SEL-121S

SINGLE POLE TRIP DISTANCE RELAY
GROUND DIRECTIONAL OVERCURRENT RELAY
GROUND TIME OVERCURRENT RELAY
RECLOSED RELAY
FAULT LOCATOR

DATA SHEET

- THREE ZONES OF TIME STEP PHASE AND GROUND DISTANCE PROTECTION
- SINGLE POLE TRIP OUTPUTS
- RESIDUAL OVERCURRENT AND TIME OVERCURRENT ELEMENTS
- NEGATIVE-SEQUENCE DIRECTIONAL ELEMENT
- SINGLE SHOT RECLOSER
- LOSS-OF-POTENTIAL LOGIC
- PROGRAMMABLE LOGIC SUPPORTING WIDE RANGE OF APPLICATIONS
- FAULT LOCATING • EVENT REPORTING • METERING
- AUTOMATIC SELF TESTING • RS-232-C COMMUNICATIONS (TWO PORTS)
- HORIZONTAL AND VERTICAL MOUNTING CONFIGURATIONS AVAILABLE
GENERAL DESCRIPTION

The SEL-121S relay provides three zones of phase and ground distance protection. Single pole tripping is permitted when either the Zone 1 ground distance element asserts or the Zone 3 ground distance element asserts and the PT input is asserted. Three pole trips are initiated for all other fault types. Ground directional overcurrent and inverse-time overcurrent elements provide backup protection for high-resistance ground faults. Like the SEL-121G relay, the SEL-121S relay uses the very popular programmable-mask logic for unsurpassed application flexibility.

The distance relay elements are memory-polarized with positive-sequence voltage to obtain expanded mho characteristics. The unique memory scheme provides polarization for at least six cycles.

Overcurrent supervision, loss-of-potential detection, high-set overcurrent elements, and other features increase the versatility of the SEL-121S relay.

A single shot recloser provides for fault type selectable automatic line restoration.

The SEL-121S Relay Function Block Diagram illustrates the basic configuration of the protective capabilities.

The SEL-121S relay generates an eleven cycle event report following each fault. Each report includes voltage, current, and sequence-of-events information for relay elements, inputs, and outputs. The relay saves the twelve most recent event reports; each can be retrieved remotely or locally through the serial communication ports.

A metering function permits interrogation of the SEL-121S relay to obtain voltage, current, real power, and reactive power readings. This function also includes per-phase measurements of voltage and current.

The CLOSE, TRIPA, TRIPB, TRIPC, A1, and ALARM output contacts may be specified as either an "a" or "b" type contact. The TRIP outputs are always an "a" type contact.

The SEL-121S relay is compatible with the SEL-PRTU Protective Relay Terminal Unit, the SEL-DTA Display/Transducer Adapter, and the SEL-PROFILE Transmission Line Fault Analysis Program.

APPLICATIONS

Single Pole Tripping

The SEL-121S relay provides single pole tripping capabilities for single-line-to-ground faults. Two-phase faults, three-phase faults, and ground time-overcurrent trips result in a three pole trip. A possible scheme might be to unconditionally single pole trip for Zone 1 single-line-to-ground faults and single pole trip for single-line-to-ground faults in Zone 3 upon assertion of the permissive trip input. Since residual current will flow during the open pole period following a single pole trip, the Pole Open (PO) feature can be used to disable the 67N and 51N ground elements for a settable time period following a single pole trip.
The mho elements are forward reaching and are supervised by the negative sequence directional (32Q) element. The diameter of the mho circle at the maximum torque angle (MTA) for Zones 1, 2, and 3 can be found by the following formula:

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

![Example Mho circles]

**Time-Step Relaying**

The SEL-121S relay provides three zones of time-step protection with separate timers for phase and ground faults in Zone 2 and a common timer for both phase and ground faults in Zone 3. In such applications, the SEL-121S relay is the only instrument needed for primary relaying. The exhaustive self testing and communications features reduce dependence on local and remote backup schemes.

**Schemes Involving Communications**

The SEL-121S relay supports direct tripping, permissive underreaching transfer tripping, and permissive overreaching transfer tripping.

In permissive transfer tripping schemes, Zone 1 is set underreaching and Zone 3 may be used to qualify the received permissive signal.

Evaluating scheme performance is made easy by reviewing the event report which shows the voltages, currents, relay elements, inputs, and outputs.
SEL-121S RELAY FUNCTION BLOCK DIAGRAM
Backup Relaying

Where adequate high-speed primary protection already exists, the SEL-121S relay can be applied as backup. Its programmability and remote-access capabilities allow the relay settings to be changed remotely for virtually any contingency.

Its application also adds event reporting and fault locating.

SPECIFICATIONS

**Relay Functions**

Expanded mho characteristics for all faults
- Three phase-to-phase zones with overcurrent supervision
- Three phase-to-ground zones with overcurrent supervision
- Infinite-impulse-response filter provides a minimum of six cycles of memory polarization for all mho elements.
- Phase and residual overcurrent supervision of ground mho elements
- Phase overcurrent supervision of phase mho elements
- High-set phase overcurrent elements

Two residual overcurrent elements for ground faults
- One time-delayed element, with nondirectional or forward directional supervision
- Inverse-time overcurrent element with selectable curve shapes

Negative-sequence directional element for directional supervision
Loss-of-potential logic
Single-shot recloser

**Relay Elements**

Phase Overcurrent Elements (secondary values)
- 50AG, 50BG, 50CG (supervise ground mho elements)
  - Pickup: 0.5A to 25 times 51NP, but less than 40A, ± 0.1A ± 2% of setting
- 50AP, 50BP, 50CP (supervise phase mho elements)
  - Pickup: 0.5A to 40A, ± 0.1 A ± 2% of setting
  - Transient Overreach: 5% of set pickup

Phase and Ground Distance Elements (secondary values)
- Zone 3 ground mho distance 21AG3, 21BG3, 21CG3
- Zone 3 phase mho distance 21AB3, 21BC3, 21CA3
- Zone 2 ground mho distance 21AG2, 21BG2, 21CG2
- Zone 2 phase mho distance 21AB2, 21BC2, 21CA2
- Zone 1 ground mho distance 21AG1, 21BG1, 21CG1
- Zone 1 phase mho distance 21AB1, 21BC1, 21CA1

Minimum Sensitivity: 0.5A

Maximum Torque Angle: 47 - 90 degrees in one-degree steps

Operating Time: 10 - 45 ms (22 ms typical)
Residual current compensation for ground mhos: \(0.25 < |K| < 6\)

Zone 1, 2, 3 reach: \(0.125\) to 64 ohms, where
\[\text{Zone 1} < \text{Zone 2} < \text{Zone 3}\]

Steady-state Error:
- 5% of set reach \(\pm 0.01\) ohm at angle of maximum torque for \(V > 5V\) and \(I > 2A\)
- 10% of set reach \(\pm 0.01\) ohm at angle of maximum torque for \(5 > V > 1V\)
  or \(0.5 < I < 2A\)

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

Positive-Sequence Voltage Memory Polarization:
All mho elements are memory-polarized by an infinite-impulse response filter with a four-cycle time constant, yielding polarization for at least six cycles.

Ground Overcurrent Elements (secondary values)
51N residual time overcurrent element:
- Selectable curve shape (4 families of curves)
- Time dial: 0.50 to 15.00 in 0.01 steps
- Pickup: 0.5A to 8A, \(\pm 0.05A \pm 3\%\) of setting
- Timing: \(\pm 4\%\) and \(\pm 1\) cycle for residual current magnitude between 2 and 20 multiples of pickup
- May be directionally controlled (51NTC setting)

67N residual overcurrent element:
- Pickup: 0.5A to 25 times 51N pickup
- Time delay: 0-8000 cycles in 0.25 cycle increments
- Transient overreach: 5% of set pickup
- May be directionally controlled (67NTC setting)

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

Negative-Sequence Directional Element (32Q)
- Angle: same as mho element maximum torque angle (MTA) setting
- Sensitivity: less than 0.32 VA of \(V^2*I^2\), at MTA
  - This element direction-controls residual overcurrent elements and adds directional security to the distance relay elements for all unbalanced faults.

Sequence-Component Elements
- Negative sequence overvoltage element (47QL)
  - Pickup: 14 volts of \(V^2\)
- Negative-sequence overcurrent element (46QL)
  - Pickup: 0.083 amps of \(I^2\)
- Positive-sequence overvoltage element (47P)
  - Pickup: 14 volts of \(V^1\)
**Fault Location**

Fault location is computed from event reports stored following each fault. The algorithm compensates for prefault current to improve accuracy for high-resistance faults during periods of substantial load flow.

**Fault Reporting**

The SEL-121S relay retains a data record for each of the 12 most recent faults. This record includes the date, time, current, voltage, relay element, input contact, and output contact information. The report may also be triggered by command or contact closure. When tripping occurs after the end of the event report, a second report is triggered at tripping.

**Self Testing**

- Analog ac channel offset errors
- Stall timer monitors processor
- Power supply voltage checks
- Setting checks
- RAM, ROM, and A/D converter tests

**Rated Input Voltage**

- 60-75 volts/phase secondary, three-phase, four-wire connection (VA, VB, VC, VN)

**Rated Input Current**

- 5 amps per phase nominal
- 15 amps per phase continuous
- 500 amps for one second thermal rating

**Output Contact Ratings**

- 30 amps make per IEEE C37-90 para 6.6.2
- 6 amps carry continuously
- MOV protection provided

**Logic Input Ratings**

- 48 Vdc: 25 - 60 Vdc
- 125 Vdc: 60 - 200 Vdc
- 250 Vdc: 200 - 280 Vdc
- Current = 6 mA at nominal voltage

**Power Supply**

- 48 Volt: 30 - 60 Vdc; 12 watts
- 125 Volt: 85 - 200 Vac or Vdc; 12 watts
- 250 Volt: 85 - 280 Vdc or 85 - 200 Vac; 12 watts

**Dielectric Strength**

- Routine tested:
  - V, I inputs: 2500 Vac for 10 seconds
  - Other: 3000 Vdc for 10 seconds (excludes 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, at a distance of 1 meter from relay.

**Dimensions**
5¼" x 19" x 13". Mounts in EIA 19" rack, or panel cutout.

**Unit Weight**
21 pounds

**Shipping Weight**
32 pounds, including two instruction manuals

**Operating Temp.**
-20 deg C to +55 deg C

**Burn-in Temp.**
Each SEL-121S relay is burned in at 60 deg C for 100 hours.

**LOGIC DESCRIPTION**

The SEL-121S logic consists of relay elements, timers, and combinations of conditions. Many of these are recorded in a Relay Word, which forms the heart of the programmable mask logic of this relay. Elements and other quantities available in the Relay Word are indicated in boldface type in this section of the data sheet.

Since so many binary variables are involved, we define the functioning using Boolean logic equations.

**Relay Elements**

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

Dimensions
5¼" x 19" x 13". Mounts in EIA 19" rack, or panel cutout.

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21 pounds

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Relay Elements

Single-phase overcurrent relays
50AG 50BG 50CG
50AP 50BP 50CP
50AH 50BH 50CH

High-set single-phase overcurrent relays
(50NG setting)
(50P setting)
(50H setting)

Zone 3 ground mho distance
21AG3, 21BG3, 21CG3
21AB3, 21BC3, 21CA3

Zone 3 phase mho distance
(Z3% setting)

Zone 2 ground mho distance
21AG2, 21BG2, 21CG2
21AB2, 21BC2, 21CA2

Zone 2 phase mho distance
(Z2% setting)

Zone 1 ground mho distance
21AG1, 21BG1, 21CG1
21AB1, 21BC1, 21CA1

Zone 1 phase mho distance
(Z1% setting)
Residual time-overcurrent pickup 51NP
Residual time-overcurrent trip 51NT (51NP, 51NTD, 51NC, 51NTC settings)

Residual overcurrent pickup 67NP
Residual overcurrent trip 67NT (67NP, 67ND setting)
Residual inst overcurrent 50N (50NG setting)

Negative-sequence directional 32Q Forward direction

Negative-sequence overvoltage 47QL V2 > 14V loss-of-potential logic
Negative-sequence overcurrent 46QL I2 > 0.083A loss-of-potential logic
Positive-sequence overvoltage 47P V1 > 14V loss-of-potential logic

Contact Inputs

Programmable input
Permissive trip
Circuit breaker monitor - A phase
Circuit breaker monitor - B phase
Circuit breaker monitor - C phase
External trigger for event report

Programmable input INI For dir. trip or other user reqts.
Permissive trip PT For perm. transfer trip. schemes
Circuit breaker monitor - A phase 52AA
Circuit breaker monitor - B phase 52AB
Circuit breaker monitor - C phase 52AC
External trigger for event report EXT

Contact Outputs

Circuit breaker trip TRIP 2 Outputs
Circuit breaker close CLOSE Includes TDPU/TDDO timer
Programmable output
Trip A pole TRIPA
Trip B pole TRIPB
Trip C pole TRIPC
System alarm ALARM Alarms for self tests, LOP, setting changes, second-level access, and 3 unsuccessful Level 1 attempts.


**Logic Settings and Timers**

Reclosing relay open interval 79OI 0-8000 cycles; 0 disables
Reclosing relay reset timer 79RS 60-8000 cycles
Zone 2 delay for phase faults Z2DP 3-2000 cycles
Zone 2 delay for ground faults Z2DG 3-2000 cycles
Zone 3 delay Z3D 3-2000 cycles
Ground overcurrent delay 67ND 0-8000 cycles
Pole open disable delay POD 0-8000 cycles
Zone 2 phase fault timer timeout Z2PTMR (Set by Z2DP)
Zone 2 ground fault timer timeout Z2GTMR (Set by Z2DG)
Zone 3 fault timer timeout Z3TMR (Set by Z3D)
Ground overcurrent timer timeout 67NTMR (Set by 67ND)
Pole open disable timeout PODTMR (Set by POD)
Direction (torque) control of 51N 51NTC
Direction (torque) control of 67N 67NTC
Switch onto fault time delay 52BT 0.5-10000 cycles
Loss-of-potential enable LOPE
Loss-of-potential ALARM enable LOPA
A1 contact output timer timeout A1T 0-8000 cycles A1TP pickup delay

**INTERMEDIATE LOGIC**

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

**Circuit-Breaker Contact Logic**

$52A3 = 52AA * 52AB * 52AC$
$52B3 = \overline{NOT}(52AA) * \overline{NOT}(52AB) * \overline{NOT}(52AC)$
$52BT = \overline{NOT}(52A3)$

Delayed by 52BT time setting at pickup and dropout

PO = \overline{NOT}(52A3) * \overline{NOT}(PODTMR)

Pole open (used to supervise forward trips and to disable 67N and 51N during pole open interval but not longer than POD)

3PT = TA * TB * TC

3 Pole Trip (used to detect a 3 pole trip condition)
Loss-of-Potential Logic

Set LOP = 47QL * NOT(46QL) + NOT(47P) * NOT(50P)  (Must be valid for three cycles to set)

Clear LOP = NOT(47QL) * (47P + NOT(52A3))

(The different set and clear conditions ensure LOP stays latched during subsequent faults, but LOP is cleared when balanced voltages return.)

Overcurrent Conditions

50G = 50AG + 50BG + 50CG
50NG = 50N + 50G  
Sensitive phase overcurrent condition  
Sensitive ground or phase overcurrent condition

50P = 50AP + 50BP + 50CP
3P50 = 50AP * 50BP * 50CP
Phase overcurrent condition  
Three-phase overcurrent condition

50H = 50AH + 50BH + 50CH
High-level phase overcurrent condition

67NP = 67N pickup * NOT(PO)
67NT = 67NP *
   (32Q + (LOP * LOPE) + NOT(67NTC)) * 67NTMR
Directionally supervised residual overcurrent element (disabled when any pole open)

51NP = 51N pickup *
   (32Q + (LOP * LOPE) + NOT(51NTC)) * NOT(PO)
Directionally supervised residual time-overcurrent element (disabled when any pole open)

Distance Relay Logic

3P21 = (21AB3*21BC3*21CA3) * 3P50  
Three-phase fault condition

FDS = 3P21 + 32Q  
Forward-direction supervision
   + TRIP output asserted
   (inst. p.u./¼ cyc. d.o.)
   + PO

Z3P = (21AB3*50AP*50BP + 21BC3*50BP*50CP + 21CA3*50CP*50AP) * FDS * NOT(LOP * LOPE)
Z3G = (21AG3*50AG + 21BG3*50BG + 21CG3*50CG) * 50N * FDS * NOT(LOP * LOPE)

Z2P = (21AB2*50AP*50BP + 21BC2*50BP*50CP + 21CA2*50CP*50AP) * FDS * NOT(LOP * LOPE)
Z2G = (21AG2*50AG + 21BG2*50BG + 21CG2*50CG) * 50N * FDS * NOT(LOP * LOPE)

Z1P = (21AB1*50AP*50BP + 21BC1*50BP*50CP + 21CA1*50CP*50AP) * FDS * NOT(LOP * LOPE)
Z1G = (21AG1*50AG + 21BG1*50BG + 21CG1*50CG) * 50N * FDS * NOT(LOP * LOPE)
Z2PT = Z2P × Z2PTMR
Z2GT = Z2G × Z2GTMR
Z3T = (Z3P + Z3G) × Z3TMR

Z3AG = 21AG3 × 50AG × 50N × FDS × NOT(LOP × LOPE)
Z3BG = 21BG3 × 50BG × 50N × FDS × NOT(LOP × LOPE)
Z3CG = 21CG3 × 50CG × 50N × FDS × NOT(LOP × LOPE)

RELAY WORD

Relay elements and intermediate logic results used in the SEL-121S relay are represented in a 24-bit Relay Word. You may select bits in this word to control outputs. The selected bits are stored in masks for each function. The bits in each mask are programmed using the LOGIC command.

RELAY WORD

<table>
<thead>
<tr>
<th>Z1P</th>
<th>Z1G</th>
<th>Z2PT</th>
<th>Z2GT</th>
<th>Z3P</th>
<th>Z3G</th>
<th>Z3T</th>
<th>50H</th>
</tr>
</thead>
<tbody>
<tr>
<td>67NP</td>
<td>67NT</td>
<td>51NP</td>
<td>51NT</td>
<td>50NG</td>
<td>50P</td>
<td>50G</td>
<td>32Q</td>
</tr>
<tr>
<td>FDS</td>
<td>3P21</td>
<td>LOP</td>
<td>52BT</td>
<td>1N1</td>
<td>PO</td>
<td>3PT</td>
<td>*</td>
</tr>
</tbody>
</table>

The Relay Word Bit Summary Table explains the meaning of each bit in the Relay Word. The "*" in the Relay Word indicates that the bit position is not used.

RELAY WORD BIT SUMMARY TABLE

- **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)
- **Z3P**: Zone 3 phase fault, instantaneous (set by Z3%)
- **Z3G**: Zone 3 ground fault, instantaneous (set by Z3%)
- **Z3T**: Zone 3 phase or ground fault, time delayed (set by Z3% and Z3D)
- **50H**: High-set phase overcurrent condition (set by 50H)
- **67NP**: Residual overcurrent pickup (set by 67NP)
- **67NT**: Residual overcurrent time delayed trip (set by 67NP, 67ND, 67NTC)
- **51NP**: Pickup of residual time-overcurrent (set by 51NP)
- **51NT**: Timeout of residual time-overcurrent (set by 51NP, 51NTD, 51NC, and 51NTC)
- **50NG**: Sensitive residual or phase overcurrent condition (set by 50NG)
- **50P**: Phase overcurrent condition (set by 50P)
- **50G**: Sensitive phase overcurrent condition (set by 50NG)
- **32Q**: Negative-sequence directional element
FDS  Forward-direction supervision
3P21 Three-phase fault condition detected by phase distance relays
LOP  Loss-of-potential condition
52BT Inverted 52A3 input delayed by 52BT setting
IN1  Logic input 1 (use for direct trip, reclose cancel, etc.)
PO   Pole open condition
3PT  3 pole trip condition

The use of the Relay Word and programmable masks MTU, MPT, MTO, MRI, MRC, and MA1 provides the user great flexibility in applying the SEL-121S relay, without rewiring panels or changing jumpers on circuit boards.

OUTPUT EQUATIONS

The logic for controlling the TRIP and A1 output relays is programmable for flexibility and testing. The logic is programmed by setting masks for various conditions, which are applied to the Relay Word.

Let \( R \) = Relay Word

\[
\begin{align*}
MTU &= \text{mask for trip (unconditional)} \\
MPT &= \text{mask for trip (with permissive trip input asserted)} \\
MTO &= \text{mask for trip (with breaker open)} \\
MA1 &= \text{mask for programmable output A1 control}
\end{align*}
\]

then:

The programmable output, \( A1 \), is given as follows:

\[
A1 = R \cdot MA1 \cdot A1T \quad \text{(Includes A1TP, A1TD settable pickup/dropout delays)}
\]

The three pole trip output, \( TRIP \), is programmable by the masks MTU, MPT, and MTO as follows:

\[
\begin{align*}
TRIP &= R \cdot MTU \\
&\quad + R \cdot MPT \cdot PT \\
&\quad + R \cdot MTO \cdot 52BT \\
&\quad + \text{TRIP (OPEN) Command}
\end{align*}
\]

close TRIP contact \( = \text{TRIP} \)
open TRIP contact \( = \neg(\neg(\text{TRIP}) \cdot \neg(\text{NOT(52A3) + TARGET RESET button pushed})) \cdot (60 \text{ ms minimum}) \text{ TRIP} \)

The single pole trip outputs, \( \text{TRIPA}, \text{TRIPB}, \text{and TRIPC} \) are not individually programmable by the mask logic. However, they are indirectly dependent on the masks because the three pole trip output, \( TRIP \), must pick up for the single pole trip outputs to operate. The following logic equations control the single pole trip outputs:
\[ TA = \text{TRIP} \times [\text{NOT}(Z3BG + Z3CG) + Z1P + Z2PT + Z2GT + Z3T + 52BT] + \text{TRIP (OPEN) Command} \]
\[ TB = \text{TRIP} \times [\text{NOT}(Z3AG + Z3CG) + Z1P + Z2PT + Z2GT + Z3T + 52BT] + \text{TRIP (OPEN) Command} \]
\[ TC = \text{TRIP} \times [\text{NOT}(Z3AG + Z3BG) + Z1P + Z2PT + Z2GT + Z3T + 52BT] + \text{TRIP (OPEN) Command} \]

A single pole trip output asserts only if the other two single pole trip outputs are not asserted.

- close TRIPA contact = \( TA + (TB \times TC) \)
- open TRIPA contact = \( \text{NOT}(TA + (TB \times TC)) \times [\text{NOT}(52AA) + \text{TARGET RESET button pushed}] \times (60\text{ms minimum TRIPA}) \)
- close TRIPB contact = \( TB + (TA \times TC) \)
- open TRIPB contact = \( \text{NOT}(TB + (TA \times TC)) \times [\text{NOT}(52AB) + \text{TARGET RESET button pushed}] \times (60\text{ms minimum TRIPB}) \)
- close TRIPC contact = \( TC + (TA \times TB) \)
- open TRIPC contact = \( \text{NOT}(TC + (TA \times TB)) \times [\text{NOT}(52AC) + \text{TARGET RESET button pushed}] \times (60\text{ms minimum TRIPC}) \)

The CLOSE output contact will close and open as follows:

- close CLOSE contact = \( (79OI \text{ expired} + \text{CLOSE command}) \times \text{NOT}(52A3) \times \text{NOT(TRIP)} \)
- open CLOSE contact = \( \text{NOT}(\text{CLOSE}) + 79RS \text{ expired} \)

The "\&" symbol indicates logical "and", and the "+" indicates logical "or".

**RECLOSELING RELAY**

The reclosing relay provides automatic reclosing for selectable fault types. The open interval and the reset timer are individually programmable.

To provide flexibility in applying the SEL-121S relay to various reclosing schemes, selecting conditions for reclose initiation and cancellation is similar to programming the output relays:

- \( RI = R \times MRI \) MRI selects reclose initiate conditions from the Relay Word
- \( RC = R \times MRC \) MRC selects reclose cancel conditions from the Relay Word

where MRI is the mask for reclose initiation, and MRC is the mask for reclose cancellation.
The open interval does not begin until the TRIP output deasserts. Since the TRIP output never asserts for less than 60 ms, the open interval may start several milliseconds after the fault has actually cleared and the breaker opened.

When the CLOSE output is asserted by the reclosing relay, it remains closed until either the 52A3 element asserts (indicating that the breaker has closed three-pole) or until the 79RS reset interval expires.

The CLOSE output can also be used to trigger external reclosers.

**FAULT TYPE SELECTION**

The Fault Type Selection Logic uses the information obtained from the mho elements to determine the correct fault type. The Fault Type Selection Logic initially examines which mho elements (AB, BC, CA, A, B, C) are picked up. This information is often sufficient to determine fault type. If additional information is required, a compensated-torque check is performed, and the maximum torque element determines fault type. This method provides accurate fault type selection for all fault types and loading configurations.

**SETTING PROCEDURE**

Use the SET and LOGIC commands to enter the settings for the SEL-121S relay via either of the serial interface ports. The settings are stored in nonvolatile memory, so they are retained when the power is off.
SET COMMAND EXAMPLE

>>>SET

SET clears events. CTRL-X cancels.
Enter date, or RETURN for no change.

ID : Example 230 kV Line
?
R1 : (Ohms prl) = 13.90
X1 : = 79.96
R0 : = 40.50
X0 : = 248.97
LL : Line Length (mi) = 100.00
?
CTR : = 200.00
PFR : = 2000.00
NTA : Max Torque Angle (deg) = 60.00
?
79Q : Open Int (cyc) = 40.00
79R : Reset Int. = 240.00
A1IP : A1 Pickup Dly (cyc) = 0.00
A1TD : A1 Dropout Dly (cyc) = 0.00
?
21% : Reach (% line) = 80.00
22% : = 120.00
23% : = 150.00
?
22D : Dly-Phase (cyc) = 30.00
22G : Dly-Gnd (cyc) = 20.00
23D : Dly (cyc) = 40.00
?
50NG : PU (Amps prl) = 100.00
50P : PU = 200.00
50H : PU = 3000.00
?
51MP : PU (Amps prl) = 100.00
51TD : Time Dly. = 3.00
51NC : Curve (1,2,3,prl) = 2
51NTC : Torque Ctrl (Y/W) = Y
?
67MP : PU (Amps prl) = 1200.00
67MD : Dly (cyc) = 10.00
67NTC : Torque control (Y/W) = Y
?
52BT : Dly (cyc) = 30.00
52D : Pole Open Dly (cyc) = 60.00
53OE : Loss of Pot (Y/W) = Y
53PA : LOP Alarm (Y/W) = Y
?
TIME1 : Port 1 timeout (min) = 5
TIME2 : = 0
AUTO : Auto port (1,2,3) = 2
RINGS : (1-30) = 3
?

New settings for: Example 230 kV Line

R 1 = 13.90 X 1 = 79.96 R 0 = 40.50 X 0 = 248.97 LL = 100.00
CTR = 200.00 PFR = 2000.00 NTA = 60.00
79Q = 40.00 79R = 240.00 A1IP = 0.00
A1TD = 0.00
21% = 80.00 22% = 120.00 23% = 150.00
22D = 30.00 22G = 20.00 23D = 40.00
50NG = 100.00 50P = 200.00 50H = 3000.00
51MP = 100.00 51TD = 5.00 51NC = 2
51NTC = Y
67MP = 1200.00 67MD = 10.00 67NTC = Y
52BT = 30.00 52D = 60.00 53OE = Y
53PA = Y
TIME1 = 5 TIME2 = 0 AUTO = 2 RINGS = 3

OK (Y/N) ? Y
Please wait...
Enabled

Example 230 kV Line

Date: 1/30/90 Time: 09:10:48

>>>
LOGIC COMMAND

The Logic command programs a series of masks to control the outputs of the SEL-121S relay. The Logic command is of the form:

```
Logic <mask>
```

where `<mask>` is any of the following:

- **MTU** - mask for trip (unconditional)
- **MPT** - mask for trip (with permissive trip input asserted)
- **MTO** - mask for trip (for breaker open)
- **MA1** - mask for programmable output A1 control
- **MRI** - mask for reclose initiate conditions
- **MRC** - mask for reclose cancel conditions

The logic programming procedure consists of typing in changes for the mask, or typing `<ENTER>`, indicating no change. Masks MTU, MPT, MTO, MA1, MRC, and MRI are programmed corresponding to the Relay Word.

The following LOGIC command example shows the setting of the MTU logic mask.

```plaintext
<<<LOGIC MTU <ENTER>
1 Selects, 0 deselects.
Z1P Z16 Z2PT Z26T Z3P Z3G Z3T 50H
 0 0 0 0 0 0 0 0
? 11110011 <ENTER>
1 1 1 1 0 0 0 1 0
? <ENTER>
G7NP 67NT 51NP 516T S0NG S0P S0G 32Q
 0 0 0 0 0 0 0 0
? 01010000 <ENTER>
0 1 0 0 0 0 0 0 0
? <ENTER>
FDS 3P21 LOP 52BT I11 P0 3PT *
0 0 0 0 0 0 0 0
? <ENTER>
```

New MTU:

```plaintext
Z1P Z16 Z2PT Z26T Z3P Z3G Z3T 50H
1 1 1 1 0 0 0 1 0
67NP 67NT 51NP 516T S0NG S0P S0G 32Q
0 1 0 1 0 0 0 0 0
FDS 3P21 LOP 52BT I11 P0 3PT *
0 0 0 0 0 0 0 0 0
```

OK (Y/N)? Y <ENTER>

Enabled

Example 230 kV line

<<<
```
```

In this example, the mask for unconditional trip MTU selects tripping for Zone 1 faults, timeout of the Zone 2 and 3 phase and ground elements, timeout of the directional overcurrent element (67N), and timeout of the 51N element.
### SAMPLE EVENT REPORT

Example 230 kV Line  
Date: 1/30/90  Time: 09:21:23.004

<table>
<thead>
<tr>
<th></th>
<th>Voltages (KV)</th>
<th>Relays</th>
<th>Outputs</th>
<th>Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(IR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IA</td>
<td>IB</td>
<td>IC</td>
<td>VA</td>
</tr>
<tr>
<td>-4</td>
<td>91</td>
<td>113</td>
<td>-211</td>
<td>21.3</td>
</tr>
<tr>
<td>-2</td>
<td>113</td>
<td>91</td>
<td>-208</td>
<td>13.4</td>
</tr>
<tr>
<td>0</td>
<td>186</td>
<td>-170</td>
<td>-16</td>
<td>112.7</td>
</tr>
<tr>
<td>-3</td>
<td>91</td>
<td>113</td>
<td>-211</td>
<td>72.2</td>
</tr>
<tr>
<td>0</td>
<td>186</td>
<td>-170</td>
<td>-16</td>
<td>112.7</td>
</tr>
<tr>
<td>3</td>
<td>182</td>
<td>-170</td>
<td>-16</td>
<td>112.7</td>
</tr>
<tr>
<td>-1</td>
<td>94</td>
<td>113</td>
<td>-208</td>
<td>92.3</td>
</tr>
<tr>
<td>-1</td>
<td>182</td>
<td>-170</td>
<td>-16</td>
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<td>119.8</td>
</tr>
<tr>
<td>-24</td>
<td>-233</td>
<td>-16</td>
<td>95.6</td>
<td>112.9</td>
</tr>
<tr>
<td>706</td>
<td>706</td>
<td>116</td>
<td>211</td>
<td>62.9</td>
</tr>
<tr>
<td>470</td>
<td>289</td>
<td>167</td>
<td>16</td>
<td>-87.6</td>
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<tr>
<td>453</td>
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<td>-110</td>
<td>211</td>
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<tr>
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<td>289</td>
<td>167</td>
<td>16</td>
<td>88.7</td>
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<td>708</td>
<td>702</td>
<td>116</td>
<td>211</td>
<td>62.9</td>
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<tr>
<td>427</td>
<td>299</td>
<td>170</td>
<td>16</td>
<td>-86.4</td>
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<tr>
<td>490</td>
<td>490</td>
<td>116</td>
<td>211</td>
<td>-61.4</td>
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<tr>
<td>907</td>
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<td>61.4</td>
</tr>
<tr>
<td>478</td>
<td>-520</td>
<td>-170</td>
<td>-16</td>
<td>88.4</td>
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<td>908</td>
<td>994</td>
<td>116</td>
<td>-208</td>
<td>61.5</td>
</tr>
<tr>
<td>283</td>
<td>151</td>
<td>85</td>
<td>53</td>
<td>-86.1</td>
</tr>
<tr>
<td>644</td>
<td>-692</td>
<td>-41</td>
<td>88</td>
<td>-70.9</td>
</tr>
<tr>
<td>-21</td>
<td>0</td>
<td>50</td>
<td>-69</td>
<td>92.6</td>
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<td>233</td>
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<td>94</td>
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<tr>
<td>56</td>
<td>0</td>
<td>107</td>
<td>41</td>
<td>99.0</td>
</tr>
<tr>
<td>-68</td>
<td>28</td>
<td>132</td>
<td>-164</td>
<td>88.7</td>
</tr>
<tr>
<td>71</td>
<td>0</td>
<td>113</td>
<td>-41</td>
<td>100.0</td>
</tr>
<tr>
<td>46</td>
<td>3</td>
<td>-138</td>
<td>176</td>
<td>89.3</td>
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<tr>
<td>-77</td>
<td>0</td>
<td>116</td>
<td>-164</td>
<td>100.1</td>
</tr>
<tr>
<td>43</td>
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<td>89.4</td>
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<td>116</td>
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<td>100.0</td>
</tr>
<tr>
<td>77</td>
<td>0</td>
<td>113</td>
<td>-58</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Event: 1AG  
Location: 79.60 mi 6.05 ohms sec  
Duration: 4.75  
Fct Current: 1035.1  

R1 = 13.90  
X1 = 79.96  
X0 = 41.50  
XD = 248.57  
LL = 100.00  
CTR = 200.00  
PIR = 2000.00  
MTA = 80.80  
A1TP = 90.00  
A1TD = 0.00  
Z1X = 80.00  
Z2X = 120.00  
Z3X = 100.00  
Z20P = 80.00  
Z30P = 200.00  
Z50P = 300.00  
Z51P = 100.00  
Z51TP = 5.00  
Z51NC = 2  
Z51TC = Y  
Z67P = 1200.00  
Z67D = 10.00  
Z67TC = Y  
Z62P = 80.00  
Z62D = 50.00  
LOPE = Y  
LOPA = Y  
TIME1 = 5  
TIME2 = 0  
AUTO = 2  
RINGS = 3

Logic settings:

MTU MPT MTO MA1 MNI MRC
F3 FF FF FF CO 33
50 50 50 50 00 00 00 00 00 00 08
EXPLANATION OF EVENT REPORT

Example 230 kV Line
Date: 1/30/90  Time: 09:21:23.004

FIDS: SEL-1216-8400-V56amp-9000129

<table>
<thead>
<tr>
<th>1A</th>
<th>IA</th>
<th>IB</th>
<th>IC</th>
<th>VA</th>
<th>VB</th>
<th>VC</th>
<th>PGPMNP</th>
<th>ABC</th>
<th>1AAAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-271</td>
<td>-365</td>
<td>-113</td>
<td>211</td>
<td>-67.4</td>
<td>59.2</td>
<td>136.0</td>
<td>P, PP</td>
<td>....</td>
<td>ABC</td>
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<tr>
<td>-416</td>
<td>-233</td>
<td>-170</td>
<td>76</td>
<td>95.6</td>
<td>124.0</td>
<td>0.5</td>
<td>P, PP</td>
<td>....</td>
<td>ABC</td>
</tr>
<tr>
<td>704</td>
<td>796</td>
<td>116</td>
<td>211</td>
<td>62.9</td>
<td>56.0</td>
<td>-139.2</td>
<td>PP, PP</td>
<td>...</td>
<td>ABC</td>
</tr>
<tr>
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<td>167</td>
<td>110</td>
<td>-87.5</td>
<td>127.3</td>
<td>2.5</td>
<td>PP, PP</td>
<td>....</td>
<td>ABC</td>
</tr>
<tr>
<td>-963</td>
<td>-969</td>
<td>-116</td>
<td>211</td>
<td>61.4</td>
<td>54.9</td>
<td>140.2</td>
<td>PP, PP</td>
<td>T, TA</td>
<td>ABC</td>
</tr>
<tr>
<td>-478</td>
<td>-299</td>
<td>-167</td>
<td>76</td>
<td>86.7</td>
<td>127.7</td>
<td>2.9</td>
<td>PP, PP</td>
<td>T, TA</td>
<td>ABC</td>
</tr>
</tbody>
</table>

Event: IA:1A output activation: 74.60 mi 6.09 ohms sec
Duration: 4.75 sec
Relay: 1035.1

R1 = 13.90  X1 = 79.96  R0 = 41.50  X0 = 248.57  LL = 100.00
CTR = 200.00  PTR = 200.00  MTA = 80.00
70D = 20.00  70R = 200.00  A1TP = 0.00  A1TD = 0.00
2D = 120.00  22D = 40.00  A2TP = 22D = 40.00
70D = 100.00  70R = 200.00  50H = 500.00
5IN = 5IN = 5IN = 5IN
67N = 1200.00  67N = 10.00  67N = 10.00
5INF = 10.00  5INF = 10.00  5INF = 10.00

Currents and voltages are in primary A, B, and C.  Rows are 1/4 cycle apart.  Time runs down page.  Obtain phase RMS value and angle using any entry as V-component, and the entry immediately underneath as the X-component.  For example, from bottom row, IA = 969
IA = 299. Therefore, IA = 1014 amps RMS primary, at an angle of ATAN(969/299) = -107 degrees, with respect to the sampling clock.

<FID>
Firmware Identification Data

<Relays>
Columns show states of internal relay elements: "OFF" = "0"


<Inputs>
Columns show states of input contacts: 1=DEAD, 0=ACTIVE

<Outputs>
Columns show states of output contacts: OFF = "0"

<Event>
Fault Indications are "2H" where 2 indicates zone and 1 type.

<Duration>
Fault duration determined from relay element(s) pickup time

<Location>
Max phase current (primary amps) taken near middle of fault

<Logic settings>
See LOGIC command for a description of mask settings

19
SAMPLE COMMAND DISPLAYS

Sample History Command

```plaintext
=>>HISTORY
Example 230 kV Line                           Data: 1/30/90  Time: 09:04:05:745
#   UNIT   TIME   TYPE   DIST  DUR  CURR
1   1/30/90  09:03:01.092 3AG  100.2  7.25  798
2   1/30/90  09:03:13.941 3AG  74.4  7.25  1016
3   1/30/90  09:03:26.883 1AG  25.3  7.25  1712
4   1/30/90  09:00:13.345 1BC  25.5  7.25  3167
5   6
6   7
7   8
9   10
11
12
```

Sample Meter Command

```plaintext
=>>METER
Example 230 kV Line                           Data: 1/30/90  Time: 13:27:05
I (A)     9.94     9.95     9.94     17.23     17.24     17.24
V (kV)    134.4    134.3    134.2    233.1    232.8    232.9
P (MW)    401.12
Q (MVAR)  1.00
```

Sample Self Test Status Report

```plaintext
=>>STATUS
Example 230 kV Line                           Data: 1/30/90  Time: 01:04:56
SELF-TESTS

W-Warn  F-Fail
OS  0  0  0  0  0  0
PS  4.99  15.14 -14.85
RAN  ROM  A/B  NDF  SET
OK  OK  OK  OK  OK
```

Targets Command

The eight-LED display on the front panel can be programmed to show relay targets (default), Relay Word bits, contact inputs, and contact outputs as shown below. This feature is especially useful for testing individual relay elements.

```plaintext
=>>TARGETS [N]
LED:  1  2  3  4  5  6  7  8
R   0  EN  A  B  C  G  Z1  Z2  Z3  RELAY TARGETS
   1  ZIP  Z1G  Z2PT  Z2GT  Z3P  Z3G  Z3T  ZSN  RELAY WORD
   2  SNP  SNR  SNK  SNG  SNO  SNF  S1N  S2N  RELAY WORD
   3  POS  POS  POS  POS  POS  POS  POS  POS  RELAY WORD
   4  50N  Z3G  Z3R  Z3G  Z3R  Z3G  Z3R  Z3G  Z3R  INTERNAL ELEMENTS
   6  TRIP  CLOSE  A1  TRIPA  TRIPB  TRIPC  ALRM  CONTACT OUTPUTS
```

The front panel targets can be reset and cleared remotely or locally using the target command. Type TARGET R <ENTER> to reset and clear the targets.
SEL-121S EXTERNAL CURRENT AND VOLTAGE CONNECTIONS

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SEL-121S DC EXTERNAL CONNECTION DIAGRAM
(TYPICAL SINGLE POLE TRIPPING APPLICATION)
SEL-121S COMMUNICATIONS AND CLOCK CONNECTIONS
ONE UNIT AT ONE LOCATION

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SHALL BE USED SOLELY IN THE PERFORMANCE OF WORK CONTRACTED FOR BY THIS COMPANY.
THE INFORMATION SHALL NOT BE USED OR DISCLOSED BY THE RECIPIENT FOR ANY OTHER PURPOSE
WHATSOEVER.
NOTE: SEL-DTA DISPLAY/TRANSUDER ADAPTER (DTA)
DATA AND CONTROL POWER

SEL RELAY COMMUNICATIONS DIAGRAM FOR CONNECTION
TO THE SEL-DTA

DWG. NO. A7-0413
DATE: 10-07-88
SEL-121S RELAY HORIZONTAL FRONT AND REAR PANEL DRAWINGS

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DWG. NO. A7-0527
DATE: 05-22-89
REV: 02-21-90

27
7/32 DIA., 4 HOLES FOR
10-32 MTG. SCREWS

DIMENSION A:
CASE: 17.00"
CUT OUT: 17.25" - 17.875"
17.375" PREFERRED

DIMENSION B:
CASE: 8.5"
CUT OUT: 8.625" - 8.9375"
8.688" PREFERRED

DIMENSION C:
CASE: 5.25"
CUT OUT: 5.35" - 5.45"

DIMENSION D:
CASE: 2.625"
CUT OUT: 2.675" - 2.725"

NOTE: ALL INSTRUMENTS MAY BE MOUNTED HORIZONTALLY (AS SHOWN) OR VERTICALLY.

PANEL CUTOUT AND DRILL PLAN FOR SEMI-FLUSH MOUNTING OF
5.25 INCH HIGH CASE

DWG. NO. A7-0174
DATE 5/11/87 JS
REV. 3/9/88
SEL-121S SINGLE POLE TRIP RELAY/FAULT LOCATOR COMMAND SUMMARY

**Level 0**

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

**Level 1**

**2ACCESS**
Answer password prompt (if password protection enabled) to gain access to Level 2. This command always pulses the ALARM relay.

**DATE**
Show or set date. DAT 2/3/89 sets date to Feb. 3, 1989. The month and date settings are overridden when IRIG-B synchronization occurs. Pulses the ALARM relay momentarily when a different year is entered than previously stored year.

**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 12 most recent faults.

**IRIG**
Force immediate execution of time-code synchronization task.

**METER**
Show primary current, voltage, 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 and Logic settings. This command does not affect the settings. The logic settings are shown in hexadecimal format for each mask.

**STATUS**
Show self test status.

**TARGETS**
Show data and set target lights as follows:
- TAR 0: Relay Targets
- TAR 1: RELAY WORD ROW #1
- TAR 2: RELAY WORD ROW #2
- TAR 3: RELAY WORD ROW #3
- TAR 4: RELAY WORD ROW #4
- TAR 5: Contact Inputs
- TAR 6: Contact Outputs
- TAR 7: Clears targets and returns to TAR 0

Be sure to return to TAR 0 when done, so LEDs display fault targets.

**TIME**
Show or set time. TIM 13/32/00 sets clock to 1:32:00 PM. This setting is overridden when IRIG-B synchronization occurs.

**TRIGGER**
Trigger and save an event record. (Type of event is EXT).

**Level 2**

**CLOSE**
Close circuit breaker, if allowed by jumper setting.

**LOGIC**
Show or set logic masks MTU, MPT, MTO, MAI, MRI, MRC. ALARM relay closes while new settings are being computed, and event data buffers are cleared.

**OPEN**
Open circuit breaker, if allowed by jumper setting.

**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 while new settings are being computed, and event data buffers are cleared.

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

---

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Pullman, WA 99163-5603
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SEL/3-90