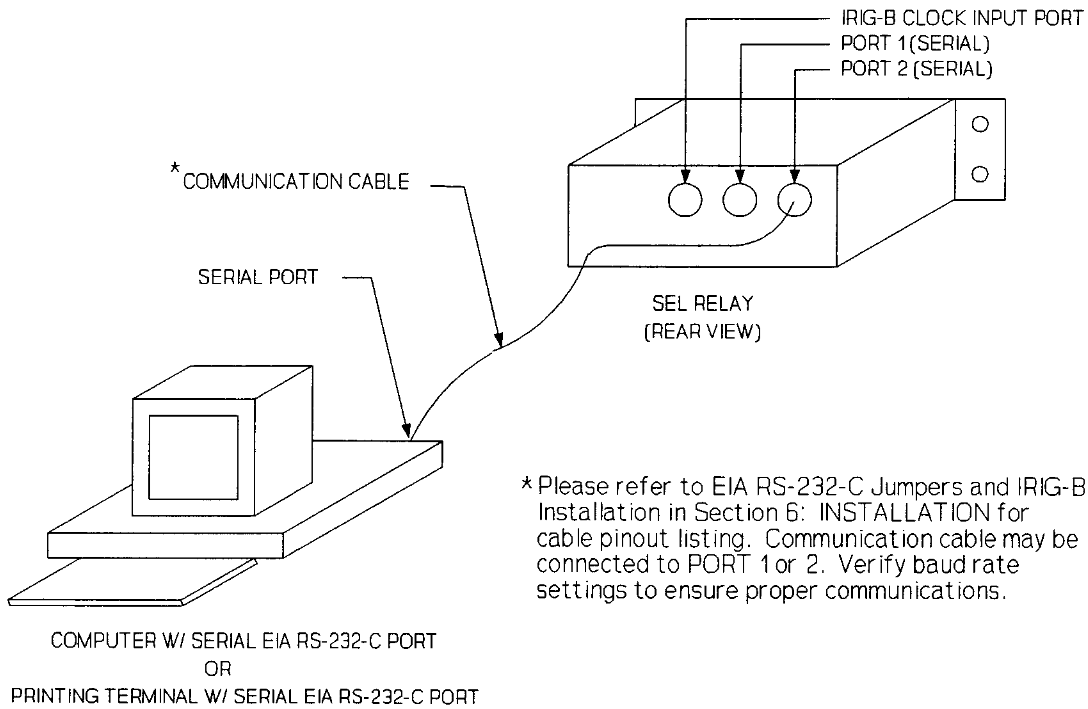


Figure 7.2: Communication Interface Setup

Step 4

Purpose: Establish control power connections.

Method: Connect a frame ground to terminal 36 on the rear panel and connect rated control dower to terminals 37 and 38. Polarity is unimportant. Relays supplied with 125 or 250 V power supplies may be powered from a 115 Vac wall receptacle for testing. In the final installation, we recommend that the relay receive control power from the station dc battery to avoid losing events stored in volatile memory when station service is lost.

Step 5

Purpose: Apply control voltage to the relay and start Access Level 0 communications.

Method: Turn on the relay power. The enable target (EN) should illuminate. If not, be sure that power is present and check the fuse or fuses. The following message should appear on the terminal:

```
Example 230 kV Line            Date: 6/2/92     Time: 01:01:01

SEL-121F
=
```

The ALARM relay should pull in, holding its "b" contacts (terminals 27,28) open. If the relay pulls in but no message is received, check the terminal configuration. If neither occurs, turn off the power and refer to Troubleshooting later in this section.

The = prompt indicates that communications with the relay are at Access Level 0, the first of three levels. The only command accepted at this level is ACCESS, which opens communications on Access Level 1.

Note: If you are using a battery simulator, be sure the simulator voltage level is stabilized before turning the relay on.

Step 6

Purpose: Establish Access Level 1 communications.

Method: Type **ACCESS** and press **<ENTER>**. At the prompt, enter the Access Level 1 password **OTTER** and press **<ENTER>**. The => prompt should appear, indicating that you have established communications at Access Level 1.

Step 7

Purpose: Verify self test status of the relay.

Method: Type **STATUS** and press **<ENTER>**. The following display should appear on the terminal:

```
Example 230 kV Line            Date: 6/2/92     Time: 01:04:56

SELF TESTS

W=Warn   F=Fail

      IR    IA    IB    IC    VA    VB    VC    VS
OS    0     0     0     0     0     0     0     0
PS     5.08       14.92       -14.99
RAM    ROM   A/D     MOF    SET
OK     OK    OK      OK     OK

=>
```

Step 8

Purpose: View the demonstration settings entered before shipment.

Method: The relay is shipped with demonstration settings; type **SHOWSET <ENTER>** to view the settings. The terminal should display the following:

```
=>SHOWSET <ENTER>

Settings for: Example 230 kV Line

R1   =13.90    X1   =79.96    R0   =41.50    X0   =248.57   LL   =100.00
CTR  =200.00   PTR  =2000.00  SPTR =2000.00  MTA  =80.10
79OI =40.00    79RS =240.00
PSVC =S        27VLO=26.60    59VHI=106.20   25DV =53.12    SYNCP=A
25T  =300.00   VCT  =30.00
A1TP =0.00     A1TD =0.00
Z1%  =80.00    Z2%  =120.00   Z3%  =150.00
Z2DP =30.00    Z2DG =30.00    Z3D  =40.00    TDUR =9.00
50NG =250.00   50P  =370.00   50H  =1500.00
51NP =270.00   51NTD=3.00     51NC =2        51NTC=Y
67NP =650.00   67NTC=Y        52BT =30       REJOE=N        LOPE =Y
TIME1=5        TIME2=0        AUTO =2        RINGS=7

Logic settings:

MTU  MPT  MTB  MTO  MA1  MA2  MA3  MA4  MRI  MRC
F4   08   00   FC   00   00   F0   04   F0   04
A2   00   00   A4   00   00   80   20   80   20
00   00   00   00   02   01   00   00   00   00


=>
```

The SET and LOGIC command descriptions in Section 3: COMMUNICATIONS include a complete explanation of the settings.

Each column in the logic settings display shows masks for the four rows of the Relay Word as follows:

Relay Word row 1:	Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q
Relay Word row 2:	67N	51NP	51NT	50NG	50P	50H	IN1	REJO
Relay Word row 3:	LOP	52BT	27S	27P	59S	59P	SSC	VSC

Logic settings appear in hexadecimal format. A table and example of hexadecimal to binary conversion appears with the SHOWSET command description in Section 3: COMMUNICATIONS.

Step 9

Purpose: Connect voltage and current sources to the relay.

Method: Turn power off and connect a source of three-phase voltages to the relay at terminals 29, 30, 31, and 32 (See Figure 7.8b). Apply 67 volts per phase (line-to-neutral) in positive-sequence rotation. Wye-connect the two current sources as shown in Figure 7.8b to generate balanced positive-sequence currents:

9a. Connect the A-phase and B-phase current sources to the dotted A and B current input terminals (1 and 2 respectively).

9b. Connect both undotted A and B current input terminals (7,8) to the undotted C current input terminal (9).

9c. Connect the dotted C current input terminal (3) to both the A and B current source returns.

9d. Set the A-phase current source to 2 amperes, at the same angle as the A-phase voltage. Set the B-phase current source to 2 amperes, at the same angle as the B-phase voltage.

Step 10

Purpose: Verify that a loss-of-potential condition is not present with balanced three-phase voltages applied to the relay.

Method: Turn the relay power on and enter Access Level 1. Type **TARGET 3 <ENTER>**. The TARGET 3 command sets the relay to display Relay Word row 3 on the front panel LEDs. The LOP bit is the first element in row 3, displayed on the LED labeled EN. With balanced positive-sequence potentials applied to the relay, the LOP bit should drop out causing the EN LED to go out. Type **TARGET 0 <ENTER>** to reset the LED display to relay targets.

Step 11

Purpose: Verify correct voltage and current connections and levels.

Method: Use the METER command to measure the voltages and currents applied in Step 10. With applied voltages of 67 volts per phase and a potential transformer ratio of 2000:1, the displayed line-to-neutral voltages should be 134 kV. With applied currents of 2.0 amperes per phase and a current transformer ratio of 200:1, the displayed line-to-neutral currents should be 400 amperes. All line-to-line quantities should be balanced, differing from the line-to-neutral measurements by a factor of 1.73. Real power P should be approximately 160.1 MW; reactive power Q should be approximately 0 MVAR.

```
=> METER <ENTER>

Example 230kV Line          Date: 06/02/92       Time: 00:01:00

                A       B       C      AB      BC      CA  IR/VS
I (A)         401     398     399     695     690     691      0
V (kV)      134.4   134.4   134.4   233.1   232.8   232.9    0.0

P (MW)      161.01
Q (MVAR)      1.02

v=>
```

If you inadvertently switched or rolled a pair of voltage or current connections, the MW reading should be incorrect.

Step 12

Purpose: Test the fault locator.

Method: Test the fault locator using the voltages and currents in Table 7.1. These voltages and currents were obtained for various locations and fault types assuming a radial line with a source impedance of 0.75 times the total 100 mile line impedance. A listing of this BASIC program is included at the end of this section.

Note: To simplify this step, apply rated logic voltage across the 52A input prior to applying each fault. These inputs should remain energized for the duration of this step to block the switch-onto-fault logic from operating. If a circuit breaker simulator is not available, set all elements in the MTO logic mask to zero.

Table 7.1: Fault Locator Test Values

LOCATION	TYPE	VA	VB	VC	IA	IB	IC	UNITS
75 miles	AG	33.5	74.93	74.81	3.23	0.00	0.00	V or A
		0.00	-129.2	129.2	-80.4	0.00	0.00	Degrees
	BC	67.00	44.32	44.32	0.00	4.77	4.77	V or A
		0.00	-139.1	139.1	0.00	-170.1	9.9	Degrees
85 miles	AG	35.59	74.39	74.27	3.03	0.00	0.00	V or A
		0.00	-128.6	128.7	-80.4	0.00	0.00	Degrees
	BC	67.00	45.52	45.52	0.00	4.47	4.47	V or A
		0.	-137.4	137.4	0.00	-170.1	9.9	Degrees
135 miles	AG	43.07	72.49	72.39	2.31	0.00	0.00	V or A
		0.00	-126.7	126.8	-80.4	0.00	0.00	Degrees
	BC	67.00	50.14	50.14	0.00	3.4	3.40	V or A
		0.00	-131.9	131.9	0.00	-170.1	9.9	Degrees

Faults at 75 miles are within Zone 1, since the Zone 1 reach setting is 80.0% of the 100 mile positive-sequence line impedance (see Z1% in the settings). Faults at 85 miles are beyond Zone 1, but within the 120% setting of Zone 2 (see Z2% in the settings). Faults at 135 miles are beyond Zones 1 and 2, but within Zone 3, set to 150% (see Z3% in the settings).

Faults listed in Table 7.1 cause certain combinations of output relays to close and front panel LEDs to illuminate. Table 7.2 shows the results. Please remember to press the target reset button between faults. Also note that these tests assume you are using a breaker simulator. If you are not using a breaker simulator, remember to zero out the MTO logic mask.

Table 7.2: Output Contact and Target LED Results

LOCATION	TYPE	OUTPUT RELAYS	TARGET LED
75 mi	AG	TRIP, A3	**G1**
75 mi	BC	TRIP, A3	**Ø1**
85 mi	AG	TRIP, A3	**G2**
85 mi	BC	TRIP, A3	**Ø2**
135 mi	AG	TRIP, A4	**G3**
135 mi	BC	TRIP, A4	**Ø3**

Output Contact Explanation

The TRIP output closes in response to any of the following:

1. Any Zone 1 three-phase, phase-phase, or line-to-ground fault
2. Any Zone 2 three-phase or phase-phase fault which persists for 30 cycles
3. Any Zone 2 line-to-ground fault which persists for 30 cycles
4. Any Zone 3 three-phase or phase-phase, or line-to-ground fault which persists for 40 cycles
5. Any forward line-to-ground fault which results in expiration of the residual time-overcurrent element (51NT)
6. IN1 input assertion if IN1 is set in a tripping logic mask
7. OPEN command execution

The A3 output contacts are set to close when reclose initiating fault conditions occur. The A4 output contacts are set to close when reclose cancelling conditions occur.

The programming of output relays A1 - A4 and four trip logic masks is explained in detail in the LOGIC command description, Section 3: COMMUNICATIONS.

Target LED Explanation

G1: The AG ground fault at 75 miles should illuminate the Zone 1 ground fault target.

G2: The AG ground fault at 85 miles should illuminate the G2 target.

G3: The AG ground fault at 135 miles should illuminate only the G3 target.

∅1: The Zone 1 BC fault at 75 miles should illuminate the ∅1 target.

∅2: The Zone 2 BC fault at 85 miles should illuminate only the ∅2 target.

∅3: The Zone 3 BC fault at 135 miles should illuminate only the ∅3 target.

Note: The target level must be at Level 0 to display the fault targets. See the TARGET command description in Section 3: COMMUNICATIONS for more information.

Each fault generates a short event report. To see the full event report for the last fault, type **EVENT 1** and press **<ENTER>**. Each event report provides an eleven-cycle record of the currents, voltages, relay element states, and all contact input and output states. The twelve newest reports are saved in volatile memory.

This checkout procedure demonstrates only a few relay features. For a complete understanding of relay capabilities, study Functional Description in Section 2: SPECIFICATIONS, the command descriptions in Section 3: COMMUNICATIONS, and Section 4: EVENT REPORTING. For more test procedures, see the Full Functional Test portion of this section.

FULL FUNCTIONAL TEST

This procedure allows you to test the protective and control functions of the relay more fully than the initial checkout procedure does.

Equipment Required

The following equipment is necessary to complete a full functional test:

1. Communications terminal with EIA RS-232-C serial communication interface
2. Data cable to connect terminal and relay
3. Source of relay control power
4. Source of synchronized three-phase voltages and at least two currents
5. Ohmmeter or contact opening/closing sensing device
6. Timer with contact inputs for start and stop

What Should Be Tested

A full functional test includes the initial checkout procedure and the additional steps described below. In general, these tests assure that the relay settings match your application rather than checking relay performance. For commissioning purposes, your company policy may require you to perform the full functional test. For maintenance purposes, a quick test of selected fault types and zones should suffice. For example, test a Zone 1 AG fault, Zone 2 BC fault, and a Zone 3 ABC fault.

SETTING TEST

Purpose: Ensure that the relay accepts settings.

Method:

1. Gain Level 2 Access (see ACCESS and 2ACCESS commands in Section 3: COMMUNICATIONS).

2. Change one setting. For example, change the Zone 1 reach from 80 to 82%.

   Type **SET** and press **<ENTER>** several times.

   Following the Z1% prompt, type **82** and press **<ENTER>**.

3. To complete the setting procedure, type **END** and press **<ENTER>**. Type **Y** **<ENTER>** at the prompt: "OK (Y or N) ?" The relay computes internal settings and compares them against fixed limits. If all settings are within acceptable ranges, the ALARM contact closes momentarily as the new settings are enabled unless an alarm condition already exists (e.g., self test failure).

4. Use the SHOWSET command to inspect settings. Make sure your change was accepted.

   Type **SHOWSET** and press **<ENTER>**.

5. Use SET and SHOWSET again to restore the initial values and check the settings.

6. Type **LOG MTU** and press **<ENTER>**.

7. Change one bit in the MTU logic mask. For example, remove the Z3T bit from the first row of the Relay Word as shown in the following example.

```
=>>LOGIC MTU <ENTER>

1 selects, 0 deselects.

Z1P  Z1G  Z2PT Z2GT Z3   Z3T  3P21 32Q
 1    1    1    1    0    1    0    0
 ? 11110000 <ENTER>
 1    1    1    1    0    0    0    0
 ? <ENTER>
67N  51NP 51NT 50NG 50P  50H  IN1  REJO
 1    0    1    0    0    1    0    0
 ? <ENTER>
LOP  52BT 27S  27P  59S  59P  SSC  VSC
 0    0    0    0    0    0    0    0
 ? <ENTER>


New MTU :

Z1P  Z1G  Z2PT Z2GT Z3   Z3T  3P21 32Q
 1    1    1    1    0    0    0    0
67N  51NP 51NT 50NG 50P  50H  IN1  REJO
 1    0    1    0    0    1    1    0
LOP  52BT 27S  27P  59S  59P  SSC  VSC
 0    0    0    0    0    0    0    0

OK (Y/N) ? Y <ENTER>
Enabled

Example 230 kV Line        Date: 6/2/92     Time:02:12:28

=>>
```

8. Type **LOG MTU** and press **<ENTER>**. Make sure the bit change is present.

9. Use LOG MTU and SHOWSET to restore the initial values and check settings.

METER TEST

Purpose: Verify the magnitude accuracy and phase balance. This test only requires a single voltage and current test source.

Method: 1. Parallel all voltage inputs by connecting terminals 29, 30, and 31 with a jumper. See Figure 7.3 for the test connections.

2. Series all current inputs as shown in Figure 7.3.

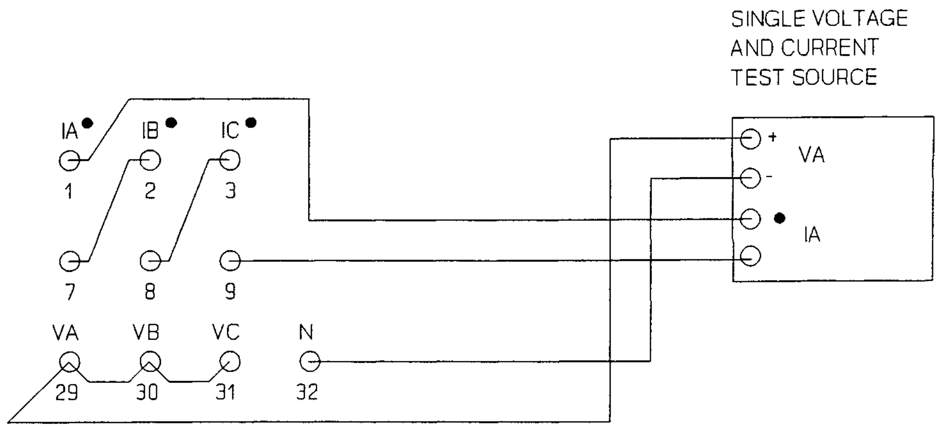


Figure 7.3: METER Test Connections

3. Apply a voltage of 50 Vac between the paralleled voltage inputs to the neutral point and a current of five amperes through the three inputs. The phase angle of the voltage and current source should be set to zero degrees.

4. Use the METER command to inspect measured voltages, currents, and power. Voltages VA, VB, and VC should equal the applied voltage times the potential transformer ratio setting. With the Example 230 kV Line settings, you should obtain:

$$VA = VB = VC = (50\text{ V})(2000) = 100\text{ kV } (\pm 0.5\%).$$

Voltages VAB, VBC, and VCA should read less than 1.5 kV.

Similarly, currents IA, IB, and IC should equal the applied current times the current transformer ratio. With the Example 230 kV Line settings, you should obtain:

$$IA = IB = IC = (5\text{ A})(200) = 1000\text{ A } (\pm 1\%).$$

Difference currents IAB, IBC, and ICA should be less than 20 amperes.
The power reading, P (MW), should read:

$$(VA)(IA) + (VB)(IB) + (VC)(IC) = 300\text{ MW}.$$

The reactive power reading Q (MVAR) should be less than 5 MVAR.

MHO ELEMENT TESTING

Before you begin testing the mho distance elements, determine the test quantities. Refer to the end of this section for a simple program (ONEBUS) to calculate voltages and currents required to simulate a power system fault at the line angle.

Note: ONEBUS is not required to test the relay, it is included in the manual as a test aid.

During mho element tests, we recommend disabling the loss-of-potential (LOP) logic by setting LOPE = N in the setting procedure. This prevents an LOP condition from blocking mho distance elements. You must enable the LOP feature during LOP testing.

A. Determining Fault Simulation Values - Phase-Phase and Phase-Ground Faults

All line impedance entries for the ONEBUS program must be entered in secondary values. Convert the primary impedance settings from your relay setting sheet or SHOWSET printout to secondary values with the following formula:

$$\text{R1 secondary} = \text{R1}\left(\frac{\text{Current Transformer Ratio}}{\text{Potential Transformer Ratio}}\right)$$

$$\text{X1 secondary} = \text{X1}\left(\frac{\text{Current Transformer Ratio}}{\text{Potential Transformer Ratio}}\right)$$

$$\text{R0 secondary} = \text{R0}\left(\frac{\text{Current Transformer Ratio}}{\text{Potential Transformer Ratio}}\right)$$

$$\text{X0 secondary} = \text{X0}\left(\frac{\text{Current Transformer Ratio}}{\text{Potential Transformer Ratio}}\right)$$

Next, calculate required voltages and currents for a single-line-to-ground and phase-phase fault at the boundary of the Zone 1 reach using the example settings provided with the relay. Enter the data shown in bold face from Figure 7.4 into the ONEBUS program:

```
ENTER Z1: R,X? 1.39,7.996 <ENTER>
ENTER Z0: R,X? 4.15,24.857 <ENTER>
ENTER RF FOR GND FLTS? 0 <ENTER>
DIST SOURCE TO BUS (PU OF LINE)? 0.75 <ENTER>
DIST BUS TO FAULT (PU OF LINE)? 0.80 <ENTER>
```

Figure 7.4: Example ONEBUS Input Data for Phase-Phase and Ground Faults

ONEBUS should produce the following output:

```
   VA      VB      VC      IA      IB      IC
 34.58   74.65   74.53    3.13    0.00    0.00    A-G
   0.0  -128.9   129.0   -80.4     0.0     0.0

   VA      VB      VC      IA      IB      IC
 67.00   44.93   44.93    0.00    4.61    4.61    B-C
   0.0  -138.2   138.2     0.0  -170.1     9.9

 IMP BUS FAULT OR QUIT (I,B,F,Q)?
```

Figure 7.5: Example ONEBUS Result Screen for Phase-Phase and Ground Faults

B. Onebus Input Description

Line 1: On the first line, enter the real and reactive values of the secondary positive-sequence impedance for the entire transmission line. Separate each value with a comma.

Line 2: On the second line, enter the real and reactive values of the secondary zero-sequence impedance for the entire transmission line.

Line 3: The "RF FOR GROUND FAULTS" input allows you to introduce ground fault resistance into the line-ground fault cases. In most instances RF will be zero.

Line 4: The "DIST SOURCE TO BUS" input models the source strength behind the relay location as a source to line impedance ratio. This setting is entered as a per unit value. For example, for a radial system with a source impedance equal to 75% of the line impedance, enter 0.75 for the per unit distance from the source to the bus. Variations of the source impedance ratio (SIR) affect the magnitude and phase angle of the calculated voltages and currents.

The source impedance ratio may be used to adjust the current magnitude in cases where calculated currents exceed the output range of your current source. For example, on a short transmission line with a low source impedance, high current magnitudes result. Raising the source impedance ratio in ONEBUS results in a lower calculated current combined with a lower voltage.

If the source impedance ratio is unknown, enter a source impedance ratio of one to determine whether calculated currents are within the range of the current source. It is desirable to keep the source impedance ratio as realistic as possible.

Line 5: The final input is the "DIST BUS TO FAULT." This is the distance from the relay terminal to the fault location. To obtain the voltages and currents for a fault at 80% of the line, enter 0.80 for the per unit distance from the bus to fault.

C. Determining Fault Simulation Values - Three-Phase Faults

You can calculate three-phase fault voltages and currents with the ONEBUS program. Enter the positive-sequence line impedance values at the prompt for zero-sequence values. The following example uses the example relay settings:

```
ENTER Z1: R,X? 1.39,7.996
ENTER Z0: R,X? 1.39,7.996
ENTER RF FOR GND FLTS? 0
DIST SOURCE TO BUS (PU OF LINE)? 0.75
DIST BUS TO FAULT (PU OF LINE)? 0.80
```

Figure 7.6: Example ONEBUS Input Data for Three-Phase Faults

The following output should result:

```
    VA      VB      VC      IA      IB      IC
 34.58   67.00   67.00    5.33    0.00    0.00    A-G
   0.0  -120.0   120.0   -80.1     0.0     0.0

    VA      VB      VC      IA      IB      IC
 67.00   44.93   44.93    0.00    4.61    4.61    B-C
   0.0  -138.2   138.2     0.0  -170.1     9.9

 IMP BUS FAULT OR QUIT (I,B,F,Q)?
```

Figure 7.7: Example ONEBUS Result Screen for Three-Phase Faults

Use the calculated single-phase fault (AG) values to simulate a three-phase fault. Voltages are applied as indicated in the program. The calculated A∅ current magnitude is applied to all three relay current inputs. Each current is applied lagging the corresponding voltage phase angle by the transmission line angle. These values are shown in Table 7.3.

Table 7.3: Three-Phase Fault Voltages and Currents at MTA

VA	VB	VC	IA	IB	IC	
34.58	34.58	34.58	5.33	5.33	5.33	Volts/Amps
0.00°	-120.00°	120.00°	-80.10°	159.90°	39.90°	Degrees

Earlier in the Test Procedures two methods of observing element status were described target LEDs and programmable output contacts. For the purposes of driving an external sense contact, the remainder of the test procedure will use the programmable output contact method.

D. Three-Phase Fault Test

Purpose: Determine the pickup of each phase-phase distance element for three-phase faults at three points on the mho characteristic: MTA, MTA +45°, and MTA -45°.

Method: 1. Program the desired programmable output contact (A1 - A4) to follow the appropriate instantaneous phase distance element using the LOGIC command. Select one of the phase distance elements from the first row of the Relay Word as indicated below:

Z1P = Zone 1 Instantaneous Phase Distance Element
Z2PT = Zone 2 Time delayed Phase Distance Element
Z3P = Zone 3 Instantaneous Phase and Ground Distance Element

Please note that the Z2PT element includes any delay set by the Z2DP timer setting.

The following example outlines the procedure for testing the Zone 1 phase distance element response to a three-phase fault.

2. Connect the sources of voltage and current to the rear panel terminals of the relay as per Figure 7.8a or Figure 7.8b. Figure 7.8a uses three current sources, while Figure 7.8b uses only two.

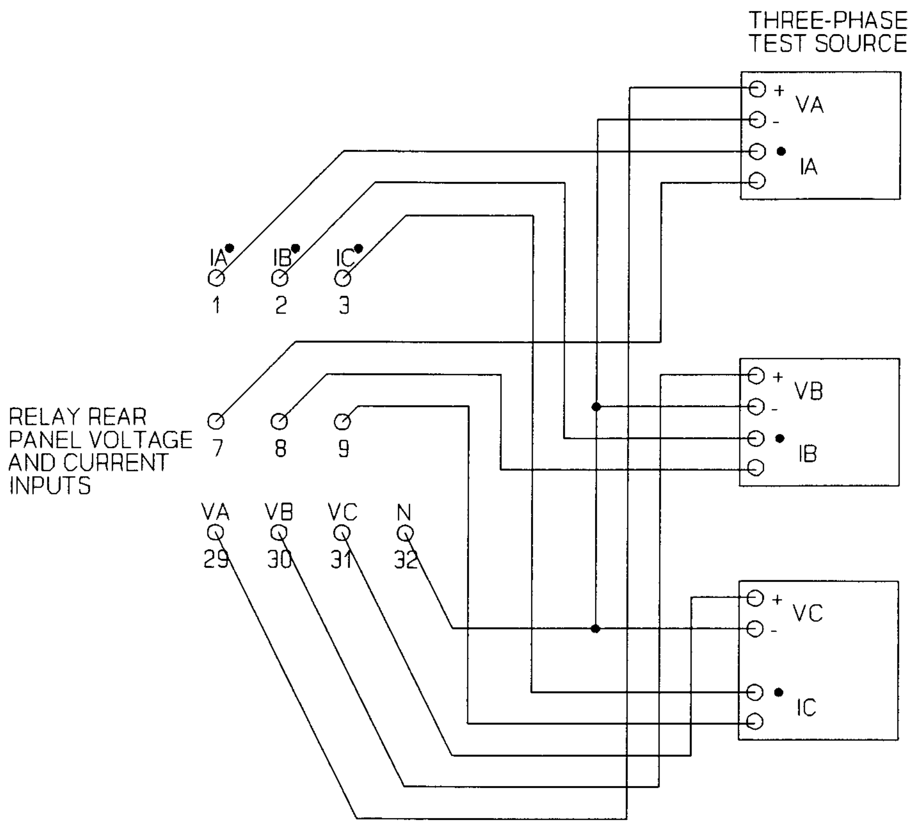


Figure 7.8a: Three-Phase Voltage and Current Source Test Connections for Three-Phase Fault Test

The two current source method yields the same results as does the three current source method. For balanced three-phase faults, the residual or 3I0 is zero. From this you can see why two current sources are adequate for three-phase element testing:

$$3I0 = IA + IB + IC = 0$$

Therefore,

$$-IC = (IA + IB)$$

This has the same effect as performing the following steps:

a. Connect the dotted output of A and B current sources to the dotted IA and IB inputs of the relay (Terminals 1 and 2 respectively).

b. Jumper together the undotted IA and IB current inputs of the relay (Terminals 7 and 8 respectively). This forms the (IA + IB) quantity.

c. Connect a jumper between the undotted IA and IB current inputs to the undotted IC current input of the relay (Terminals 8 to 9).

d. Connect the dotted IC current input of the relay to the common current source return of current Source A and B (Terminal 3 to source common current return).

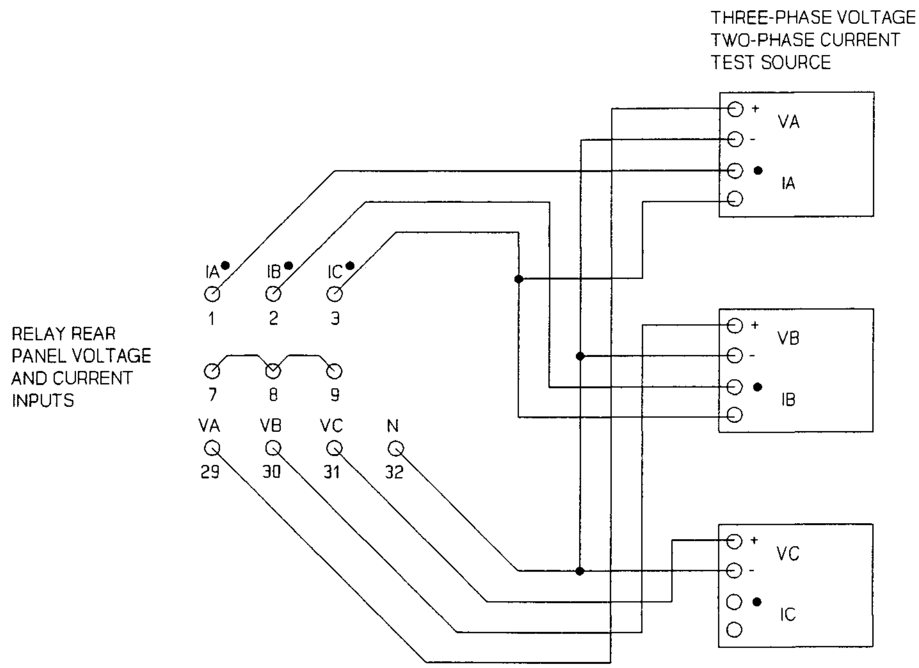


Figure 7.8b: Three-Phase Voltage and Two-Phase Current Source Test Connections for Three-Phase Fault Test

3. Determine the voltages and currents required to simulate a fault at the boundary of the desired relay reach (using ONEBUS or similar method). Table 7.4 shows currents and voltages required to test the example Zone 1 reach at MTA. These quantities were calculated using ONEBUS.

Table 7.4: Zone 1 Three-Phase Fault Test Quantities at MTA

VA	VB	VC	IA	IB	IC	
34.58	34.58	34.58	5.33	5.33	5.33	Volts/Amps
0.00°	-120.00°	120.00°	-80.1°	159.9°	39.9°	Degrees

4. Adjust the voltages and currents of the test set to the values shown in Table 7.4. Do not turn on the currents at this point.

5. Turn on the voltage sources VA, VB, and VC.

6. Apply current to the relay and ramp the current source magnitudes together until the monitored output contact closes, indicating pickup. Record the pickup current threshold and compare to the calculated threshold.

   To calculate the phase distance element reach for a three-phase fault you need only consider a single phase. For example, if the AØ voltage magnitude is 34.58 $V_{l\text{-}n}$ and the current magnitude for the boundary characteristic is 5.33 A, calculate the phase distance element reach as follows:

   Zone 1 reach secondary,

   $$Z1_{sec} = \frac{34.58\ V\ \angle 0°}{5.33A\ \angle -80.1°} = 6.48\Omega\ \angle 80.1°\ \text{secondary along the MTA}$$

   In primary ohms,

   Zone 1 reach primary along the MTA,

   $$Z1_{pri} = (6.48\Omega\ \angle 80.1°)\left(\frac{PTR}{CTR}\right) = 64.8\Omega\ \angle 80.1°\text{primary}$$

   Where PTR = 2000 and CTR = 200.

7. Obtain two other convenient test points. Consider a square inscribed in a mho circle with one diagonal being the diameter along the MTA. The two corners of that square on the other diagonal are reached by increasing the current by a factor of 1.414 at angles of ±45 degrees away from the angle obtained using the BASIC program.

   For the three-phase example, the required voltages do not change. The current magnitudes are 5.33 A (1.414) = 7.54 A at the angles listed as follows:

Table 7.5: Zone 1 Three-Phase Fault Test Quantities at MTA ±45°

	Angle IA	Angle IB	Angle IC
MTA +45°	-125.1°	114.9°	-5.1°
MTA - 45°	-35.1°	-155.1°	84.9°

8. Test the relay at the two additional current phase angle settings (MTA +45° and MTA -45°). Record the results.

E. Phase-Phase Mho Element Tests

Purpose: Determine the pickup of the phase-phase distance element at three points on the mho characteristic: MTA, MTA +45° and MTA -45°.

Method:

1. Use the LOGIC command to program a single output relay (A1-A4) to follow the appropriate instantaneous phase-phase distance element. Select a phase-phase element from the Relay Word as indicated below:

   Z1P = Zone 1 Instantaneous Phase-Phase Distance Element
   Z2PT = Zone 2 Time-delayed Phase-Phase Distance Element
   Z3 = Zone 3 Instantaneous Phase and Ground Distance Element

   Please note the Z2PT element includes any delay set by the Z2DP timer.

   The following example outlines the test procedure for the Zone 1 phase distance element.

2. Connect the sources of voltage and current to the relay rear panel terminals (see Figure 7.9a or b). Note that two current sources are employed in Figure 7.9a, while only one current source is used in Figure 7.9b.

   The single current source method yields the same results as the two current source method. Single current source method also assures that the phase angle of the two involved currents is always 180° apart.

   These steps connect a single current source to the relay for a BC phase-phase fault test.

   a. Connect B current source dotted output to dotted relay IB input (Terminal 2).

   b. Jumper undotted relay IB and IC current inputs together (Terminals 8 and 9 respectively).

   c. Connect dotted relay IC current input to common current source return of current Source B (Terminal 3 to source common current return).

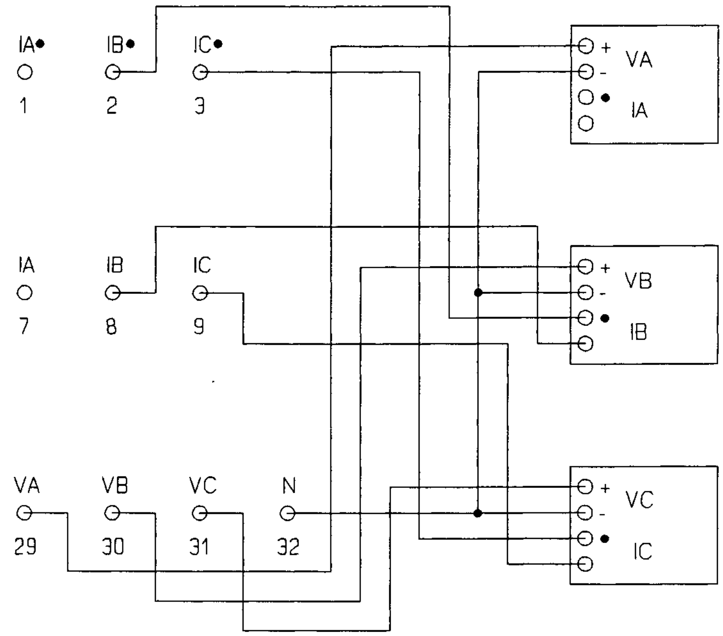


Figure 7.9a: Three-Phase Voltage and Two-Phase Current Source Test Connections for Phase-Phase Mho Test

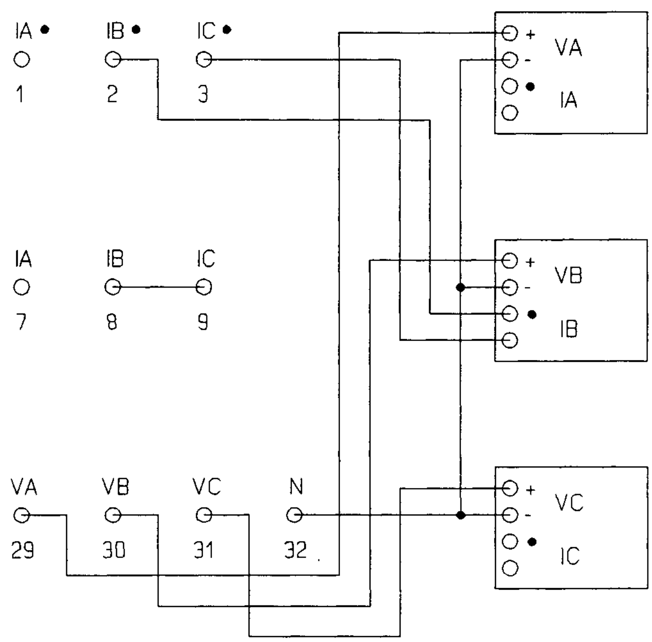


Figure 7.9b: Three-Phase Voltage and One-Phase Current Source Test Connections for Phase-Phase Mho Test

3. Determine the voltages and currents required to simulate a phase-phase fault at the boundary of the desired relay reach (using ONEBUS or similar method). Currents and voltages required to test the Zone 1 phase-phase element reach of the example settings appear in Table 7.6:

Table 7.6: Zone 1 Phase-Phase Test Voltages and Currents, BC Fault

VA	VB	VC	IA	IB	IC	
67.00	44.93	44.93	0.00	4.61	4.61	Volts/Amps
0.0°	-138.2°	138.2°	0.0°	-170.1°	9.9°	Degrees

4. Adjust the test set voltages and currents to the values in Table 7.6. Do not turn on the currents at this point.

5. Turn on the voltage sources VA, VB, and VC.

6. Apply current to the relay and ramp the current source magnitudes together until the monitored output contact closes, indicating pickup. Record the pickup current threshold and compare it to the calculated threshold.

   To calculate the phase-phase element reach, first calculate the resultant test voltage (VBC) and current (IBC).

   <u>BC Fault</u>

   $VB = 44.93\ V \angle -138.2°$
   $VC = 44.93\ V \angle 138.2°$
   $VBC = VB - VC = 59.90\ V \angle -90°$

   $IB = 4.61\ A \angle -170.1°$
   $IC = 4.61\ A \angle 9.9°$
   $IBC = IB - IC = 9.22\ A \angle -170.1°$

   Zone 1 reach secondary along the MTA,

   $$Z1_{sec} = \frac{VBC}{IBC} = \frac{59.90\ V \angle -90°}{9.22\ A \angle -170.1°} = 6.50\Omega \angle 80.1° \text{ secondary}$$

   In primary ohms,

   Zone 1 reach primary along the MTA,

   $$Z1_{pri} = (6.50\Omega \angle 80.1°)\left(\frac{PTR}{CTR}\right) = 65.0\Omega \angle 80.1° \text{ primary}$$

   Where PTR = 2000 and CTR = 200.

7. Find two other convenient test points. Consider a square inscribed in a mho circle with one diagonal being the diameter along the MTA. The two corners of that square on the other diagonal are reached by increasing the current by a factor of 1.414 at angles of ±45 degrees from the angle obtained using the ONEBUS program.

   For our Zone 1 BC phase-phase example, the required voltages remain unchanged. The current magnitudes are (4.61)(1.414) = 6.52 amperes at the angles listed as follows:

Table 7.7: Zone 1 Phase-Phase Test Quantities at MTA ±45°

	Angle IB	Angle IC
MTA +45°	144.9°	-35.1°
MTA -45°	-125.1°	54.9°

8. Test the relay at the two additional current phase angle settings (MTA +45°, MTA -45°). Record the results.

F. Phase-Ground Mho Element Tests

Purpose: Determine the pickup of the ground distance element at three points on the mho characteristic: MTA, MTA +45° and MTA -45°.

Method: 1. Use the LOGIC command to program a single output relay (A1-A4) to follow the appropriate instantaneous ground distance element. Select a ground element from the Relay Word as indicated below:

   Z1G = Zone 1 Instantaneous Ground Distance Element
   Z2GT = Zone 2 Time-delayed Ground Distance Element
   Z3 = Zone 3 Instantaneous Phase and Ground Distance Element

   Please note the Z2GT element includes any delay set by the Z2DG timer.

   The following example outlines the test procedure for the Zone 1 ground distance element.

2. Connect the sources of voltage and current to the relay rear panel terminals (see Figure 7.10).

   These steps connect a single current source to the relay for a A-phase-ground fault test.

a. Connect A current source dotted output to dotted relay IA input (Terminal 1).

b. Connect A current source return to relay IA return (terminal 7).

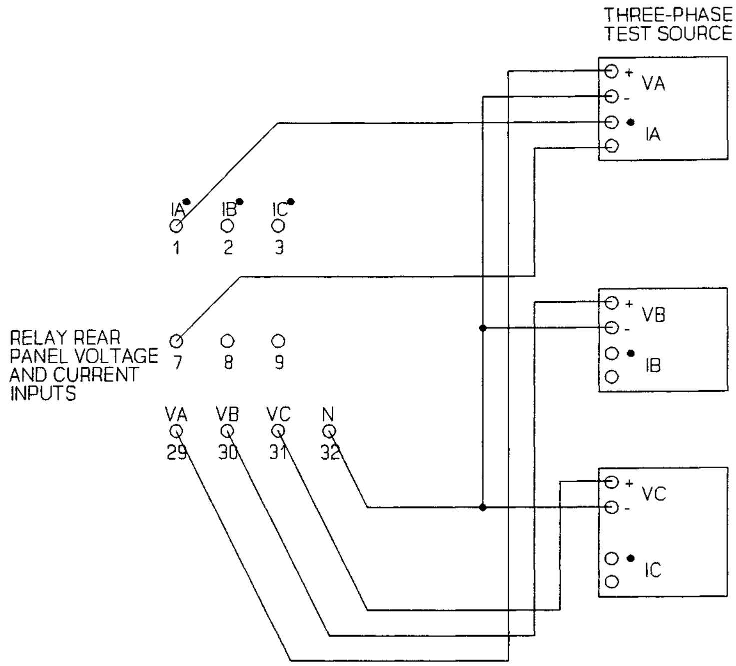


Figure 7.10: Three-Phase Voltage and One-Phase Current Source Test Connections for Phase-Ground Distance Element Test

3. Determine the voltages and currents required to simulate a phase-phase fault at the boundary of the desired relay reach (using ONEBUS or similar method). Currents and voltages required to test the Zone 1 ground distance element reach of the example settings appear in Table 7.8:

Table 7.8: Zone 1 Ground Element Test Quantities, AG Fault

VA	VB	VC	IA	IB	IC	
34.58	74.65	74.53	3.13	0.00	0.00	Volts/Amps
0.0°	-128.9°	129.0°	-80.4	0.0°	0.0°	Degrees

4. Adjust the test set voltages and currents to the values in Table 7.8. Do not turn on the currents at this point.

5. Turn on the voltage sources VA, VB, and VC.

6. Apply current to the relay and ramp the current source magnitudes together until the monitored output contact closes, indicating pickup. Record the pickup current threshold and compare it to the calculated threshold.

   To calculate the ground distance element reach, first calculate the residual current compensation factor, K0.

   $$K0 = (Z0 - Z1)/(3 \times Z1)$$

   Where:

   $$Z0 = R0 + jX0$$
   $$Z1 = R1 + jX1$$

   For the example relay settings, K0 is calculated:

   $$K0 = [(41.5 + j248.57) - (13.9 + j79.96)]/[3 \times (13.9 + j79.96)]$$

   $$K0 = 0.70 \angle 0.57°$$

   Next, calculate the applied residual current by summing the three phase currents.

   $$IR = IA + IB + IC$$

   For the test above,

   $$IR = 3.13\ A \angle -80.1° + 0.0\ A \angle 0.0° + 0.0\ A \angle 0.0°$$
   $$IR = 3.13\ A \angle -80.1°$$

   Zone 1 reach secondary along the MTA,

   $$Z1_{sec} = \frac{VAG}{IA + (K0 \times IR)} = \frac{34.58\ V \angle 0°}{3.13\ A \angle -80.1° + (0.7 \angle 0.57° \times 3.13\ A \angle -80.1)}$$

   $$= 6.50\Omega \angle 79.9°\ sec$$

   In primary ohms,

   Zone 1 reach primary along the MTA,

   $$Z1_{pri} = (6.50\Omega \angle 79.9°)\left(\frac{PTR}{CTR}\right) = 65.0\Omega \angle 79.9°\ primary$$

   Where PTR = 2000 and CTR = 200.

7. Find two other convenient test points. Consider a square inscribed in a mho circle with one diagonal being the diameter along the MTA. The two corners of that square on the other diagonal are reached by increasing the current by a factor of 1.414 at angles of ±45 degrees from the angle obtained using the ONEBUS program.

   For our Zone 1 AG phase-ground example, the required voltages remain unchanged. The current magnitudes are (3.13)(1.414) = 4.43 amperes at the angles listed as follows:

Table 7.9: Zone 1 Phase-Ground Test Quantities at MTA ±45°

	Angle IA
MTA +45°	-125.1°
MTA -45°	-35.1°

8. Test the relay at the two additional current phase angle settings (MTA +45°, MTA -45°). Record the results.

DIRECTIONAL ELEMENT TESTS

Purpose: Verify the operate and restrain boundaries of the negative-sequence directional element.

Method: Program the desired programmable output (A1 - A4) to follow the 32Q bit in Relay Word row 1. Use the SET command to disable the LOP scheme. This prevents test-condition voltages from setting the loss-of-potential condition and defeating the directional sensing ability of the relay.

1. Apply the following voltages to the relay:

Table 7.10: 32Q Test Voltages

VA	VB	VC	
30.00	0.00	0.00	Volts
0.0°	0.0°	0.0°	Degrees

For the voltages shown in Table 7.10, the resulting negative-sequence voltage is ten volts. The following equations illustrate the equations you should use to calculate magnitude and angle of V2.

$$V2 = \tfrac{1}{3}\,[VA + a^2(VB) + a(VC)]$$

Where: $a \equiv 1 \angle 120°$ and $a^2 \equiv 1 \angle 240°$

$$\begin{aligned} V2 &= \tfrac{1}{3}\,[30V \angle 0° + 0V \angle (0° + 240°) + 0V \angle (0+120°)] \\ &= \tfrac{1}{3}\,[30V \angle 0° + 0V \angle -120° + 0V \angle 120°] \\ &= 10V \angle 0° \end{aligned}$$

To calculate I2, substitute currents for voltages in the equations above.

Please note that the angular relationship of V2 and I2 using a single voltage and current differs by 180° from using three voltages and a single current. Figure 7.11 illustrates the difference between using a single voltage and current and using three voltages and a single current. For the sake of simplicity, this test uses the single voltage and current method. The relay declares ground faults in the forward direction when I2 leads V2 ±90° from the MTA.

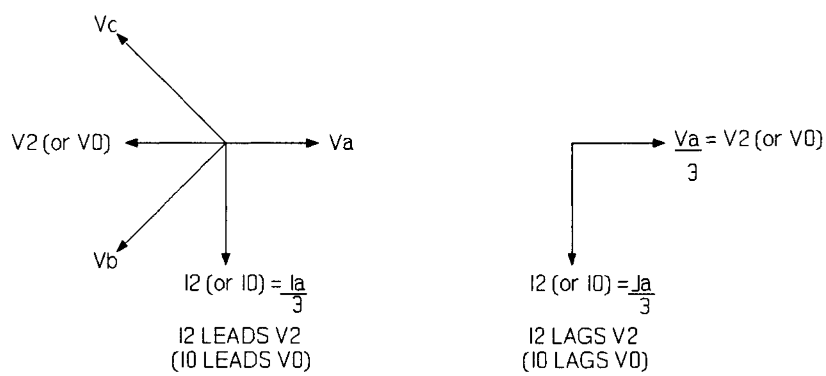


Figure 7.11: Three Voltage vs. One Voltage for Directional Tests

2. Apply IA = 3 amperes, corresponding to negative-sequence currents of one ampere. IB and IC are zero for this test.

3. Move the phase angle of the current with respect to the voltage and observe the boundary of the directional element at MTA ±90 degrees.

RESIDUAL OVERCURRENT ELEMENT TESTS

Purpose: Verify the pickup thresholds of the 67N and 51NP residual overcurrent elements.

Method:

1. Using the LOGIC command, set the desired programmable output (A1 - A4) to follow the appropriate overcurrent element. Select one of the overcurrent elements from the Relay Word as indicated below:

   67N = Instantaneous Residual Element (pickup set by 67NP setting)
   51NP = Residual Time-Overcurrent Pickup Element

2. Disable all directional and LOP functions for this test. Set 51NTC, 67NTC, and LOPE = N.

3. Apply current to one phase and observe the pickup and dropout of each element. Record the results.

RESIDUAL TIME-OVERCURRENT ELEMENT TIMING TESTS

Purpose: Verify the 51NT residual time-overcurrent element operating time.

Method:

1. Disable all directional functions for this test. Set 51NTC and LOPE = N.

2. Set a programmable output (A1-A4) to follow the 51NP time-overcurrent pickup element. Use the assertion of this output (open to close) to start an external timer.

3. Set another programmable output to follow the timeout of the time-overcurrent element timeout via the 51NT bit in the Relay Word. Use the assertion of this output to stop the external timer.

4. Calculate the expected operating time of the 51NT element using the appropriate equation for the curve number. This is dictated by the relay 51NC setting. TD is the relay 51ND time dial setting. M is the multiple of pickup current to be applied to the relay. Using example relay settings and a current multiple of pickup equal to three, the equation for the inverse curve (2) is:

   $$t_M = TD\left(0.180 + \frac{5.95}{M^2 - 1}\right)$$

   Where M = Multiples of Pickup = 3
   TD = Time Dial =3

   $$t_M = 2.77 \text{ seconds}$$

For example, if the relay measures 4.05 amperes of residual current, the 51NT bit in the Relay Word asserts 2.77 seconds after the 51NP bit in the Relay Word asserts. Table 7.11 shows the current quantities of the previous example.

Table 7.11: Current Quantities for 51N Timing Test Example

IA	IB	IC	
4.05	0.00	0.00	Amperes
0.0°	0.0°	0.0°	Degrees

5. Apply a multiple of pickup current to one phase. Record the operating time of the 51NT element and compare to the calculated time.

6. Repeat the test for various multiples of pickup current (e.g., M = 3, 5, and 7) and various time dial settings (e.g., TD = 1, 5, and 10) for each of the four curve indexes.

PHASE OVERCURRENT ELEMENT TESTS

Purpose: Verify the pickup thresholds of the 50NG, 50P, and 50H phase overcurrent elements.

Method: 1. Using the LOGIC command, set the desired programmable output (A1 - A4) to follow the appropriate non-directional instantaneous phase overcurrent element. Select one of the phase overcurrent elements from the Relay Word as indicated below:

50NG = Low-set instantaneous phase and residual overcurrent element
50P = Instantaneous phase overcurrent element
50H = High-set instantaneous phase overcurrent element

2. Apply current to one phase and observe the pickup and dropout of each element. Record the results. Pickup of the 50H element generates an event report.

LOSS-OF-POTENTIAL TEST

Purpose: Verify the SET LOP and CLEAR LOP conditions. The following equations show the SET LOP and CLEAR LOP logic equations.

SET LOP = 47QL * NOT(46QL)
+ NOT(47P) * NOT(50P)

CLEAR LOP = NOT(47QL) * 47P

Where: 47QL = 14 V of V2
46QL = 0.083 A of I2
47P = 14 V of V1
50P = Current in any phase over the 50P setting

Method: Table 7.13 provides the voltage and current sets required to create SET LOP and CLEAR LOP conditions.

Table 7.12: Conditions To Test the SET LOP and CLEAR LOP Logic

SET LOP:

VA	VB	VC	IA	IB	IC	
0.00	67.00	67.00	0.00	0.00	0.00	Volts/Amps
0.0°	-120.0°	120.0°	0.0°	0.0°	0.0°	Degrees

CLEAR LOP:

VA	VB	VC	IA	IB	IC	
67.00	67.00	67.00	0.00	0.00	0.00	Volts/Amps
0.0°	-120.0°	120.0°	0.0°	0.0°	0.0°	Degrees

Note: The relay may use LOP detection in a number of different ways. Check your LOPE setting and consult the SPECIFICATIONS section to determine how the relay is set to use LOP detection.

Z2DG AND Z3DG TIMER TESTS

Purpose: Verify the Z2DG and Z3D timer accuracies.

Method:

1. Program the Z3 bit in the Relay Word into one of the available outputs (A1 - A4) to start an external timer.

2. Program the Z2GT bit into a different output to stop the timer.

3. Apply a Zone 2 AG fault as in Table 7.13 for a duration which exceeds the Z2DG setting.

Table 7.13: Standard Zone 2 AG Fault Using Factory Relay Settings

2AG Fault

VA	VB	VC	IA	IB	IC	
35.59	74.39	74.27	3.03	0.00	0.00	Volts/Amps
0.0°	-128.6°	128.7°	-80.4°	0.0°	0.0°	Degrees

4. Repeat steps 1 to 3, substituting Z3T for Z2GT in the appropriate programmable output. Table 7.14 shows a standard Zone 3 AG fault. Apply this 3AG fault for a duration which exceeds the Z3D setting.

Table 7.14: Standard Zone 3 AG Fault Using Factory Relay Settings

3AG Fault

VA	VB	VC	IA	IB	IC	
43.07	72.49	72.39	2.31	0.00	0.00	Volts/Amps
0.0°	-126.7°	126.8°	-80.4°	0.0°	0.0°	Degrees

Note: If an external timer is not available, use event report time tags to calculate Z2DG and Z3D time delays with the following steps.

5. Mask only the Z2GT bit of the Relay Word into the MTU mask. Zero the MTO mask out so no other condition can assert the TRIP output.

6. Apply the Zone 2 AG fault as given in Table 7.12.

7. For Z2DG settings greater than approximately 6 cycles, the relay generates two event reports: one for the Z3 element pickup, the other for TRIP output assertion (and the Z2GT bit of the Relay Word).

8. Calculate the Z2DG time delay using the difference between the Z3 element pickup in the first event report and the TRIP (and Z2GT bit) assertion in the second event report.

9. The Z3D timer can be tested with the same method using the Zone 3 AG fault in Table 7.13.

Z2DP TIMER TEST

Purpose: Verify the Z2DP timer accuracy.

Method:

1. Program the Z3 bit in the Relay Word into one of the available outputs (A1 - A4) to start an external timer.

2. Program the Z2PT bit into a different programmable output to stop the timer.

3. Apply the Zone 2 BC fault shown in Table 7.15 for a duration which exceeds the Z2PT setting.

Table 7.15: Standard Zone 2 BC Fault Using Factory Relay Settings

2BC Fault

VA	VB	VC	IA	IB	IC	
67.00	45.52	45.52	0.00	4.47	4.47	Volts/Amps
0.0°	-137.4°	137.4°	0.0°	-170.1°	9.9°	Degrees

Note: If an external timer is not available, use event report time tags to calculate the Z2DP time delay with the following steps.

4. Mask only the Z2PT bit of the Relay Word into the MTU mask. Zero the MTO mask out so no other condition can assert the TRIP output.

5. Apply the Zone 2 BC fault as given in Table 7.15.

6. For Z2DP settings exceeding approximately 6 cycles, the relay generates two event reports: one for the Z3 element pickup, the other for TRIP output assertion (and the Z2PT bit of the Relay Word).

7. Calculate the Z2DP time delay using the difference from the Z3 element pickup in the first event report to TRIP (and Z2PT bit) assertion in the second event report.

REMOTE-END-JUST-OPENED TESTS

Purpose:

1. Verify operation of relay REJO logic.
2. Verify that elements set in the MPT logic mask are enabled to trip during a REJO condition.

Method:

1. Check the relay settings and note the REJOE setting and pickup settings for the 50NG and 50P overcurrent elements.
2. Set the relay to trip upon assertion of the REJO bit by selecting only REJO in the MTU logic mask.
3. If REJOE=P, apply balanced, three-phase current above the 50P setting. If REJOE=G, apply balanced, three-phase current above the 50NG setting.
4. Remove current from two phases at the same time, leaving one current on. The relay should trip when the REJO bit asserts and generate an event report. Examine the event report to ensure that the REJO bit asserted for 1.5 cycles approximately 0.5 cycles following dropout of the two phase currents.
5. Remove the REJO bit from the MTU logic mask.
6. Next, verify that the relay trips for assertion of elements set in the MPT mask while the REJO bit is asserted. Deassert all the elements in the MTU, MTO, and MTB logic masks. Set the Z3 bit in the MPT logic mask.
7. Apply balanced voltages to the relay. Apply balanced currents above the 50P or 50NG overcurrent element settings (depending upon REJOE setting). Apply a Zone 2 AG fault, with IB = IC = 0 A (Table 7.16 shows quantities for use with the relay factory standard settings).
8. The relay should trip upon assertion of the REJO and Z3 bits. Examine the relay event report to verify this.

SWITCH-ONTO-FAULT TESTS

Purpose: 1. Verify 52BT timer accuracy and MTO (Switch-Onto-Fault) Logic Mask.

2. Verify that elements enabled to trip via the MTO logic mask are only enabled when the breaker is open for a duration exceeding the 52BT setting (52BT bit in Relay Word is asserted).

Method: 1. Program one of the available output contacts (A1 - A4) to follow the 52BT bit in the Relay Word.

2. Use the 52A contact input deassertion (control voltage on to off) to start an external timer.

3. Use the 52BT programmed contact output assertion (open to close) to stop the timer.

4. Compare the timer value to the 52BT setting.

5. To make sure the elements in the MTO logic mask are only enabled when 52BT = 1, apply a fault to pick up an element masked into the MTO logic mask but not the MTU mask.

6. Table 7.16 contains prefault and fault voltage and current quantities for a Zone 2 AG fault.

Table 7.16: Zone 2 AG Fault Quantities

Prefault:

VA	VB	VC	IA	IB	IC	
67.00	67.00	67.00	0.00	0.00	0.00	Volts/Amps
0.0°	-120.0°	120.0°	0.0°	0.0°	0.0°	Degrees

2AG Fault:

VA	VB	VC	IA	IB	IC	
35.59	74.39	74.27	3.03	0.00	0.00	Volts/Amps
0.0°	-128.6°	128.7°	-80.4°	0.0°	0.0°	Degrees

7. Apply the Zone 2 AG fault with the breaker closed (52A = 1 and 52BT = 0). The relay should not trip instantaneously.

8. Open the breaker to deassert the 52A input which asserts the 52BT bit in the Relay Word. Use the TARGET 4 command to verify that 52BT is set.

9. Apply the same Zone 2 AG fault and verify that the relay trips instantaneously.

RECLOSER TEST

Purpose: Verify that the reclosing relay functions properly.

Note: This test should be performed using a breaker simulator to simulate the action of the breaker 52A auxiliary contacts. A simple latching relay works well as a breaker simulator.

Method:

1. Program the MRI (Mask for Reclose Initiate) with the Z1G bit in the Relay Word. Make certain this same bit is not masked into the MRC (Mask for Reclose Cancel).

2. Program the MTU (Mask for Unconditional Trip) with the Z1G bit also.

3. Apply a Zone 1 AG fault as shown in Table 7.16. Make certain the 52A input is energized for 79RS cycles prior to applying the fault. The TRIP output contact closure should result in the circuit breaker simulator deenergizing the 52A input and removal of current inputs to the relay.

Table 7.17: 1AG Fault

Prefault:

VA	VB	VC	IA	IB	IC	
67.00	67.00	67.00	0.00	0.00	0.00	Volts/Amps
0.0°	-120.0°	120.0°	0.0°	0.0°	0.0°	Degrees

1AG Fault

VA	VB	VC	IA	IB	IC	Volts/Amps
33.50	74.93	74.81	3.23	0.00	0.00	Degrees
0.0°	-129.2°	129.2°	-80.4°	0.0°	0.0°	

4. Immediately following TRIP output closure, remove the A-Phase fault current. This allows the open interval timer (79OI) to run. Record the duration between

TRIP output contact opening or 52A input deassertion (whichever occurs later) and CLOSE output contact closure.

5. Record this time and compare to the 790I setting.

SYNCHRONIZING AND POLARIZING VOLTAGE ELEMENT TESTS

Purpose: Verify the pickup levels of the 27P, 59P, 27S, and 59S voltage elements.

Method:

1. Verify the 27VLO and 59VHI settings. Calculate the element secondary pickup voltage, using the relay PTR setting for the 59P and 27P elements and the SPTR setting for the 59S and 27S elements.

2. Connect three-phase potentials to the relay voltage inputs. Set the 59P bit in an available output contact logic mask. Apply balanced, three-phase voltages to the relay below the 59VHI setting. Increase the applied voltage until the 59P bit asserts, causing the monitored output contact to close. Note the voltage applied.

3. Set the 27P bit in an available output contact logic mask. Decrease the applied voltage until the 27P bit asserts, causing the output contact to close. Note the voltage applied.

4. Connect a single voltage source to the relay synch-check voltage input, VS and VSN. Set the 59S bit in an available output contact logic mask. Apply voltage to the synch-check voltage input below the 59VHI setting. Increase the applied voltage until the 59S bit asserts, causing the monitored output contact to close. Note the voltage applied.

5. Set the 27S bit in an available output contact logic mask. Decrease the applied voltage until the 27S bit asserts, causing the output contact to close. Note the voltage applied.

VOLTAGE CHECKING LOGIC TESTS

Purpose: Verify operation of the relay voltage checking function.

Method:

1. Using the SHOWSET command, check the relay PSVC setting. If PSVC = S or E, continue this test with Step 2. IF PSVC = P, continue this test at Step 5. If PSVC = N, the voltage checking scheme is disabled.

2. Set a contact to close upon assertion of the 59S bit. Connect that contact to start an external timer.

3. Set a second contact to close upon assertion of the VSC bit. Connect that contact to stop the external timer.

4. Connect a voltage source to the synch-check voltage input. Apply voltage above the 59VHI setting. When the 59S bit asserts, the external timer should start. When the voltage conditions of hot synch/dead pol. have been valid for VCT time, the VSC bit should assert, stopping the external timer. Verify that the timer reading is equal to the VCT timer setting. If PSVC = E, continue with Step 5.

5. Set a contact to close upon assertion of the 59P bit. Connect that contact to start an external timer.

6. Set a second contact to close upon assertion of the VSC bit. Connect that contact to stop the external timer.

7. Connect a three-phase voltage source to the polarizing voltage inputs. Apply voltage above the 59VHI setting. When the 59P bit asserts, the external timer should start. When the voltage conditions of hot pol/dead synch have been valid for VCT time, the VSC bit should assert, stopping the external timer. Verify that the timer reading is equal to the VCT timer setting.

SYNCHRONISM CHECKING LOGIC TESTS

Purpose: Verify operation of the relay synchronism checking function.

Method:

1. Using the SHOWSET command, check the relay SYNCP, 25T, and 25DV settings.

2. Set a contact to close upon assertion of the 59P bit.

3. Connect a voltage source to the polarizing voltage input selected in the SYNCP setting. Connect a second voltage source to the voltage input which lags the input selected by the SYNCP setting. Figure 7.12 shows voltage connections when SYNCP = A. Apply voltage to the first voltage input above the 59VHI setting. Adjust the phase angle of the second voltage source to lag the first by 120°. Increase the second voltage input until the 59P bit asserts.

4. Set a contact to close upon assertion of the 59S bit. Connect that contact to start an external timer.

5. Set a second contact to close upon assertion of the SSC bit. Connect that contact to stop the external timer.

6. Connect a voltage source to the synch-check voltage input. Apply voltage above the 59VHI setting. When the 59S bit asserts, the external timer should start. When the sync check voltage conditions have been valid for 25T time, the SSC bit should assert, stopping the external timer. Verify that the timer reading is equal to the 25T timer setting.

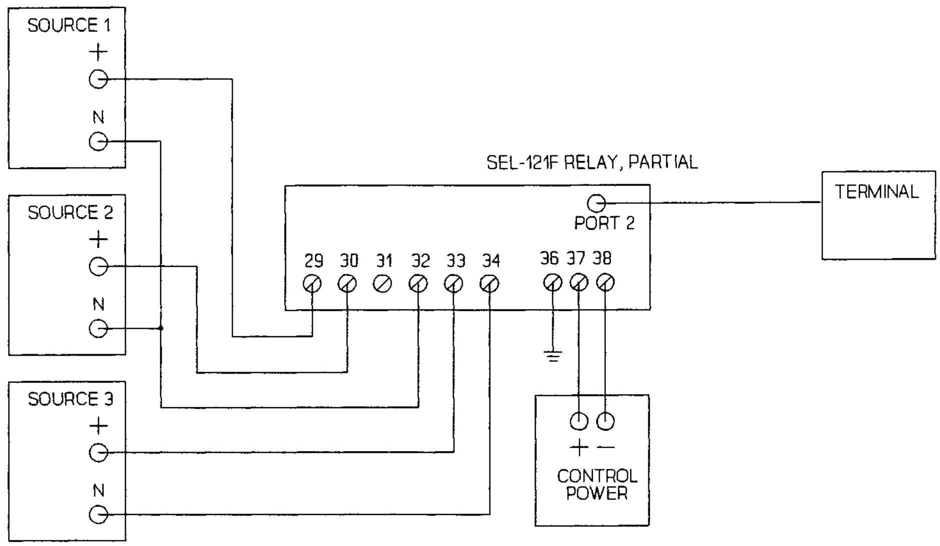


Figure 7.12: Voltage Connections When SYNCP = A

INPUT CIRCUITS TEST

Purpose: Verify that logic inputs assert when control voltage is applied across the respective terminal pair.

Method: 1. Set target LEDs to display the contact inputs by typing **TAR 5 <ENTER>**. The front panel LEDs should now follow the contact inputs.

2. Apply control voltage to each input and make sure the corresponding target LED turns on. Energizing the PT, BT, DT, and ET inputs should trigger an event report. Table 7.18 lists the contact inputs and terminal numbers.

Table 7.18: Contact Inputs and Terminal Numbers

Programmable Input	(IN1)	39, 40
Permissive Trip	(PT)	41, 42
Block Trip	(BT)	43, 44
Direct Close	(DC)	45, 46
52A		47, 48
External Trigger	(ET)	49, 50

SERIAL PORTS TEST

Purpose: Verify operation of serial PORT 1.

Method: The initial checkout procedure assumes you connected a terminal to PORT 2. Set the baud rate of PORT 1 to match that of PORT 2 and switch your terminal connector cable from relay PORT 2 to PORT 1. Be sure you can communicate through this port.

IRIG-B TIME CODE INPUT TEST

Purpose: Verify operation of the IRIG-B clock input port.

Method:

1. Connect a source of demodulated IRIG-B time code to the relay Auxiliary Port in series with a resistor to monitor the current. Adjust the source to obtain an "ON" current of about 10 mA.

2. Execute the IRIG command. Make sure the relay clock displays the correct date and time.

   Note: A recording of the IRIG-B signal passed through a simple demodulator provides a convenient, inexpensive test of the IRIG-B port. Please contact the factory for further details.

POWER SUPPLY VOLTAGES TEST

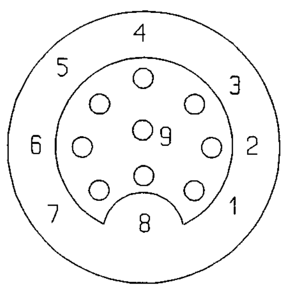
Purpose: Verify that correct output voltages are presented to PORT 1, PORT 2, and the auxiliary port. These voltages are required by external devices including a dc powered modem or the SEL-DTA unit.

Method:

1. Execute the STATUS command and inspect the voltage readings for the +5 and ±15 volt supplies.

2. At the Auxiliary Port, use a voltmeter to read the +5 and ±12 volt outputs. The 12 volt outputs are derived from the 15 volt supplies using three-terminal regulators. The following pins are the read points:

   Pin 6: +5 Vdc
   Pin 7: +12 Vdc
   Pin 8: -12 Vdc



(female connector as viewed from rear panel)

Figure 7.13: Nine-Pin Connector Pin Number Convention

3. Compare the +5 volt readings from the status report and voltmeter. The voltage difference should be less than 50 MV, and both readings should be within 0.15 volts of five volts.

   The 12 volt supplies should be within 0.5 volts of their nominal values.

CALIBRATION

When testing this relay, first verify relay calibration. Consider all tests invalid if you determine that the relay is out of calibration. System calibration requires trimming analog channel gains and offsets.

Each SEL relay is fully tested and calibrated before it leaves the factory. Although periodic calibration is unnecessary, you should consider calibrating the relay for the conditions listed below:

1. Replacement of any analog components in the system, such as operational amplifiers, the A/D converter, or sample/hold amplifiers.

2. Replacement of input transformers or their secondary burden resistors.

3. Out-of-tolerance indication of analog voltages or currents (STATUS command).

Equipment Required

1. AC digital voltmeter
2. One calibrated voltage and current source
3. Computer terminal

Calibration Procedures

Offset Adjustments

1. Be sure voltage inputs are zero at the rear panel and remove the top cover of the relay.

2. Turn the system power on.

3. Execute the STATUS command to observe the offsets while adjusting potentiometers R120 - R125 for indications of 5 mV or less (clockwise rotation results in positive offset). Note that the STATUS command is updated approximately every 30 seconds.

Gain Adjustments

The procedure below uses an ac voltage and current source at the relay inputs. This allows gain adjustments to accommodate ratio error in the input transformers and error in the burden resistors at the input CT secondaries.

1. Connect a 50 volt, 60 Hz source to all three voltage inputs. Connect a 2 ampere, 60 Hz source to all three current inputs. Both voltages and currents should have phase angles equal to zero degrees.

2. Turn on the system power.

3. Type **METER 222 <ENTER>** to repeat the METER command and display 222 times (you may cancel any command using the **<CTRL>X** key sequence).

4. Adjust R109-R114 for correct indication (counterclockwise increases gain).

5. Replace the relay cover.

TROUBLESHOOTING

Inspection Procedure

Complete the following procedure before disturbing the system. After you finish the inspection, proceed to the Troubleshooting Table.

1. Measure and record control power voltage at terminals 37 and 38.

2. Check to see that the power is on, but do not turn system off if it is on.

3. Measure and record the voltage at all control inputs.

4. Measure and record the state of all output relays.

5. Inspect the cabling to the serial communications ports and be sure a communications device is connected to at least one communications port.

Troubleshooting Table

All Front Panel LEDs Dark

1. Power is off.

2. Blown fuse.

3. Input power not present.

4. Self test failure.

5. Target command improperly set.

Note: For 1, 2, 3, and 4 the ALARM relay contacts should be closed.

System Does Not Respond to Commands

1. Communications device not connected to system.

2. Relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.

3. Internal ribbon cable connector loose or disconnected.

4. System is processing event record. Wait several seconds.

5. System is attempting to transmit information, but cannot due to handshake line conflict. Check communications cabling.

6. System is in the XOFF state, halting communications. Type **<CTRL>Q** to put system in XON state.

Tripping Output Relay Remains Closed Following Fault

1. Auxiliary contact inputs improperly wired.

2. Output relay contacts burned closed.

3. Interface board failure.

No Prompting Message Issued to Terminal upon Power-Up

1. Terminal not connected to system.

2. Wrong baud rate.

3. Terminal improperly connected to system.

4. Other port designated AUTO in the relay settings.

5. Port timeout interval set to a value other than zero.

6. Main board or interface board failure.

System Does Not Respond to Faults

1. Relay improperly set. Review your settings with the SHOWSET command.

2. Improper test settings.

3. PT or CT input cable wiring error.

4. Analog input cable between transformer-termination and main board loose or defective.

5. Check self test status with STATUS command.

6. Check input voltages and currents with METER command and TRIGGER and EVENT sequence.

Terminal Displays Meaningless Characters

1. Baud rate set incorrectly. Check terminal configuration. See Section 3: COMMUNICATIONS.

Self Test Failure: +5 Volts

1. Power supply +5 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self Test Failure: +15 Volts

1. Power supply +15 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self Test Failure: -15 Volts

1. Power supply -15 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self Test Failure: Offset

1. Offset drift. Adjust offsets.

2. A/D converter drift.

3. Loose ribbon cable between transformers and main board.

Self Test Failure: ROM Checksum

1. EPROM failure. Replace EPROM(s).

Self Test Failure: RAM

1. Static RAM IC failure. Replace RAM(s).

Self Test Failure: A/D Converter

1. A/D converter failure.

2. RAM error not detected by RAM test.

Alarm Contact Closed

1. Power is off.

2. Blown fuse.

3. Power supply failure.

4. Improper EPROMs or EPROM failure.

5. Main board or interface board failure.

FIRMWARE UPGRADE INSTRUCTIONS

SEL may occasionally offer firmware upgrades to improve the performance of your relay. These instructions explain how to install new firmware.

The modifications require that you power down the relay, remove its front panel, pull out the drawout unit, exchange several integrated circuit chips, and reassemble the relay. If you do not wish to perform the modifications yourself, we can assist you. Simply return the relay and integrated circuit chips to us. We will install the new chips and return the unit to you within a few days.

Warning: This procedure requires that you handle electrostatic discharge sensitive components. If your facility is not equipped to work with these components, we recommend that you return the relay to SEL for firmware installation.

Upgrade Instructions

1. If the relay is in service, disable its control functions.

2. Turn off control power to the relay.

3. Remove the front panel by unscrewing the four front panel screws (one in each corner).

4. With the front panel leaning forward, you can see the aluminum drawout chassis. The main board is attached to the top of the drawout chassis. The power supply and interface board are attached to the bottom of the drawout chassis. Several ribbon cables connect the boards to each other and to other portions of the relay.

5. Disconnect the analog input ribbon cable (the rightmost cable) from the main board.

6. The front panel display cable connects the relay interface board to the front panel display board. It is located on the left side of the front panel. Disconnect this cable from the display board.

7. Two hex head screws hold the drawout chassis in place. These screws are on the bottom of the chassis in each front corner. Remove both screws.

8. Remove the drawout assembly by pulling the spacers on the bottom of the drawout chassis. You should be able to remove the assembly with your fingers.

9. Because steps 10 through 12 involve handling electrostatic discharge (ESD) sensitive devices and assemblies, perform these steps at an ESD safe work station. This will help prevent possible damage by electrostatic discharge.

10. Note the orientation of the ICs to be replaced. Use a small screwdriver to pry the indicated ICs free from their sockets. Be careful not to bend the IC pins or damage adjacent components.

11. Carefully place the new ICs in the appropriate sockets.

12. Check the orientation of the ICs. Be sure that each IC is in its corresponding socket. Look for IC pins that bent under or did not enter a socket hole.

13. Slide the drawout assembly back into the relay chassis. Using your fingers, push the assembly in until the retaining screw holes in the drawout assembly align with corresponding holes in the relay chassis.

14. Install the retaining screws and reconnect the two ribbon cables.

15. With breaker control disabled, turn relay power back on and enter your settings. Execute the STATUS, METER, and TRIGGER commands to ensure that all functions are operational. Set and record your Access Level 1 and 2 passwords and the date and time. The relay is now ready to resume protective functions.

16. Please return the old ICs to SEL in the same packing materials. New chips are shipped with a mailing label to simplify this process. When we receive the old parts, we will record a firmware upgrade for each of your relays.

Factory Assistance

If you have any questions regarding the performance, application, or repair of this or any other SEL product, do not hesitate to contact the factory. Our staff is happy to assist you.

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ONEBUS: PROGRAM TO COMPUTE TEST SET SETTINGS FOR TESTING DISTANCE RELAYS

The BASIC program in this note determines voltages and currents which would appear on distance relay terminals for ground and phase faults on a radial system with source impedance at the same angle as line impedance. It is useful in determining test voltage and current settings for SEL distance relays and fault locating equipment.

The program was initially designed to run on a TRS-80 Model 100 briefcase computer but may be installed on virtually any personal computer or laptop.

The program first prompts you for the positive- and zero-sequence impedances of the transmission line. Enter the data in secondary ohms for the entire length of the protected line.

Next, you may enter fault resistance, which is used in the ground-fault computations.

Enter source impedance as a per-unit value with a base of the previously-entered transmission line data. For example, if the radial system has a source impedance of about ten percent of the entered line impedance, enter 0.1 for the per-unit distance from the source to the bus.

Specify the distance from the bus to the fault as a fraction of the total line length. To obtain the voltages and currents for a fault one-half the way down the line from the bus, enter 0.5 for the distance from the bus to the fault.

After you enter this data, the program begins computations. The display then shows voltages and currents for both an AG and BC fault. These data can be entered into any active test source.

The bottom line of the display offers you a choice of entering new impedance data (I), changing the distance from the source to the bus (B), specifying a new fault location (F), or quitting (Q).

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140 Iowa Ave, Suite 201 • Belleville, IL 62220-3940 Tel: (618) 233-1010 Fax: (618) 233-1042
454 S Anderson Rd, BTC 531 • Rock Hill, SC 29730-3390 Tel: (803) 329-6300 Fax: (803) 329-6320

```
1     REM SCHWEITZER ENGINEERING LABORATORIES, INC.
2     REM 2350 NE Hopkins Court
3     REM Pullman, WA  99163-5603
4     REM
10    REM COMPUTE DOBLE SETTINGS FOR A ONE-BUS SYSTEM
20    REM HOMOGENEOUS SYSTEM
30    REM SOURCE VOLTS= 67 L-N
40    REM
50    REM ENTER IMPEDANCES FOR 100% OF LINE
60    INPUT "ENTER Z1: R,X";R1,S1
70    INPUT "ENTER Z0: R,X";R0,S0
75    INPUT "ENTER RF FOR GND FLTS";RF
80    REM
90    REM ENTER BUS LOC. FROM SOURCE
100   INPUT "DIST SOURCE TO BUS (PU OF LINE)";S
120   INPUT "DIST BUS TO FAULT (PU OF LINE)";F
130   REM
140   REM  PHASE A TO GROUND
150   REM COMPUTE POS SEQ CURRENT
160   X = R0+2*R1: Y = S0+2*S1
170   R3 = R1-R0:   S3 = S1-S0
180   AR=1/(S+F):  AI=0
190   BR=X      :  BI=Y
195   BR=BR+3*RF/(S+F)
200   GOSUB 2000
210   I = RR    :   J = RI
220   IA = 3*67*I:  JA=3*67*J
225   IB=0:JB=0:IC=0:JC=0
230   AR=X:AI=Y:BR=I:BI=J
232   GOSUB 1000
234   UA=67*(1-S*RR):VA=67*(-S*RI)
240   AR=R3      :AI=S3
250   BR=I       :BI=J
260   GOSUB 1000
270   TR=S*RR    :TS=S*RI
280   UB=67*(-0.5+TR)
290   VB=67*(-SQR(3)/2+TS)
300   UC=67*(-0.5+TR)
310   VC=67*(SQR(3)/2+TS)
315   FF$="A-G"
320   GOSUB 4041
500   REM  B-C FAULT
510   AR=1: AI=0
520   BR=2*R1*(S+F):BI=2*S1*(S+F)
530   GOSUB 2000
540   I=RR:J=RI
550   IA=0:JA=0
560   AR=I:AI=J:BR=0:BI=-67*SQR(3)
570   GOSUB 1000
580   IB=RR:JB=RI:IC=-IB:JC=-JB
590   UA=67:VA=0
600   AR=I:AI=J:BR=S*R1:BI=S*S1
610   GOSUB 1000
620   AR=RR:AI=RI:BR=0:BI=SQR(3)
630   GOSUB 1000
635   TR=RR:TS=RI
640   UB=67*(-0.5+TR)
650   VB=67*(-SQR(3)/2+TS)
660   UC=67*(-0.5-TR)
670   VC=67*(0.5*SQR(3)-TS)
675   FF$="B-C"
680   GOSUB 4041
900   INPUT "IMP BUS FAULT OR QUIT (I,B,F,Q)";A$
910   IF A$ = "I" THEN GOTO 50
920   IF A$ = "B" THEN GOTO  75
930   IF A$ = "F" THEN GOTO 120 ELSE GOTO 999
999   END
1000  REM MULT SUBROUTINE
1010  REM AR,AI * BR,BI = RR,RI
1020  RR=AR*BR-AI*BI
1030  RI=AI*BR+AR*BI
1040  RETURN
2000  REM DIVISION SUBROUTINE
2010  REM AR,AI / BR,BI = RR,RI
2020  D = BR*BR + BI*BI
2030  RR = AR*BR + AI*BI
2040  RR = RR/D
2050  RI = BR*AI - AR*BI
2060  RI = RI/D
2070  RETURN
3000  REM RECT TO POLAR CONV
3010  REM AR,AI, TO RH, TH
3020  PI = 3.14159265358
3030  IF (AR=0 AND AI=0) THEN    RH=0: TH=0: RETURN
3040  IF (AR=0 AND AI>0) THEN    RH=AI: TH=90:RETURN
3050  IF (AR=0 AND AI<0) THEN RH=-AI: TH=-90: RETURN
3060  IF (AR>0) THEN TH=(180/PI)*ATN(AI/AR)
3070  IF (AR<0) THEN TH=(180/PI)*ATN(AI/AR)+180
3080  IF TH>180 THEN TH = TH-360
3090  RH=SQR(AR*AR+AI*AI)
3100  RETURN
4041  AR=UA:AI=VA:GOSUB 3000
4042  UA=RH:VA=TH
4043  AR=UB:AI=VB:GOSUB 3000
4044  UB=RH:VB=TH-VA
4045  AR=UC:AI=VC:GOSUB 3000
4046  UC=RH:VC=TH-VA
4047  AR=IA:AI=JA:GOSUB 3000
4048  IA=RH:JA=TH-VA
4049  AR=IB:AI=JB:GOSUB 3000
4050  IB=RH:JB=TH-VA
4055  AR=IC:AI=JC:GOSUB 3000
4060  IC=RH:JC=TH-VA
4061  VA=0
4100  PRINT " VA   VB   VC   IA   IB   IC"
4130  PRINT USING"##.# ";UA;UB;UC;IA;IB;IC,
4132  PRINT FF$
4140  PRINT USING"#### ";VA;VB;VC;JA;JB;JC
4150  RETURN
```

APPENDICES
TABLE OF CONTENTS

APPENDIX A - FIRMWARE VERSIONS FOR THIS MANUAL

This manual, dated June 4, 1992, covers SEL relays that contain firmware bearing the following part numbers and revision numbers:

Firmware Part/Revision No.	Description of Firmware
Firmware Revision 1, 121F Mainboard Configurations	
SEL-121F-R113	60 Hz, 5A, Miles, ABC
SEL-121F-R210	60 Hz, 5A, Kilometers, ABC
SEL-121F-R111	60 Hz, 5A, Miles, ABC
SEL-121F-R208	60 Hz, 5A, Kilometers, ABC
SEL-121F-R110	60 Hz, 5A, Miles, ABC
SEL-121F-R207	60 Hz, 5A, Kilometers, ABC
SEL-121F-R109	60 Hz, 5A, Miles, ABC
SEL-121F-R206	60 Hz, 5A, Kilometers, ABC
SEL-121F-R108	60 Hz, 5A, Miles, ABC
SEL-121F-R205	60 Hz, 5A, Kilometers, ABC
Firmware Revision 4, 121F/221F Mainboard Configurations	
SEL-121F-R411	60 Hz, 5A, Miles, ABC
SEL-121F-R510	60 Hz, 5A, Kilometers, ABC
SEL-121F-R608	60 Hz, 5A, Miles, ACB
SEL-121F-R708	60 Hz, 5A, Kilometers, ACB
SEL-121F-R758	60 Hz, 1A, Kilometers, ABC
SEL-121F-R807	50 Hz, 5A, Kilometers, ABC
SEL-121F-R907	50 Hz, 1A, Kilometers, ABC
SEL-121F-1-R407	60 Hz, 5A, Miles, ABC, Special Recloser
SEL-121F-8-R404	60 Hz, 5A, Miles, ABC, Modified Command Levels
SEL-121F-R409	60 Hz, 5A, Miles, ABC
SEL-121F-R508	60 Hz, 5A, Kilometers, ABC
SEL-121F-R606	60 Hz, 5A, Miles, ACB
SEL-121F-R706	60 Hz, 5A, Kilometers, ACB
SEL-121F-R756	60 Hz, 1A, Kilometers, ABC
SEL-121F-R805	50 Hz, 5A, Kilometers, ABC
SEL-121F-R906	50 Hz, 1A, Kilometers, ABC
SEL-121F-1-R405	60 Hz, 5A, Miles, ABC, Special Recloser
SEL-121F-8-R403	60 Hz, 5A, Miles, ABC, Modified Command Levels
SEL-121F-R755	60 Hz, 1A, Kilometers, ABC
SEL-121F-R905	50 Hz, 1A, Kilometers, ABC

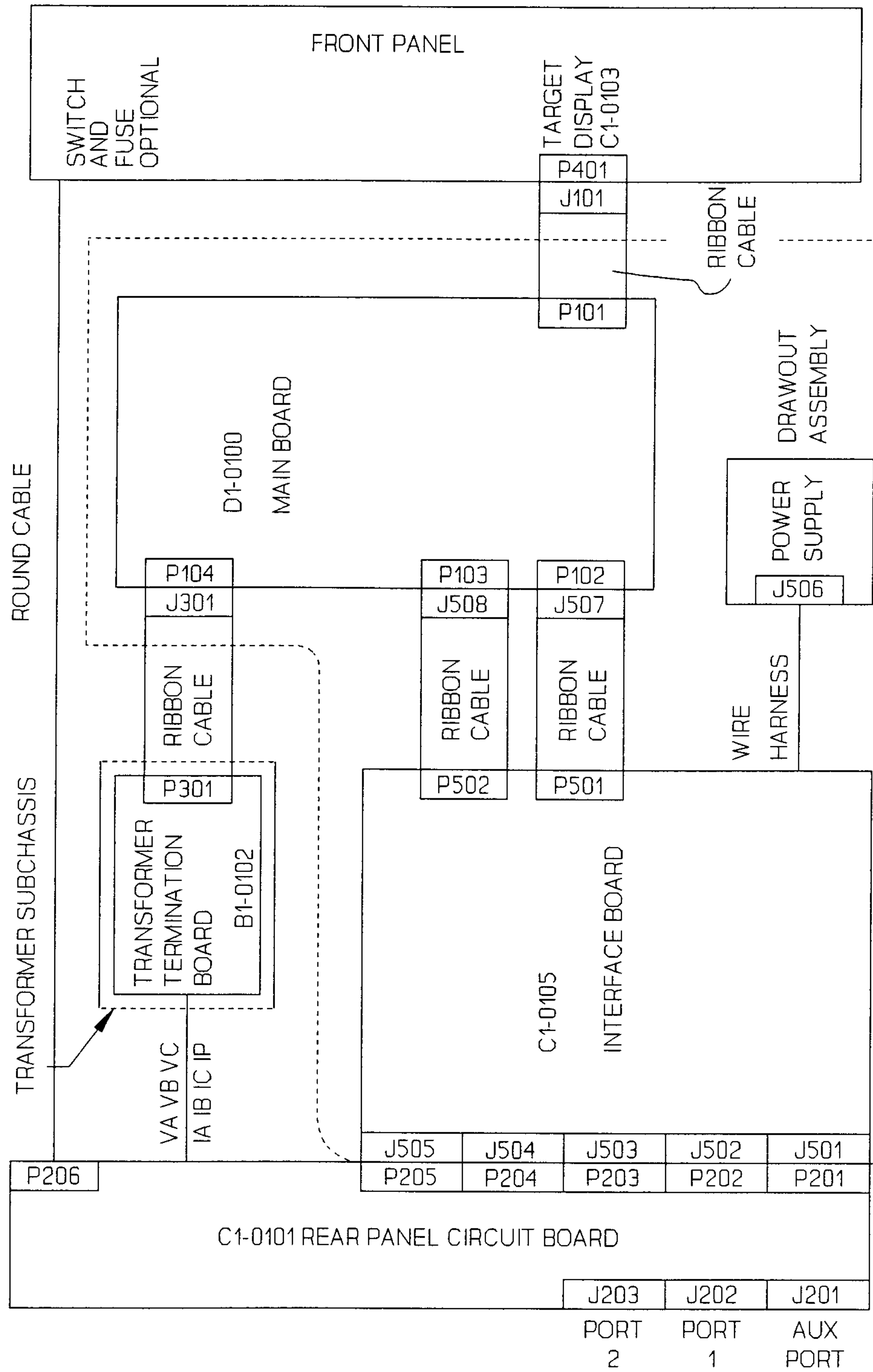
Firmware Revision 4, 121F/221F Mainboard Configurations (continued)	
SEL-121F-R408	60 Hz, 5A, Miles, ABC
SEL-121F-R507	60 Hz, 5A, Kilometers, ABC
SEL-121F-R605	60 Hz, 5A, Miles, ACB
SEL-121F-R705	60 Hz, 5A, Kilometers, ACB
SEL-121F-R754	60 Hz, 1A, Kilometers, ABC
SEL-121F-R804	50 Hz, 5A, Kilometers, ABC
SEL-121F-R904	50 Hz, 1A, Kilometers, ABC
SEL-121F-1-R404	60 Hz, 5A, Miles, ABC, Special Recloser
SEL-121F-8-R402	60 Hz, 5A, Miles, ABC, Modified Command Levels
SEL-121F-R407	60 Hz, 5A, Miles, ABC
SEL-121F-R506	60 Hz, 5A, Kilometers, ABC
SEL-121F-R604	60 Hz, 5A, Miles, ACB
SEL-121F-R704	60 Hz, 5A, Kilometers, ACB
SEL-121F-R753	60 Hz, 1A, Kilometers, ABC
SEL-121F-R803	50 Hz, 5A, Kilometers, ABC
SEL-121F-R903	50 Hz, 1A, Kilometers, ABC
SEL-121F-1-R403	60 Hz, 5A, Miles, ABC, Special Recloser
SEL-121F-8-R401	60 Hz, 5A, Miles, ABC, Modified Command Levels
SEL-121F-R406	60 Hz, 5A, Miles, ABC
SEL-121F-R505	60 Hz, 5A, Kilometers, ABC
SEL-121F-R603	60 Hz, 5A, Miles, ACB
SEL-121F-R703	60 Hz, 5A, Kilometers, ACB
SEL-121F-R752	60 Hz, 1A, Kilometers, ABC
SEL-121F-R802	50 Hz, 5A, Kilometers, ABC
SEL-121F-R902	50 Hz, 1A, Kilometers, ABC
SEL-121F-1-R402	60 Hz, 5A, Miles, ABC, Special Recloser
SEL-121F-8-R400	60 Hz, 5A, Miles, ABC, Modified Command Levels

To find the firmware revision number in your relay, obtain an event report (which identifies the firmware) using the EVENT command. This is an FID number with the Part/Revision number in bold:

FID=**SEL-121F-8-R401**-656mpsmsu2-D920317

For a detailed explanation of the Firmware Identification Number (FID) refer to section 4.

APPENDIX B - INTERNAL DIAGRAMS



Module Interconnections Diagram

SEL-121F DISTANCE RELAY/FAULT LOCATOR COMMAND SUMMARY

Access Level 0

ACCESS	Answer password prompt (if password protection enabled) to gain access to Level 1. Three unsuccessful attempts pulses ALARM relay.

Access Level 1

2ACCESS	Answer password prompt (if password protection enabled) to gain access to Level 2. This command always pulses the ALARM relay.
DATE m/d/y	Show or set date. DAT 2/3/92 sets date to Feb. 3, 1992. This setting is overridden when IRIG-B synchronization occurs. Pulses the ALARM relay momentarily when a different year is entered than the previously stored.
EVENT	Show event record. EVE 1 shows long form of most-recent event.
HISTORY	Show DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION, and CURRENT for the twelve latest events.
IRIG	Force immediate execution of time code synchronization task.
METER n	Show primary current, voltage, and real and reactive power. METER runs once. METER n runs n times.
QUIT	Return to Access Level 0 and reset targets to target 0.
SHOWSET	Show the relay settings and logic settings -- does not affect the settings. The logic settings are shown in hexadecimal format for each.
STATUS	Show self test status.
TARGET n	Show data and set target lights as follows: TAR 0: Relay Targets — TAR 1: RELAY WORD #1 TAR 2: RELAY WORD #2 — TAR 3: RELAY WORD #3 TAR 4: INTERNAL ELEMENTS — TAR 5: Contact Inputs TAR 6: Contact Outputs — TAR R: Returns to TAR 0 and clears Be sure to return to TAR 0 when done, so LEDs display fault targets.
TIME h/m/s	Show or set time. TIM 13/32/00 sets clock to 13:32:00 PM. This setting is overridden when IRIG-B synchronization occurs.
TRIGGER	Trigger and save an event record. (Type of event is EXT).

Access Level 2

CLOSE	Close circuit breaker, if Jumper JMP104 is installed.
LOGIC n	Show or set logic masks MTU, MPT, MTO, MTB, MRI, MRC, MA1-MA4. ALARM relay closes momentarily while the new settings are stored in EEPROM and event data buffers are cleared.
OPEN	Open circuit breaker, if Jumper JMP104 is installed.
PASSWORD	Show or set passwords. Pulses the ALARM relay momentarily when new passwords are set. PAS 1 OTTER sets Level 1 password to OTTER. PAS 2 TAIL sets Level 2 password to TAIL.
SET	Initiate setting procedure. ALARM relay closes momentarily while the new settings are stored in EEPROM and event data buffers are cleared.

Use the following to separate commands and their parameters: space, comma, semicolon, colon, or slash.

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Patents Pending

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Access Level 1

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