SEL-121H PHASE DISTANCE RELAY, DIRECTIONAL GROUND RELAY, FAULT LOCATOR

DATA SHEET

- Use in permissive transfer trip and unblocking protection schemes
- Current reversal logic provides security for healthy parallel lines
- Weak-infeed logic permits rapid clearing of both line ends
- Open breaker echo logic reduces fault clearing time
- Three zones of phase distance protection provide complete line coverage
- Multiple residual overcurrent elements give sensitivity for high impedance ground faults
- Three ground directional polarization methods span variety of system conditions
- Switch-onto-fault logic permits instantaneous tripping for reclosing or line pickup
- Programmable Mask Logic provides application and testing flexibility
- Load compensating fault locator reduces line patrolling for improved system reliability
- Eleven-cycle event report simplifies fault and system analysis
- Serial communication ports allow local or remote interaction with the relay
GENERAL DESCRIPTION

Use the SEL-121H Relay in Communication-Based Protection Schemes

The SEL-121H relay supports the following communication-based protection schemes:

- Permissive Overreaching Transfer Trip (POTT) schemes
- Permissive Underreaching Transfer Trip (PUTT) schemes
- Directional Comparison Unblocking (DCUB) schemes
- Direct Underreaching Transfer Trip (DUTT) schemes
- Direct Transfer Trip (DTT) schemes

Current Reversal Logic

In double-circuit applications, faults near one end of the line may result in sequential trip of the faulted line, which causes a current reversal in the healthy line. To preserve the security of the healthy line, the SEL-121H relay uses reverse Zone 3 elements and associated logic to block permissive tripping and keying for a short time following the current reversal.

Weak-Infeed Logic

Applying the SEL-121H relay on a weak-source terminal allows you to use the weak-infeed logic to echo the strong-source terminal permissive trip signal. The weak-infeed logic uses a combination of breaker status, reverse Zone 3 elements, and voltage elements to detect a forward fault. You can use the received permissive trip signal to trip the weak source terminal under certain conditions.

Open Breaker Echo Logic

With the local breaker open, the remote end typically clears faults near the local end in Zone 2 time. With the local breaker open and no reverse Zone 3 elements picked up, the SEL-121H relay can echo the permissive trip signal to the remote end and clear Zone 2 faults faster.

Three Zones of Phase Distance Protection

The relay has three zones of phase-phase mho distance elements with independent timers. Zone 3 elements are reversible. Four zones of three-phase mho distance elements with timers provide protection for three-phase faults. Three-phase elements are memory polarized from a four-cycle filter. Zone 4 provides sensitive switch-onto-fault protection; the Zone 4 element can alarm for load encroachment.

Multiple Residual Overcurrent Elements

The relay has three steps of instantaneous/definite-time directional ground overcurrent protection. Zone 3 is reversible. A ground inverse-time overcurrent element is available for sensitive ground fault detection. Four curve shapes are available and the time-dial is settable in small increments to simplify coordination with downstream protective devices.
Three Ground Directional Polarization Methods

The relay has sensitive negative-sequence, zero-sequence voltage, and zero-sequence current directional polarization elements to control the ground overcurrent elements. Zero-sequence elements may be used together to provide dual zero-sequence polarization.

Switch-Ongo-Fault Logic

Select sensitive elements to trip for a settable time after the breaker closes. Zone 2 faults can be cleared with no time-delay on reclose. A high-set, non-directional phase overcurrent element can clear close-in, zero-voltage three-phase faults on line pickup.

Programmable Mask Logic

The SEL-121H relay also has programmable mask logic. Configure the TRIP and auxiliary outputs to operate when any of 32 protective elements and logic outputs pick up. Implement complete protective schemes using a minimum of wiring and panel space. Programmable contact closure simplifies testing by indicating pickup and dropout of elements under test.

Load Compensating Fault Locator

The relay has a fault locating algorithm which automatically compensates for prefault load flow and fault resistance. Accurate fault location reduces search and outage time; lower outage time means higher overall system reliability.

Eleven-Cycle Event Report

The relay generates an eleven-cycle event report after each fault, or upon command. The report provides four cycles of prefault data and seven cycles of fault data. The data includes voltages, currents, relay elements, and relay inputs and outputs. The report also shows the calculated fault location, time and date of event, and relay settings. This information simplifies post-fault analysis and improves understanding of protective scheme operation. The relay stores the last twelve event reports for local or remote retrieval. Reclosing sequences are stored intact and no information is lost when several events occur in a short time.

Serial Communication Ports

The relay is equipped with two serial communication ports to provide local or remote access to setting, metering, and fault analysis capability. Remote communications allow operators to retrieve fault information from a remote relay immediately, without leaving their stations.

A two-level password security scheme prevents unauthorized access to the relay. The first level allows examination of settings and power system data. Setting changes are made from the second level.

The relay requires no special communication software: you can use a dumb terminal, printing terminal, or computer with serial port and terminal emulation software.
## GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th><strong>Voltage Inputs</strong></th>
<th>115 volt nominal phase-to-phase, three-phase four-wire connection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Inputs</strong></td>
<td>0.07 VA burden at 67 V line-to-neutral</td>
</tr>
<tr>
<td><strong>Output Contact Current Ratings</strong></td>
<td>5 amps per phase nominal; 0.06 VA burden</td>
</tr>
<tr>
<td></td>
<td>15 amps per phase continuous; 500 amps for one second thermal rating</td>
</tr>
<tr>
<td><strong>Optical Isolator Logic Input Ratings</strong></td>
<td>30 amp make per IEEE C37.90 para 6.6.2</td>
</tr>
<tr>
<td></td>
<td>6 amp carry continuously; MOV protection provided</td>
</tr>
<tr>
<td><strong>Power Supply</strong></td>
<td>48 Vdc: 25 - 60 Vdc</td>
</tr>
<tr>
<td></td>
<td>125 Vdc: 60 - 200 Vdc</td>
</tr>
<tr>
<td></td>
<td>250 Vdc: 200 - 280 Vdc</td>
</tr>
<tr>
<td><strong>Time Code Input</strong></td>
<td>Demodulated IRIG-B</td>
</tr>
<tr>
<td><strong>Communications</strong></td>
<td>Two EIA RS-232-C serial communications ports</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>5¾&quot; x 19&quot; x 13&quot; (13.3 cm x 48.2 cm x 33.0 cm) (H x W x D)</td>
</tr>
<tr>
<td><strong>Mounting</strong></td>
<td>Available in horizontal or vertical mounting configurations.</td>
</tr>
<tr>
<td><strong>Dielectric Strength</strong></td>
<td>V, I inputs: 2500 Vdc for 10 seconds</td>
</tr>
<tr>
<td></td>
<td>Other: 3000 Vdc for 10 seconds (excludes RS-232-C)</td>
</tr>
<tr>
<td><strong>Operating Temp.</strong></td>
<td>-4°F to 131°F (-20°C to +55°C)</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>IEC 68-2-30 Temperature/Humidity Cycle Test - six day (type tested)</td>
</tr>
<tr>
<td><strong>Interference Tests</strong></td>
<td>IEEE C37.90 SWC Test (type tested)</td>
</tr>
<tr>
<td></td>
<td>IEC 255-6 Interference Test (type tested)</td>
</tr>
<tr>
<td><strong>Impulse Tests</strong></td>
<td>IEC 255-5 0.5 joule 5000 volt test (type tested)</td>
</tr>
<tr>
<td><strong>RFI Tests</strong></td>
<td>Type-tested in field from a ½-wave antenna driven by 20 watts at 150 MHz and 450 MHz randomly keyed on and off one meter from relay.</td>
</tr>
<tr>
<td><strong>ESD Test</strong></td>
<td>IEC 801-2 Electrostatic Discharge Test (type tested)</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>21 lbs (9.1 kg); shipping weight 32 lbs (14.1 kg), including two manuals.</td>
</tr>
<tr>
<td><strong>Burn-in</strong></td>
<td>140°F (60°C) for 100 hours.</td>
</tr>
<tr>
<td><strong>Warranty</strong></td>
<td>Four years from date of purchase.</td>
</tr>
</tbody>
</table>
FUNCTIONAL SPECIFICATIONS

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

- Independent timers for Zone 2 and 3 distance elements
- Overcurrent elements supervise all distance elements
- Loss-of-potential logic can supervise all distance elements
- Zone 3 elements are reversible

Phase-Phase Distance Elements (secondary quantities)

21P1: 0.125 to 64 ohms
21P2: 0.125 to 64 ohms
21P3: 0.125 to 64 ohms

Three-Phase Distance Elements (secondary quantities)

21ABC1: 0.125 to 64 ohms
21ABC2: 0.125 to 64 ohms
21ABC3: 0.125 to 64 ohms
21ABC4: offset mho with diameter 1.50 times Zone 3

Maximum Torque Angle (MTA)

Adjustable from 47 - 90 degrees in 0.01 degree increments.

Figure 1: Phase-Phase and Three-Phase Mho Element Characteristics

Zone 2 and 3 settings are limited as follows:

For Zone 3 Forward: Zone 1 < Zone 2 < Zone 3
For Zone 3 Reverse: Zone 1 < Zone 2, Zone 1 < Zone 3
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 distance element operating time curves on page 19.

Distance Element Timers

Zone 2 timer (Z2DP) range: (0 - 2000 cycles in ¼ cycle steps)
Zone 3 timer (Z3DP) range: (0 - 2000 cycles in ¼ cycle steps)

Mho Element Expansion

The phase distance elements use the compensator distance principle, which expands the mho distance characteristics. The phase-phase elements are strongly polarized from the non-involved phase and do not require memory polarization. The three-phase elements use memory polarization to achieve expanded characteristics.

Figure 2 illustrates the expanded mho characteristics for phase-phase faults in front of the relay. Figure 3 illustrates the expanded mho characteristics for three-phase faults in front of the relay. In both figures, the amount of mho expansion depends on the relative strength of the source. To determine the amount of expansion mho characteristics experience, relay reach and positive-sequence source impedance must be known. Use the equations to plot the circle center and radius of the mho characteristics.

Figures 2 and 3 show an example for an SIR of two, and compare the SEL-121H relay expanded mho characteristic with theoretical self-polarized mho characteristics.

Phase-phase Elements:

\[
\begin{align*}
\text{CENTER} &= \frac{1}{2} (-Z_S + Z_R) \\
\text{RADIUS} &= \frac{1}{2} (Z_S + Z_R)
\end{align*}
\]

Where:

\[Z_S = \text{Positive-sequence source impedance}\]
\[Z_R = \text{Relay reach in positive-sequence ohms}\]
Figure 2: Expanded Phase-Phase Mho Characteristics

Three-Phase Elements:

Figure 3: Expanded Three-Phase Mho Characteristics
Residual Overcurrent Protection for Ground Faults

S1N Residual Time overcurrent Element (secondary quantities)

- 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: 0.25 to 6.3 A, ± 0.05 A ± 2% of setting.
- Timing: ±4% and ±1 cycle for residual current magnitude between 2 and 20 multiples of pickup.
- May be directionally controlled (S1NTC setting).

S0N1, S0N2, S0N3 Residual Overcurrent Elements (secondary quantities)

- Pickup: 0.25 A to 48 times S1N pickup for S1N pickup < 3.15 A.
  0.50 A to 48 times S1N pickup for S1N pickup ≥ 3.15 A.
- Transient overreach: 5% of set pickup.
- May be directionally controlled (S2Q, S2V, and S2I enables).

Residual Overcurrent Element Timers

Zone 2 timer (Z2DG) range: (0 - 2000 cycles in 4 cycle steps)
Zone 3 timer (Z3DG) range: (0 - 2000 cycles in 4 cycle steps)

![Diagram of Residual Overcurrent Zones of Protection]

Figure 4: Residual Overcurrent Zones of Protection

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Residual Overcurrent Directional Element Ranges and Sensitivities

Negative-sequence directional element

- The angle between the measured negative-sequence voltage and current adjusted by the MTA setting determines fault direction (I2 leads V2 ±90° from MTA).

Zero-sequence directional element

Voltage polarization

- The angle between the measured zero-sequence voltage and residual current adjusted by the MTA setting determines fault direction (I0 leads V0 ±90° from MTA).
- Does not require an external polarizing source.

Current polarization

- The relay measures the angle between the measured residual current and zero-sequence current from an external source to determine fault direction.

| Table 1: Directional Element Sensitivities at Maximum Torque Angle (MTA) |
|--------------------------|--------------------------|--------------------------|
| Element                  | Negative-Sequence 32Q    | Zero-Sequence 32D        |
| Sensitivity              | 0.10                     | (0.29)(51NP)             |
| Units                    | (V2)(I2)                 | (V0)(IR)                 |
|                          |                          | (IR)(IP)                 |

Note: 51NP is the pickup setting of the 51N element in secondary amps.

Nondirectional Phase Overcurrent Elements

- 50AL, 50BL, 50CL  (current detectors)
- 50AM, 50BM, 50CM  (current detectors, used in loss-of-potential logic)

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

Loss-of-Potential (LOP) Detection

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• Declares an LOP condition when zero-sequence voltage is detected in the absence of zero-sequence current (one or two potential fuses blown).
• Declares an LOP condition when positive sequence voltage drops below 14 volts secondary and phase current is below the 50M setting (three potential fuses blown).
• Clears LOP condition when balanced three-phase voltages return.
• When you set LOPE = Y, LOP blocks distance elements and causes directional elements to default forward.
• Use LOP condition to close programmable output contacts to alarm for a blown fuse condition.

**Open Breaker Echo Keying**

• Echoes the received permissive trip signal to the remote terminal when no reverse Zone 3 elements are picked up and the local line breaker is judged open by the 52A input.
• Received permissive trip signal must be present for a settable time before echoing is permitted.
• Echo duration is settable.

**Weak-Infeed Conditional Logic**

• Conditions a received permissive trip signal to allow tripping of a weak-infeed terminal if no reverse elements are asserted and the breaker is closed (Echo-Conversion-To-Trip).
• 27AB, 27BC, 27CA elements monitor the magnitudes of phase-to-phase voltages.
• 59N monitors the magnitude of the zero-sequence voltage.
• Voltage setting ranges:
  - 27PP elements: 0 - 260 V_{ss} secondary, ±5%, ±1 V
  - 59N elements: 0 - 150 V_{ss} secondary, ±5%, ±1 V

**Current Reversal Logic**

• Reverse phase distance elements, reverse ground overcurrent elements, and breaker status supervise the current reversal logic.
• Settable current reversal timer (Z3RBT).
• Breaker status defeats current reversal logic (BZ3RB) for a settable time during a line test.
LOGIC INPUTS

The relay has six opto-isolator inputs to sense external conditions: received permissive trip and block trip signals, breaker status, direct close, direct trip, and external event report trigger. Assert an input 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 factory configured as either form a or form b.

RELAY WORD

The Relay Word consists of four 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.

Table 2: Relay Word

<table>
<thead>
<tr>
<th>1ABC</th>
<th>2ABC</th>
<th>3ABC</th>
<th>4ABC</th>
<th>LOP</th>
<th>50H</th>
<th>50M</th>
<th>50L</th>
</tr>
</thead>
<tbody>
<tr>
<td>51NT</td>
<td>67N1</td>
<td>67N2</td>
<td>67N3</td>
<td>51NP</td>
<td>Z1P</td>
<td>Z2P</td>
<td>Z3P</td>
</tr>
<tr>
<td>Z2PT</td>
<td>Z3PT</td>
<td>Z3RB</td>
<td>KEY</td>
<td>50MF</td>
<td>PTEE</td>
<td>ECTT</td>
<td>DF</td>
</tr>
<tr>
<td>ALRM</td>
<td>TRIP</td>
<td>TC</td>
<td>DT</td>
<td>52BT</td>
<td>WFC</td>
<td>Z2GT</td>
<td>Z3GT</td>
</tr>
</tbody>
</table>

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The Relay Word Bit Summary Table explains each bit in the Relay Word.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ABC</td>
<td>Zone 1 three-phase instantaneous element (set by Z1%)</td>
</tr>
<tr>
<td>2ABC</td>
<td>Zone 2 three-phase instantaneous element (set by Z2%)</td>
</tr>
<tr>
<td>3ABC</td>
<td>Zone 3 three-phase instantaneous element (set by Z3%)</td>
</tr>
<tr>
<td>4ABC</td>
<td>Zone 4 three-phase instantaneous element (equal to 1.5 x Z3%)</td>
</tr>
<tr>
<td>LOP</td>
<td>Loss-of-potential condition</td>
</tr>
<tr>
<td>50H</td>
<td>High-level overcurrent element (set by 50H)</td>
</tr>
<tr>
<td>50M</td>
<td>Medium-level overcurrent element (set by 50M)</td>
</tr>
<tr>
<td>50L</td>
<td>Phase fault current supervision (set by 50L)</td>
</tr>
<tr>
<td>51NT</td>
<td>Residual time overcurrent trip (set by 51NP, 51NTD, and 51NC)</td>
</tr>
<tr>
<td>67N1</td>
<td>Residual instantaneous overcurrent (set by 50N1P)</td>
</tr>
<tr>
<td>67N2</td>
<td>Residual instantaneous overcurrent (set by 50N2P)</td>
</tr>
<tr>
<td>67N3</td>
<td>Residual instantaneous overcurrent (set by 50N3P)</td>
</tr>
<tr>
<td>51NP</td>
<td>Residual time overcurrent pickup</td>
</tr>
<tr>
<td>ZIP</td>
<td>Zone 1 phase-phase element (set by Z1%)</td>
</tr>
<tr>
<td>Z2P</td>
<td>Zone 2 phase-phase element (set by Z2%)</td>
</tr>
<tr>
<td>Z3P</td>
<td>Zone 3 phase-phase element (set by Z3%)</td>
</tr>
<tr>
<td>Z2PT</td>
<td>Zone 2 phase-phase or three-phase timeout (set by Z2DP)</td>
</tr>
<tr>
<td>Z3PT</td>
<td>Zone 3 phase-phase or three-phase timeout (set by Z3DP)</td>
</tr>
<tr>
<td>Z3RB</td>
<td>Zone 3 reverse block timer output (TDDO time set by Z3RBT)</td>
</tr>
<tr>
<td>KEY</td>
<td>Communication channel keying bit</td>
</tr>
<tr>
<td>50MF</td>
<td>Asserts a settable delay after LOP and 50M pickup (delay set by 50MFD)</td>
</tr>
<tr>
<td>PTEE</td>
<td>Permissive Trip Echo Enable (limited duration pulse set by echo timers, ETDPU and EDUR)</td>
</tr>
<tr>
<td>ECTT</td>
<td>Echo-Conversion-To-Trip</td>
</tr>
<tr>
<td>DF</td>
<td>Direction forward for ground faults</td>
</tr>
<tr>
<td>ALRM</td>
<td>System alarm</td>
</tr>
<tr>
<td>TRIP</td>
<td>Trip contact closure</td>
</tr>
<tr>
<td>TC</td>
<td>Trip (OPEN) Command</td>
</tr>
<tr>
<td>DT</td>
<td>Direct Trip (or other user defined external purposes)</td>
</tr>
<tr>
<td>52BT</td>
<td>Inverted time delayed 52a follower (delay set by 52BT setting)</td>
</tr>
<tr>
<td>WFC</td>
<td>Weak-infeed condition (set by 27PP and 59N)</td>
</tr>
<tr>
<td>Z2GT</td>
<td>Zone 2 timeout-ground (set by Z2DG)</td>
</tr>
<tr>
<td>Z3GT</td>
<td>Zone 3 timeout-ground (set by Z2DG)</td>
</tr>
</tbody>
</table>
PROGRAMMABLE OUTPUT LOGIC

The relay uses programmable logic masks to control the TRIP and programmable output relays. Logic masks are saved in nonvolatile memory with the other settings. They are set with the LOGIC command and retained through losses of control power.

To program each logic mask, select elements of the Relay Word. If any element in the Relay Word asserts and the same element is selected in a logic mask, the output contact associated with the logic mask closes.

The output equations follow:

Let \( R = \) Relay Word

\[
\begin{align*}
MTU &= \text{mask for trip} \\
MPT &= \text{mask for trip} \\
MTB &= \text{mask for trip} \\
MTO &= \text{mask for trip}
\end{align*}
\]

then:

\[
TRIP = R \cdot MTU + R \cdot MPT \cdot PT \cdot NOT(Z3RB) + R \cdot MTB \cdot NOT(BT) + R \cdot MTO \cdot 52BT
\]

Close TRIP contact = TRIP
Open TRIP contact = NOT (TRIP) * [(NOT(50L) + NOT(50NL)) + TARGET RESET button pushed] * (trip duration timer expires)

Close CLOSE contact = (DC + CLOSE COMMAND) * NOT
Open CLOSE contact = NOT (CLOSE) + 63.75 cycle CLOSE reset timer

\[
\begin{align*}
A1 &= R \cdot MA1 \\
A2 &= R \cdot MA2 \\
A3 &= R \cdot MA3 \\
A4 &= R \cdot MA4
\end{align*}
\]

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

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 occurs
- 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. 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 the elements of the Relay Word.

SERIAL INTERFACES

Connectors labeled 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.

Port baud rates are 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, no parity. Communications use XON/XOFF flow control.
EVENT REPORTING

The relay retains a data record for each of the last twelve events. The record includes fault location, input voltages and currents, relay elements, input contacts, and output contacts. The relay saves a report when any of the following occur:

- The relay trips
- Selected relay elements assert
- User executes the TRIGGER or OPEN commands
- DT (Direct Trip) or ET (External Trigger) input is asserted

Two sample event reports are included near the end of this data sheet.

FAULT LOCATION

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

METERING

The meter function shows the line-neutral and line-line ac voltage and current 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.

SELF TESTING

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

The relay closes the ALARM contact after any self test fails. When the relay detects certain failures, it disables the breaker control functions and places the output relay driver port in an
input mode. No outputs may be asserted when the relay is in this configuration. The relay runs all self tests at least every five minutes.

Table 4 shows a list of the self tests performed by the relay.

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offset</td>
<td>Measures dc offset of analog input channels.</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Measures internal power supply voltages.</td>
</tr>
<tr>
<td>Read-Only Memory</td>
<td>Verifies RAM operation.</td>
</tr>
<tr>
<td>Analog-to-Digital Converter</td>
<td>Verifies ROM operation.</td>
</tr>
<tr>
<td>Master Offset Settings</td>
<td>Verifies A/D operation.</td>
</tr>
<tr>
<td></td>
<td>Measures dc offset of multiplexer channel.</td>
</tr>
<tr>
<td></td>
<td>Verifies checksum of setting group.</td>
</tr>
</tbody>
</table>

CONNECTIONS

Figure 5 shows typical ac connections for an SEL-121H relay. Figure 6 shows connections for one terminal in a typical permissive overreaching transfer trip (POTT) scheme. The receive contact (RX), is connected to the relay permissive trip (PT) input. When the KEY bit in the Relay Word asserts, the A1 output contact closes to assert the transmit input (TX) of the communication equipment.

The protection scheme uses unsupervised instantaneous Zone 1 elements and instantaneous Zone 2 elements supervised by the permissive trip (PT) input. Time-delayed Zone 2 and Zone 3 elements provide time-stepped backup protection in the event of a communication channel failure.

Figure 7 shows the tripping and output contact masks used to implement this protection scheme.

Mask for Unconditional Tripping (MTU) Selects Elements for Unqualified Tripping

The MTU mask contains the Zone 1 instantaneous elements 1ABC, Z1P, and 67N1. It also contains the residual time overcurrent element 51NT and the time-delayed Zone 2 and Zone 3 phase distance and ground overcurrent elements Z2PT, Z2GT, Z3PT, and Z3GT. The 50MF bit provides non-directional, time-delayed, phase overcurrent protection under loss-of-potential conditions. ECTT asserts to trip the relay under weak-infeed conditions when a permissive signal is received from the strong source terminal and the breaker is closed. TC and DT allow you to trip the relay by command or input assertion.
Mask for Permissive Tripping (MPT) Selects Elements for PT-Qualified Tripping

When the PT input is asserted and no reverse block condition is present, bits set in the MPT mask are enabled for tripping. The MPT mask normally contains the forward looking instantaneous Zone 2 elements.

Mask for Trip while Breaker Is Open (MTO) Selects Elements for Switch- Onto-Fault Tripping

Use the MTO mask to provide switch-onto-fault protection. Elements set in the MTO mask are enabled for tripping when the breaker is open and for a short time after it closes. The MTO mask elements are enabled when the 52BT bit is asserted. 52H1 is an inverted, time-delayed follower of the 52a input signal.

Zone 1 and Zone 2 instantaneous phase distance and ground overcurrent elements provide fast tripping for faults in the reenergized section during a line pickup or test. The 50H element provides tripping for close-in bolted faults.

Program the A1 Output to Key-Permissive Signal via Mask MA1

The MA1 logic mask contains the KEY bit. This bit performs the permissive echo function. It also asserts to transmit permission to the remote terminal when forward reaching elements set in the MPT mask assert. The KEY bit is supervised by the reverse block logic.

Use the A4 Output to Indicate Loss-of-Potential (LOP) via Mask MA4

When a loss-of-potential condition occurs, the LOP bit asserts to close the A4 output contact. The A4 contact is connected to an annunciator which can alert the operator to the LOP condition.

Figure 5: SKL-121H Relay Typical AC Current and Voltage Connections
Figure 6: SEL-121H Relay Typical DC Connections to Communication Equipment

<table>
<thead>
<tr>
<th>TRIP MASKS</th>
<th>OUTPUT MASKS</th>
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</thead>
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<tr>
<td><strong>MDL</strong> -- Mask for Unidirectional Tripping</td>
<td><strong>M41</strong> -- A1 Output Mask</td>
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<tr>
<td>ZMT</td>
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<td>ZMT</td>
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**Figure 7:** Programmable Logic Mask Settings for Scheme in Figure 6
RELAY ELEMENT OPERATING TIME CURVES

Figure 8 shows operating times for the SEL-121H relay phase-phase mho distance elements and the 50H instantaneous phase overcurrent element. At each reach percentage or current multiple, ten tests were run. The diagrams show maximum, average, and minimum operating times at each test point. Operating times include output contact closure time.

For the distance element test, a phase-phase fault was applied at a location representing a percentage of the Zone 1 relay reach setting. Tests were performed for source impedance ratios (SIR) of 0.1, 1.0, and 5.0. No prefault load current was included. System frequency is 60 Hz.

Balanced three-phase currents and no voltages were applied to the relay for the 50H overcurrent element tests. This test simulates a bolted 3φ fault in front of the relay location when line side PTs are employed. Test currents are shown as a multiple of the pickup setting. No prefault load current was included. System frequency is 60 Hz.

Figure 8: Phase Distance Speed Curves and Phase Overcurrent Speed Curve
Residual Time-Overcurrent Element Moderately Inverse Time Characteristic

Residual Time-Overcurrent Element Inverse Time Characteristic

Residual Time-Overcurrent Element Very Inverse Time Characteristic

Residual Time-Overcurrent Element Extremely Inverse Time Characteristic

Figure 9: Residual Time-Overcurrent Curves
Figure 10: Relay Dimensions, Panel Cutout, and Drill Diagrams
SAMPLE COMMAND DISPLAYS

Meter

```
>>>METER <ENTER>
Example 230 kv Line       Date: 10/8/90      Time: 07:56:36
A   B   C   AB  BC  CA
  202  198  197  349  339  344
V (kv)  134.0  133.8  133.6  231.5  230.9  231.9
P (W)   78.61
Q (VAR) 13.85
```
SET clears events. CTRL-X cancels.

Enter data, or RETURN for no change.

ID : Example 230 kv line

K1 : (ohms pri) = 8.56
X1 : (ohms sec) = 77.77
R0 : (ohms sec) = 35.12
X0 : (ohms sec) = 236.96
LL : Line length (mi) = 100.00

CTR : 200.00
FTR : 200.00
MTA : 83.70
LOCAT : Locate faults (Y/N) = Y

Z1% : Reach (% line) = 80.00
Z2% : 120.00
Z3% : 120.00

Z2DP : DLY-Phase(cyc) = 20.00
Z3DP : DLY-Phase(cyc) = 60.00
ATDP : AT Pickup DLY (cyc) = 0.00
ATDO : AT Dropout DLY (cyc) = 0.00

SOL : PU (Amps pri) = 275.00
BGM : PU (cyc) = 500.00
SDMFD : DLY (cyc) = 20.00
SGM : PU (cyc) = 3420.00

F1MP : PU (Amps pri) = 230.00
F1NTD : Time Delay (mil) = 4.00
F1NC : Curve (1.3G gap) = 3
F1NTC : Torque Ctrl (Y/N) = Y

S01MP : PU (Amps pri) = 835.00
S01NP : 276.00
S01NP : 282.00

Z2DG : DLY-End(cyc) = 30.00
Z3DG : DLY-End(cyc) = 60.00

DOUR : Trip duration (cyc) = 9.00
DST : DLY (cyc) = 27.00
Z3REM : Rev block dly(cyc) = 4.50
BCXRB : Block RB dly(cyc) = 1.50

ETDPU : Echo dly(cyc) = 2.00
EDUR : Echo dur(cyc) = 3.50
WFC : Enable (Y/N) = Y
ZPP0 : PU (kV pri) = 160.00
SNH : PU (kv pri) = 6.00

SE : Enable (Y/N) = Y
Z2VE : = N
Z3IE : = N
LOPE : LOSS of Pot (Y/N) = Y

TIME1 : Port 1 timeout (min) = 5.00
TIME2 : = 8.00
AUTO : Auto-port (1-3) = 2
RING : (1-3) = 7.00

New settings for Example 230 kv line

K1 = 8.56 X1 = 77.77 R0 = 35.12 X0 = 236.96 LL = 100.00
CTR = 200.00 PIR = 200.00 MTA = 83.70 LOCAT = Y
Z1% = 100.00 Z2% = 120.00 Z3% = 120.00
SOL = 275.00 GM = 500.00 SDMFD = 20.00 ATDP = 0.00
S01MP = 835.00 S01NP = 276.00 S01NP = 282.00
Z2RD = 30.00 Z3DG = 60.00
DOUR = 9.00 DST = 27.00 ZONE3-R = 4.50 ZZ3RB = 1.50
ETDPU = 2.00 EDUR = 3.50 WFC = Y
ZPP0 = 160.00 SNH = 6.00
SE = Y Z2VE = N Z3IE = N LOPE = Y
TIME1 = 5.00 TIME2 = 8.00 AUTO = 2 RING = 7.00

OK (Y/N) ? Y<ENTER>
Please wait...
Enabled

Example 230 kv line

Date: 1/1/90 Time: 01:03:32
# SAMPLE EVENT REPORT FOR INTERNAL ZONE 2 FAULT

**Example 230 kV Line**

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**Event:** B20  
**Location:** 84.70 mi 6.63 ohms sec

**Duration:** 2.50  
**Fit Current:** 1418.9

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<th>35.12</th>
<th>x0</th>
<th>296.96</th>
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**Fault Summary**

**Relay Settings**

**Logic Mask Settings**

![Image of the page]
# EXPLANATION OF SAMPLE EVENT REPORT FOR INTERNAL ZONE 2 FAULT

**Example 230 kV Line**  
**Date:** 9/18/90  
**Time:** 9:20:59.241

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**Event:** ZUC  
**Location:** No 47  
**Type:** 6.33 omhs sec  
**Duration:** 2.50  
**Flt Current:** 1410.9

Currents and voltages are in primary amps and kV. Rows are ½ cycle apart. Time runs down page. Obtain phase RMS value and angle using any entry as Y-component and the entry immediately underneath as the X-component. For example, from bottom row, 1BY = 1092, 1BX = -840. Therefore, 1B = 1378 amps primary at an angle of ATAN (1092/-840) = 128°, with respect to the sensing clock.

### <FLD>
**FIRWARE Identification Data**

### <Relays>
Columns show states of internal relay elements --> Designators

### <Inputs>
Columns show states of input contacts:

### <Outputs>
Columns show states of output contacts:

### <Event>
Fault indications are ***Z*** where Z indicates zone and T type  
1 is one of 1-Zone 1, 2-Zone 2, 3-Zone 3, 4-Zone 4, 5-3IN, 6-50IN, "**" is indeterminate  
1 is one of AB, BC, CA = single-phase to ground, AB, BC, CA = 2-phase,  
ABC, BCA, CAB = 2-phase to ground, ABC = 3-phase.

Followed by a *** if a TRIP triggered the report  
Other indications are TRIP = triggered by TRIP output and EXT = externally or otherwise triggered

### <Logic Settings>
- Relative time (in seconds) for fast (2) and slow (3) operation
- Fault current (primary amps) taken near middle of fault
- Primary series impedance settings for transmission line (ohms)
- Line length corresponding to specified line impedances
- Maximum torque angle (degrees) and fault locator enable (Y/N)
- Reaches of 3- and 2-phase who, percent of positive sequence line impedances
- Assignment for automatic message transmissions (1, 2, or 3)

---

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SAMPLE EVENT REPORT FOR CURRENT REVERSAL AT BREAKER 1

Example 230 KV Line Breaker 1  Date: 9/18/90  Time: 09:33:50.620  Date and time of event

FID=SEL-12118400-V656mtr=r-0900623

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<thead>
<tr>
<th>Currents (amps)</th>
<th>Voltagess (KV)</th>
<th>Relays Outputs</th>
<th>Inputs</th>
</tr>
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<td>IB</td>
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</tr>
</tbody>
</table>

Event: 348  Location: -77.14 mi  -6.04 ohms sec
Duration: 3.00  Fit Current: 1011.6

Logic settings:

MTU  MPT  MTR  MTO  MA1  MA2  MA3  MA4
80  40  00  04  00  00  00  00  00
C4  22  00  00  00  00  00  00  00
GA  00  00  00  10  00  00  00  00  00
33  00  00  00  00  00  00  00  00

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EXPLANATION OF SAMPLE EVENT REPORT FOR CURRENT REVERSAL AT BREAKER 1

The previous event report illustrates relay security during an out-of-section fault resulting in current reversal. The report shows that no trip occurred at Breaker 1 following the current reversal because the current reversal logic blocked tripping by permissive trip logic. Also notice that the current reversal logic blocked the relay from keying the permissive trip signal when the Zone 2 elements asserted.

Referring to Figure 11, the relay at Breaker 1 initially sees the fault with a reverse Zone 3 67N3 ground overcurrent element. The relay at Breaker 3 trips instantaneously via its Zone 1 ground elements. The protection at Breaker 4 must wait to receive a permissive signal from the protection at Breaker 3, resulting in a short duration sequential clearance for the fault. Referring to Figure 12, after Breaker 3 opens, the fault current redistributes and the relay at Breaker 1 sees the fault as a forward Zone 2 ground fault.

The SEL-121H relay current reversal logic initiates with the assertion of any reverse Zone 3 element and drops out a settable time after the Zone 3 elements. This prevents the relay from tripping or keying via the permissive logic when the current reverses and Zone 2 elements pick up.

Figure 11: Fault Inception, All Sources In

Figure 12: Faulted System with Breaker 1 Open
SEL-121H RELAY COMMAND SUMMARY

Access Level 0

ACCESS
Answer password prompt (if password protection is enabled) to enter Access Level 1. Three unsuccessful attempts pulse ALARM contacts closed for one second.

Access Level 1

2ACCESS
Answer password prompt (if password protection is enabled) to enter Access Level 2. This command always pulses the ALARM contacts closed for one second.

DATE [m/d/y]
Show or set date. DAT 2/3/90 sets date to Feb. 3, 1990. IRIG-B time code input overrides existing month and day settings. DATE pulses ALARM contacts when year entered differs from year stored.

EVENT
Show event record. EVE 1 shows newest event; EVE 12 shows oldest.

HISTORY
Show DATE, TIME, TYPE, DIST (distance), DUR (duration), and CURR (maximum fault current) for the last twelve events.

IRIG
Force immediate attempt to synchronize internal relay clock to time-code input.

METER [N]
Display primary phase-to-neutral and phase-to-phase voltages and currents and real and reactive power. Option N displays meter data N times.

QUIT
Return control to Access Level 0; return target display to Relay Targets.

SHOWSET
Display settings without affecting them.

STATUS
Show self test status.

TARGET [N][K]
Show data and set target LEDs as follows:
- TAR 0: Relay Targets
- TAR 2: Relay Word row #2
- TAR 4: Relay Word row #4
- TAR 6: Contact Output States
- Option K displays target data K times.

TARGET 1: Relay Word row #1
TARGET 3: Relay Word row #3
TARGET 5: Contact Input States
TARGET R: Clears Targets and returns to TAR 0

TIME [h/m/s]
Show or set time. TIM 13/32/00 sets clock to 1:32:00 PM. IRIG-B synchronization overrides this setting.

TRIGGER
Trigger and save an event record (event type is EXT).

Access Level 2

CLOSE
Close circuit breaker, if allowed by jumper setting.

LOGIC [N]
Show or set logic masks MTU, MPT, MTB, MTO, MA1-MA4. Command pulses ALARM contacts closed for one second and clears event buffers when new settings are stored.

OPEN
Open circuit breaker, if allowed by jumper setting.

PASSWORD
Show or set passwords. Command pulses ALARM contacts closed momentarily after password entry. PAS 1 OTTER sets Level 1 password to OTTER. PAS 2 TAIL sets Level 2 password to TAIL.

SET [N]
Initiate set procedure. Optional N directs relay to begin setting procedure at that setting. SET EDUR initiates setting procedure at EDUR setting. SET initiates setting procedure at beginning. Command pulses ALARM contacts closed and clears event buffers when new settings are stored.

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