SEL-221

PHASE AND GROUND DISTANCE RELAY
DIRECTIONAL GROUND RELAY
RECLOSELING RELAY
FAULT LOCATOR

- 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
- Fault locating
- Metring
- EIA-232 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
**PRODUCT OVERVIEW**

**SEL-221-16 Description**

The SEL-221-16 Distance Relay with Fault Locator simultaneously provides high-speed and time-delayed protection for transmission, subtransmission, and distribution lines. An 18-bit Relay Word combines mho distance elements, overcurrent elements, directional elements, 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, this 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-to-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, and Loss-of-Potential logic.

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.

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, and VC)
- Currents (IA, IB, IC, and IR)
- 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, 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-2020 Communications Processor, the SEL-PRTU Protective Relay Terminal Unit, the SEL-DTA2 Display/Transducer Adapter, the SEL-RD Relay Display, and the SEL-PROFILE Transmission Line Fault Analysis Program.

**Obsolete Relay Replacement**

The SEL-221-16 Relay is an ideal relay to use as a replacement for obsolete or aging electromechanical relays that are used in a step-distance scheme. The relay has three forward-looking zones of phase and ground distance protection as well as a directional ground overcurrent relay. A single-shot recloser is also included. It occupies less space on a panel than the electromechanical relays that it can replace. It also adds valuable features such as fault locating, metering functions, and remote communications.

**OPERATING PRINCIPLES**

**Mho Distance Elements**

The SEL-221-16 Relay uses mho characteristics for phase and ground distance protection. Figure 1 shows the impedance characteristics of the phase and ground distance elements.

![Diagram of Phase and Ground Mho Distance Elements](image)

**Figure 1:** Phase and Ground Mho Distance Elements
The mho elements use positive-sequence memory polarization that expand in proportion to the source impedance to provide positive, secure operation for close-in faults. Independent timers are settable for Zone 2 phase, Zone 2 ground, and Zone 3 elements. Fault detectors and negative-sequence directional elements supervise the distance elements. Loss-of-Potential logic, if enabled, also supervises the distance elements.

**Overcurrent Elements**

**Residual Overcurrent Elements**

Residual overcurrent elements provide backup protection for ground faults. A time-overcurrent element detects highly-resistive ground faults. It is available with either US curves (moderately inverse, inverse, very inverse, and extremely inverse) or IEC curves (standard inverse, very inverse, extremely inverse, and long time delay). This element may be nondirectional or forward-reaching, as enabled in relay settings.

An instantaneous residual overcurrent element may be nondirectional or forward-reaching, as enabled in the settings. Negative-sequence directional polarization is used for the residual overcurrent elements.

**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 are used in the Loss-of-Potential logic to detect blown voltage transformer fuses. Low-set phase overcurrent elements may be used in the Remote-End-Just-Opened (REJO) logic to detect remote breaker clearance of in-section faults.

High-set nondirectional phase overcurrent elements provide switch-onto-fault protection for close-in faults.

**Negative-Sequence Directional Element**

Directional polarization is based upon negative-sequence voltage and current. The negative-sequence directional element may be used to polarize the ground directional overcurrent protection.

**Loss-of-Potential (LOP) Detection**

The Loss-of-Potential logic detects one, two, or three blown secondary voltage transformer fuses. This protection may be enabled or disabled with a simple setting. When enabled, an LOP condition blocks all mho distance elements. LOP detection may be selected to close a programmable output relay or the ALARM contact for indication purposes.

**Remote-End-Just-Opened (REJO) Protection**

User-selected elements are enabled to trip if the remote breaker clears. The REJO logic can provide pilotless accelerated tripping in many applications.
Switch-Opto-Fault Protection

User-selected elements are enabled to trip for 52BT time after the line breaker closes. The switch-on-to-fault logic requires no communications channel equipment.

Reclosing Relay

The reclosing relay consists of a single reclosing shot with a settable open interval timer and a settable reset timer. Reclose initiate and reclose cancel conditions are selected in settable logic masks.

IRIG-B Input

The relay accepts demodulated IRIG-B from an external source such as the SEL-2020 Communications Processor or other clock source to set its internal clock.

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. These masks determine the state of the output relay and reclosing sequence, depending on which elements are asserted in the Relay Word.

Table 1 shows the SEL-221-16 Relay Word.

<table>
<thead>
<tr>
<th>ZIP</th>
<th>Z1G</th>
<th>Z2PT</th>
<th>Z2GT</th>
<th>Z3</th>
<th>Z3T</th>
<th>3P21</th>
<th>32Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>67N</td>
<td>51NP</td>
<td>51NT</td>
<td>50NG</td>
<td>50P</td>
<td>50H</td>
<td>INI</td>
<td>REJO</td>
</tr>
<tr>
<td>LOP</td>
<td>TRIP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

An event report is triggered when certain relay elements pick up, the TRIP output contacts close, 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.

**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, 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.

**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, and VC)
- +5 V Power Supply
- ±15 V Power Supplies
• Random-Access Memory (RAM)
• Read-Only Memory (ROM)
• Analog-to-Digital Conversion Time
• Master Offset
• Settings

**Contact Inputs and Outputs**

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. The programmable input, permissive trip, block trip, and direct close inputs are monitor points and are displayed in the event report only. They control no relay functions.

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."

**Communications Ports**

Relay rear-panel connectors labeled Port 1 and Port 2 are EIA-232 serial data interfaces. Port 2 has both front (2F) and rear (2R) panel connectors. Generally, Port 1 is used for remote communications via a modem, while Port 2R is used for communicating with an SEL-2020 Communications Processor or SEL-PRTU Protective Relay Terminal Unit. Port 2R may also be connected to the SEL-DTA or SEL-RD, which serves as a local operator interface. Port 2F on the front panel is used for local communications. Communicating through Port 2F disables communications through Port 2R.
Figure 2: SEL-221-16 Relay External AC Current and Voltage Connections

Figure 3: SEL-221-16 Relay External DC Connection Diagram (Typical)
# Technical Specifications

## General Specifications

<table>
<thead>
<tr>
<th>AC Input Voltage</th>
<th>115 volt nominal phase-to-phase, three-phase four-wire connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Input Current</td>
<td>5 amps per phase nominal</td>
</tr>
<tr>
<td></td>
<td>15 amps per phase continuous</td>
</tr>
<tr>
<td></td>
<td>500 amps for one second thermal rating</td>
</tr>
<tr>
<td>Output Contacts</td>
<td>IEEE C37.90 Tripping Output Performance Requirements. 30 A make.</td>
</tr>
<tr>
<td></td>
<td>6 A carry; MOV protected.</td>
</tr>
<tr>
<td>Logic Input Ratings</td>
<td>24 Vdc: 15 - 30 Vdc</td>
</tr>
<tr>
<td></td>
<td>48 Vdc: 30 - 60 Vdc</td>
</tr>
<tr>
<td></td>
<td>125 Vdc: 80 - 150 Vdc</td>
</tr>
<tr>
<td></td>
<td>250 Vdc: 150 - 300 Vdc</td>
</tr>
<tr>
<td></td>
<td>Current = 4 mA at nominal voltage</td>
</tr>
<tr>
<td>Power Supply Ratings</td>
<td>24/48 Volt: 20 - 60 Vdc</td>
</tr>
<tr>
<td></td>
<td>125/250 Volt: 85 - 350 Vdc or 85 - 264 Vac. 10 watts nominal, 14 watts max. (all output relays energized)</td>
</tr>
<tr>
<td>Time Code Input</td>
<td>Relay accepts demodulated IRIG-B time code</td>
</tr>
<tr>
<td>Serial Communications</td>
<td>Two EIA-232 serial communications ports. Port 2 has front and rear connectors.</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>Voltage and current inputs: 2500 Vac for 10 seconds</td>
</tr>
<tr>
<td></td>
<td>Power supply, logic inputs, and contact outputs: 3000 Vdc for 10 seconds</td>
</tr>
<tr>
<td>Burn-in Temperature</td>
<td>60°C (140°F) for 96 hours or equivalent</td>
</tr>
<tr>
<td>Dimensions</td>
<td>8.81 cm x 48.26 cm x 22.86 cm (3.47&quot; x 19.00&quot; x 9.00&quot;) (H x W x D)</td>
</tr>
<tr>
<td>Unit Weight</td>
<td>5.5 kg (12 pounds)</td>
</tr>
<tr>
<td>Shipping Weight</td>
<td>7.7 kg (17 pounds), including one instruction manual.</td>
</tr>
<tr>
<td>Mounting</td>
<td>Available in horizontal or vertical mounting configurations.</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40°C to 70°C (-40°F to 158°F)</td>
</tr>
</tbody>
</table>


Exceptions:
5.5.2 (2) Performed with 200 frequency steps per octave
5.5.3 Digital Equipment Modulation Test not performed
5.5.4 Test Signal turned off between frequency steps to simulate keying.

IEC 68-2-30 Basic environmental testing procedures, Part 2: Tests, Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle).
Humidity, 95% between 25°C and 55°C.

IEC 255-5 Electrical relays, Part 5: Insulation tests for electrical relays.
Impulse voltage test, 0.5 Joule, 5000 volt.
Dielectric test, Series C.

IEC 255-21-1 Electrical relays, Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment, Section One - Vibration test (sinusoidal).

IEC 255-21-2 Electrical relays, Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment, Section Two - Shock and bump tests.

IEC 255-22-1 Electrical disturbance tests for measuring relays and protection equipment, Part 1: 1 MHz burst disturbance tests.

IEC 529 Degrees of protection provided by enclosures (IP30).

IEC 801-2 Electromagnetic compatibility for industrial-process measurement and control equipment, Part 2: Electrostatic discharge requirements.

IEC 801-3 Electromagnetic compatibility for industrial process measurement and control equipment, Part 3: Radiated electromagnetic field requirements.

Exceptions:
9.1 Frequency sweep approximated with 200 frequency steps per octave.
IEC 801-4 Electromagnetic compitibility for industrial-process measurements and control equipment Part 4: Electrical fast transient/burst requirements.

**Relay Element Ranges**

**Distance Elements**
Secondary Reach Setting Range: 0.125 - 64.0 ohms

**Minimum Sensitivity**
Secondary, defined by the fault detector minimum setting: 0.5 Amps

**Maximum Torque Angle (MTA)**
47° - 90°

**Residual Current Compensation (K) Factor Range**
Magnitude limits: 0.0833 < |K| < 2.0
Range limits: 47° < MTA + \( \angle K \) < 113°

Where: \( K = \frac{Z_{0} - Z_{1}}{3 \times Z_{1}} \)

\( Z_{0} = R_{0} + jX_{0} \)
\( Z_{1} = R_{1} + jX_{1} \)

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.

Transient Overreach: ±5% of set reach, plus steady-state error

**Zone 2 and 3 Distance Element Timers**
Range in quarter-cycle steps: 3 - 2000 cycles

**Nondirectional Phase Overcurrent Elements**

Low-set ground fault detectors
Pickup in secondary Amps: 0.5A to 25 times 51NP, but less than 40 A. ±0.1 A ±2% of setting

Transient overreach: ±5% of set pickup

Phase fault detectors
Pickup in secondary Amps: 0.5 to 40 A, ±0.1 A ±2% of setting

Transient overreach: ±5% of set pickup
High-set phase overcurrent elements
Pickup in secondary Amps: 0.5 to 80 A, ±0.1 A ±2% of setting

Transient overreach: ±5% of set pickup

Ground Overcurrent Elements
Residual instantaneous overcurrent
Supervises ground distance elements
Pickup in secondary Amps: 0.5 A to 25 times 51N pickup, but less than 40 A

Transient overreach: ±5% of set pickup

Residual time-overcurrent element
(available with either US curves or IEC curves)

US Curves
Moderately Inverse, Inverse,
Very Inverse, Extremely Inverse
Time dial in 0.01 steps: 0.50 to 15.00
Pickup in secondary Amps: 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

IEC Curves
Standard Inverse, Very Inverse,
Extremely Inverse, Long Time Delay
Time dial in 0.01 steps: 0.05 to 1.00
Pickup in secondary Amps: 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
High-set Instantaneous Residual overcurrent element

Pickup in secondary Amps: 0.5 A to 50 times 51N pickup

Transient overreach: ±5% of set pickup

May be directionally controlled

**Negative-Sequence Directional Elements**

Sensitivity: 0.32 VA (V2 x I2) at MTA

**Sequence-Component Elements**

Used in Loss-of-Potential logic

**Negative-sequence overvoltage element**

Pickup of V2 (fixed): 14 V

**Negative-sequence overcurrent element**

Pickup of I2 (fixed): 0.083 A

**Miscellaneous Timers**

Set in cycles with quarter-cycle resolution

79OI: Reclose Relay Open Interval: 0.0 - 8,000 cycles
79RS: Reclose Relay Reset Time: 60.0 - 8,000 cycles
A1TP: A1 Output Contact TDPUs Timer: 0.0 - 8,000 cycles
52BT: Switch-On-To-Fault Timer: 0.5 - 10,000 cycles
TDUR: Minimum Trip Duration Timer: 0.0 - 2,000 cycles
(0 Disables the OPEN Command)

TDPU = Time Delayed Pickup
TDDO = Time Delayed Dropout
Figure 5: SEL-221-16 Vertical Front and Rear Panel Drawings
Figure 6: SEL-221-16 Relay Dimensions, Panel Cutout, and Drill Plan
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