SEL-151C

PHASE OVERCURRENT RELAY
WITH VOLTAGE AND DISTANCE CONTROL
NEGATIVE-SEQUENCE OVERCURRENT RELAY
GROUND OVERCURRENT RELAY
SELECTABLE SETTING GROUPS
CIRCUIT BREAKER MONITOR
FAULT LOCATOR
SELOGIC® CONTROL EQUATIONS

INSTRUCTION MANUAL

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PM151C-01

Warning

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

ATTENTION!

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

20001120

SEL-151C INSTRUCTION MANUAL ADDENDUM

This addendum explains SEL-151C relay operations that differ from those described in the SEL-151 Instruction Manual. The major differences are that the SEL-151C relay has no reclosing relay or fault locator, but adds phase mho distance elements for more selective torque control.

Consider using the SEL-151C relay in bus applications where the mho elements can discriminate between remote faults and the combined loads of several feeders.

Differences between the SEL-151 and SEL-151C Relay Words are underlined below.

<u>SEL-151</u>

R1	**51P**	**50L**	**<u>50H</u>**	**51QP**	**50Q**	**51NP**	**50NL**	**50NH**
R2	**51T**	**50LT**	**<u>50C</u>**	**51QT**	**50QT**	**51NT**	**50NLT**	**<u>27</u>**
R3	**<u>79RS</u>**	**<u>79CY</u>**	**<u>79LO</u>**	**<u>79SH</u>**	**52AT**	**52BT**	**IN6**	**IN5**
R4	**PDEM**	**QDEM**	**NDEM**	**TF**	**CF**	**TCMA**	**ST**	
R5	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
R6	**J**	**KT**	**!L**	**V**	**W**	**X**	**Y**	**ZT**

<u>SEL-151C</u>

R1	**51P**	**50L**	**<u>50M</u>**	**51QP**	**50Q**	**51NP**	**50NL**	**50NH**
R2	**51T**	**50LT**	**<u>50MT</u>**	**51QT**	**50QT**	**51NT**	**50NLT**	**<u>50H</u>**
R3	**<u>21P</u>**	**<u>50C</u>**	**<u>27</u>**		**52AT**	**52BT**	**IN6**	**IN5**
R4	**PDEM**	**QDEM**	**NDEM**	**TF**	**CF**	**TCMA**	**ST**	
R5	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
R6	**J**	**KT**	**!L**	**V**	**W**	**X**	**Y**	**ZT**

Note: **50H**, **50C**, and **27** are in different locations in each Relay Word.

79RS, **79CY**, **79LO**, and **79SH** are not in the SEL-151C Relay Word because the SEL-151C relay does not include a reclosing relay.

The SEL-151C relay has an extra definite-time phase overcurrent element (**50MT**) with pickup (**50M**). These elements have the same setting range and tolerance as **50LT** and **50L**, respectively.

The SEL-151C relay has a single-zone self-polarized mho distance element (**21P**).

FUNCTIONS AND SETTINGS NOT INCLUDED IN THE SEL-151C RELAY

The SEL-151C relay has no reclosing relay. Thus, it does not have the following SEL-151 relay settings:

79OI1, 79OI2, 79OI3, 79OI4, 79RST, M79SH, RC, SEQ, RE as an input option

The SEL-151C relay can perform circuit breaker closing via the CLOSE command or a DC (Direct Close) input. The Close Failure function is operable in the SEL-151C relay (setting CFT, Relay Word bit **CF**).

There is no fault locator in the SEL-151C relay. Thus, the SEL-151C relay does not have the following SEL-151 relay settings:

R1, X1, R0, X0, RS, XS, LL (line impedance and length parameters)

EXTRA ELEMENTS AND SETTINGS IN THE SEL-151C RELAY

The SEL-151C relay has an extra definite-time phase overcurrent element (**50MT**) with pickup (**50M**).

50M	- pickup for **50MT** (amps, secondary)	0.50 to 100.00 amps
50MT	- time delay for **50MT** element (cycles)	0 to 16000 cycles

The column space allotted for "79" in the SEL-151 relay event report shows the phase overcurrent elements in the SEL-151C relay. The new column is labeled "50M" and appears with the other "P" columns as shown below.

```
P     Q  N   I   Out  In

555T5 55 555 D B T13A 135
100C0 10 100 E K &&&L &&&
 LMIH     LH M R C24R 246
```

Event Report Column	Elements Asserted		Symbol Displayed
50M	**50M**	**50MT**	
	0	0	.
	0	1	(not possible)
	1	0	p
	1	1	t

The **50H** element cannot be torque controlled in the SEL-151C relay, so the "50H" column appears to the right of the "TCI" (torque control, internal) column in the event report. The **50M** and **50MT** elements can be torque controlled.

The SEL-151C relay has three single-zone self-polarized mho distance elements (21AB, 21BC, and 21CA). The following SEL-151C relay settings cover the distance elements.

ZP	- Reach (ohms, secondary)	1 to 64 ohms
MTA	- Maximum Torque Angle (degrees)	0 to 90 degrees
21PC	- **21P** = 21AB + 21BC + 21CA (21PC = 2) or **21P** = 21AB * 21BC * 21CA (21PC = 3)	

For more information, see Figure 2.20 in the SEL-151 Instruction Manual.

21P is also an optional internal torque control element for the phase overcurrent elements (via the TCI setting for the SEL-151C relay). **50C** and **27** are optional internal torque control elements for the phase overcurrent elements in both relays.

Element Choices for TCI			Setting TCI =	
21P	50C	27		
0	0	0	0	Rows 1–4 are settings for both relays
0	0	1	V	
0	1	0	I	
0	1	1	3	
1	0	0	Z	Rows 5–8 are additional settings for the SEL-151C relay only
1	0	1	5	
1	1	0	6	
1	1	1	7	

To fully utilize the relay's resources, self tests are delayed when any of the following elements are picked up:

51P, 50H, 51QP, 50Q, 51NP, 50NL, 50NH
51T, 51QT, 50QT, 51NT, 50NLT, and 21P.

Therefore, you should be careful to set the relay so that under normal conditions none of these elements are picked up.

In the event reports of both relays, the TCI column displays these symbols. This column allows you to monitor internal torque controlling elements in the event report.

Event Report Column	Elements Asserted			Symbol Displayed	
TCI	21P	50C	27		
	0	0	0	0	Rows 1–4 are symbols for both relays
	0	0	1	V	
	0	1	0	I	
	0	1	1	3	
	1	0	0	Z	Rows 5–8 are additional symbols for the SEL-151C relay only
	1	0	1	5	
	1	1	0	6	
	1	1	1	7	

Front Panel Target LED Differences

The two right most target LEDs indicate enable (EN) and alarm (ALRM) in the SEL-151C relay.

FIRMWARE IDENTIFICATION DIFFERENCES

See Firmware Identification in Section 4: EVENT REPORTING in the SEL-151 Instruction Manual for comparison.

For the SEL-151C relay family, version specifications are interpreted as follows:

V[VS] = V[ABCDEFG]

Option	Specifier	Specifier Meaning	Option Description
A	5, 6	50 Hz, 60 Hz	Power System Frequency
B	1, 5	1 amp, 5 amps	Nominal Amps per Phase
C	6	120 & 67 volts	Nominal Volts per Phase
D	n	none	Fault Locator type
E	p, n	positive, negative	Phase-Sequence of Power System
F	0	none	Recloser
G	e	enable and alarm	Target LEDs

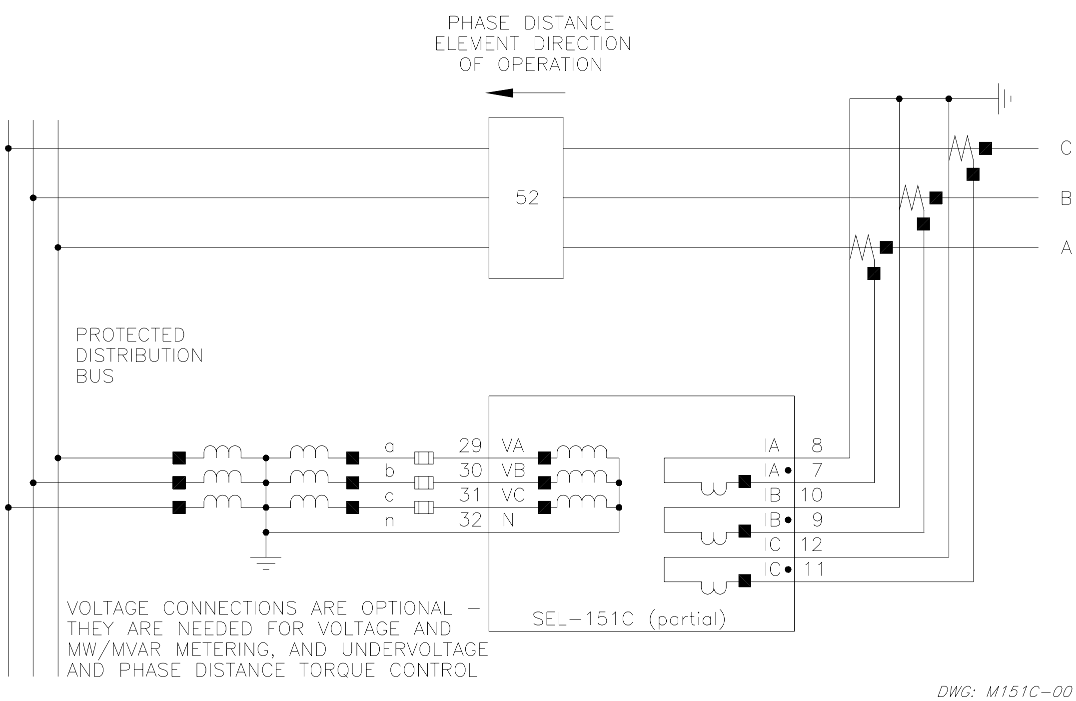

Figure 1: SEL-151C Relay Typical AC Current and Voltage Connections

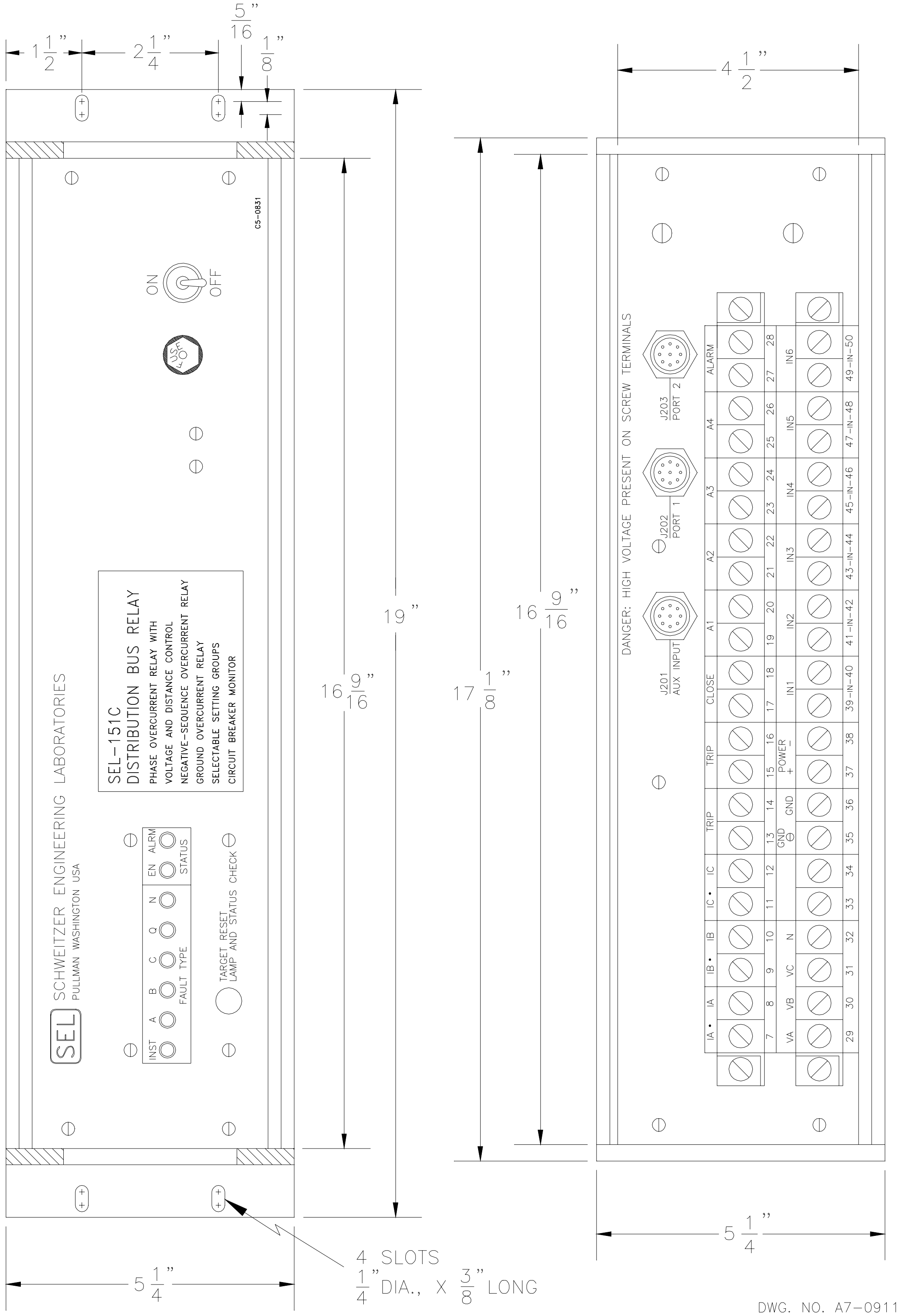

Figure 2: SEL-151C Distribution Bus Relay Horizontal Front and Rear Panel Drawings

SEL RELAY INSTRUCTION MANUAL ADDENDUM

ACB PHASE ROTATION OPTION

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

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

SEL-151/151C/251/251C INSTRUCTION MANUAL ADDENDUM FOR 1 AMP VERSION RELAYS

This addendum explains the differences in the 1 A versions of the above listed relays as compared to the 5 A versions. 1 A or 5 A refer to the nominal secondary rating of the current transformers (CTs).

Overcurrent Element Pickups and Demand Ammeter Thresholds

To keep the same operational sensitivity:

$$1 \text{ A setting ranges} = (1/5) \cdot (5 \text{ A setting ranges})$$

Phase	1 A Setting Ranges	
51P	0.2 to 2.4 A secondary	
50L	0.1 to 20 A secondary	
50M	0.1 to 20 A secondary	(element available in SEL-151C and SEL-251C relays only)
50H	0.1 to 20 A secondary	
50C	0.1 to 20 A secondary	

Neg.-seq.	
51QP	0.2 to 2.4 A secondary
50Q	0.1 to 20 A secondary

Ground/ Residual		
51NP	0.05 to 2.4 A secondary	
50NL	0.1 to 20 A secondary	(for $0.2 \leq 51NP \leq 2.4$ A)
	0.06 to 10 A secondary	(for $0.1 \leq 51NP < 0.2$ A)
	0.03 to 5 A secondary	(for $0.05 \leq 51NP < 0.1$ A)
50NH	0.1 to 20 A secondary	(for $0.2 \leq 51NP \leq 2.4$ A)
	0.06 to 10 A secondary	(for $0.1 \leq 51NP < 0.2$ A)
	0.03 to 5 A secondary	(for $0.05 \leq 51NP < 0.1$ A)

MANUAL CHANGE INFORMATION

The date code at the bottom of each page of this manual reflects the creation or revision date. Date codes are changed only on pages that have been revised and any following pages affected by the revisions (i.e., pagination). If significant revisions are made to a section, the date code on all pages of the section will be changed to reflect the revision date.

Each time revisions are made, both the main table of contents and the affected individual section table of contents are regenerated and the date code is changed to reflect the revision date.

Changes in this manual to date are summarized below (most recent revisions listed at top).

Revision Date	Summary of Revisions
The *Manual Change Information* section has been created to begin a record of revisions to this manual. All changes will be recorded in this Summary of Revisions table.	
20020212	This revision includes the following changes: – Replaced Standard Product Warranty page with warranty statement on cover page. **Appendix A:** – Updated Firmware Version information.
970421	This revision includes the following changes: **Appendix A:** – Added New Firmware Versions.

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INTRODUCTION

GETTING STARTED

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

OVERVIEW

The SEL-151 DISTRIBUTION RELAY is designed to protect distribution lines for all fault types. The following list outlines protective features, performance, and versatility gained when applying the SEL-151 DISTRIBUTION RELAY to your installations.

- Develop traditional and advanced schemes using flexible SELOGIC™ Control Equations
- Phase overcurrent elements have voltage control for load security
- Negative-sequence elements reject load for more sensitive phase fault protection
- Ground/Residual overcurrent elements cover ground faults
- Choose fast or electromechanical reset characteristic for time-overcurrent elements
- Overcurrent elements inhibit recloser reset to prevent nuisance "trip-reclose" cycling
- Sequence coordination avoids unnecessary tripping for faults beyond line reclosers
- Undervoltage logic detects high-side transformer fuse operations
- Six selectable setting groups cover all feeder protection contingencies
- Circuit breaker monitor sums interrupted current in each pole to aid maintenance
- Fault locator reduces line patrol and outage time for increased service reliability
- Eleven-cycle event report simplifies fault and system analysis
- Comprehensive voltage, current, power, unbalance, and demand metering
- Connects to SEL-RD RELAY DISPLAY for easy information access

The SEL-151 DISTRIBUTION RELAY improves every aspect of feeder protection:

Security:	Undervoltage supervision and negative-sequence avoid load encroachment
Reliability:	Field-proven hardware; new backup concepts
Sensitivity:	Negative-sequence overcurrent elements for better phase fault coverage
Flexibility:	SELOGIC Control Equations handle virtually every conceivable scheme
Capability:	Brings transmission relay features to distribution applications
Economy:	Low price and unique features make the relay an exceptional value

GENERAL DESCRIPTION

The SEL-151 DISTRIBUTION RELAY protects, controls, and monitors distribution feeders. It offers important new and unique features, like user-programmable SELogic Control Equations, negative-sequence overcurrent elements, and selectable setting groups. The advanced relay design enhances security, reliability, sensitivity, and operation.

SELogic Control Equations: The Next Step in Programmable Relay Logic

In 1987, SEL® invented Programmable Mask Logic. The SEL-151 relay offers SELogic Control Equations, the next step in user-programmability. SELogic Control Equations include ANDing, ORing, and inverting functions, timing, and programmable inputs and outputs. SELogic Control Equations add power and flexibility while simplifying programming.

Phase, Ground, and Negative-Sequence Overcurrent Protection

Phase and negative-sequence overcurrent elements detect phase faults. Negative-sequence overcurrent elements reject three-phase load to provide more sensitive coverage of phase-to-phase faults. Phase overcurrent elements are needed only for three-phase faults where negative-sequence quantities are not produced.

On heavily-loaded feeders, undervoltage torque control of phase overcurrent elements adds security. Choose between three-phase and single-phase-pair undervoltage torque control. When phase overcurrent elements are used only for three-phase faults, the three-phase undervoltage option enhances security.

Ground/Residual overcurrent elements detect ground faults, and external inputs can torque control selected overcurrent elements.

There are two reset characteristic choices for the time-overcurrent elements. One choice resets the elements if current drops below pickup for at least one cycle. The other choice emulates electromechanical induction disc elements where the reset time depends on the time dial setting, the percentage of disc travel, and the amount of current between zero and pickup.

Sophisticated Multiple-Shot Reclosing Relay Includes Reset Inhibit and Sequence Coordination

The reclosing relay allows up to four reclosing shots with separate, settable open interval timers and reset interval timer. Overcurrent conditions during the reclosing relay reset interval inhibit the reset interval timer. This prevents the reclosing relay from resetting when a trip condition is imminent. A close failure timer can limit CLOSE output contact assertion. Reclose cancel conditions are programmable. A programmable input can be used as a reclose enable input to disable/enable the reclosing relay.

The SEL-151 relay includes easily programmable sequence coordination to keep the relay in step with line reclosers, preventing undesired tripping for faults beyond line reclosers.

Six Selectable Groups of Settings and Logic

The relay stores six setting groups. Select the active setting group by contact input or command. Use these setting groups to cover a wide range of distribution feeder protection contingencies. Selectable setting groups make the SEL-151 relay ideal for bus-tie and substitute breaker applications and other applications requiring frequent setting changes.

Circuit Breaker Monitor Tracks Breaker Performance and Helps Maintenance Planning

Separate circuit breaker trip counters differentiate and tally relay-initiated trips and external trips. Running sums of interrupted current for relay and external trips indicate breaker wear and tear on a pole-by-pole basis. Use these data to schedule breaker maintenance.

Trip failure logic provides alarm and breaker failure functions. A close failure alarm indicates circuit breaker closing circuit or mechanism problems. The trip circuit monitor detects abnormal open or short circuits in the circuit breaker tripping circuit or status input.

Fault Locator Reduces Line Patrol and Outage Time

The SEL-151 relay includes a fault locator which uses fault type, prefault, and fault conditions to provide an accurate estimate of fault location without communications channels, special instrument transformers, or source impedance information, even during conditions of substantial load flow and fault resistance. Fault locating reduces line patrol and outage time.

Analyze Operations Using Event Reports

Eleven-cycle event reports triggered by user selected conditions provide the current, voltage, and sequence-of-events information you need to understand relay and circuit breaker performance, as well as stress on the feeder for every fault.

Comprehensive Metering Supports Protection, Operation, and Demand Analysis

The relay measures phase, negative-sequence, and zero-sequence voltage and current, as well as MW and MVAR. Demand and peak demand values for current, MW, and MVAR are also available. Metering also supports protection, because you can inspect the quantities monitored by relay elements. Check for load encroachment and unbalance through instantaneous, demand, and peak-demand measurements.

Access SEL-151 Relay Information Via the SEL-RD RELAY DISPLAY

You can connect up to four SEL-151 relays to one SEL-RD RELAY DISPLAY. Access relay target, meter, status, fault history, and circuit breaker information via the relay display. You can even change the active setting group via the display.

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SPECIFICATIONS

GENERAL SPECIFICATIONS

Voltage Inputs	115, 208, or 230 volt nominal phase-to-phase, three-phase, 4-wire connection 150 volt phase-to-neutral saturation limit Burden: 0.07 VA at 67 V; 0.5 VA at 120 V (phase-to-neutral)
Current Inputs	5 amps nominal; 0.06 VA burden 15 amps continuous 110 amp saturation limit 500 amp one second thermal rating
Output Contact Current Ratings	30 amp make per IEEE C37.90, paragraph 6.7.2 6 amp carry continuously; MOV protection provided
Optical Isolator Logic Input Ratings	48 Vdc: 25 - 60 Vdc 125 Vdc: 60 - 200 Vdc 250 Vdc: 200 - 280 Vdc Current = 6 mA at nominal voltage
Time Code Input	Relay accepts demodulated IRIG-B time code input
Communications	Two EIA RS-232-C serial communications ports
Power Supply	48 Volt: 30 - 60 Vdc; 12 watts 125/250 Volt: 85 - 280 Vdc or 85 - 200 Vac; 12 watts
Dimensions	5¼" x 19" x 13" (13.3 cm x 48.2 cm x 33.0 cm) (H x W x D)
Mounting	Available in horizontal and vertical mounting configurations
Dielectric Strength	V, I inputs: 2500 Vac for 10 seconds Other: 3000 Vdc for 10 seconds (excludes EIA RS-232-C)
Operating Temp.	-40°F to 158°F (-40°C to 70°C)
Environment	IEC 68-2-30 Temperature/Humidity Cycle Test - six day (type tested)
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 quarter-wave antenna driven by 20 watts at 150 MHz and 450 MHz, randomly keyed on and off one meter from relay.

ESD Test IEC 801-2 Electrostatic Discharge Test (type tested)

Unit Weight 21 pounds (9.1 kg)

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

Burn-in 140°F (60°C) for 100 hours.

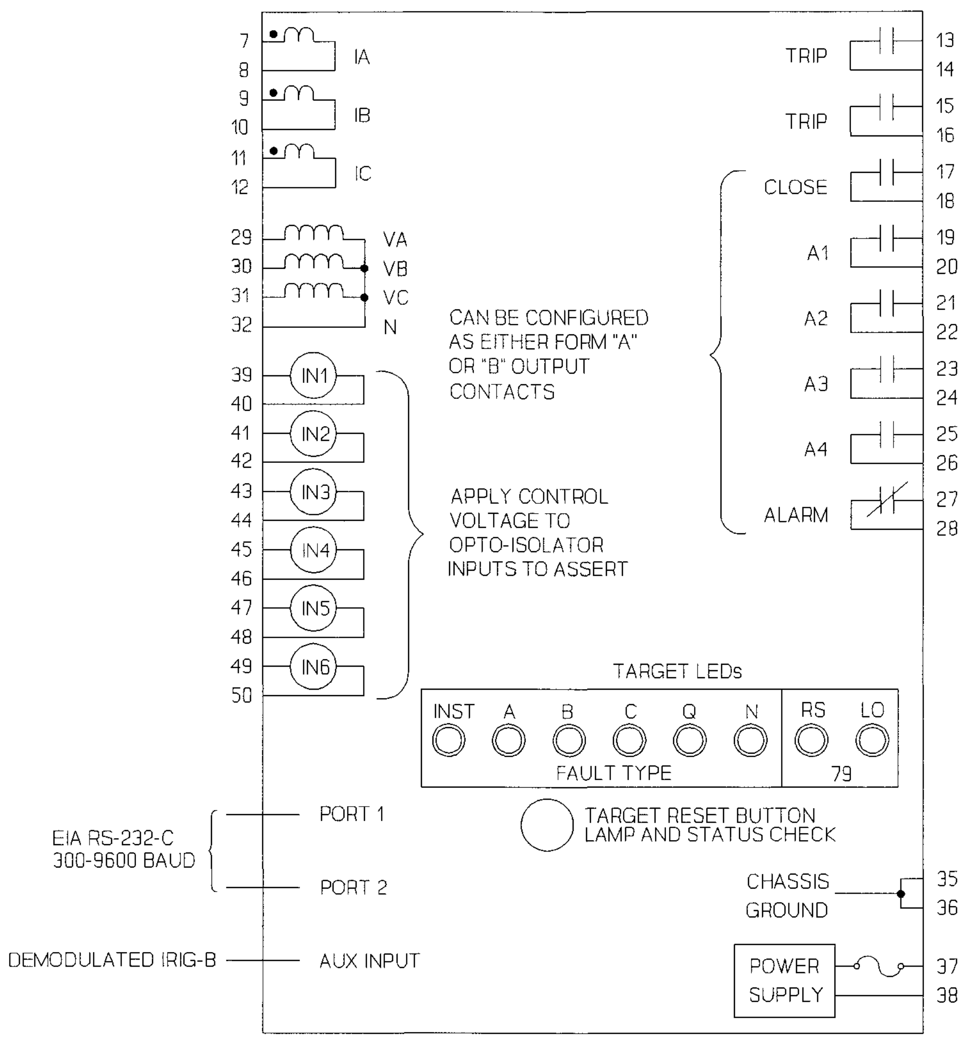


Figure 2.1: SEL-151 Relay Inputs, Outputs, and Targets Diagram

FUNCTIONAL SPECIFICATIONS

Phase Overcurrent Elements for Phase and Three-Phase Faults - See Figures 2.17 and 2.20

51T Phase Time-Overcurrent Element
- Curve families: moderately inverse, inverse, very inverse, extremely inverse
- Time dial: 0.5 to 15.00 in 0.01 steps.
- Pickup (**51P**): 1 to 12 A ±2% of setting ±0.1 A secondary
- Time delay or one cycle reset time
- Timing: ±5% and ±1 cycle for currents between 2 and 20 multiples of pickup
- Internally and externally torque controllable

50LT Phase Definite-Time Overcurrent Element
- Pickup (**50L**): 0.5 to 100 A ±2% of setting ±0.1 A secondary
- Time delay: 0 to 16,000 cycles in 1 cycle steps
- Internally and externally torque controllable

50H Phase Instantaneous Overcurrent Element
- Pickup: 0.5 to 100 A ±2% of setting ±0.1 A secondary
- Internally and externally torque controllable

50C Phase Instantaneous Overcurrent Element
- Pickup: 0.5 to 100 A ±2% of setting ±0.1 A secondary
- Can be used to override voltage control through TCI setting choice

Negative-Sequence Overcurrent Elements for Phase-to-Phase Faults - See Figure 2.18

51QT Negative-Sequence Time-Overcurrent Element
- Element measures $3xI_2$ negative-sequence current
- Curve families: moderately inverse, inverse, very inverse, extremely inverse
- Time dial: 0.5 to 15.00 in 0.01 steps.
- Pickup (**51QP**): 1 to 12 A ±3% of setting ±0.18 A secondary
- Time delay or one cycle reset time
- Timing: ±5% and ±1 cycle for currents between 2 and 20 multiples of pickup
- Externally torque controllable

50QT Negative-Sequence Definite-Time Overcurrent Element
- Element measures $3xI_2$ negative-sequence current
- Pickup (**50Q**): 0.5 to 100 A ±3% of setting ±0.18 A secondary
- Time delay: 0 to 16,000 cycles in 1 cycle steps
- Externally torque controllable

Residual Overcurrent Elements for Ground Faults - See Figure 2.19

51NT Ground/Residual Time-Overcurrent Element
- Curve families: moderately inverse, inverse, very inverse, extremely inverse
- Time dial: 0.5 to 15.00 in 0.01 steps
- Pickup (**51NP**): 0.25 to 12 A secondary
- Time delay or one cycle reset time
- Timing: ±5% and ±1 cycle for currents between 2 and 20 multiples of pickup
- Externally torque controllable

50NLT Ground/Residual Definite-Time Overcurrent Element
- Pickup (**50NL**): 0.5 to 100 A secondary (for 1 ≤ 51NP ≤ 12 A secondary)
  0.25 to 50 A secondary (for 0.5 ≤ 51NP < 1 A secondary)
  0.125 to 25 A secondary (for 0.25 ≤ 51NP < 0.5 A secondary)
- Time delay: 0 to 16,000 cycles in 1 cycle steps
- Externally torque controllable

50NH Ground/Residual Instantaneous Overcurrent Element
- Pickup: same range as **50NLT**
- Externally torque controllable

Accuracy
- Residual element pickup accuracy is dependent upon the 51NP setting. Pickup accuracy of the 51NP, 50NL, and 50NH elements is shown below in the given 51NP setting range.

1.0 ≤ 51NP ≤ 12.0 A sec	Pickup ±2% ±0.100 A sec
0.5 ≤ 51NP < 1.0 A sec	Pickup ±2% ±0.050 A sec
0.25 ≤ 51NP < 0.5 A sec	Pickup ±2% ±0.025 A sec

Undervoltage Torque Control Elements for Load Security (27) - See Figure 2.20

- 27AB, 27BC, 27CA Phase-to-Phase Undervoltage Elements
- Setting Range: 0 to 250 V line-to-line secondary ±5%, ±1 V
- Two setting limits: 27H and 27L (high and low, respectively)
- Element asserts only if voltage is between 27H and 27L
- User selects either three-phase or phase-to-phase undervoltage condition
- Control can be overridden by **50C** element through TCI setting choice
- Detect high-side transformer fuse operations

Time Delayed 52A or 52B Functions Handle Fuse-Saving and Inrush

The time delay pickup and time delay dropout settings (52APU and 52ADO, respectively) are provided to generate the **52AT** and **52BT** functions. The **52AT** and **52BT** bits can be used to supervise overcurrent elements for fuse saving and inrush conditions.

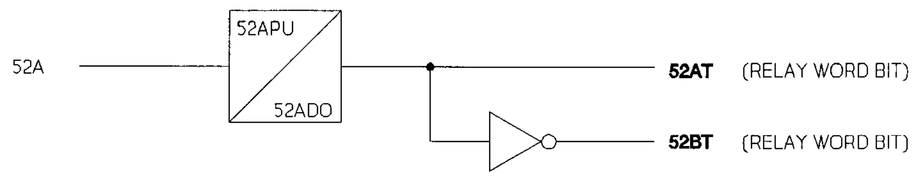


Figure 2.2: Time Delayed 52A and 52B Functions

Trip Failure Timer Detects Breaker Failure or Slow Trip - See Figure 2.24

A relay trip starts a trip failure timer. If the trip condition lasts longer than the TFT setting, the **TF** bit in the Relay Word asserts. The **TF** bit deasserts 60 cycles after the trip condition drops out. The **TF** bit can be assigned to an output contact to alarm for slow trips or to provide breaker failure tripping. It can also be used to cancel reclosing or trigger an event report.

Close Failure Timer Detects Failure to Close or Slow Close - See Figure 2.25

A close failure timer monitors the length of time the CLOSE output contact remains asserted. If CLOSE output contact assertion exceeds the CFT time setting, the close attempt is unsuccessful. The relay opens the CLOSE output contact, the reclosing relay locks out, and the **CF** bit in the Relay Word asserts. The **CF** bit asserts for 60 cycles. Use the **CF** bit to alarm for close failures or slow-close conditions and to trigger event reports.

Trip Circuit Monitor Alarm Checks Trip Circuit and Verifies Circuit Breaker Status Input

You can assign one of the six programmable inputs to the trip circuit monitor (TCM) logic.

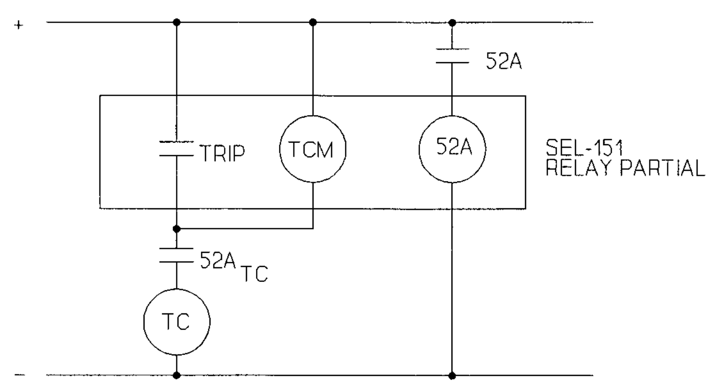


Figure 2.3: Trip Circuit Monitor (TCM) DC Voltage Connections

When the circuit breaker is closed (consequently $52A_{TC}$ is closed) and the TRIP output contact is not asserted, the TCM input allows a few milliamperes of current through the trip coil. The voltage drop is across the TCM input because the input has a much higher impedance than the trip coil.

Trip circuit monitor logic ensures that the 52A and TCM inputs agree. When the circuit breaker is closed, inputs 52A and TCM are energized; 52A and $52A_{TC}$ contacts are closed. When the circuit breaker is open, inputs 52A and TCM are deenergized; 52A and $52A_{TC}$ contacts are open. If the two inputs disagree for 60 cycles, the trip circuit monitor alarm (**TCMA**) bit asserts in the Relay Word. The **TCMA** bit deasserts 60 cycles after the TCMA condition ends.

Table 2.1: Trip Circuit Monitor Alarm (TCMA) Truth Table

TCM input	52A	TCMA Relay Word bit	Notes
0	0	0	
0	1	1	(a)
1	0	1	(b)
1	1	0	

(a) Abnormal open circuit in TCM input/lower trip circuit path
or a short circuit exists across the TCM input (e.g., TRIP output is asserted)
or 52A contact short circuited or "stuck closed"

(b) $52A_{TC}$ short circuited or "stuck closed"
or there is an abnormal open circuit in the 52A input circuit path

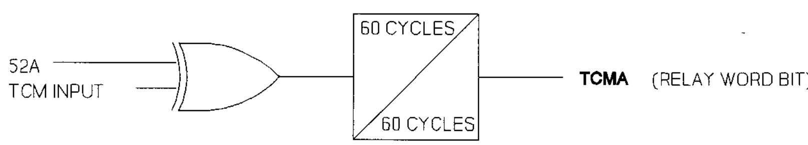


Figure 2.4: Trip Circuit Monitor Alarm (TCMA) Logic

Besides alarming for an abnormal open circuit in the trip circuit, the **TCMA** bit provides 52A input verification. It effectively compares the circuit breaker status input to $52A_{TC}$.

The **TCMA** bit can be used to alarm, cancel reclosing, or trigger event reports.

In Figure 2.3, a 52A contact is connected to relay input 52A. You can connect a 52B contact instead. Wire a 52B contact to a relay input !52A to perform the 52A function. Input options 52AR or !52AR can also be used (see SEL-151 Relay SELogic™ Control Equations).

SEL-151 RELAY SELogic CONTROL EQUATIONS

SELogic Control Equations put relay logic in the hands of the relay applications engineer. Assign the inputs to suit your application, logically combine selected relay elements for various control functions, use non-dedicated timers for special applications, and assign output relays to your logic functions.

Programming SELogic Control Equations consists of assigning functions to the programmable inputs, designing the internal logic you need, expressing that logic in terms of the relay elements and internal logic variables, and defining the output functions. The SET command controls all SELogic Control Equations programming (See Section 3: COMMUNICATIONS). Section 5: APPLICATIONS gives several examples of implementing protection schemes with SELogic Control Equations. Sample SELogic Control Equations are given in Example Event Report 2 in Section 4: EVENT REPORTING.

Assign Inputs to the Functions You Need

Program the six isolated inputs (IN1 ... IN6) to the functions your application requires. Choose from the following functions:

			Default Logic States
SS1	Setting Group Selection Input 1	(assign to IN1 only)	0
SS2	Setting Group Selection Input 2	(assign to IN2 only)	0
SS3	Setting Group Selection Input 3	(assign to IN3 only)	0
TCP	External Torque Control (Phase and Negative-Sequence Elements)		1
!TCP	(inverted sense of TCP)		0
TCG	External Torque Control (Residual Overcurrent Elements)		1
!TCG	(inverted sense of TCG)		0
52A	Circuit Breaker Status (52A contact input)*		N/A
!52A	Circuit Breaker Status (52B contact input)*		N/A
52AR	Circuit Breaker Status (52A contact input)/Reclose Initiate*		N/A
!52AR	Circuit Breaker Status (52B contact input)/Reclose Initiate*		N/A
DC	Direct Close	(requires circuit breaker status)	0
RE	Reclose Enable	(requires circuit breaker status)	1
TCM	Trip Circuit Monitor	(requires circuit breaker status)	N/A
ET	External Trigger of Event Report		0
DT	Direct Trip		0
(blank)	Unassigned input		

* Only one of the circuit breaker status input options 52A, !52A, 52AR, or !52AR should be assigned to an input.

52A or !52A

If 52A or !52A is assigned to an input, only circuit breaker status information is provided. Reclose initiation is provided by the assertion of the internal TRIP condition. When the TRIP condition drops out and the circuit breaker is open (per 52A or !52A), the open interval starts timing.

52AR or !52AR

If 52AR or !52AR is assigned to an input, not only does the input provide circuit breaker status information, but it provides reclose initiation, too. The sensed transition of the circuit breaker status, indicating that the circuit breaker is opening, initiates reclosing. If the TRIP condition is present, it has to drop out before the open interval starts timing.

In most applications, circuit breaker trips external to the relay (e.g., by control switch or SCADA) must not cause reclose initiation. If input option RE (Reclose Enable) is assigned to an input, the RE input is de-energized to prevent automatic reclosing. Certain control switch contacts can be wired to the RE input to defeat reclosing for control switch trips.

Also, if 52AR or !52AR is assigned to an input, the circuit breaker status function is time delayed by 10 cycles to qualify circuit breaker opening. This is done for certain application needs (see SYSTEM RESTORATION AFTER UNDER-FREQUENCY LOADSHEDDING in Section 5: APPLICATIONS). If this type of application is not needed, then it is better to assign 52A or !52A to an input instead and avoid the 10 cycle time delay. This time delay shows up in event reports and needs to be accounted for when making setting 52ADO.

The 10 cycle delay affects the circuit breaker monitor, too. The TDUR timer should be set somewhat greater than 10 cycles so that relay initiated circuit breaker trips are counted as such and not as external circuit breaker trips. Also, if an external trip occurs, no interrupted current values will likely be accumulated by the circuit breaker monitor because of the 10 cycle time delay.

Inputs IN5 and IN6 also appear directly in the Relay Word for use in the programmable logic. Inputs IN1, IN2, and IN3 can be assigned to functions other than just SS1, SS2, and SS3, respectively.

Assert an input by applying control voltage to the corresponding rear panel input terminals. Control voltage polarity is not important. When a function is not assigned to an input, the relay uses the respective default logic state shown above.

Figure 2.5 shows how Relay Word rows R5 and R6 in Table 2.2 and the output functions are derived.

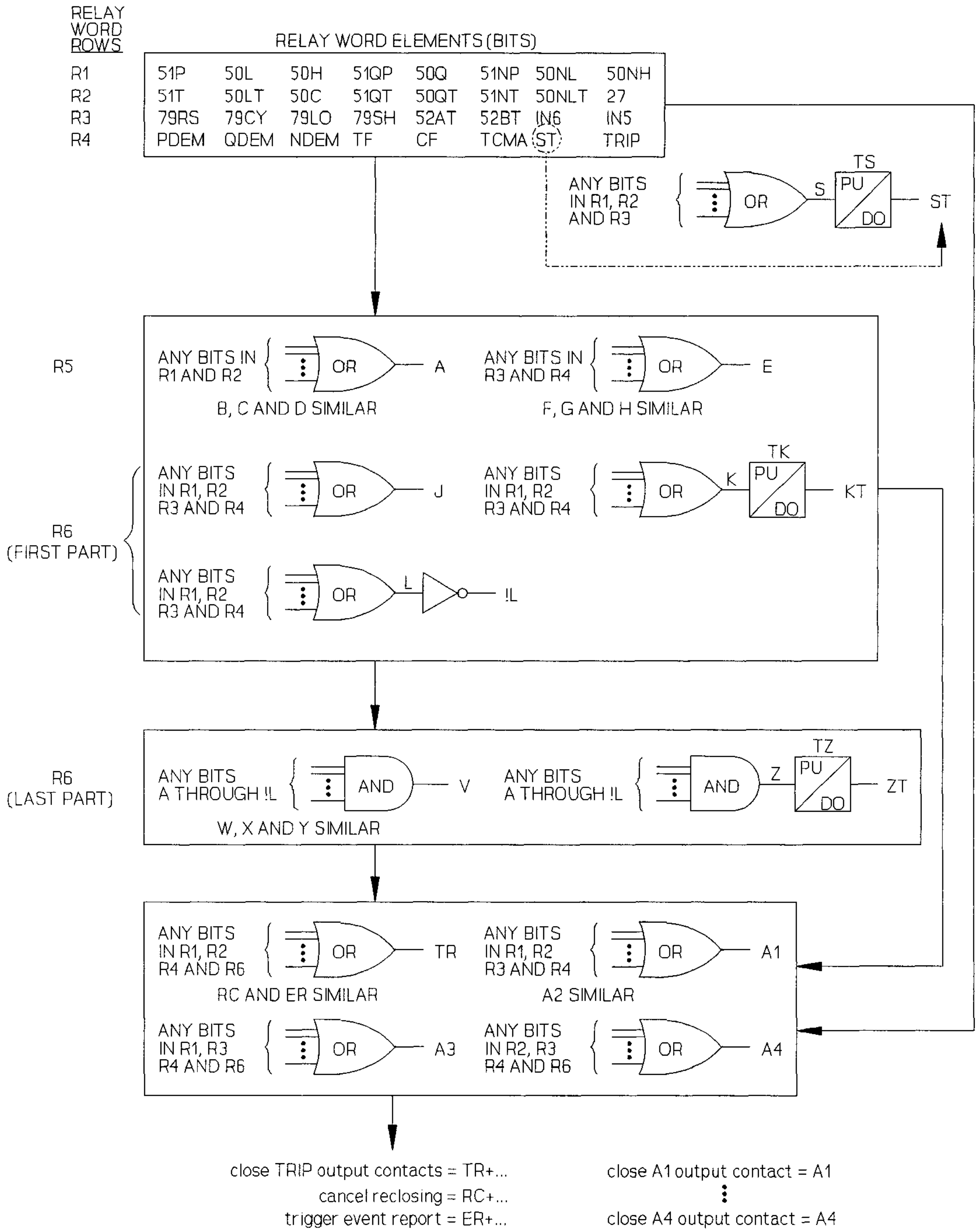


Figure 2.5: SEL-151 Relay SELOGIC Control Equations Block Diagram

Select Combinations of Relay Elements for Tripping and Other Purposes

The 48-bit Relay Word contains relay elements, intermediate logic results, and programmable logic variables.

Table 2.2: SEL-151 Relay Word

R1	**51P**	**50L**	**50H**	**51QP**	**50Q**	**51NP**	**50NL**	**50NH**
R2	**51T**	**50LT**	**50C**	**51QT**	**50QT**	**51NT**	**50NLT**	**27**
R3	**79RS**	**79CY**	**79LO**	**79SH**	**52AT**	**52BT**	**IN6**	**IN5**
R4	**PDEM**	**QDEM**	**NDEM**	**TF**	**CF**	**TCMA**	**ST**	**TRIP**
R5	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
R6	**J**	**KT**	**!L**	**V**	**W**	**X**	**Y**	**ZT**

! indicates NOT

51P	Phase time-overcurrent element pickup
50L	Phase definite-time overcurrent element pickup
50H	Phase instantaneous overcurrent element
51QP	Negative-sequence time-overcurrent element pickup
50Q	Negative-sequence definite-time overcurrent element pickup
51NP	Ground/Residual time-overcurrent element pickup
50NL	Ground/Residual definite-time overcurrent element pickup
50NH	Ground/Residual instantaneous overcurrent element
51T	Phase time-overcurrent element
50LT	Phase definite-time overcurrent element
50C	Phase instantaneous overcurrent element (can override voltage control by **27**)
51QT	Negative-sequence time-overcurrent element
50QT	Negative-sequence definite-time overcurrent element
51NT	Ground/Residual time-overcurrent element
50NLT	Ground/Residual definite-time overcurrent element
27	Phase undervoltage element for internal torque control and blown-fuse detection
79RS	Reclosing relay is in the reset state
79CY	Reclosing relay is in the reclose cycle state
79LO	Reclosing relay is in the lockout state
79SH	Shot bit; asserts for shots selected by the M79SH setting
52AT	Time delayed 52A
52BT	Inverse of **52AT**
IN6	Input IN6 bit; asserts for control voltage applied to input IN6
IN5	Input IN5 bit; asserts for control voltage applied to input IN5
PDEM	Phase demand current threshold exceeded
QDEM	Negative-sequence demand current threshold exceeded
NDEM	Ground/Residual demand current threshold exceeded

TF	Trip failure condition
CF	Close failure condition
TCMA	Trip circuit monitor alarm: asserts for abnormal open or short circuit in the circuit breaker tripping circuit or circuit breaker status input
ST	Output from timer TS, driven by any OR-combination of elements in R1 through R3 assigned to setting S
TRIP	Follows state of the TRIP output contacts
A B C D	Select any OR-combination of elements in R1 and R2
E F G H	Select any OR-combination of elements in R3 and R4
J	Select any OR-combination of elements in R1 through R4
KT	Output from timer TK, driven by any selected OR-combination of elements in R1 through R4 assigned to setting K
!L	Output from an inverter, driven by any selected OR-combination of elements in R1 through R4 assigned to setting L
V W X Y	Select any AND-combination of elements **A** through **!L**
ZT	Output from timer TZ, driven by any selected AND-combination of elements **A** through **!L** assigned to setting Z

Time Delayed Variables ST, KT, and ZT

Relay Word variables **ST**, **KT**, and **ZT** are outputs from time delay pickup/dropout timers TS, TK and TZ, respectively. TS and TK are driven by any OR-combination of Relay Word elements in R1...R3 and R1...R4, respectively. Any AND-combination of Relay Word elements **A** through **!L** may drive timer TZ.

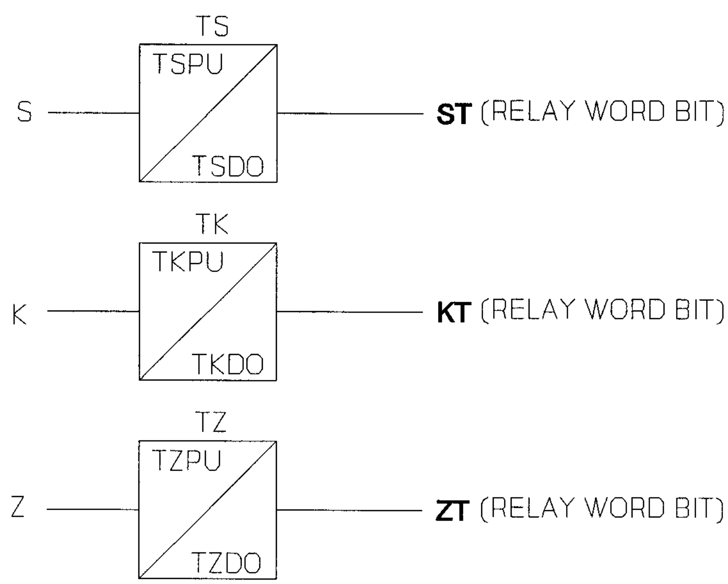


Figure 2.6: Relay Word Bit Realizations

Use !L for Inversion

Variable L is any OR-combination of elements in R1 through R4. The inverse of L (!L) is in the Relay Word. Also, output contacts A1 ... A4 and the ALARM can be factory-configured as either "a" or "b" contacts for an additional inversion.

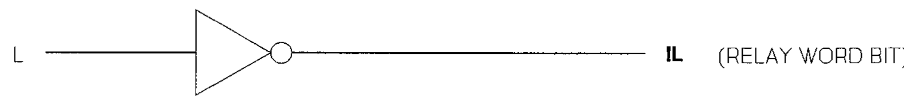


Figure 2.7: Relay Word Bit Realization

Programming Output Contacts

Write output equations to define tripping and other control functions.

TRIP: Select any OR-combination of elements in R1, R2, R4, and R6 via the TR(1246) variable. Direct Trip input and OPEN command also assert TRIP. See Figure 2.23 for information about TRIP output contact operation.

A1, A2: Select any OR-combination of elements in R1, R2, R3, and R4.

A3: Select any OR-combination of elements in R1, R3, R4, and R6.

A4: Select any OR-combination of elements in R2, R3, R4, and R6.

The CLOSE and ALARM functions have dedicated outputs:

CLOSE: Asserts by recloser, DC input, or CLOSE command (see Figure 2.24 for an illustration of CLOSE output contact operations).

ALARM: The ALARM output closes for the following conditions:
- Three unsuccessful Level 1 access attempts: 1 second pulse
- Any Level 2 attempt: 1 second pulse
- Self test failures: permanent contact closure or 1 second pulse depending on which test fails (see Table 2.5)
- The ALARM output closes momentarily when relay settings, setting groups, or passwords are changed. It also closes when a date is entered, if the year stored in EEPROM differs from the year entered (see DATE command).

All output relay contacts except TRIP may be factory-configured as "a" or "b." All relay contacts are rated for circuit breaker tripping duty.

Viewing Logic Equations

Use the SHOWSET command to print all relay settings including the SELOGIC Control Equations configuration. You can inspect settings in the sample event report in Section 4: EVENT REPORTING.

SELOGIC Control Equations Setting in Each Setting Group

When you switch groups, you switch logic settings as well as relay element settings. You can program groups for different operating conditions, such as feeder paralleling, station maintenance, seasonal operations, and cogeneration on/off.

TARGETS

Read targeting information locally by inspecting the LEDs or remotely with the TARGET command and event reports. The TARGET command can access other information as well (see Section 3: COMMUNICATIONS).

The INST target indicates that no overcurrent condition in Relay Word row R1 has been asserted longer than the ITT (instantaneous target time) timer setting before TRIP asserts. This gives you control over what qualifies as a close-in fault.

The phase current indicators (A, B, C) show which phases exceed the 51P pickup setting at the time of trip.

The negative-sequence and residual current indicators (Q, N) similarly show if these currents exceed the respective 51QP and 51NP pickup settings at the time of trip.

The last two indicators (RS, LO) show the state of the reclosing relay (reset or lockout).

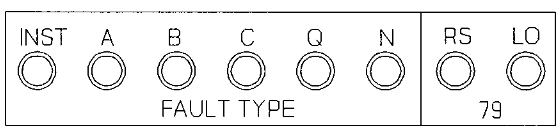


Figure 2.8: SEL-151 Relay Front Panel Target LEDs

The FAULT TYPE LEDs latch and remain lit until the TRIP output deasserts and one of the following occurs:

- Next trip occurs
- Operator presses front panel TARGET RESET/LAMP AND STATUS CHECK button
- Operator executes TARGET R command

When a new TRIP occurs, the FAULT TYPE LEDs clear, then display and latch the FAULT TYPE targets for the new TRIP condition.

When an operator presses the TARGET RESET/LAMP AND STATUS CHECK button, all eight LEDs illuminate for a one-second lamp test and to indicate that the relay is operational.

MULTIPLE SHOT RECLOSING RELAY

The four-shot reclosing relay has individual open interval times for each shot and a settable reset interval timer.

If a trip occurs and no reclose cancel condition exists, the relay starts to time on the appropriate open interval (if any remain) when the trip drops out and 52A input deasserts. When the open interval timer expires, the shot counter is incremented and the CLOSE output contact asserts. A close failure timer limits the duration of CLOSE output contact assertion in case 52A does not assert. See Functional Specifications for a description of close failure timer operation. If the close failure timer is not used, the CLOSE output contact remains asserted until 52A asserts.

If the circuit breaker recloses successfully, the reset interval timer starts. Assertion of any element in Relay Word row R1 indicates an overcurrent condition. Detection of an overcurrent condition reinitializes the reset interval timer and inhibits it from timing. When the overcurrent conditions drop out, the reset interval timer starts. When this timer expires, the reclosing relay goes to the reset state (**79RS** = 1) and shot = 0.

Any of the six programmable inputs can be set as a reclose enable (RE) input. If the RE input is de-energized (RE = 0), the relay goes to lockout (**79LO** = 1). When the reclose enable input is de-energized, the CLOSE output contact cannot automatically assert via the reclosing relay.

If no input is assigned to the RE input, RE = 1 internally (reclosing is always enabled). If a scheme is set up this way, you can defeat automatic reclosing by setting the open intervals to zero.

One input must be designated either 52A, !52A, 52AR, or !52AR. Otherwise, automatic reclosing and other close operations using the CLOSE output contact are unavailable (CLOSE Command, Direct Close).

The number of nonzero open interval time periods determines available reclosing shots (four shots maximum). The Relay Word bit **79SH** can assert (**79SH** = 1) for different shots, 0 through 4. For example, if you only want **79SH** to assert for shots 0 and 1, enter the following setting:

M79SH = 11000

79SH can be used to supervise overcurrent elements and reclose cancel conditions.

Reclosing relay timing accuracy is ±1 cycle.

Reclose Cancel Conditions

The internal reclose cancel variable RC(1246) can be set to equal any OR-combination of elements in Relay Word rows R1, R2, R4, and R6. Reclosing is also cancelled if:

An input assigned to RE (reclose enable) is not asserted,
An input assigned to DT (direct trip) is asserted,
The CF (close fail) condition occurs, or
The OPEN command is enabled and executed.

Sequence Coordination

To keep in step with line reclosers, the reclosing relay includes sequence coordination. Sequence coordination can prevent overreaching relay overcurrent elements from tripping for faults beyond line reclosers. A sequence coordination example follows.

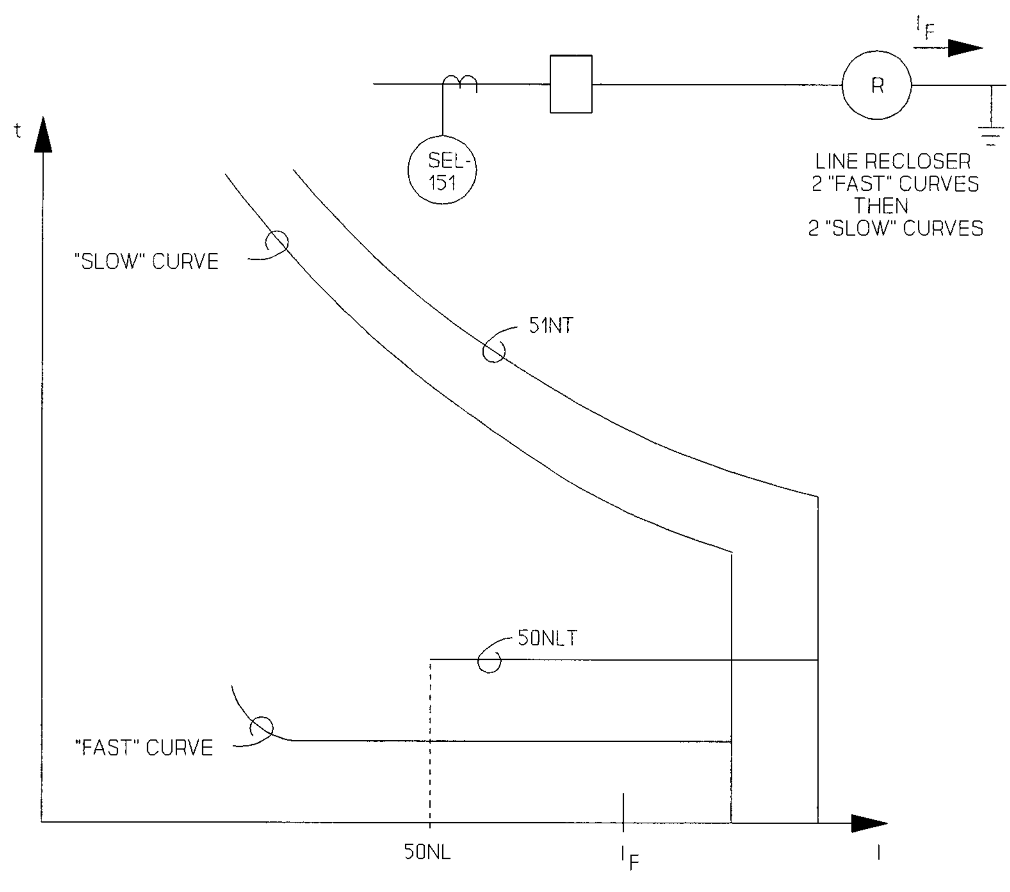


Figure 2.9: Sequence Coordination, Ground/Residual Overcurrent Elements

A partial setting list is given:

M79SH = 11000 (**79SH** = 1 for only shot = 0 and 1)

Using SELOGIC Control Equations:

B(12) = **50NLT**
G(34) = **79SH**
X(56) = **B*G**
TR(1246)= **51NT+X** (effectively, TR(1246) = **51NT+(50NLT*79SH)**)
SEQ(1) = **50NL**

close TRIP output contacts = TR + ...
= **51NT+50NLT*79SH** + ...

The M79SH setting selects for which shots (0, 1, 2, 3, or 4) the **79SH** bit is asserted (**79SH** = 1). **79SH** supervises **50NLT** for tripping. **50NL** is the pickup for **50NLT**.

The SEQ(1) variable can be set to any OR-combination of elements in Relay Word row R1. The combination you select determines which overcurrent conditions control sequence coordination. If the circuit breaker is closed and the TRIP output contacts are not asserted, SEQ(1) increments the reclosing relay shot counter every time SEQ(1) goes from the state SEQ(1) = 1 to SEQ(1) = 0.

The SEL-151 relay is reset (**79RS** = 1, shot = 0) and has four open intervals set (four shots to lockout).

In the example, a permanent ground fault greater than **50NL** in magnitude occurs beyond the line recloser. Because **50NLT** and the line recloser fast curve are properly coordinated, the line recloser operates twice on its fast curve and the SEL-151 relay doesn't trip. After operating on two fast curves, the line recloser disables its fast curve and operates on its slow curve.

During the two line recloser fast curve operations, the **50NL** element picked up and dropped out twice without the SEL-151 relay tripping. Because SEQ(1) = **50NL**, the shot counter incremented twice, so shot = 2. Every time SEQ(1) increments the shot counter, the reset interval timer is reinitialized.

Because **79SH** = 1 for shots 0 and 1 only, **50NLT** is now disabled at shot = 2. **50NLT** will remain cut out until the newly reinitialized reset interval timer expires. The line recloser then operates on its two slow curves, causing the relay shot counter to increment to shot = 4. The line recloser then goes to lockout. When the SEL-151 relay reset interval timer expires, shot = 0 again.

Sequence coordination prevents the SEL-151 relay from tripping for a fault beyond a line recloser. However, proper coordination was present between the line recloser fast curve and **50NLT** in this example.

No phase overcurrent elements were enabled for tripping in this example. This is usually not the case in practice but was done to simplify the example.

SELECTABLE SETTING GROUPS

The relay accepts six groups of relay and logic settings.

Program relay elements and logic with the SET command. To program group 1 settings and logic, use SET 1 and provide the requested information. The COPY command makes it easy to copy settings and logic from one group to another (e.g., **COPY 1 4** copies group 1 to group 4). Afterward, you can edit group 4 settings and logic with the SET command.

The relay determines which group of settings and logic to use by monitoring the setting group selection inputs (SS1, SS2, and SS3). To use inputs, program one or more of the setting selection inputs SS1, SS2, and SS3 to the respective inputs IN1, IN2, and IN3. You can also use the GROUP command to specify a setting group.

Table 2.3: Setting Group Selection Input Truth Table

SS3	SS2	SS1	
0	0	0	GROUP Command Selection
0	0	1	group 1
0	1	0	group 2
0	1	1	group 3
1	0	0	group 4
1	0	1	group 5
1	1	0	group 6
1	1	1	GROUP Command Selection

If SS1, SS2, or SS3 is not assigned to an input, it defaults to 0. If no inputs are assigned as setting group selection inputs the GROUP command entry controls group selection. With only SS1 assigned, GROUP command selection determines settings to use if the input assigned to SS1 is not asserted. If the input is asserted, setting group 1 is used.

For example, to switch between group 1 and group 5, program input IN1 to SS1 and use the GROUP command to select group 5. With IN1 asserted, the relay uses group 1. With IN1 deasserted, it uses group 5.

When the status of any assigned setting group selection input changes, the relay waits a settable time period (TGR) for inputs to stabilize before changing the active setting group. Thus, if a setting group selection input status changes and reverts to its previous state before TGR expires, the relay does not change the active setting group. The TGR setting is one of several global settings and is entered with the SET G command.

Active setting group changes (via setting group selection inputs or GROUP command) disable the relay for less than 0.5 seconds to allow loading of new active settings. The ALARM output contacts close during this time and all timers and relay elements reset.

The DEMR setting allows you to specify whether or not demand values for current, MW, and MVAR are reset when the active setting group changes. The relay resets demand values as it would for METER RD execution. The following example illustrates a situation when you should reset demand values.

You might want to change the active setting group for distribution feeder switching where significant load is removed from the feeder. If the new active setting group has lower demand current thresholds (PDEM, QDEM, and NDEM settings) than the previous active setting group, the corresponding **PDEM**, **QDEM**, and **NDEM** demand ammeter threshold bits could assert. This is because the respective demand ammeters have not yet adjusted to the lower loading level, as dictated by the relatively long demand ammeter time constant (setting DATC = 5 to 60 minutes). If **PDEM**, **QDEM**, and **NDEM** are assigned to programmable output contacts (A1 - A4), a false alarm would result. To overcome this problem, set DEMR = Y. With this setting, the relay resets demand values to zero when the active setting group changes.

The DEMR setting is entered with the SET G command. See Section 3: COMMUNICATIONS for more details on the SET, COPY, GROUP, and METER RD commands.

CIRCUIT BREAKER MONITOR

The SEL-151 relay detects every circuit breaker trip operation. It designates each trip as one caused by the relay or an external device and maintains a running count of each.

The relay also maintains a running sum of the interrupted current in each circuit breaker pole for relay and external trips. Running sums for relay trips use the current present one cycle after the trip output contacts assert. Running sums for external trips use the currents present when the circuit breaker status input indicates that the circuit breaker has opened.

You can access the circuit breaker operation data using the BREAKER commands. See Section 3: COMMUNICATIONS for more details on these commands.

METERING

The SEL-151 relay provides complete voltage and current metering. It also determines real and reactive power values, demand values, peak demand values, and negative- and zero-sequence components of the voltages and currents.

If voltage is measured at the bus and there are current-limiting reactors on the feeder, the relay can derive voltage to the load-side of the reactors for metering and fault locating purposes (see Figure 2.11).

You can access and reset metering data using different METER commands. See Section 3: COMMUNICATIONS for more information.

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-RD relay display, which serves as a local operator interface.

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

The serial data format is:

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

The serial communications protocol and port pin definitions appear in Section 3: COMMUNICATIONS.

SELF TESTS

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

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

Offset

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

Power Supply

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

Table 2.4: Power Supply Self Test Limits

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

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

Random Access Memory

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

Read Only Memory

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

Analog-to-Digital Converter

The analog-to-digital converter (ADC) changes voltage signals derived from power system voltages and currents into numbers for processing by the microcomputer. The ADC test verifies converter function by checking conversion time. The test fails if conversion time is excessive or a conversion starts and never finishes. There is no warning state for this test. While an ADC failure disables protective functions, control functions remain intact. The relay transmits a STATUS message and closes the ALARM relay contacts.

Master Offset

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

Settings

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

Table 2.5 shows relay actions for any self test condition: warning (W) or failure (F).

Table 2.5: Self Test Summary

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

IRIG-B INPUT DESCRIPTION

The port labelled J201/AUX INPUT receives demodulated IRIG-B time code input. The IRIG-B input circuit is a 56 ohm resistor in series with an optocoupler input diode. The input diode has a forward drop of about 1.5 volts. Driver circuits should put approximately 10 mA through the diode when "on."

The IRIG-B serial data format consists of a one second frame containing 100 pulses and divided into fields. The relay decodes second, minute, hour, month, and day fields and sets the relay clock accordingly.

When IRIG-B data acquisition is activated either manually (with the IRIG command) or automatically, the relay reads two consecutive frames. It updates the older frame by one second and compares the frames. If they do not agree, the relay considers the data erroneous and discards it.

The relay reads the time code automatically about once every five minutes. It stops IRIG-B data acquisition ten minutes before midnight on New Year's Eve so the relay clock can implement the year change without interference from the IRIG-B clock.

SIGNAL PROCESSING

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

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

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

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

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

TORQUE CONTROL

Elements in Relay Word row R1 may be torque controlled. Elements derived from row R1 elements are torque controlled if the row R1 element is torque controlled. For example, if row R1 elements **51P** and **50NL** are torque controlled, row R2 elements **51T** and **50NLT** are also torque controlled. **51P** and **50NL** are the pickups for **51T** and **50NLT**, respectively. See Figures 2.17, 2.18, and 2.19 for more information.

Phase overcurrent elements can be externally and internally torque controlled. Negative-sequence and ground/residual overcurrent elements can only be externally torque controlled.

External Torque Control

The ETC(1) setting selects overcurrent elements to be externally torque controlled. Only overcurrent elements in Relay Word row R1 can be selected. As an example:

ETC = **51P**, **50Q**, **50NL**	**51P**, **50Q**, **50NL**, and consequently **51T**, **50QT**, and **50NLT** are selected for external torque control

TCP External Torque Control (Phase and Negative-Sequence Overcurrent Elements)

TCG External Torque Control (Ground/Residual Overcurrent Elements)

TCP and TCG are assigned to programmable inputs. The inverted sense of TCP or TCG is available, too (!TCP or !TCG, respectively).

If input IN3 = TCP, the phase and negative-sequence overcurrent elements selected in the ETC(1) setting (**51P** and **50Q** and consequently **51T** and **50QT** in this example) are enabled for operation when input IN3 is energized. If input IN3 = !TCP, the phase and negative-sequence overcurrent elements selected in the ETC(1) setting are enabled for operation when input IN3 is de-energized.

If neither TCP or !TCP is assigned to an input, the phase and negative-sequence overcurrent elements selected in the ETC(1) setting are not externally torque controlled. The selected phase and negative-sequence overcurrent elements are always enabled with respect to external torque control.

If input IN4 = TCG, the ground/residual overcurrent elements selected in the ETC(1) setting (**50NL** and consequently **50NLT** in this example) are enabled for operation when input IN4 is energized. If input IN4 = !TCG, the ground/residual overcurrent elements selected in the ETC(1) setting are enabled for operation when input IN4 is de-energized.

If neither TCG nor !TCG is assigned to an input, the ground/residual overcurrent elements selected in the ETC(1) setting are not externally torque controlled. The selected ground/residual overcurrent elements are always enabled with respect to external torque control.

Internal Torque Control

The ITC(1) setting selects phase overcurrent elements to be internally torque controlled. Only phase overcurrent elements in Relay Word row R1 can be selected. As an example:

ITC = **51P**, **50H**	**51P**, **50H**, and consequently **51T** are selected for internal torque control

The TCI setting selects the elements which perform internal torque control:

TCI = 0, V, I, or 3	0 = none, V = **27**, I = **50C**, 3 = both

If you set TCI equal to V, the **27** element torque controls phase overcurrent elements selected in the ITC(1) setting (**51P** and **50H** and consequently **51T** in this example). If **27** asserts, the selected phase overcurrent elements are enabled with respect to internal torque control.

If you set TCI equal to I, the **50C** element torque controls phase overcurrent elements selected in the ITC(1) setting (**51P** and **50H** and consequently **51T** in this example). If **50C** asserts, the selected phase overcurrent elements are enabled with respect to internal torque control.

If you set TCI equal to 3, the phase overcurrent elements selected in the ITC(1) setting (**51P** and **50H** and consequently **51T** in this example) are torque controlled by "**27** + **50C**". If either **27** or **50C** asserts, the selected phase overcurrent elements are enabled with respect to internal torque control.

If you set TCI equal to 0, the phase overcurrent elements selected in the ITC(1) setting (**51P** and **50H** and consequently **51T** in this example) are not internally torque controlled. The phase overcurrent elements are always enabled with respect to internal torque control.

Transformer Blown-Fuse Detection

Delta-wye connected distribution transformer banks are frequently protected by fuses connected in the bank high side, as shown in Figure 2.10. When one high-side fuse blows, unbalanced voltages are applied to the transformer bank and its connected load.

The SEL-151 Relay includes logic that detects high-fuse operations by measuring the low-side voltages. The logic also rejects operations of low-side Voltage Transformer (VT) fuses.

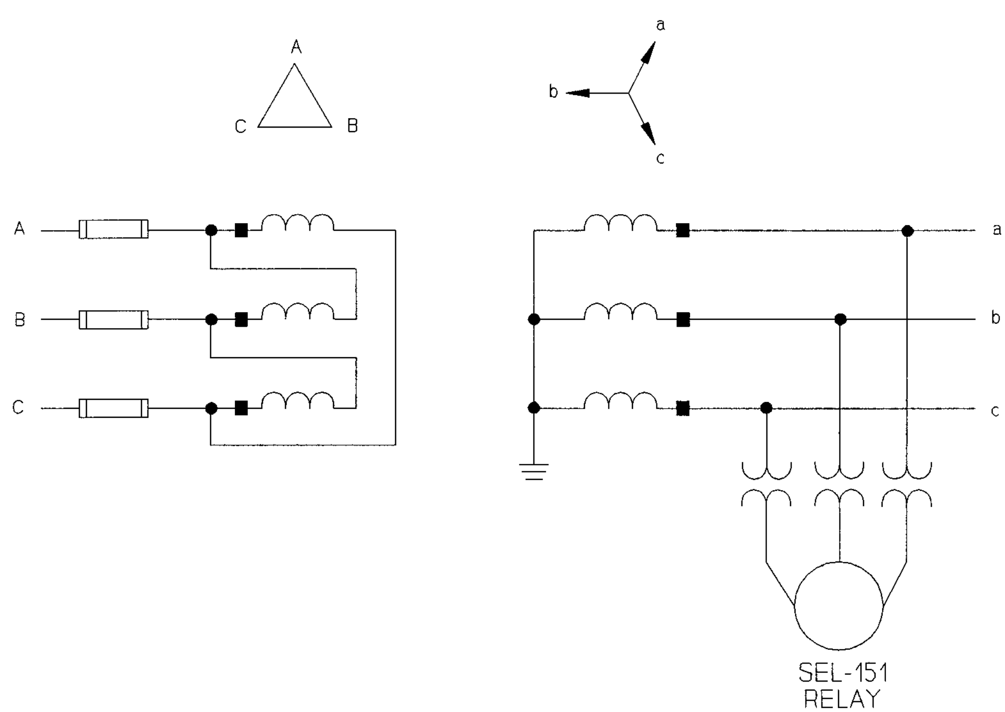


Figure 2.10: Distribution Transformer Bank Protected by High-Side Fuses

What Happens When a High-Side Fuse Blows?

When a transformer high-side fuse operates, the low-side phase-to-phase voltage magnitudes drop. One phase-to-phase voltage magnitude goes to zero, and the remaining two drop to 0.87 per unit of nominal voltage. If two high-side fuses operate, the low-side phase-to-phase voltages all go to zero.

If a VT secondary fuse blows while the transformer bank is otherwise operating normally, two of the phase-to-phase voltages presented to the relay drop to 0.58 per unit of nominal. If two VT secondary fuses operate, one phase-to-phase voltage measured by the relay goes to zero while the other two drop to 0.58 per unit.

With these facts in mind, the logic described below is easy to understand.

How Does the SEL-151 Relay Detect Transformer Fuse Operations?

When the relay setting 27C=4, the 27 phase-to-phase undervoltage logic detects high-side fuse operations. To use the relay undervoltage logic in this application, make the following relay setting calculations:

27L = 0.40 · Vnom
27H = 0.72 · Vnom
27C = 4

where:

Vnom = Nominal Phase-to-Phase Voltage, V secondary

The setting option, 27C = 4, enables the following logic for the **27** Relay Word bit:

27 = (Any phase-to-phase voltage less that 0.4 pu) * (Any phase-to-phase voltage greater than 0.72 pu)

27 = (27LAB + 27LBC + 27LCA) * (!27HAB + !27HBC + !27HCA)

If a transformer fuse operates, one phase-to-phase voltage goes to zero (satisfying the left portion of the equation above) and the remaining phase-to-phase voltages stay above 0.72 per unit (satisfying the right portion of the equation). If a VT fuse operates, the phase-to-phase voltages drop below the 0.72 per unit threshold and the **27** equation is not satisfied.

Use the Detection Logic to Trip or Indicate

Since certain faults may also present these voltages to the SEL-251 Relay, you may wish to use a nondedicated SELogic Control Equation timer, such as the **ST** timer to provide some coordinated time delay on pickup of the condition.

Set the SELOGIC Control Equation, S(123) = **27**. Use the time-delayed pickup timer, TSPU = 300 to 600 cycles to provide a 5- to 10-second time delay. You can use the **ST** bit, which includes the time-delayed pickup, in any of the SELOGIC Control Equations for tripping or programmable output contact operation.

DEMAND AMMETERS

The SEL-151 relay provides demand ammeters for phase, negative-sequence, and zero-sequence (ground/residual) currents. Peak demands are saved. The demand ammeters behave much like low-pass filters, responding to gradual trends. The demand ammeter time constant is used for all three demand ammeters. The time constant is settable from 5 to 60 minutes.

Figure 2.22 shows the phase, negative-sequence, and ground/residual demand ammeters from top to bottom. Let's concentrate on the bottom diagram (ground/residual demand ammeter) to understand demand ammeter functions in general.

Present ground/residual current (IR) is the input into the ground/residual demand ammeter and ground/residual demand current (ND(t)) is the output. If the ground/residual demand current is ND(0) at t=0 and the ground/residual current (IR) is constant, at t=DATC the ground/residual demand current will be:

$$ND(DATC) = 0.9(IR - ND(0)) + ND(0) = 0.9IR + 0.1ND(0)$$

If the ground/residual demand current was reset at t=0 (ND(0) = 0), at t=DATC the ground/residual demand current would be:

$$ND(DATC) = 0.9(IR)$$

For all demand ammeters in general, if demand current is reset at t=0 and a constant input current is applied, the demand current output will be 90% of the constant input current value at t=DATC.

Settable demand ammeter thresholds are available for all three demand ammeters in units of amps secondary. The thresholds are PDEM, QDEM, and NDEM for the phase, negative-sequence, and ground/residual demand ammeters, respectively.

If demand currents exceed a threshold, the respective Relay Word bit **PDEM**, **QDEM**, or **NDEM** is asserted. These Relay Word bits can alarm for phase overload and negative-sequence or residual current unbalance and can warn of impending overcurrent relay pickup and timing to trip due to such overload and unbalance conditions.

FAULT LOCATOR

The fault locator operates only if an event report is triggered and at least one of the over-current element pickups in Relay Word row R1 is picked up. To disable the fault locator, set line length (LL) to 0.001.

The following parameters in Figure 2.10 are used for fault locating.

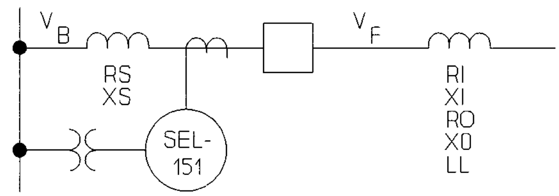


Figure 2.11: Current-Limiting Reactor and Line Impedances

The resistive and reactive impedances (RS, R1, R0 and XS, X1, X0, respectively) are set in units of ohms primary.

The RS and XS settings compensate for current-limiting reactors to the load-side of the PT's, so the voltage V_F can be derived and used for fault locating and metering. Current-limiting reactors are assumed to have zero mutual coupling between phases, so the RS and XS settings represent the positive-, negative-, and zero-sequence impedance values of the current-limiting reactors.

The positive- and zero-sequence primary line impedance values (R1, X1 and R0, X0, respectively) correspond to a line length (LL). The LL setting does not have specified units, which allows the use of any unit of measure (miles, km, feet, etc.). The algorithm assumes that negative-sequence line impedance equals positive-sequence line impedance.

The actual fault location algorithm is composed of two steps. First the relay determines fault type, then it calculates location.

The relay determines fault type independently of relay element operations. Fault type determination is based on a phase current magnitude comparison.

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

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

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

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

Once the relay determines fault type, the fault locator uses the Takagi algorithm to locate the fault. Using prefault and fault data, it compensates for errors introduced by fault resistance in the presence of load flow. If the event record contains no sound prefault data, the relay gives a location based on a simple reactance measurement.

The fault locator depends on accurate distribution line parameters and instrument transformer ratios. Pay special attention to these potential sources of difficulty:

- Instrument transformer errors due to overburden by other devices
- Capacitive potential transformer capacitor value
- Distribution line parameter errors

Although the fault location computation takes several seconds, the relay can handle several faults in quick succession. The relay stores all fault data, then processes each fault in turn. For example, suppose three faults occur within a few seconds. The relay stores data from them as they occur. The fault location computations begin with the first (oldest) fault and proceed until all three fault records are processed. The relay transmits each summary event report when the corresponding fault location is available.

The relay does not consider shunt capacitance of a line. The capacitance causes the fault location to appear more remote by a factor of approximately 1/cos(bL), where bL is the line length in radians. One wavelength at 60 Hz is 3100 miles. For example, the line length of a 100 mile line in radians is calculated:

$$(100/3100)(2)(3.14159) = 0.2027 \text{ radians.}$$

The indication neglecting capacitance is about cos (0.2027) = 0.98 times the actual location, or about two miles short for a fault at the far end of a 100 mile line.

When a station uses shunt reactor compensation and the relay is connected to measure reactor plus line current, the shunt reactors reduce fault locating error due to shunt capacitance.

Nomographs

The relay fault locator is designed for circuits having a constant per-unit length impedance. This is often the case with transmission lines. However, distribution lines often have conductor changes, resulting in different per-unit length impedances. Nomographs are used to compensate for these changes. Fault studies are run for different fault locations on the distribution system. Relay location voltage and current information is taken from the fault study and applied to the relay. The resultant fault location from the relay fault locator is shown on the nomograph with respect to the actual location.

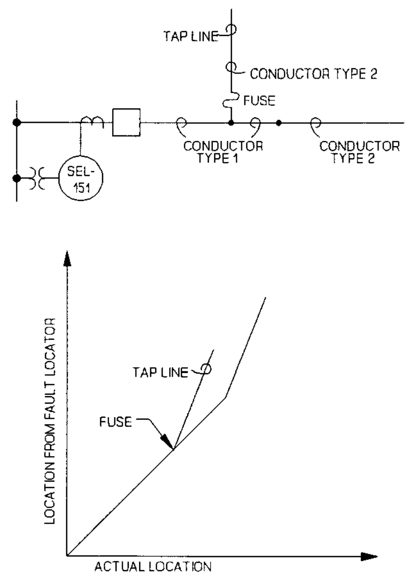


Figure 2.12: Nomograph for Fault Locating

EVENT REPORT

The event report displays current and voltage quantities in primary units. The relay encodes relay element states, outputs, and inputs using a simple process, making the report compact and easy to interpret. Use the EVENT command to access the eleven cycle event reports. Use the HISTORY command to list summary event reports. See Section 3: COMMUNICATIONS for more information on these commands.

Event Report Triggering

Set the variable ER(1246) to any OR-combination of elements in Relay Word rows R1, R2, R4, and R6 to trigger an event report for any desired combination of conditions the relay can detect. Event reports also trigger for:

- Any TRIP output
- Assertion of an input assigned to the ET function
- TRIGGER command execution

See Section 4: EVENT REPORTING for more information on event reports.

TIME-OVERCURRENT ELEMENT CURVE-TIMING AND TIME DELAY RESET EQUATIONS

The following time-overcurrent equations are applicable to the phase, negative-sequence, and ground/residual time-overcurrent elements.

There are two reset characteristic choices for the phase, negative-sequence, and ground/residual time-overcurrent elements via the 51RS, 51QRS, and 51NRS settings, respectively. One choice resets the elements if current drops below pickup for at least one cycle. The other choice (time delay reset) emulates electromechanical induction disc elements, where the reset time depends on the time dial setting, the percentage of disc travel, and the amount of current between zero and pickup. The time delay reset equations ($t_r = \ldots$) are given below.

t_M = curve operating time in seconds
t_r = reset time in seconds (for time delay reset)
TD = time dial setting
M = multiples of pickup. For curve operating time (t_M), $M > 1$.
For reset time (t_r), $M \leq 1$.

Curve 1: Moderately Inverse - see Figure 2.13

$$t_M = TD\left[0.157 + \frac{0.668}{M-1}\right] \qquad t_r = \frac{TD}{0.949 - 0.936M}$$

Curve 2: Inverse - see Figure 2.14

$$t_M = TD\left[0.180 + \frac{5.95}{M^2-1}\right] \qquad t_r = \frac{TD}{0.172 - 0.168M}$$

Curve 3: Very Inverse - see Figure 2.15

$$t_M = TD\left[0.0963 + \frac{3.88}{M^2-1}\right] \qquad t_r = \frac{TD}{0.246 - 0.240M}$$

Curve 4: Extremely Inverse - see Figure 2.16

$$t_M = TD\left[0.0352 + \frac{5.67}{M^2-1}\right] \qquad t_r = \frac{TD}{0.194 - 0.192M}$$

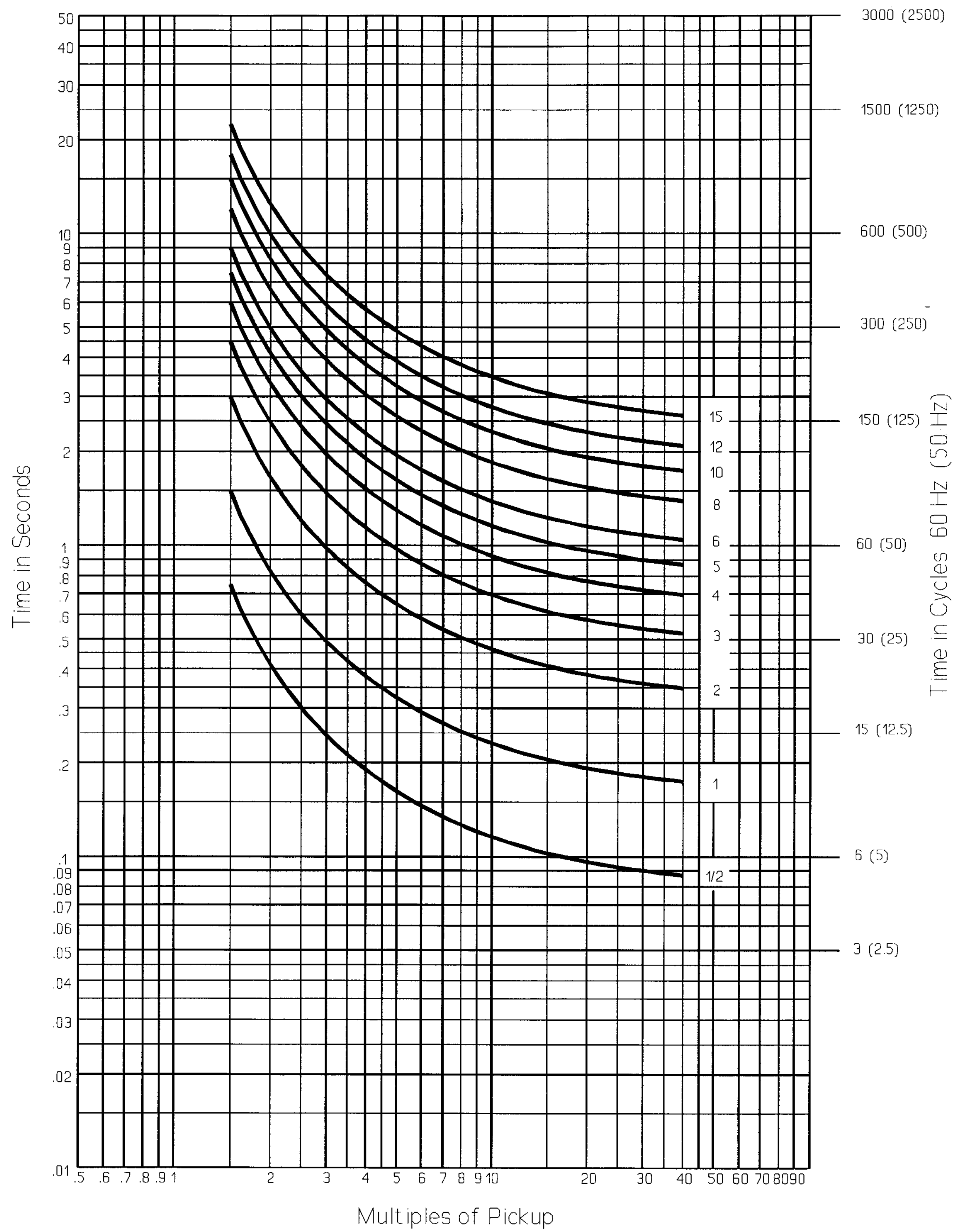


Figure 2.13: Time-Overcurrent Element Moderately Inverse Time Characteristic (Curve 1)

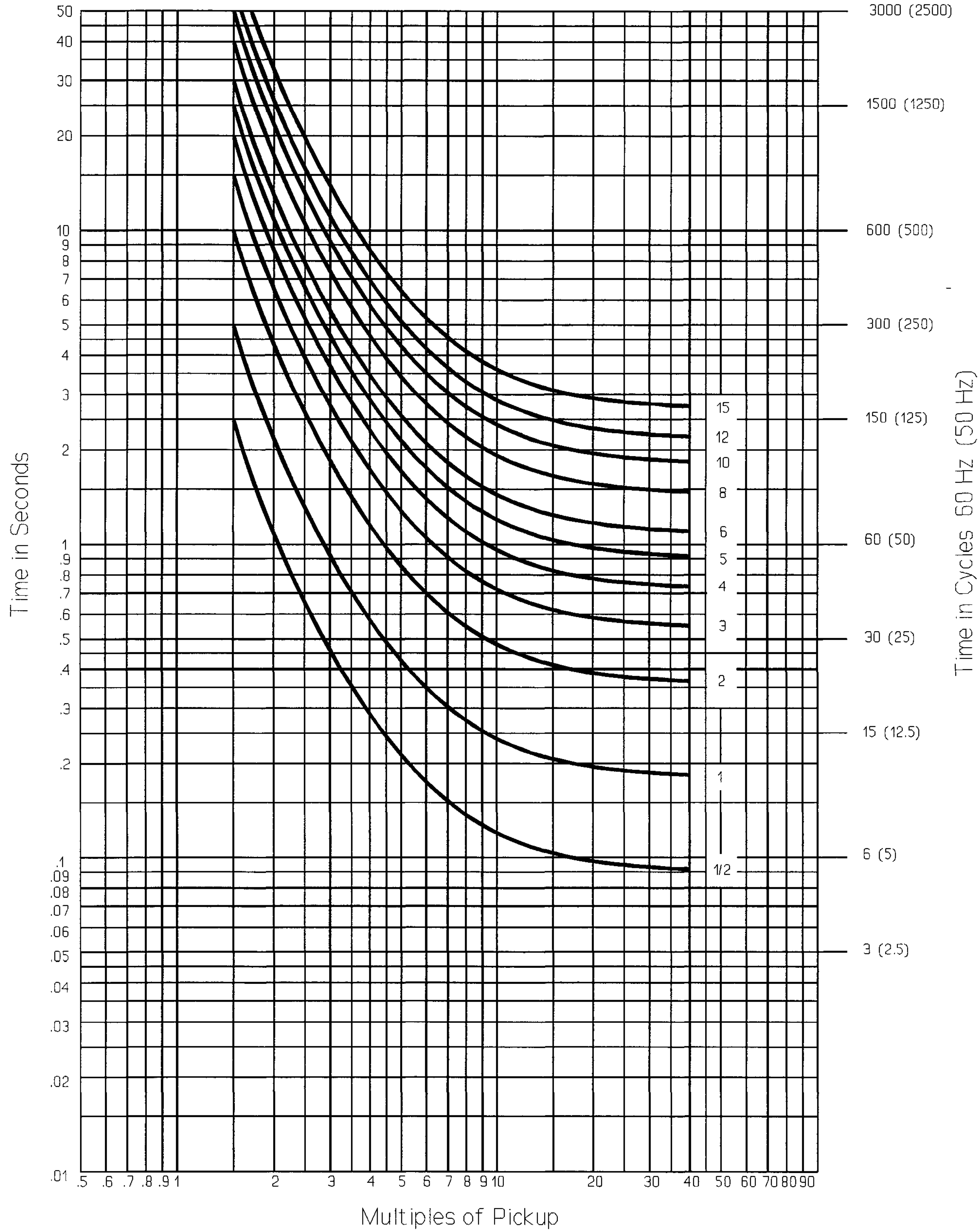


Figure 2.14: Time-Overcurrent Element Inverse Time Characteristic (Curve 2)

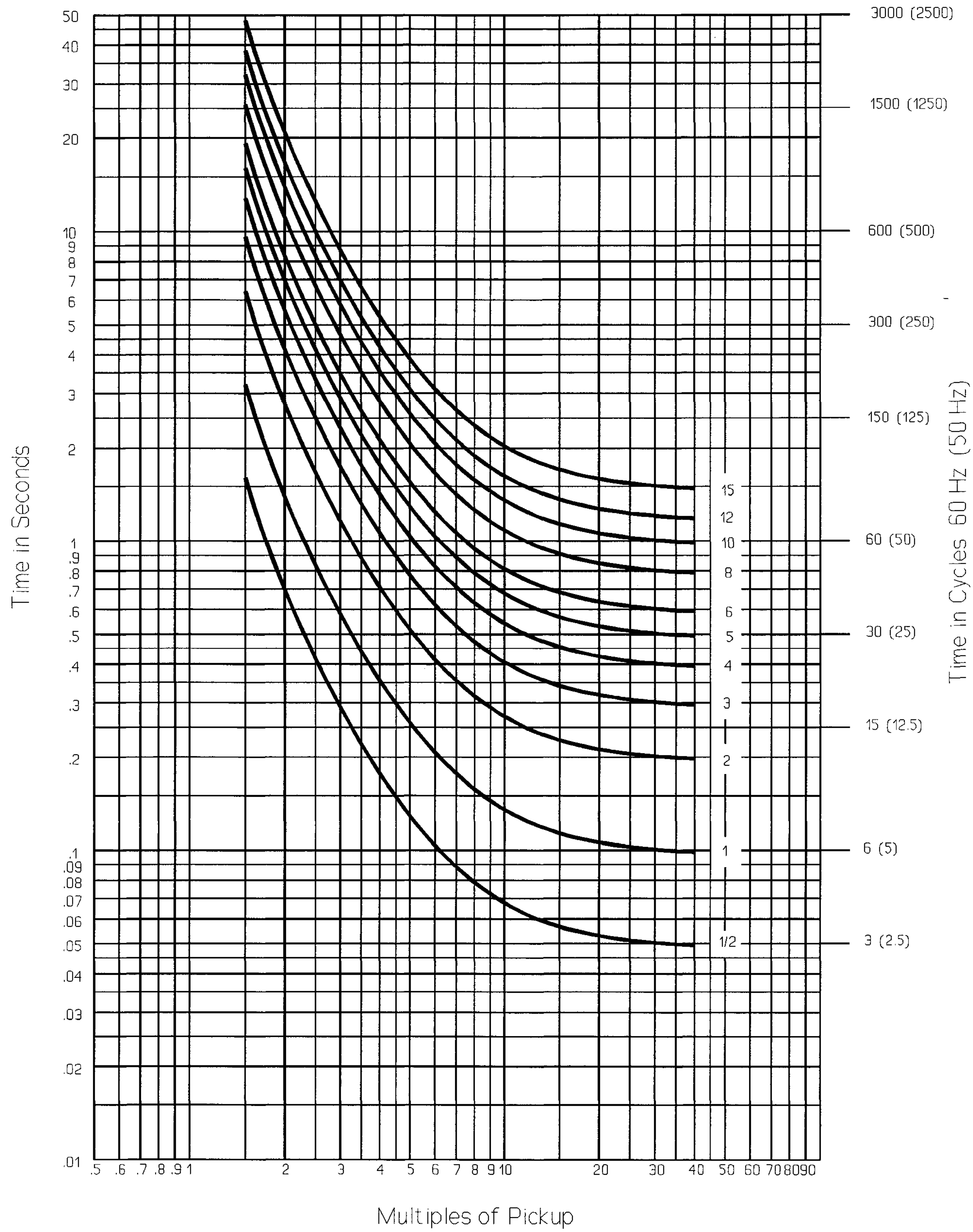


Figure 2.15: Time-Overcurrent Element Very Inverse Time Characteristic (Curve 3)

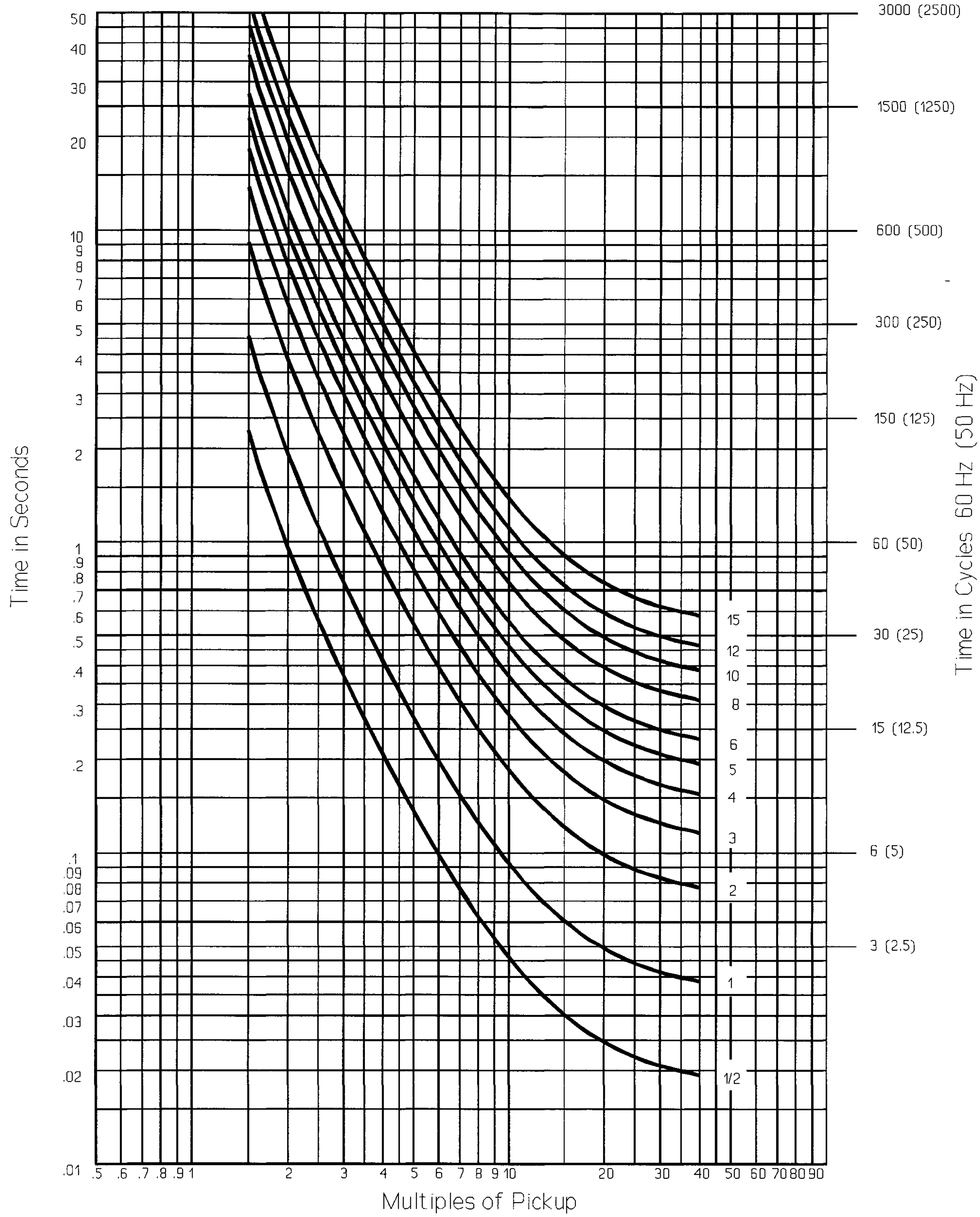


Figure 2.16: Time-Overcurrent Element Extremely Inverse Time Characteristic (Curve 4)

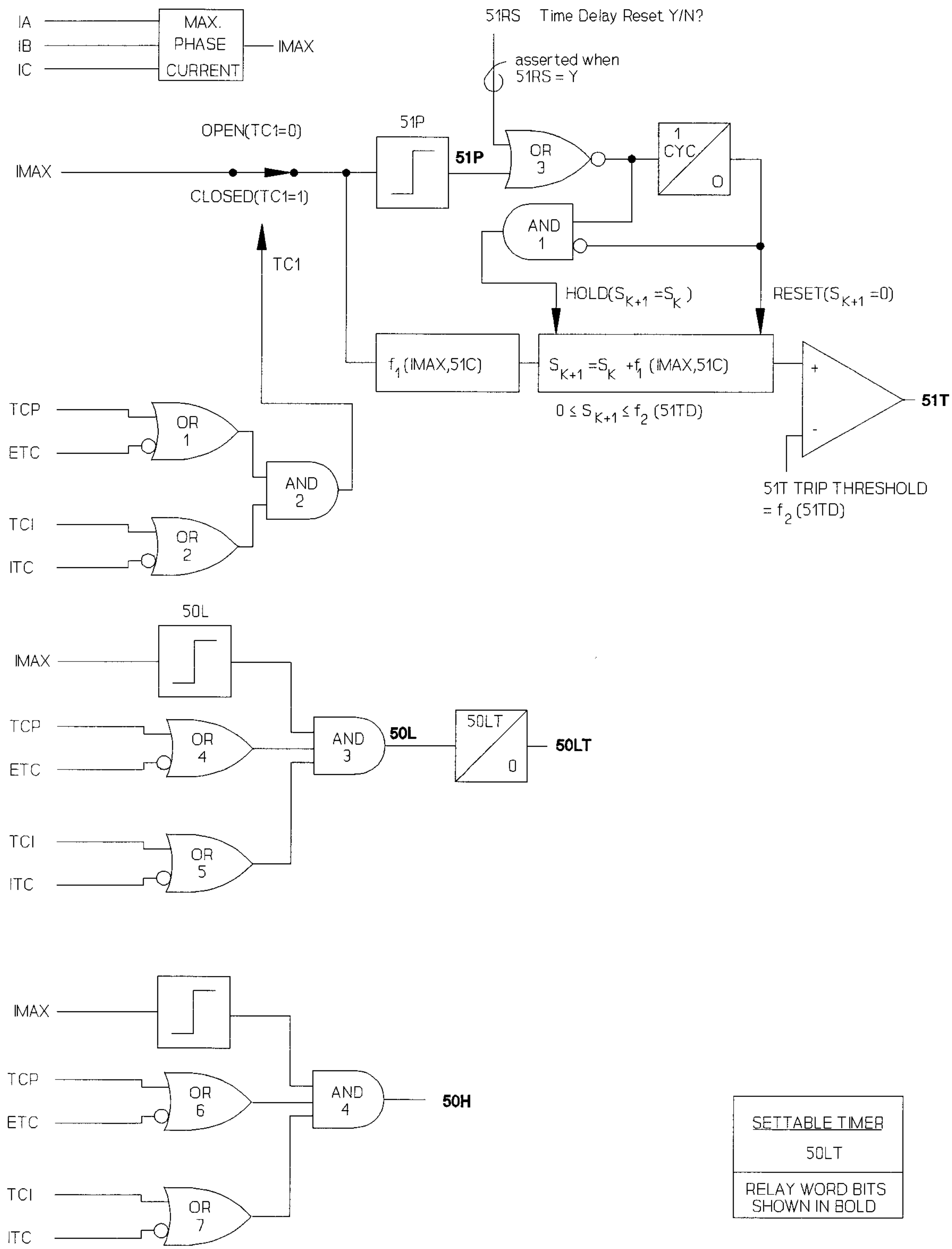


Figure 2.17: SEL-151 Phase Overcurrent Logic Diagrams

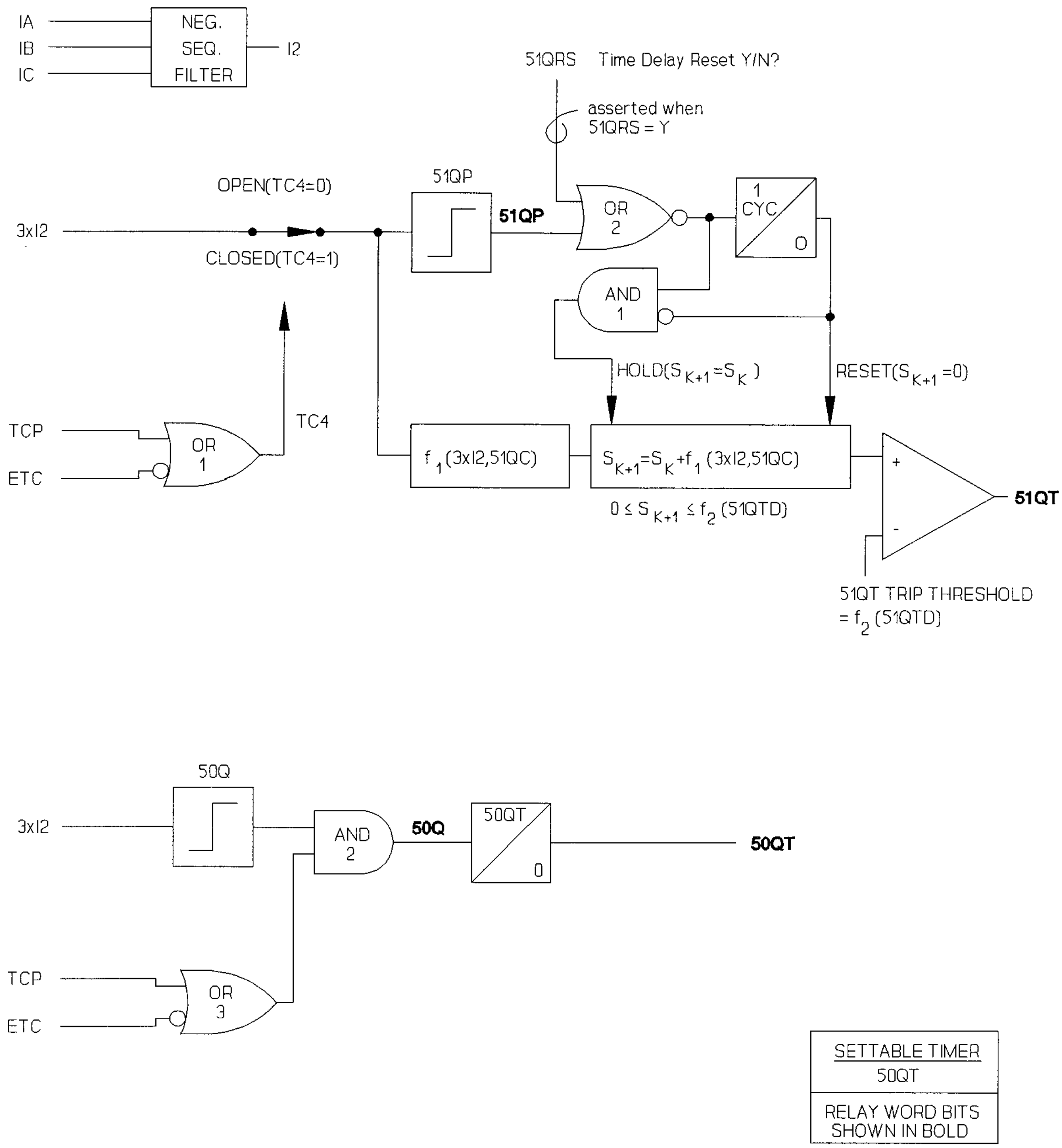


Figure 2.18: SEL-151 Negative-Sequence Overcurrent Logic Diagrams

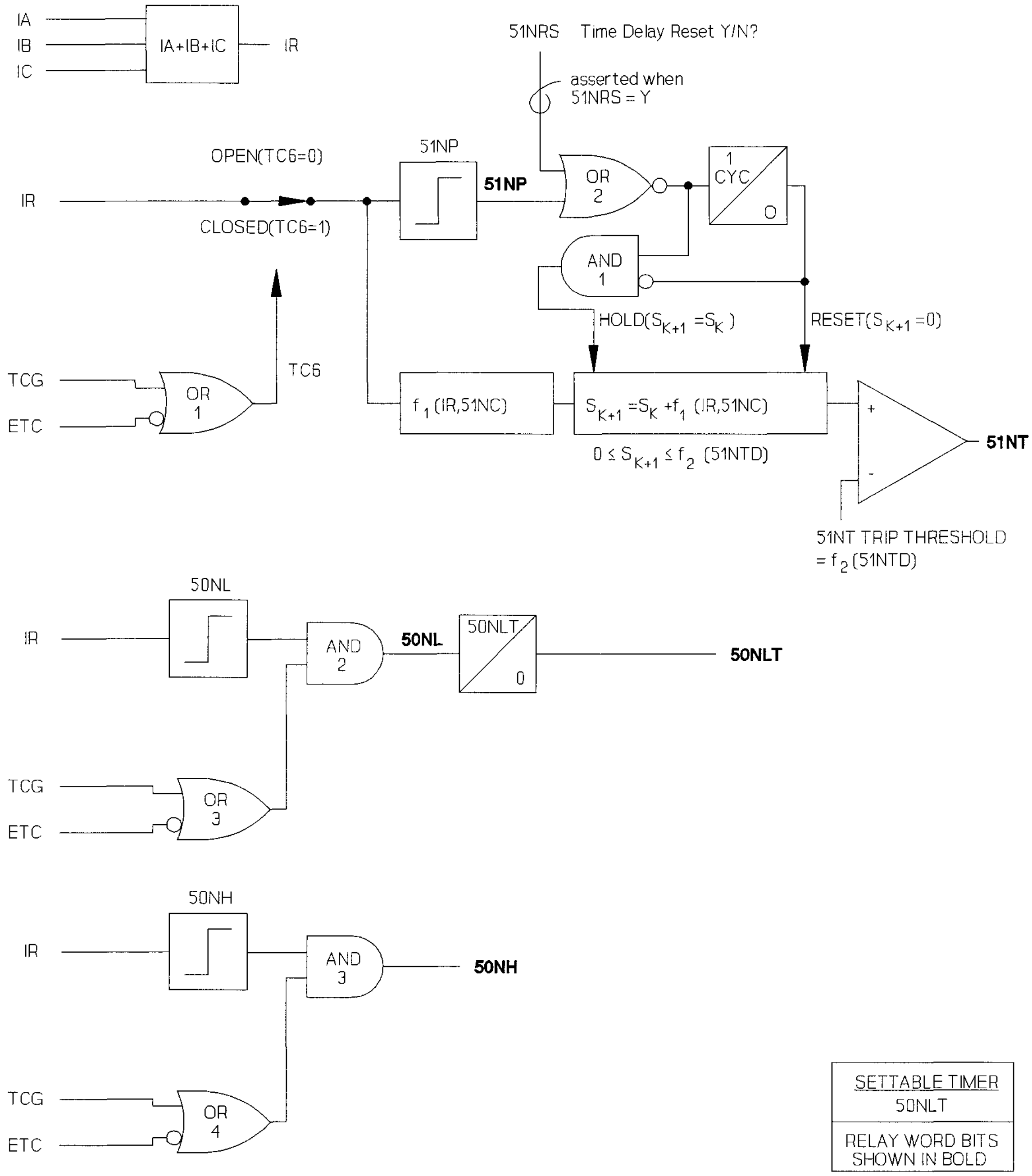


Figure 2.19: SEL-151 Ground/Residual Overcurrent Logic Diagrams

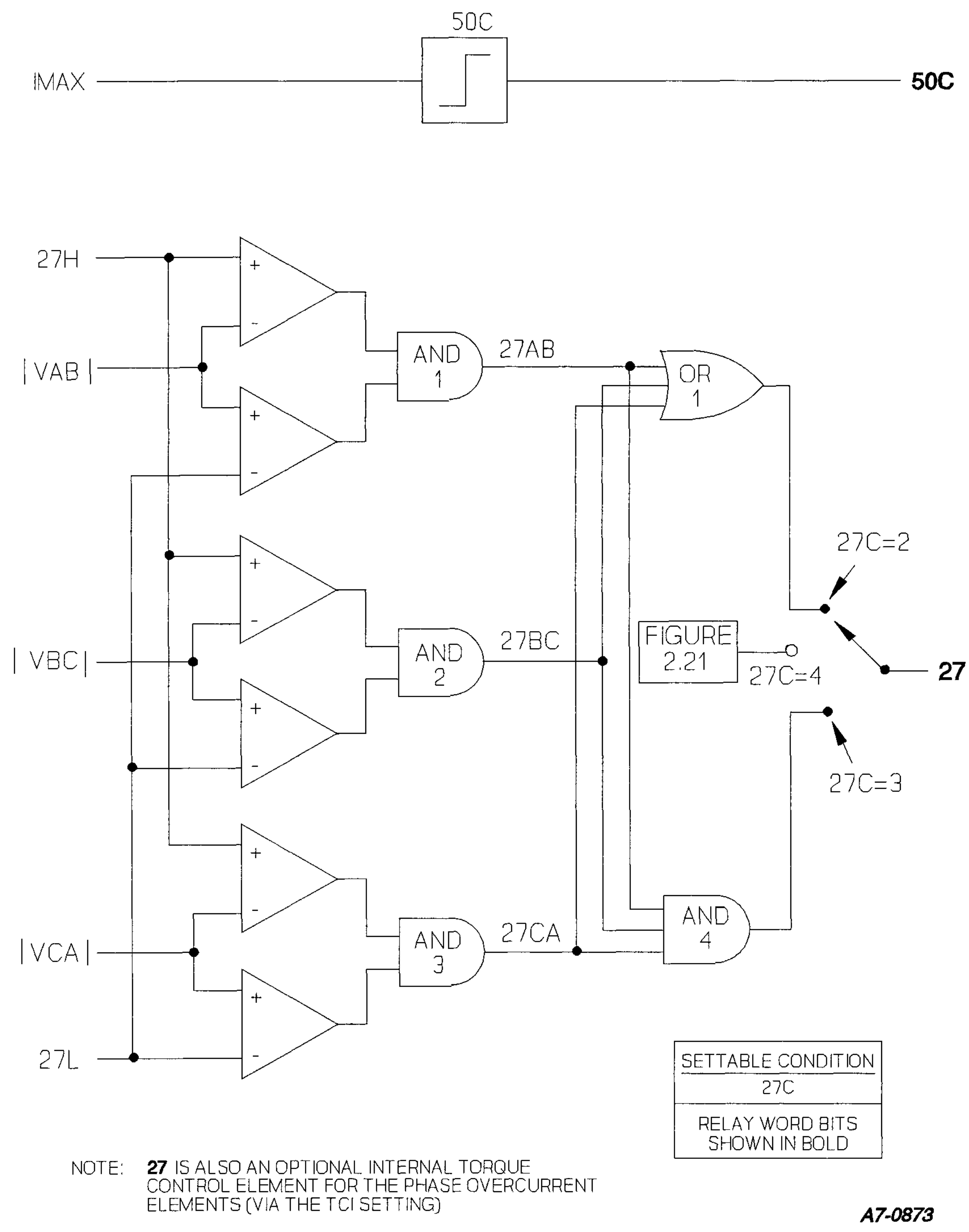


Figure 2.20: SEL-151 Overcurrent and Undervoltage Elements

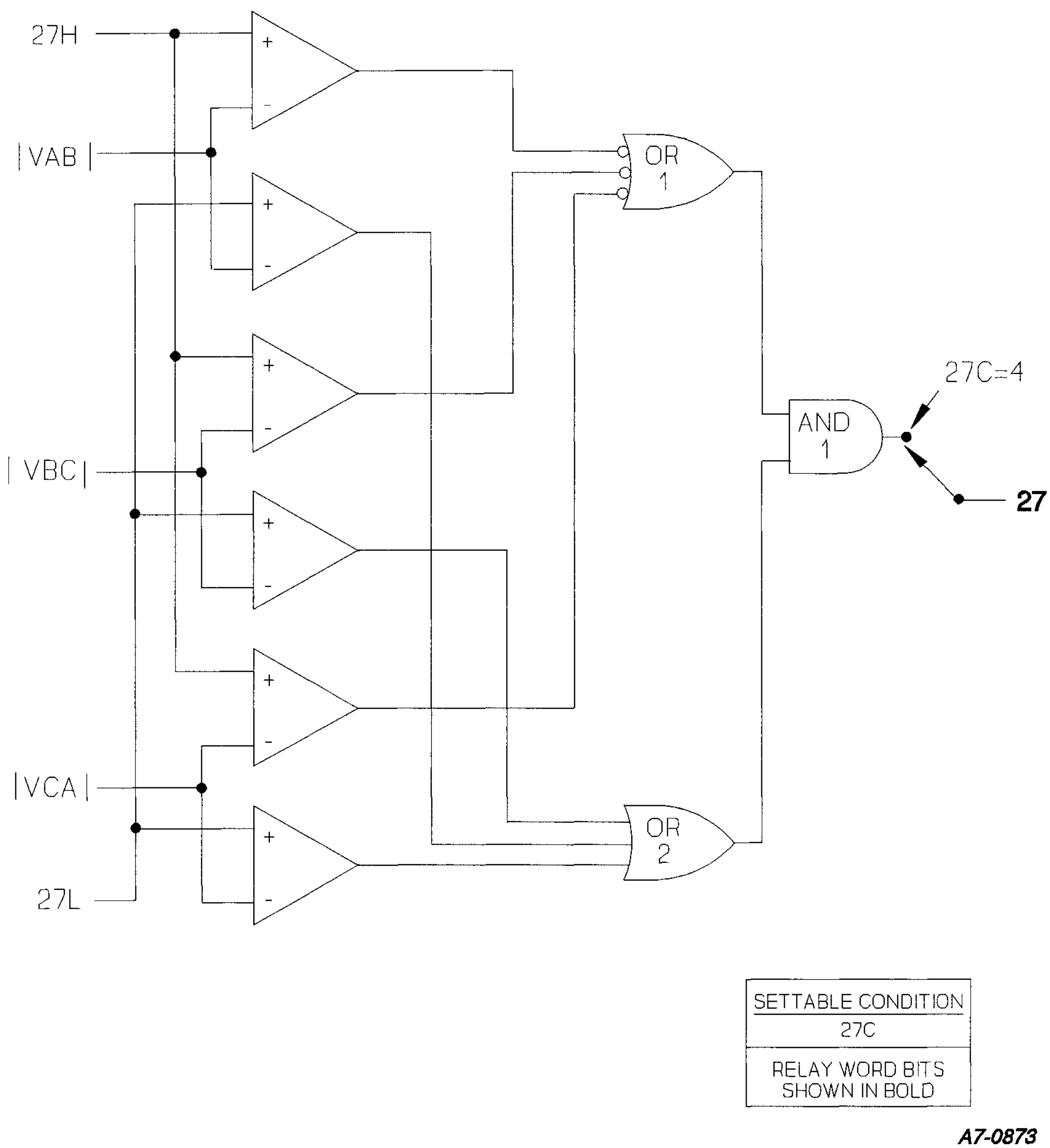


Figure 2.21: SEL-151 Transformer Blown-Fuse Detection Logic

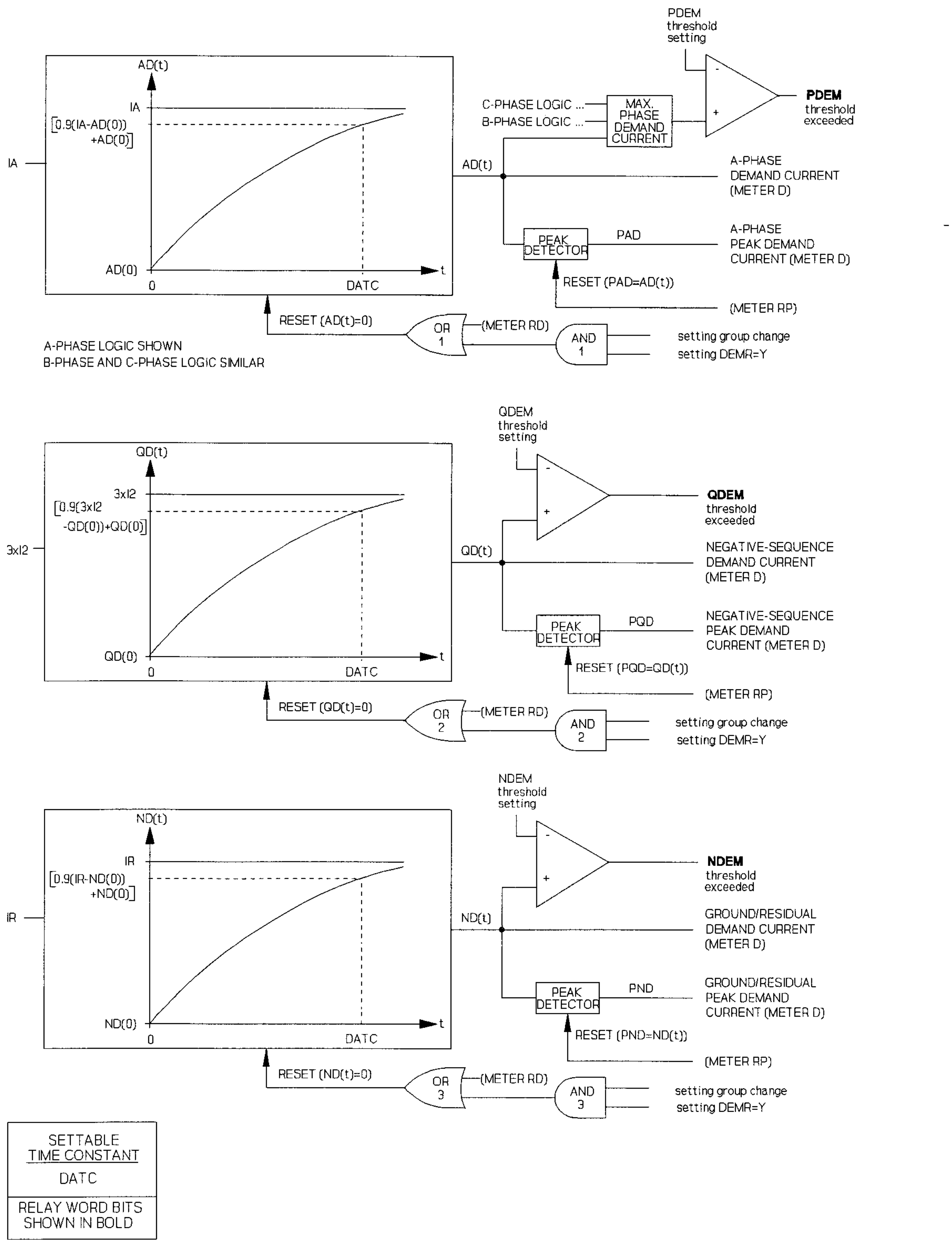
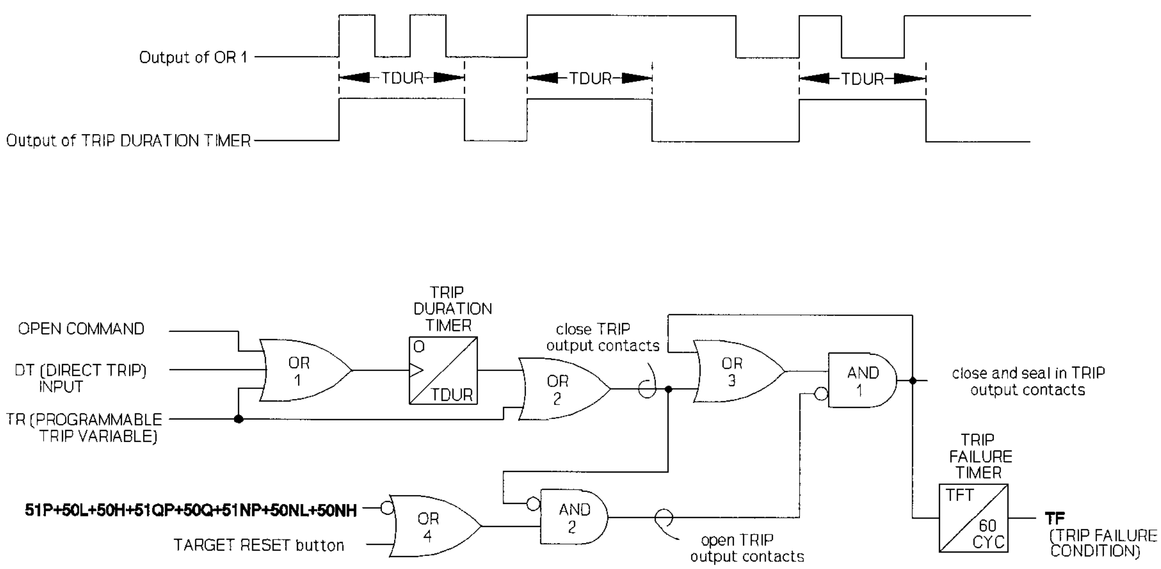
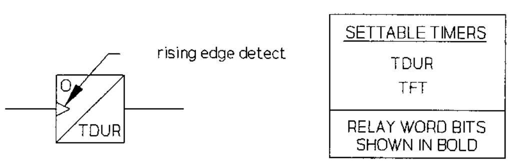


Figure 2.22: SEL-151 Demand Ammeters

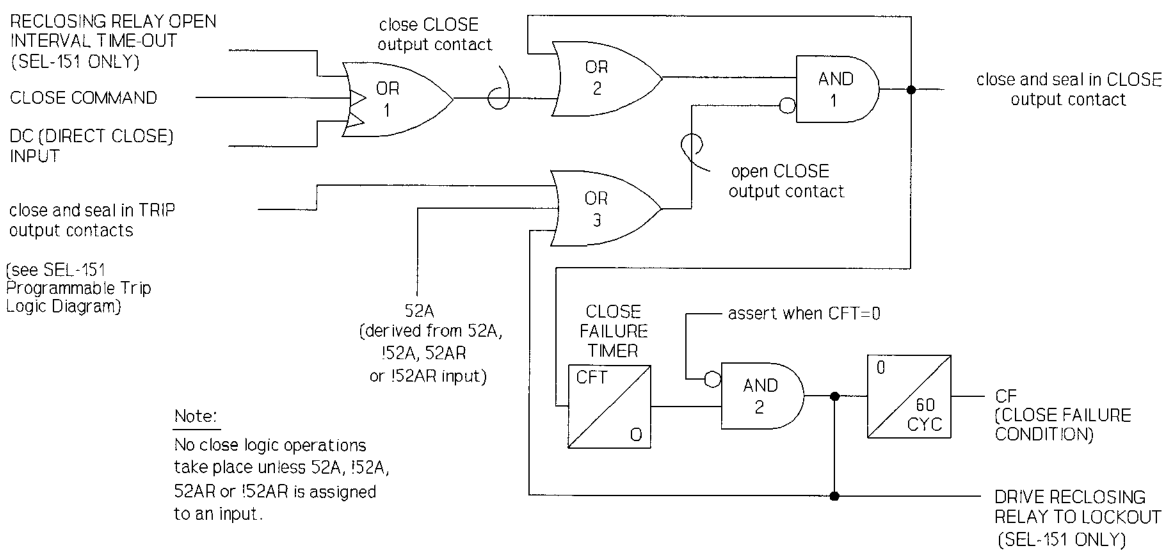




Note: Make the following settings:

TDUR > 0	to trip for OPEN command execution or DT (Direct Trip) input energization
TFT > TDUR	to have a meaningful TF, trip failure condition

Figure 2.23: SEL-151 Programmable Trip Logic Diagram



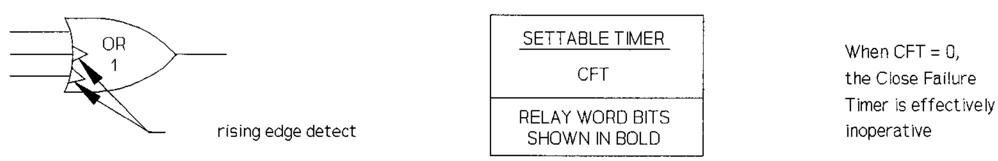


Figure 2.24: SEL-151 Close Logic Diagram

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COMMUNICATIONS

INTRODUCTION

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

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

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

3. The relay transmits messages in response to changes in system status, e.g., self test warning.

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

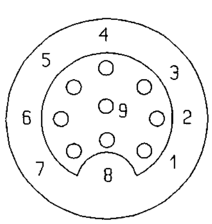
Note: In this manual, commands to type appear in bold/upper case: **OTTER**. Keys to press appear in bold/upper case/brackets: **<ENTER>**.

Relay output appears boxed and in the following format:

```
Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 01:01:01
```

SERIAL PORT CONNECTIONS AND CONFIGURATIONS

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



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

Figure 3.1: Nine-Pin Connector Pin Number Convention

Table 3.1 lists port pin assignments and signal definitions.

Table 3.1: Serial Port Connector Pin Assignments

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

COMMUNICATIONS PROTOCOL

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

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

<command><CR> or <command><CRLF>

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

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

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

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

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

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

   The relay transmits XON (ASCII hex 11) and asserts the RTS output when the buffer drops below ¼ full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is over ¾ full. The relay deasserts the RTS output when the buffer is approximately 95% full. Automatic transmission sources should monitor for the XOFF character so they do not overwrite the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and may resume when the relay sends XON.

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

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

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

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

6. The relay input buffer is limited to 128 characters. If the buffer is over 75% full, the relay will send an XOFF to the terminal to terminate transmission. This should be avoided, as the relay may never send an XON if there are no termination characters (carriage returns) within the buffered text.

COMMAND CHARACTERISTICS

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

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

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

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

Startup

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

```
Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 01:01:01

SEL-151
=
```

The ALARM relay should pull in.

The = represents the Access Level 0 prompt.

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

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

```
=ACCESS <ENTER>
```

The response is:

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

Enter the Level 1 password **OTTER** and press **<ENTER>**. The response is:

```
Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 01:01:44

Level 1
=>
```

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

Use a similar procedure to enter Access Level 2:

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

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


Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 01:03:32

Level 2
=>>
```

You can enter any command at this prompt.

Command Format

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

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

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

In this manual, commands to type appear in bold/upper case: **OTTER**. Keys to press appear in bold/upper case/brackets: **<ENTER>**. Some commands have optional parameters; these appear after the command in bold/lower case.

COMMAND DESCRIPTIONS

Access Level 0 Command

ACCESS

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

The following display indicates successful access:

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


Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 14:03:57

Level 1
=>
```

The => prompt indicates Access Level 1.

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

Access Level 1 Commands

2ACCESS

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

The following display indicates successful access:

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


Example 21.6 kV distribution feeder   Date: 7/1/92   Time: 14:12:01

Level 2
=>>
```

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

BREAKER

BREAKER displays running sums of circuit breaker trips for relay and external trips and interrupted current in each circuit breaker pole for relay and external trips.

Relay trips are determined by coinciding change in circuit breaker auxiliary contact input status (52A drops out or 52B asserts) and relay TRIP output contact assertion. Consideration should be given to the TDUR (trip duration) timer setting so TRIP output contact assertion always encompasses the status change of the circuit breaker auxiliary contact for a relay initiated trip. See the note concerning circuit breaker status input options in the SET G command section.

External trips are determined by coinciding change in circuit breaker auxiliary contact input status (52A drops out or 52B asserts) and the absence of relay TRIP output contact assertion.

For trips, the relay measures interrupted current in each pole one cycle after the rising edge of TRIP contact assertion.

For external trips, the relay measures interrupted current in each pole when the status of the circuit breaker auxiliary contact input changes (52A drops out or 52B asserts). Remember to consider the time delay between the change of circuit breaker auxiliary contact status and the opening of circuit breaker main contacts. If circuit breaker auxiliary contact operation lags too far behind circuit breaker main contact operation, current may already be interrupted when the circuit breaker auxiliary contact changes status. Thus, no interrupted current would be measured.

BREAKER also displays the date and time when circuit breaker trip counters and interrupted current sums were last reset (set to zero). Cumulative currents appear in kA (kiloamperes).

```
=>BREAKER <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 09:09:58

Rly Trips=15     From: 1/1/91   11:01:31
IA=42.65    IB=37.91    IC=34.20      KA

Ext Trips=2      From: 1/1/91   11:01:31
IA=0.65     IB=0.67     IC=0.62       KA

=>
```

If power to the relay is interrupted, the accumulated circuit breaker information is lost.

If the 52A, !52A, 52AR, or !52AR function is not assigned to an input, circuit breaker trips and interrupted currents cannot be accumulated.

BREAKER R

BREAKER R resets (sets to zero) the circuit breaker trip counters and interrupted current sums. The relay also stores reset date and time.

```
=>BREAKER R <ENTER>
Reset Trip Counters and Current Sums:
Are you sure (Y/N) ? Y <ENTER>


Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 09:10:30

Rly Trips=0       From: 4/2/91   09:10:30
IA=0.00      IB=0.00      IC=0.00        KA

Ext Trips=0       From: 4/2/91   09:10:30
IA=0.00      IB=0.00      IC=0.00        KA

=>
```

DATE mm/dd/yy

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

To set the date to June 1, 1992, enter:

```
=>DATE 6/1/92 <ENTER>
6/1/92
=>
```

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

EVENT n

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

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

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

The following incidents clear the event buffers:

- Control power interruption
- Changing any relay setting via the SET commands
- Changing any relay setting group via the COPY command

Switching setting groups does not clear the buffers.

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

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

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

HISTORY

HISTORY displays the date, time, event type, reclosing relay shot, maximum phase current and phase, and fault type targets for each of the last twelve events. If the event is a fault, the fault location also appears. The full eleven-cycle event reports also include this information (**EVENT n** to display).

```
=>HISTORY <ENTER>

Example 21.6 kV distribution feeder          Date: 7/1/92    Time: 09:11:27

#  DATE       TIME          EVENT   LOCAT    SHOT   CURR   GROUP   TARGETS
1  4/2/91     01:36:59.070  AG T     2.43     0     2798     2     INSTAQN
2  3/17/91    08:07:40.129  CG T     3.52     1     2361     3     INSTCQN
3  3/17/91    08:07:35.133  CG T     3.51     0     2364     3     INSTCQN
4  3/15/91    01:07:35.862  TRIG              0     345      1
5
6
7
8
9
10
11
12

=>
```

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

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

The EVENT column provides an abbreviated indication of the event type.

The following incidents trigger an event report:

- TRIP output contact assertion
- ER (Event Report trigger) programmable variable assertion
- Input assigned to ET (External Trigger) function assertion
- TRIGGER command execution

If an event report is triggered and at least one of the overcurrent elements pick up in Relay Word row R1, the fault locator operates. If the fault locator operates successfully, the EVENT column shows phase involvement.

The relay determines phase involvement independently from relay elements and labels it with a selection from the following list. Phase involvement is determined solely using uncompensated and load compensated current magnitudes. The relay measures these magnitudes at the midpoint of the first continuous relay element pickup sequence in the event report (for algorithmic details, see the Fault Locator description in Section 2: SPECIFICATIONS).

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

If the TRIP output contacts are asserted during the event report, a "T" follows the EVENT designation. This helps to determine clearing times for faults which persist beyond the end of the first event report. For example, if the relay trips for a BG fault after completing the initial report, the second report shows "BG T" for EVENT.

If an event report is triggered but the fault locator does not operate, the event report triggering condition appears in the EVENT column. These conditions are:

TR	:	Programmable TRipping variable
DT	:	Direct Trip input
OPEN	:	OPEN command
ER	:	Programmable Event Report trigger variable
ET	:	External Trigger input
TRIG	:	TRIGGER command

If two or more event report triggering conditions happen to coincide when the fault locator does not operate, the relay uses the previous hierarchy to display the event report triggering condition in the EVENT column.

The LOCAT column shows the equivalent distance to a fault. Event report distances appear without units, which allows you to use any unit of measure for line parameter settings. The relay calculates distance using the Takagi algorithm or a reactance measurement, depending on whether prefault data are available in the event report. For some long duration boundary faults, the fault location may not be possible for every report generated when relay operation is sporadic. The DIST column may contain "999999" in such cases. While this behavior can be contrived under test conditions, it is extremely rare in actual practice.

The SHOT column lists the reclosing relay shot when the event report was initiated.

The CURR column shows maximum phase current magnitude measured at the middle of the fault in primary amperes. This information can help you identify the row pair used by the relay for fault location calculations. If the fault locator is not run for an event report, the event report shows maximum phase current when the event report was triggered.

The GROUP column has the number of the setting group active at the time the report was triggered.

The TARGETS column lists the FAULT TYPE front panel targets illuminated at event report initiation.

If the event buffers are cleared, the event summaries listed by the HISTORY command are lost (see EVENT in this section).

IRIG

IRIG directs the relay to read the demodulated IRIG-B time code input (J201) on the rear panel.

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

```
=>IRIG <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 01:45:40

=>
```

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

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

METER n

METER displays **present** values of the following:

IA: A phase current (primary amps)
B: B phase current (primary amps)
C: C phase current (primary amps)
R: Ground/residual current (primary amps)

3I2: 3 x negative-sequence current (primary amps)
P: Three-phase real power (MW)
Q: Three-phase reactive power (MVAR)
VA: A phase voltage (primary volts)
VB: B phase voltage (primary volts)
VC: C phase voltage (primary volts)
3V0: 3 x zero-sequence voltage (primary volts)

AB: AB phase-to-phase voltage (primary volts)
BC: BC phase-to-phase voltage (primary volts)
CA: CA phase-to-phase voltage (primary volts)
3V2: 3 x negative-sequence voltage (primary volts)

```
=>METER <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92  Time: 09:12:49


MET IA=356    B=364    C=361    R=6
   3I2=5      P=12.910    Q=1.130

VA=12021  VB=12015  VC=12043  3V0=20
AB=20827  BC=20839  CA=20836  3V2=17

=>
```

P is positive when three-phase real power flows out from the bus and into the line. If P is negative, three-phase real power flows in the opposite direction. Q is positive when three-phase reactive power flows from the bus and into the line (net load on the line has a lagging power factor). If Q is negative, three-phase reactive power flows in the opposite direction (net load on the line has a leading power factor). If Q = 0, no net reactive power is flowing past the relay (net load on the line has a unity power factor).

The optional parameter n selects the number of times the relay displays meter data. To display a series of eight meter readings, type **METER 8 <ENTER>**.

METER D

METER D displays **demand** and **peak demand** values of the following:

IA: A phase current (primary amps)
B: B phase current (primary amps)
C: C phase current (primary amps)
R: Ground/residual current (primary amps)

3I2: 3 x negative-sequence current (primary amps)
P: Three-phase real power (MW)
Q: Three-phase reactive power (MVAR)

The demand ammeter time constant setting (DATC) is also used in determining I, P, and Q demand values.

```
=>METER D <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92  Time: 09:13:33


DEM IA=347     B=349     C=349     R=4
   3I2=3       P=12.897     Q=0.997

PK  IA=412     B=410     C=414     R=15
   3I2=13      P=14.701     Q=1.280

=>
```

If control power to the relay is interrupted, the demand and peak demand values reset to zero.

METER RD

METER RD resets **demand** values to zero.

```
=>METER RD <ENTER>
Reset Demand Meter: Are you sure (Y/N) ? Y <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 09:14:15


DEM IA=0       B=0       C=0       R=0
   3I2=0       P=0.000     Q=0.000

PK  IA=412     B=410     C=414     R=15
   3I2=13      P=14.701    Q=1.280

=>
```

The demand values automatically reset if an active setting group change is made with global setting DEMR=Y (see SET G p in this section).

METER RP

METER RP resets **peak demand** values to their respective demand values.

```
=>METER RP <ENTER>
Reset Peak Demand: Are you sure (Y/N) ? Y <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 10:31:26


DEM IA=341     B=345     C=348     R=5
   3I2=4       P=12.875    Q=0.757

PK  IA=341     B=345     C=348     R=5
   3I2=4       P=12.875    Q=0.757

=>
```

QUIT

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

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

```
=>QUIT <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92   Time: 01:45:40

=
```

SHOWSET n

SHOWSET n displays the relay and logic settings for setting group n (n = 1, 2, 3, 4, 5, or 6). You cannot enter or modify settings with this command. The SET command description provides complete information about changing settings and logic. To display the active setting group, execute SHOWSET without the parameter n.

The display also includes the global settings (settings common to all groups).

The SHOWSET output pauses twice, as shown in the following example. Press **<ENTER>** to continue viewing the next section of settings.

```
=>SHOWSET 1 <ENTER>
Settings for group 1

Example 21.6 kV distribution feeder
CTR  =120.00  PTR  =180.00
R1   =0.58    X1   =1.50    R0   =1.44    X0   =4.56
RS   =0.00    XS   =0.00    LL   =2.42
DATC =15      PDEM =12.00   QDEM =12.00   NDEM =0.99
79OI1=60      79OI2=600     79OI3=900     79OI4=0
79RST=1800    M79SH=00000
50C  =99.99   27L  =0.00    27H  =0.00    27C  =2      TCI  =0
50Q  =99.99   50QT =0
51QP =6.00    51QTD=15.00   51QC =3       51QRS=N
50NL =19.99   50NLT=2       50NH =100.00
51NP =1.50    51NTD=2.00    51NC =3       51NRS=N
50L  =99.99   50LT =0       50H  =40.00
51P  =6.00    51TD =6.00    51C  =3       51RS =N
52APU=1200    52ADO=0       TSPU =0       TSDO =0
TKPU =0       TKDO =0       TZPU =0       TZDO =0

PRESS RETURN ? <ENTER>
SELogic Equations

S(123)  =
A(12)   =
B(12)   =50NLT
C(12)   =50NL
D(12)   =
E(34)   =79RS+79CY+52AT
F(34)   =IN6
G(34)   =
H(34)   =
J(1234) =
K(1234) =
L(1234) =
A1(1234)=TF
A2(1234)=NDEM

PRESS RETURN ? <ENTER>

V(56)   =B*E*F
W(56)   =C*E*F
X(56)   =
Y(56)   =
Z(56)   =
A3(1346)=79CY
A4(2346)=
TR(1246)=50H+51T+51NT+V
RC(1246)=50H+TF
ER(1246)=51P+51QP+51NP+TF+W
SEQ(1)  =
ETC(1)  =
ITC(1)  =

Global settings
DEMR =Y       CFT  =60      TDUR =4       TFT  =30      TGR  =180
ITT  =5       TIME1=15      TIME2=0       AUTO =2       RINGS=3
IN1  =SS1     IN2  =DT      IN3  =RE      IN4  =
IN5  =52A     IN6  =

=>
```

STATUS

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

The STATUS report format appears below.

```
=>STATUS <ENTER>

Example 21.6 kV distribution feeder    Date: 7/1/92      Time: 01:08:44

SELF TESTS

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

=>
```

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

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

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

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

The MOF test checks dc offset in the MUX-PGA-A/D circuit.

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

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

TARGET n k

TARGET selects the information to be displayed on the target LEDs and to be communicated by this command.

When relay power is first turned on, the LED display indicates the functions marked on the front panel.

Using the TARGET command, you may select any one of the following nine sets of data to display on the LEDs.

Table 3.2: Target LED Assignment									
LED:	1	2	3	4	5	6	7	8	
n									
O	INST	A	B	C	Q	N	RS	LO	Front Panel Targets
1	51P	50L	50H	51QP	50Q	51NP	50NL	50NH	Relay Word row R1
2	51T	50LT	50C	51QT	50QT	51NT	50NLT	27	Relay Word row R2
3	79RS	79CY	79LO	79SH	52AT	52BT	IN6	IN5	Relay Word row R3
4	PDEM	QDEM	NDEM	TF	CF	TCMA	ST	TRIP	Relay Word row R4
5	A	B	C	D	E	F	G	H	Relay Word row R5
6	J	KT	!L	V	W	X	Y	ZT	Relay Word row R6
7	.	.	IN6	IN5	IN4	IN3	IN2	IN1	Inputs
8		TRIP	CLOS	A1	A2	A3	A4	ALRM	Output Contacts

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

The optional command parameter k selects the number of times the relay displays target data for parameter n. The example below shows a series of ten target readings for Relay Word row R3. Target headings repeat every eight rows. You cannot use parameter k without parameter n.

```
=>TARGET 3 10 <ENTER>


 79RS 79CY 79LO 79SH 52AT 52BT IN6  IN5
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1

 79RS 79CY 79LO 79SH 52AT 52BT IN6  IN5
 1    0    0    0    1    0    1    1
 1    0    0    0    1    0    1    1

=>
```

When you are finished, type **TAR 0 <ENTER>** to return to the functions marked on the front panel so field personnel do not misinterpret displayed data.

When a serial port times out (see TIME1, TIME2 settings) and an automatic message is sent to that port, the relay automatically clears the targets and displays the TAR 0 data.

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

If you place the relay in service with a target level other than Level 0, it automatically returns to target level 0 when an automatic message transmits to a timed out port. While this feature prevents confusion among station operators and readers, it can be inconvenient if the relay tester requires targets to remain on another level. Targets remain in the specified level if you assign the AUTO setting to a port with zero timeout or set both TIME1 and TIME2 to zero. This halts automatic message transmission to a port which may be timed out.

TARGET R

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

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

 INST A    B    C    Q    N    RS   LO
 0    0    0    0    0    0    1    0

=>
```

TIME hh:mm:ss

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

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

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

TRIGGER

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

```
=>TRIGGER <ENTER>
Triggered

=>

Example 21.6 kV distribution feeder    Date: 7/1/92    Time: 10:45:20

Event   : TRIG    Location:          Shot:   0    Targets:
Currents: (ABCQN; amps, primary)    347    354    355      5      6

=>
```

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

Access Level 2 Commands

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

CLOSE

The CLOSE command asserts the CLOSE output relay when jumper JMP104 is installed on the main board, the circuit breaker status input (52A, !52A, 52AR, or !52AR) indicates an open circuit breaker, and the TRIP outputs are not asserted. The CLOSE output relay then remains closed until the circuit breaker status input indicates that the circuit breaker has closed or until the close failure timer (CFT) expires.

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

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

After CLOSE command execution, if the response is "Breaker OPEN" instead of "Breaker CLOSED," the circuit breaker status input (52A, !52A, 52AR, or !52AR) did not indicate circuit breaker closure.

COPY m n

COPY m n copies settings and logic from setting group m to group n (m and n equal any combination of 1, 2, 3, 4, 5, or 6).

Usually, there are only a few setting or logic differences between groups. If you enter one setting group with the SET command, you can copy it to other groups with the COPY command. Use SET to modify copied setting groups.

COPY command execution clears the event report buffer. If n is the active setting group, the ALARM output contact closes momentarily.

```
=>>COPY 4 6
Are you sure (Y/N) ? Y <ENTER>

Please wait...
Settings copied

=>
```

GROUP n

GROUP n designates the Group Variable. This variable specifies which setting group to use when no Setting Group Selection inputs are assigned or all assigned inputs are deasserted (n = 1, 2, 3, 4, 5, or 6). You can execute this command at any time, but the setting group changes only when no Setting Group Selection inputs are assigned or all assigned inputs are deasserted. Otherwise, the current setting group remains active; the Group Variable becomes the Active Group only when no Setting Group Selection inputs are assigned or all assigned inputs are deasserted.

GROUP n command execution does not clear the event report buffer. However, any time the active setting group is changed, the relay pulses ALARM output contacts.

If global setting DEMR=Y and the active setting group is changed, the demand values are reset (see SET G p in this section).

```
=>>GROUP 3 <ENTER>
Change Group Variable:
Are you sure (Y/N) ? Y <ENTER>


=>>
Active Group = 1
Group Variable = 3

=>
```

The above response to **GROUP 3** command execution indicates that only Setting Group Selection input SS1 in energized (see Table 2.3) because the active group did not change to group 3, but remained group 1.

If you do not designate a setting group, the relay displays present group information:

```
=>>GROUP <ENTER>

Active Group = 1
Group Variable = 3

=>
```

OPEN

The OPEN command closes the TRIP output contacts when jumper JMP104 is installed on the main board. TRIP output contacts remain closed for at least the duration of TDUR (you must enter a TDUR setting) starting with the rising edge of the trip output. The TRIP outputs drop out only if none of the overcurrent element pickups in Relay Word row R1 are picked up or if you push the TARGET RESET button on the front panel.

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

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

Example 21.6 kV distribution feeder    Date: 7/1/92  Time: 10:45:20

Event    : TRIG    Location:          Shot:  0    Targets:
Currents: (ABCQN; amps, primary)    347   354   355     5     6

=>>
```

After OPEN command execution, if the relay responds "Breaker CLOSED" instead of "Breaker OPEN," the circuit breaker status input (52A, !52A, 52AR, or !52AR) did not indicate circuit breaker opening.

PASSWORD (1 or 2) password

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

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

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

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

The relay sets the password, pulses the ALARM relay closed, and transmits the response "Set."

After entering new passwords, type **PASSWORD <ENTER>** to inspect them. Make sure they are what you intended and record the new passwords.

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

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

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

SET n p

SET n allows entry of relay settings and logic for setting group n. At the setting procedure prompts (?), enter new data or press **<ENTER>** to retain existing settings. You can jump to a specific setting by entering the setting name as parameter p. If p is a SELOGIC™ Control Equations element, you do not need to include the parenthetical (e.g., just K, not K(1234), not just K). If you do not specify a setting, the procedure initiates at the first setting, Relay ID.

The relay prompts you for each group setting and checks the new setting against established limits. If a setting falls within its setting range, the relay prompts you for the next group setting. If a setting is outside its established limits, an "Out of range" or "Invalid" error message results. You have another chance to enter the setting. If you want to retain the old setting, press **<ENTER>** and proceed to the next group setting.

The logic variable expressions should contain the name of each Relay Word bit (e.g., **51P**) and the correct delimiter "+" for OR logic, "*" for AND logic, and "," for the ETC(1) and ITC(1) torque control logic variables. Enter the logic expression with no spaces between the Relay Word bits and the delimiters. Some examples:

A(12) = **51P+51QP+51NP**	OR logic variable A takes bits from Relay Word rows 1 and 2 and uses the + delimiter.
V(56) = **A*F*KT**	AND logic variable V takes bits from Relay Word rows 5 and 6 and uses the * delimiter.
ITC(1) = **50L,50H**	The **50L** and **50H** phase overcurrent elements from Relay Word row 1 are selected for internal torque control. The respective time delayed elements they control (**50LT** and **50HT**) are also internally torque controlled through this setting.

Note that AND logic variables **V**, **W**, **X**, **Y**, and **ZT** cannot select other AND variables from Relay Word rows 5 and 6. They can only select the OR logic variables **A**, **B**, **C**, **D**, **E**, **F**, **H**, **J**, **KT**, and **!L** from Relay Word rows 5 and 6. This prevents recursive logic such as:

V(56) = **V*W**	(this setting is not possible)

If no function is desired for a logic variable, type **NA <ENTER>**.

To fully utilize the relay's resources, self tests are delayed when any of the following elements are picked up:

51P,	50H,	51QP,	50Q,	51NP,	50NL,	50NH
51T,	51QT,	50QT,	51NT,	and	50NLT.	

Therefore, you should be careful to set the relay so that under normal conditions none of these elements are picked up.

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

After you enter all data, the relay displays new group and global settings and prompts for approval to enable new group settings. Answer **Y <ENTER>** to approve the new settings; the relay enables them and clears the event buffer. If the active group is the same as the one you are setting, the ALARM output pulses closed.

A list of relay settings follow. Setting ranges and explanations have been added.

=>>SET 1 <ENTER>

SET clears events. CTRL-X cancels.
SEL-151-R400 Group Settings
Group = 1
Active group = 1
Enter data, or **<ENTER>** for no change
GROUP 1

			Range
ID	: Example 21.6 kV distribution feeder	?	39 characters
CTR	: . . . . = 120.00 Current transformer ratio	?	0.001-10000
PTR	: . . . . = 180.00 Potential transformer ratio	?	"
R1	: Ohms Pri . . . . = 0.58 Positive-sequence line resistance	?	0.001-10000
X1	: . . . . = 1.50 Positive-sequence line reactance	?	"
R0	: . . . . = 1.44 Zero-sequence line resistance	?	"

X0	: . . . . Zero-sequence line reactance	= 4.56	?	"
RS	: . . . . Current-limiting reactor resistance	= 0.00	?	"
XS	: . . . . Current-limiting reactor reactance	= 0.00	?	"
LL	: Line Len . . . . Line length (unitless); If LL=0.001, no fault location information	= 2.42	?	0.001-10000
DATC	: Dem, 5-60 min . . . . Demand ammeter time constant	= 15	?	
PDEM	: Ph Dem Thr, A sec . . . . Phase demand ammeter threshold for **PDEM**	= 12.00	?	1.00-12.00
QDEM	: 3I2 Dem Thr, A sec . . . . Negative-sequence demand ammeter threshold for **QDEM**	= 12.00	?	0.25-12.00
NDEM	: IR Dem Thr, A sec . . . . Ground/residual demand ammeter threshold for **NDEM**	= 1.00	?	"
79OI1	: Open Int 1, cyc . . . . Reclosing relay open interval time no. 1	= 60	?	0-16000
79OI2	: . . . . Reclosing relay open interval time no. 2	= 600	?	"
79OI3	: . . . . Reclosing relay open interval time no. 3	= 900	?	"
79OI4	: . . . . Reclosing relay open interval time no. 4	= 0	?	"
79RST	: Reset Int, cyc . . . . Reclosing relay reset interval time	= 7200	?	"
M79SH	: Shot Mask . . . . Reclosing relay shot mask: designate **79SH** bit assertion for shots 0, 1, 2, 3, or 4	= 00000	?	00000 to 11111 binary
50C	: A sec . . . . Pickup for phase instantaneous overcurrent element **50C**	= 100.00	?	0.50-100.00
27L	: V l-l sec . . . . Low-set limit for undervoltage element **27**	= 0.00	?	0-250

27H	: V l-l sec . . . . = 0.00 High-set limit for undervoltage element **27**		?	"
27C	: 2, 3 Ph or 4 = HS Blown Fuse . . . . . = 2 Select whether **27** is a phase-to-phase or three phase-to-phase element, or select 4 to enable blown-fuse detection		?	
TCI	: 0=none, V=27, I=50C, 3=both . . . . = 0 Internal torque control conditions		?	
50Q	: A sec . . . . = 100.00 Pickup for negative-sequence definite-time overcurrent element **50QT** The element responds to 3*I2		?	0.50-100.00
50QT	: Dly, cyc . . . . = 0 Time delay for negative-sequence definite-time overcurrent element **50QT**		?	0-16000
51QP	: A sec . . . . = 6.00 Pickup for negative-sequence time-overcurrent element **51QT** The element responds to 3*I2		?	1.00-12.00
51QTD	: Time Dial . . . . = 15.00 Time dial for negative-sequence time-overcurrent element **51QT**		?	0.50-15.00
51QC	: Curve 1,2,3 or 4 . . . . = 3 Curve for negative-sequence time-overcurrent element **51QT** 1=moderately inverse, 2=inverse, 3=very inverse, 4=extremely inverse		?	
51QRS	: Dly Reset Y/N? . . . . = N Time delay reset for negative-sequence time-overcurrent element **51QT?** (If N, **51QT** resets 1 cycle after **51QP** drops out)		?	
50NL	: A sec . . . . = 20.00 Pickup for ground/residual definite-time overcurrent element **50NLT** Setting range dependent on 51NP setting.		?	0.125-100.00
50NLT	: Dly, cyc . . . . = 2 Time delay for ground/residual definite-time overcurrent element **50NLT**		?	0-16000

50NH	: A sec . . . . = 100.00 Pickup for ground/residual instantaneous overcurrent element **50NH** Setting range dependent on 51NP setting.	?	0.125-100.00
51NP	: A sec . . . . = 1.50 Pickup for ground/residual time-overcurrent element **51NT**	?	0.25-12.00
51NTD	: Time Dial . . . . = 3.00 Time dial for ground/residual time-overcurrent element **51NT**	?	0.50-15.00
51NC	: Curve 1,2,3 or 4 . . . . = 2 Curve for ground/residual time-overcurrent element **51NT** 1=moderately inverse, 2=inverse, 3=very inverse, 4=extremely inverse	?	
51NRS	: Dly Reset Y/N? . . . . = N Time delay reset for ground/residual time-overcurrent element **51NT**? (If N, **51NT** resets 1 cycle after **51NP** drops out)	?	
50L	: A sec . . . . = 100.00 Pickup for phase definite-time overcurrent element **50LT**	?	0.50-100.00
50LT	: Dly, cyc . . . . = 0 Time delay for phase definite-time overcurrent element **50LT**	?	0-16000
50H	: A sec . . . . = 40.00 Pickup for phase instantaneous overcurrent element **50H**	?	0.50-100.00
51P	: A sec . . . . = 6.00 Pickup for phase time-overcurrent element **51T**	?	1.00-12.00
51TD	: Time Dial . . . . = 6.00 Time dial for phase time-overcurrent element **51T**	?	0.50-15.00
51C	: Curve 1,2,3 or 4 . . . . = 3 Curve for phase time-overcurrent element **51T** 1=moderately inverse, 2=inverse, 3=very inverse, 4=extremely inverse	?	
51RS	: Dly Reset Y/N? . . . . = N Time delay reset for phase time-overcurrent element **51NT**? (If N, **51T** resets 1 cycle after **51P** drops out)	?	

52APU	: 52A PU, cyc . . . . Time delay pickup for **52AT**	= 1200	?	0-16000
52ADO	: 52A DO, cyc . . . . Time delay dropout for **52AT**	= 0	?	"
TSPU	: Tmr PU, cyc . . . . Timer TS time delay pickup (timer TS output is Relay Word bit **ST**)	= 0	?	"
TSDO	: Tmr DO, cyc . . . . Timer TS time delay dropout (timer TS output is Relay Word bit **ST**)	= 0	?	"
TKPU	: . . . . Timer TK time delay pickup (timer TK output is Relay Word bit **KT**)	= 0	?	"
TKDO	: . . . . Timer TK time delay dropout (timer TK output is Relay Word bit **KT**)	= 0	?	"
TZPU	: . . . . Timer TZ time delay pickup (timer TZ output is Relay Word bit **ZT**)	= 0	?	"
TZDO	: . . . . Timer TZ time delay dropout (timer TZ output is Relay Word bit **ZT**)	= 0	?	"

Set remaining settings equal to combinations of elements in the Relay Word via SELOGIC Control Equations. You can clear logic settings by entering NA.

The following settings S(123) through A2(1234) can be set to equal any OR-combination of elements in the Relay Word rows indicated in parentheses.

S(123) = ? Input into timer TS (TS output is Relay Word bit **ST**)

Settings A(12) through J(1234) are for Relay Word bits **A** through **J**, respectively.

A(12) = ?
B(12) = 50NLT ?
C(12) = 50NL ?
D(12) = ?
E(34) = 79RS+79CY+52AT ?
F(34) = IN6 ?
G(34) = ?
H(34) = ?
J(1234) = ?

K(1234)	= ?	Input into timer TK (TK output is Relay Word bit **KT**)
L(1234)	= ?	Input into an inverter (output is Relay Word bit **!L**)
A1(1234)	= TF ?	A1 output contact setting
A2(1234)	= NDEM ?	A2 output contact setting

The following settings V(56) through Z(56) can be set to equal any AND-combination of Relay Word bits **A** through **!L**, which are in Relay Word row R5 and the first three bits of row R6.

V(56)	= B*E*F ?	
W(56)	= C*E*F ?	
X(56)	= ?	
Y(56)	= ?	
Z(56)	= ?	Input into timer TZ (TZ output is Relay Word bit **ZT**)

The following settings A3(1346) through SEQ(1) can be set to equal any OR-combination of elements in the Relay Word rows indicated in parentheses.

A3(1346)	= 79CY ?	A3 output contact setting
A4(2346)	= ?	A4 output contact setting
TR(1246)	= 50H+51T+51NT+V ?	Programmable tripping conditions
RC(1246)	= 50H+TF ?	Programmable reclose cancel conditions
ER(1246)	= TF+W+51NP+51QP+51P	Programmable event report trigger conditions
SEQ(1)	= ?	Sequence coordination overcurrent pickup(s)

Note: SELOGIC Control Equations cannot exceed 90 characters (including + or * characters). Exceeding this limit may overflow the relay input buffer and cause it to XOFF the terminal from which you are entering settings (see Communications Protocol in this section).

The following settings specify overcurrent elements in Relay Word row R1 to be torque controlled (e.g., ETC(1) = **51P,50NL**).

ETC(1)	= ?	Externally torque controlled elements
ITC(1)	= ?	Internally torque controlled phase overcurrent elements (choose from **51P,50L**, and **50H** only)

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

SET G p

SET G allows entry of global settings which are used with all setting groups. At the setting procedure prompts, enter new data or press **<ENTER>** for no change. You can jump to a specific global setting by entering the setting name as parameter p. If you do not specify a setting, the procedure starts at the first global setting DEMR.

The relay prompts you for each global setting and checks entries against established limits as it does during group setting entry (see SET n p in this section). For the programmable contact inputs IN1 to IN6, if no function is desired, type **NA <ENTER>**. Type **END <ENTER>** after the last setting change. The relay displays the new global settings and the active group settings. Answer **Y <ENTER>** to enable the new global settings. The relay will pulse the ALARM output as the new global settings are stored in memory.

Following is a list of global settings with setting ranges and explanations.

=>>SET G <ENTER>

```
SET clears events.  CTRL-X cancels.
SEL-151-R400 Global Settings
Enter data, or <ENTER> for no change
                                                              Range
DEMR    : Dem Reset Grp Chg Y/N? . . . . . . . = Y      ?
          Reset the demand values when an active setting group
          change is made.

CFT     : Cl Fail Time, cyc . . . . . . . . . . . . = 60     ?      0-16000
          Close failure time.  If CFT = 0, CLOSE output contact
          deasserts if breaker closes per circuit breaker status input
          (52A, !52A, 52AR, or !52AR) or TRIP output contacts assert.

TDUR    : Trip Dur, cyc . . . . . . . . . . . . . . = 4      ?      0-63
          Trip duration time

TFT     : Trip Fail Time, cyc . . . . . . . . . . . = 30     ?        "
          Trip failure time

TGR     : Grp Chg Dly, cyc . . . . . . . . . . . . = 180    ?      0-16000
          Setting Group Selection inputs (SS1, SS2, SS3) have to stabilize
          for time TGR before the relay changes setting groups.

ITT     : Inst Tar Time, cyc . . . . . . . . . . . = 5      ?      0-63
          INST front panel target illuminates if TRIP occurs less than ITT
          time after any Relay Word row R1 overcurrent element picks up

TIME1   : PORT 1 Timeout, min . . . . . . . . . . = 15     ?      0-30
TIME2   : PORT 2 Timeout, min . . . . . . . . . . = 0      ?        "

AUTO    : Autoport 1,2 or 3 . . . . . . . . . . . . = 2      ?
          1 = PORT 1,  2 = PORT 2,  and 3 = both
          PORT to receive automatic messages

RINGS   : Rings 1-30 . . . . . . . . . . . . . . . . = 3      ?
          Number of rings after which modem on PORT 1 answers
```

Inputs IN1 through IN6 can be assigned to one of the following functions:

SS1	Setting Group Selection Input 1	(assign to IN1 only)
SS2	Setting Group Selection Input 2	(assign to IN2 only)
SS3	Setting Group Selection Input 3	(assign to IN3 only)
TCP	External Torque Control (Phase and Negative-Sequence Elements)	
!TCP	(inverted sense of TCP)	
TCG	External Torque Control (Residual Overcurrent Elements)	
!TCG	(inverted sense of TCG)	
52A	Circuit Breaker Status (52A contact input)*	
!52A	Circuit Breaker Status (52B contact input)*	
52AR	Circuit Breaker Status (52A contact input)/Reclose Initiate*	
!52AR	Circuit Breaker Status (52B contact input)/Reclose Initiate*	
DC	Direct Close	(requires circuit breaker status)
RE	Reclose Enable	(requires circuit breaker status)
TCM	Trip Circuit Monitor	(requires circuit breaker status)
ET	External Trigger of Event Report	
DT	Direct Trip	
(blank)	Unassigned Input	

Type **NA <ENTER>** to clear settings.

```
IN1    = SS1  ?
IN2    = DT   ?
IN3    = RE   ?
IN4    =      ?
IN5    = 52A  ?
IN6    =      ?
```

* Only one of the circuit breaker status input options 52A, !52A, 52AR, or !52AR should be assigned to an input.

52A or !52A

If 52A or !52A is assigned to an input, only circuit breaker status information is provided. Reclose initiation is provided by the assertion of the internal TRIP condition. When the TRIP condition drops out and the circuit breaker is open (per 52A or !52A), the open interval starts timing.

52AR or !52AR

If 52AR or !52AR is assigned to an input, not only does the input provide circuit breaker status information, but it provides reclose initiation, too. The sensed transition of the circuit breaker status, indicating that the circuit breaker is opening, initiates reclosing. If the TRIP condition is present, it has to drop out before the open interval starts timing.

In most applications, circuit breaker trips external to the relay (e.g., by control switch or SCADA) must not cause reclose initiation. If input option RE (Reclose Enable) is assigned to an input, the RE input is de-energized to prevent automatic reclosing. Certain control switch contacts can be wired to the RE input to defeat reclosing for control switch trips.

Also, if 52AR or !52AR is assigned to an input, the circuit breaker status function is time delayed by 10 cycles to qualify circuit breaker opening. This is done for certain application needs (see SYSTEM RESTORATION AFTER UNDERFREQUENCY LOADSHEDDING in Section 5: APPLICATIONS). If this type of application is not needed, then it is better to assign 52A or !52A to an input instead and avoid the 10 cycle time delay. This time delay shows up in event reports and needs to be accounted for when making setting 52ADO.

The 10 cycle delay affects the circuit breaker monitor, too. The TDUR timer should be set somewhat greater than 10 cycles so that relay initiated circuit breaker trips are counted as such and not as external circuit breaker trips. Also, if an external trip occurs, no interrupted current values will likely be accumulated by the circuit breaker monitor because of the 10 cycle time delay.

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

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

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

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

SEL-151 RELAY COMMAND SUMMARY

Access Level 0

ACCESS	Answer password prompt (if password protection is enabled) to enter Access Level 1. Third unsuccessful attempt pulses 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.
BREAKER	Display running sum of circuit breaker trips for relay and external trips (circuit breaker trip counters). Also display running sum of interrupted current in each circuit breaker pole for relay and external trips.
BREAKER R	Reset circuit breaker trip counters and interrupted current sums to zero for both relay and external trips. Relay stores reset date and time.
DATE m/d/y	Set or display date. DAT 6/1/92 sets date to June 1, 1992. IRIG-B time code input overrides existing month and day settings. DATE pulses ALARM contacts when year entered differs from year stored. To display the date only, enter DATE.
EVENT n	Show event record. EVE or EVE 1 shows newest event; EVE 12 shows oldest (n=1, 2, 3,...,11, or 12).
HISTORY	Show DATE, TIME, EVENT, LOCAT (location), SHOT, TARGETS, 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 present phase, residual, and negative-sequence current values; present real and reactive power values; present line-to-neutral, line-to-line, zero-sequence, and negative-sequence voltage values. Optional n displays METER data n times.
METER D	Display demand and peak demand values of phase, residual, and negative-sequence current values and real and reactive power values.
METER RD	Reset demand values.
METER RP	Reset peak demand values.
QUIT	Return control to Access Level 0; return target display to Relay Targets.
SHOWSET n	Display settings of setting group n without affecting them (n = 1, 2, 3, 4, 5, or 6).
STATUS	Show self test status.

Access Level 1 Continued

TARGET n k	Show data and set target LEDs as follows (n = 0, 1, 2, . . . 7, or 8): TAR 0: Front Panel Targets — TAR 1: Relay Word row R1 TAR 2: Relay Word row R2 — TAR 3: Relay Word row R3 TAR 4: Relay Word row R4 — TAR 5: Relay Word row R5 TAR 6: Relay Word row R6 — TAR 7: Input States TAR 8: Output Contact States — Optional k displays target data k times.
TARGET R	Clears targets and returns to TAR 0
TIME h/m/s	Set or display time. TIM 13/32/00 sets clock to 1:32:00 PM. IRIG-B synchronization overrides this setting. To display the time only, enter TIME.
TRIGGER	Trigger and save an event record (event type is EXT).

Access Level 2

CLOSE	Close circuit breaker, if allowed by jumper setting.
COPY m n	Copy setting group m to setting group n (m and n equal any combination of 1, 2, 3, 4, 5, or 6). Clears buffers. If n is the active setting group, the ALARM output contacts pulse closed.
GROUP n	Designate the active setting group when no Setting Group Selection Inputs are assigned to inputs or all Setting Group Selection Inputs assigned to inputs are deasserted (n = 1, 2, 3, 4, 5, or 6). The ALARM output contacts pulse closed when the active group changes. GROUP n command execution does not clear the event buffer.
OPEN	Open circuit breaker, if allowed by jumper setting.
PASSWORD	Show or set passwords. ALARM contacts pulse closed after password entry. PAS 1 OTTER sets Level 1 password to OTTER. PAS 2 TAIL sets Level 2 password to TAIL.
SET n p	Initiate setting procedure for setting group n (n = 1, 2, 3, 4, 5, or 6). Option p directs the relay to begin the setting procedure for setting group n at setting p (if p = 51P, the setting procedure starts at setting 51P, bypassing all settings before 51P). If no optional p is entered, the setting procedure starts at the beginning. The relay clears event buffers when new settings are stored. If n is the active setting group, the ALARM output contact pulses closed.
SET G p	Initiate setting procedure for the global setting group. Option p directs the relay to begin the setting procedure for the global setting group at setting p (if p = TDUR, the setting procedure starts at setting TDUR, bypassing all settings before TDUR). If optional p is not used, the setting procedure starts at the beginning. The SET G command pulses ALARM contacts closed and clears event buffers when new settings are stored.

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EVENT REPORTING
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TABLES

Table 4.1: Event Report Triggering Actions 4-1

EVENT REPORTING

EVENT REPORT GENERATION

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

Table 4.1: Event Report Triggering Actions

- Programmable event report triggering variable (ER) assertion
- TRIGGER command execution
- ET (External Trigger) input assertion
- TRIP output contact assertion

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

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

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

SUMMARY EVENT REPORT

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

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

The summary event report includes:

- Relay terminal identifier
- Date and time
- Event type
- Fault location
- Reclosing relay shot
- FAULT TYPE front panel targets
- Currents (phase, 3 x negative-sequence, and residual) measured near the middle of the fault or when the event report was triggered if no fault occurred.

The following shows an example summary event report.

```
Example 21.6 kV distribution feeder  Date: 7/1/92 Time: 01:36:50.070

Event   : AG T   Location:   2.43   Shot:  0    Targets: INSTAQN
Currents: (ABCQN; amps, primary)   2798    213    211   2741   2742

=>
```

See HISTORY in Section 3: COMMUNICATIONS for more information. The relay clears the event report and history buffer for the following conditions:

- Loss of control power
- Entry of new setting via SET or SET G command
- COPY command execution

LONG EVENT REPORT

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

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

INTERPRETING VOLTAGE AND CURRENT DATA

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

1. Two pole, low pass filters with cutoff frequencies of approximately 85 Hz filter input analog signals.

2. The relay samples filtered analog signals four times per power system cycle and converts them to numerical values.

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

   1, -1, -1, 1

   The filter has the property of a double differentiator smoother.

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

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

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

The following example illustrates why the older data is the leading component of the phasor.

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

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

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

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

RELAY ELEMENT, OUTPUT CONTACT, AND INPUT DATA

Relay elements, inputs, and output contact states appear in the right-hand columns of the event report. The following information lists symbols corresponding to asserted combinations of elements ("1" indicates element/output contact assertion or input energization).

Event Report Column	Elements			Symbol
P	Phase overcurrent			
51	51P	51T		
	0	0		.
	0	1		1
	1	0		p
	1	1		T
50L	50L	50LT		
	0	0		.
	0	1		(not possible)
	1	0		p
	1	1		T
50H	50H			
	0			.
	1			p
TCI	Internal torque control			
	50C	27		
	0	0		.
	0	1		V
	1	0		I
	1	1		3
Q	Negative-sequence overcurrent			
51	51QP	51QT		
	0	0		.
	0	1		1
	1	0		p
	1	1		T
50	50Q	50QT		
	0	0		.
	0	1		(not possible)
	1	0		p
	1	1		T
N	Ground\residual overcurrent			
51	51NP	51NT		
	0	0		.
	0	1		1
	1	0		p
	1	1		T
50L	50NL	50NLT		
	0	0		.
	0	1		(not possible)
	1	0		p
	1	1		T
50H	50NH			
	0			.
	1			p
I	Demand current thresholds			
DEM	PDEM	QDEM	NDEM	
	0	0	0	.
	0	0	1	N
	0	1	0	Q
	0	1	1	3
	1	0	0	P
	1	0	1	5
	1	1	0	6
	1	1	1	7
79	Reclosing relay states			
	79RS	79CY	79LO	
	0	0	0	.(no 52A or !52A)
	0	0	1	L
	0	1	0	C
	0	1	1	(not possible)
	1	0	0	R
	1	0	1	(not possible)
	1	1	0	(not possible)
	1	1	1	(not possible)

Event Report Column	Elements			Symbol
BKR	Circuit breaker alarms			
	TF	CF	TCMA	
	0	0	0	.
	0	0	1	M
	0	1	0	C
	0	1	1	3
	1	0	0	T
	1	0	1	5
	1	1	0	6
	1	1	1	7
Out	Output contacts			
T&C	TRIP	CLOSE		
	0	0		.
	0	1		C
	1	0		T
	1	1		(not possible)
1&2	A1	A2		
	0	0		.
	0	1		2
	1	0		1
	1	1		B (Both)

Event Report Column	Elements		Symbol
3&4	A3	A4	
	0	0	.
	0	1	4
	1	0	3
	1	1	B (Both)
ALR	Alarm		
	0		.
	1		A
In	Inputs		
1&2	IN2	IN1	
	0	0	.
	0	1	1
	1	0	2
	1	1	B (Both)
3&4	IN4	IN3	
	0	0	.
	0	1	3
	1	0	4
	1	1	B (Both)
5&6	IN6	IN5	
	0	0	.
	0	1	5
	1	0	6
	1	1	B (Both)

EXAMPLE EVENT REPORTS

Externally Triggered Event Report

Recall from Section 3: COMMUNICATIONS that the relay records an eleven cycle event report when you issue the TRIGGER command. This command does not affect the protective functions of the relay. The event type listing "TRIG" signifies an event triggered on command. Use the TRIGGER command to generate an event report for plotting voltage and current phasors during normal load conditions prior to releasing the relay for service.

Example Event Report 1 shows the first cycle of an event report triggered under normal operating conditions for a 21.6 kV distribution feeder. The report was generated with the TRIGGER command. In this excerpt, you can immediately see that load currents are balanced by the lack of significant current in the residual current column IR. Also, note that the line breaker is closed, as signified by a "B" in the column labelled In: 1 & 2 (IN2 = 52A).

Event report data for the voltages and currents appears in rectangular format. You can easily convert these rectangular values to polar format as described in Interpreting Voltage and Current Data. Section 6: INSTALLATION includes a blank voltage and current polarity check form for plotting voltage and current phasors. A direction and polarity check form completed using the first two rows of data from the event report appears on the following page.

Using the voltage and current phasor diagrams on the bottom of the SEL Direction and Polarity Check Form, note that the current and voltage phase rotation is ABC in the counter-clockwise direction. This phase rotation must match that of your system. In addition, note that load is flowing out from Breaker 1 as indicated by each phase current lagging the respective phase voltage by the load flow angle.

Fault Triggered Event Report

Example Event Report 2 shows all eleven cycles of a fault triggered event report. The first two cycles show prefault conditions. The event report was triggered when the **50NL** element picked up on an AG fault. **50NL** is set to trigger event reports via the programmable event report trigger variable ER(1246). **50NL** is not set to initiate tripping. Tripping is initiated when **50NLT** expires 2 cycles later (setting 50NLT = 2). **50NLT** is set to initiate tripping via the programmable tripping variable TR(1246). Comments to the right of the event report and settings explain additional details.

Example Event Report 1

```
Example  21.6 kV distribution feeder       Date: 11/5/92     Time: 01:07:35.862

FID=SEL-151-R405-V656rp1r-D921102

              Currents                         Voltages        P    Q  N    I    Out  In
              (A pri)                          (V pri)
                                                             555T 55 555 D 7B T13A 135
   IR      IA       IB      IC        VA        VB       VC  100C 10 100 E 9K &&&L &&&
                                                              LHI     LH M  R C24R 246

   -1     310     -171    -141     12377     -4872    -7505  .... .. ... . R. .... 13B]—— One cycle of data
    3      16      262    -276     -1520     11479    -9959  .... .. ... . R. .... 13B|
    1    -310      171     141    -12377      4872     7505  .... .. ... . R. .... 13B|
   -3     -16     -262     276      1520    -11479     9959  .... .. ... . R. .... 13B]


Event    : TRIG   Location   :           Shot: 0    Targets:          ———————————— Event Summary
Currents: (ABCQN; amps, primary)    310    313    310      2      3 ——┘
```

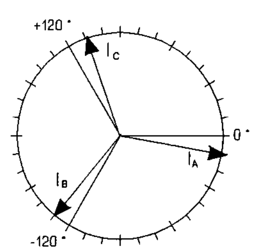
SEL DIRECTION AND POLARITY CHECK FORM

STATION 21.6 kV Distribution Feeder DATE: 7 / 1 / 92 TESTED BY ____________
SWITCH NO. ____________ EQUIPMENT SEL-151 Relay
INSTALLATION ________ ROUTINE X OTHER ____________

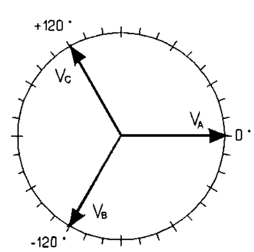
LOAD CONDITIONS:
STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS
SEL READINGS: 11.401 MW (+)(-) 1.987 MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I(a)	I(b)	I(c)	V(a)	V(b)	V(c)	
1st LINE CHOSEN (Y COMPONENT)	310	-171	-141	12377	-4872	-7505	
2nd LINE CHOSEN (X COMPONENT)	16	262	-276	-1520	11479	-9959	
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$	310	313	310	12470	12470	12470	ROW 1
ANGLE IN DEGREES ARCTAN Y/X	87	-33	-153	97	-23	-143	
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0	-97	-97	-97	-97	-97	-97	
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM	-10	-130	-250	0	-120	-240	ROW 2

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



CURRENTS



VOLTAGES

Example Event Report 2

```
Example  21.6 kV distribution feeder        Date: 11/5/92    Time: 01:36:59.0  Time-tag corresponds to the 16th
                                                                                 quarter-cycle of this event
                                                                                 report.
FID=SEL-151-R405-V656rp1r-D921102

            Currents                        Voltages        P    Q  N   I   Out  In
            (A pri)                         (V pri)
                                                           555T 55 555 D 7B T13A 135
   IR     IA     IB     IC       VA      VB      VC       100C 10 100 E 9K &&&L &&&
                                                           LHI     LH M  R C24R 246

    0     98   -296    198     4451  -12313    7864     .... .. ... . R. .... 13B   One cycle of data
    4    287    -59   -225    11650   -1971   -9678     .... .. ... . R. .... 13B
    0    -98    296   -198    -4450   12314   -7865     .... .. ... . R. .... 13B   Input 1 (1) is energized
   -4   -287     59    225   -11649    1972    9679     .... .. ... . R. .... 13B   Input 2 is not energized
                                                                                    Input 3 (3) is energized
    0     98   -296    198     4449  -12314    7863     .... .. ... . R. .... 13B   Input 4 is not energized
    4    287    -59   -225    11650   -1971   -9677     .... .. ... . R. .... 13B   Both (B) inputs 5 and 6
    0    -98    296   -198    -4450   12315   -7863     .... .. ... . R. .... 13B     are energized
   -4   -287     59    225   -11651    1970    9677     .... .. ... . R. .... 13B
                                                                                    Reclosing relay is in the reset
    0     98   -296    198     4450  -12314    7864     .... .. ... . R. .... 13B     state (R; 79RS = 1)
    4    287    -59   -225    11650   -1970   -9678     .... .. ... . R. .... 13B
  296    200    285   -191    -4211   12207   -7816     .... .. ... . R. .... 13B
 -206   -468     47    215   -10197    1421    9127     .... .. p.. . R. .... 13B
                                                                                    Respective time-overcurrent
-1254  -1168   -247    164     3341  -11808    8132     .... .. p.. . R. .... 13B     elements start timing at
  903   1123    -36   -185     8107    -511   -8402     p... p. p.. . R. .... 13B     fault inception (p)
 2067   1991    215   -143    -2275   11535   -8401     p... p. p.. . R. .... 13B
-1460  -1655     38    164    -7165     155    8164     p... p. pp. . R. .... 13B
                                                                                    50NL element picks up (p) and
-2267  -2192   -211    138     2215  -11532    8387     p... p. pp. . R. .... 13B     initiates this event report;
 1537   1728    -36   -160     7147    -132   -8108     p... p. pp. . R. .... 13B     50NLT element starts timing
 2268   2193    210   -138    -2214   11530   -8386     p... p. pp. . R. .... 13B
-1538  -1731     36    160    -7145     132    8110     p... p. pp. . R. .... 13B

-2270  -2197   -210    138     2215  -11531    8386     p... p. pp. . R. .... 13B
 1538   1733    -36   -160     7146    -133   -8109     p... p. pp. . R. .... 13B
 2270   2197    210   -138    -2215   11531   -8388     p... p. pp. . R. .... 13B
-1538  -1733     36    160    -7148     131    8109     p... p. pT. . C. T.3. 13B
                                                                                    50NLT element expires after 2
-2272  -2197   -208    138     2214  -11530    8387     p... p. pT. . C. T.3. 13B     cycles (T; setting 50NLT = 2);
 1540   1733    -38   -160     7148    -131   -8108     p... p. pT. . C. T.3. 13B     TRIP output contact asserts
 2272   2197    208   -138    -2214   11530   -8388     p... p. pT. . C. T.3. 13B     (T;50NLT enabled for tripping)
-1540  -1735     38    160    -7147     132    8107     p... p. pT. . C. T.3. 13B
                                                                                    TRIP output contact (T) is
-2272  -2195   -210    138     2213  -11531    8388     p... p. pT. . C. T.3. 13B     asserted for a minimum of
 1540   1737    -36   -160     7146    -131   -8109     p... p. pT. . C. T.3. 13B     4 cycles (TDUR = 4)
 2272   2193    210   -138    -2213   11530   -8387     p... p. pT. . C. T.3. 13B
-1540  -1737     36    160    -7146     130    8107     p... p. pT. . C. T.3. 136
                                                                                    52A input drops out (IN5 = 52A)
-2256  -2183   -210    138     2213  -11529    8387     p... p. pT. . C. T.3. 136     indicating that the circuit
 1513   1703    -36   -160     7147    -131   -8119     p... p. pT. . C. T.3. 136     breaker is opening
 1754   1761    201   -135    -2411   11545   -8379     p... p. p.. . C. T.3. 136
 -541   -552    125     42    -8512     707    8591     p... p. p.. . C. T.3. 136
                                                                                   All overcurrent elements drop
 -214   -231    -17     19     3672  -11815    8028     .... .. p.. . C. T.3. 136     out after the circuit breaker
   17     19     -7     -2    11630   -1851   -9632     .... .. ... . C. T.3. 136     interrupts the fault current
    9     10      1     -1    -4430   12289   -7847     .... .. ... . C. T.3. 136
   -2     -2      0      0   -11637    1959    9659     .... .. ... . C. ..3. 136
                                                                                    Reclosing relay is in the
   -1     -1      0      0     4451  -12313    7864     .... .. ... . C. ..3. 136     reclose cycle state
    0      0      0      0    11650   -1971   -9678     .... .. ... . C. ..3. 136     (C; 79CY = 1)
    0      0      0      0    -4450   12314   -7865     .... .. ... . C. ..3. 136
    0      0      0      0   -11649    1972    9679     .... .. ... . C. ..3. 136

Event    :  AG T   Location:        2.43   Shot: 0    Targets: INSTAQN          Event Summary
Currents (A pri), ABCQN              2798    213     211   2741    2742
```

```
Settings for group 1 ------------------------------------ Group 1 is enabled because IN1=SS1 and is energized.
                                                            SS2 = SS3 = 0 by default because they are not assigned
                                                            to inputs
Example  21.6 kV distribution feeder
CTR  =120.00    PTR  =180.00
R1   =0.58      X1   =1.50      R0   =1.44      X0   =4.56
RS   =0.00      XS   =0.00      LL   =2.42
DATC =15        PDEM =12.00     QDEM =12.00     NDEM =0.99
79OI1=60        79OI2=600       79OI3=900       79OI4=0
79RST=1800      M79SH=00000
50C  =99.99     27L  =0.00      27H  =0.00      27C  =2      TCI  =0
50Q  =99.99     50QT =0
51QP =6.00      51QTD=15.00     51QC =3         51QRS=N
50NL =19.99     50NLT=2         50NH =99.99
51NP =1.50      51NTD=2.00      51NC =3         51NRS=N
50L  =99.99     50LT =0         50H  =40.01
51P  =6.00      51TD =6.00      51C  =3         51RS =N
52APU=1200      52ADO=0         TSPU =0         TSDO =0 ---- There is a time delay pickup (52APU) on the 52AT function
TKPU =0         TKDO =0         TZPU =0         TZDO =0

SELogic Equations
S(123)  =
A(12)   =
B(12)   =50NLT
C(12)   =50NL
D(12)   =
E(34)   =79RS+79CY+52AT
F(34)   =IN6 ---------------- Input IN6 functions as a permissive trip input for the 50NLT element
G(34)   =
H(34)   =
J(1234) =
K(1234) =
L(1234) =
A1(1234)=TF
A2(1234)=NDEM
V(56)   =B*E*F -------------- The 50NLT element is supervised by 52AT when the reclosing relay is in the lockout
W(56)   =C*E*F                 state (79RS = 0 and 79CY = 0 when the reclosing relay is in the lockout state)
X(56)   =
Y(56)   =
Z(56)   =
A3(1346)=79CY
A4(2346)=
TR(1246)=50H+51T+51NT+V ------ Programmable tripping conditions
RC(1246)=50H+TF -------------- Programmable reclose cancel conditions
ER(1246)=51P+51QP+51NP+TF+W --------------- Programmable event report trigger conditions
SEQ(1)  =
ETC(1)  =
ITC(1)  =

Global settings
DEMR =Y         CFT  =60        TDUR =4         TFT  =30     TGR  =180
ITT  =5         TIME1=15        TIME2=0         AUTO =2      RINGS=3
IN1  =SS1       IN2  =DT        IN3  =RE        IN4  =
IN5  =52A       IN6  =   ---------------------------------------- Input IN6 is used as a permissive trip
                                                                     input in the above logic
```

FIRMWARE IDENTIFICATION

The SEL-151 relay provides a means of interpreting Firmware Identification Data (FID). The FID string is included near the top of each long event report. The string format is as follows:

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

Where:

[PN] = Product Name (e.g., SEL-151)

[RN] = Revision Number (e.g., 400)

[VS] = Version Specifications (e.g., 656rp1rqys)

[RD] = Release Date (e.g., YYMMDD = 940901)

[ER] = Version Specification: EEPROM

For the SEL-151 relay family, version specifications are interpreted as follows:

V[VS] = V[ABCDEFG]

Option	Specifier	Specifier Meaning	Option Description
A	5, 6	50 Hz, 60 Hz	Power System Frequency
B	1, 5	1 amp, 5 amps	Nominal Amps per Phase
C	6	120 & 67 volts	Nominal Volts per Phase
D	r	radial	Fault Locator type
E	p, n	positive, negative	Phase-Sequence of Power System
F	1	standard	Recloser
G	r, e	recloser, enable & alarm	Target LEDs
H	q	standard	Neg.-Seq. OC Elements
I	y	wye	Voltage Connection
J	s	standard	Fast Meter Commands

EEPROM version specifications are interpreted as follows:

E[ER] = E[Z]

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

Please contact Schweitzer Engineering Laboratories, Inc. for information concerning available versions of the SEL-151 relay. Version specifications provided above are not intended for ordering purposes but to aid in identification of the software installed in a relay.

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APPLICATIONS

This section is included as a tool for applying the SEL-151 relay. The information does not represent suggested settings or standards. Please refer to the functional description and be sure the settings you choose result in relay performance appropriate to your application.

FUSE SAVING SCHEMES

In a fuse saving scheme, the SEL-151 relay should trip instantaneously for faults on the load side of tap fuses near the substation, attempting to save the fuse if the fault is transient. If the fault is permanent, the fuse will eventually operate on a subsequent shot where relay tripping is delayed. The **50NL** ground/residual instantaneous overcurrent element in Figure 5.1 is incorporated in fuse saving schemes in the following examples.

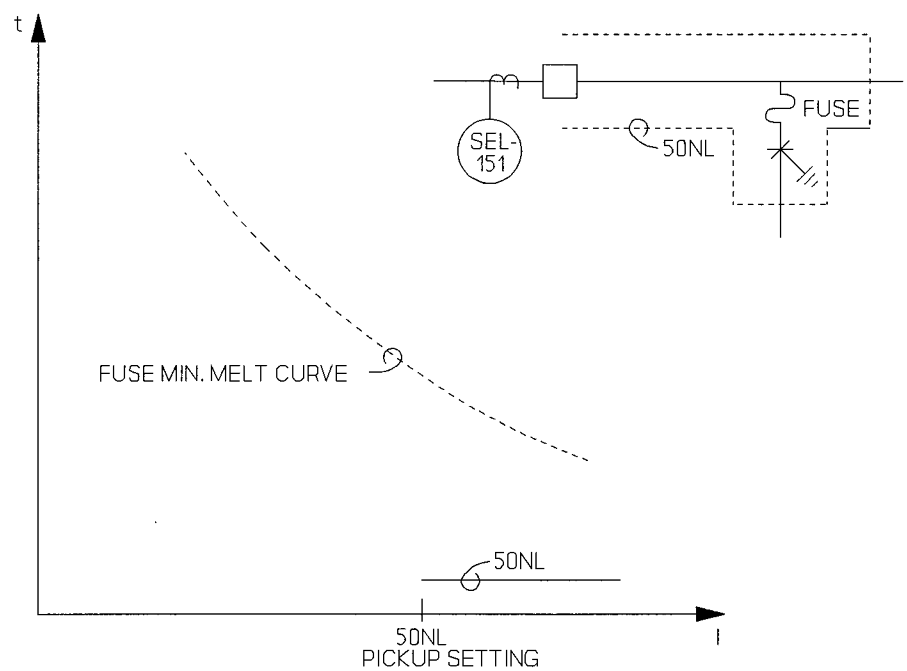


Figure 5.1: Fuse Saving Using Ground/Residual Elements

At least two fuse saving scheme implementations are possible. One scheme uses the **79SH** Relay Word bit while the other scheme uses the **52AT** Relay Word bit. In the following examples, the goal is to enable element **50NL** for the first one or two shots and disable it for the remaining shots. With **50NL** disabled, the tap fuses operate if the fault is permanent. More information about these two schemes appears below.

Fuse Saving Scheme Using the 79SH Bit

The **79SH** bit asserts (**79SH** = 1) for selected reclosing relay shot counter states (shot = 0, 1, 2, 3, or 4). **79SH** is controlled by the M79SH setting. To assert **79SH** for shot = 0 and shot = 1, M79SH is set as:

M79SH = 11000

The digits of the M79SH setting (from left to right) are for shots 0 through 4. For a reclosing scheme with only three shots (three automatic reclosures) only the first four digits of the M79SH setting are pertinent (shots 0 through 3). The shot counter increments when the reclosing relay issues an automatic reclosure (CLOSE output contact assertion). Shot = 0 when the circuit breaker is closed and the reclosing relay is reset.

With the M79SH setting shown above, **79SH** remains set from the end of the preceding reset interval (79RST), until the relay issues the second close (shot=2).

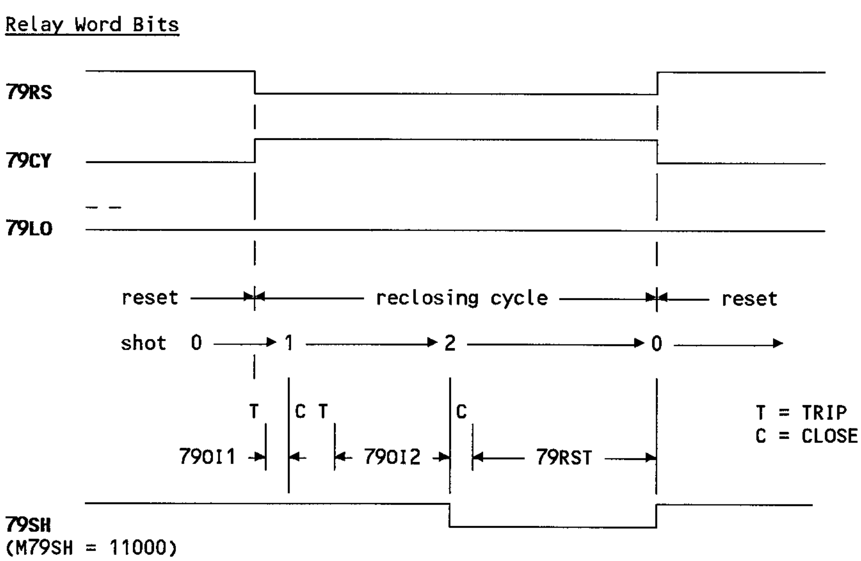


Figure 5.2: Reclosing Cycle for Permanent Fault Beyond Tap Fuse

If element **50NL** is supervised by **79SH**, then **50NL** is enabled for shot = 0 and shot = 1 only.

Using SELogic™ Control Equations:

B(12)	= **50NL**	
E(34)	= **79SH**	
V(56)	= **B*E**	
TR(1246)	= **V**+...	(TR is the programmable trip condition)

effectively, TR(1246) = **50NL*79SH**+...

close TRIP output contacts = TR + ...

i.e., **50NL** is enabled for tripping for shot = 0 and shot = 1 only. If the reclosing relay is reset (shot = 0) and a permanent ground fault occurs beyond the tap fuse in Figure 5.1 (ground fault $3I_0$ current > 50NL), the **50NL** element trips the feeder circuit breaker twice. Thus, the tap fuse is "saved" during initial trip (shot = 0) and the subsequent trip after the first reclosure (shot = 1). For the second reclosure (shot = 2), **50NL** is not enabled for tripping (shot = 2) and the tap fuse clears the permanent fault. Figure 5.2 details this reclosing cycle.

If the ground fault was transient, the **50NL** element would have tripped the circuit breaker the first time (shot = 0), extinguishing the fault, and the tap fuse would have been saved.

Fuse Saving Scheme using the 52AT Bit

The 52APU and 52ADO settings affect Relay Word bits **52AT** and **52BT** as follows:

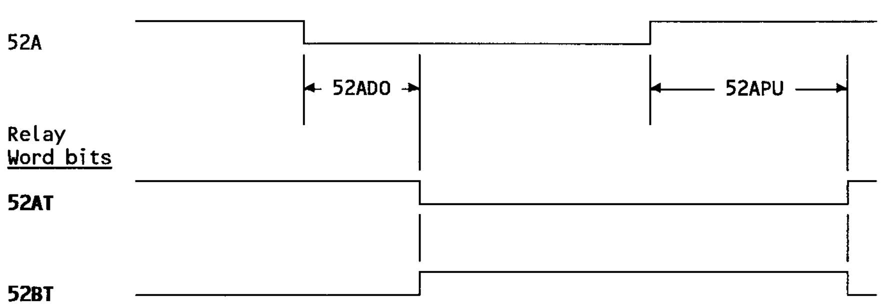


Figure 5.3: Effect of 52APU and 52ADO Settings on Relay Word Bits 52AT and 52BT

Note that the **52BT** bit is the inverse of the **52AT** bit. The discussion involves only the **52AT** bit.

If **50NL** is supervised by **52AT**, **50NL** continues to be disabled for 52APU time after circuit breaker closure. 52A asserts when the circuit breaker closes.

Using SELOGIC Control Equations:

B(12)	= **50NL**	
E(34)	= **52AT**	
V(56)	= **B*E**	
TR(1246)	= **V**+...	(TR is the programmable trip condition)

effectively, TR(1246) = **50NL*52AT**+...

close TRIP output contacts = TR + ...

If the circuit breaker has been closed longer than 52APU time before a fault occurs, **52AT** = 1 and **50NL** is enabled for tripping. If a permanent ground fault occurs beyond the tap fuse in Figure 5.1 (ground fault $3I_0$ current > 50NL), the **50NL** element trips the feeder circuit breaker. The circuit breaker opens. The reclosing relay closes the circuit breaker after the first open interval time expires.

50NL is disabled for time period 52APU after the circuit breaker closes (**52AT** = 0). The 52APU setting should be long enough to allow the tap fuse to clear the fault. Time period 52ADO is set to zero, or at least shorter than any reclosing relay open interval time.

A fuse saving scheme using the **52AT** bit makes only one attempt to save the fuse at the first reclosing cycle trip.

TRIP SAVING SCHEME

Trip saving is the opposite of fuse saving. In a trip saving scheme, the SEL-151 relay definite-time overcurrent elements have total coordination with tap fuses near the substation. No attempt is made to save the fuse in a fault situation. For a fault to the load side of a tap fuse, the fuse will clear the fault and the SEL-151 relay will not operate at all. A ground coordination example follows.

Using SELOGIC Control Equations:

TR(1246) = **50NLT**+... (TR is the programmable trip condition)

close TRIP output contacts = TR + ...

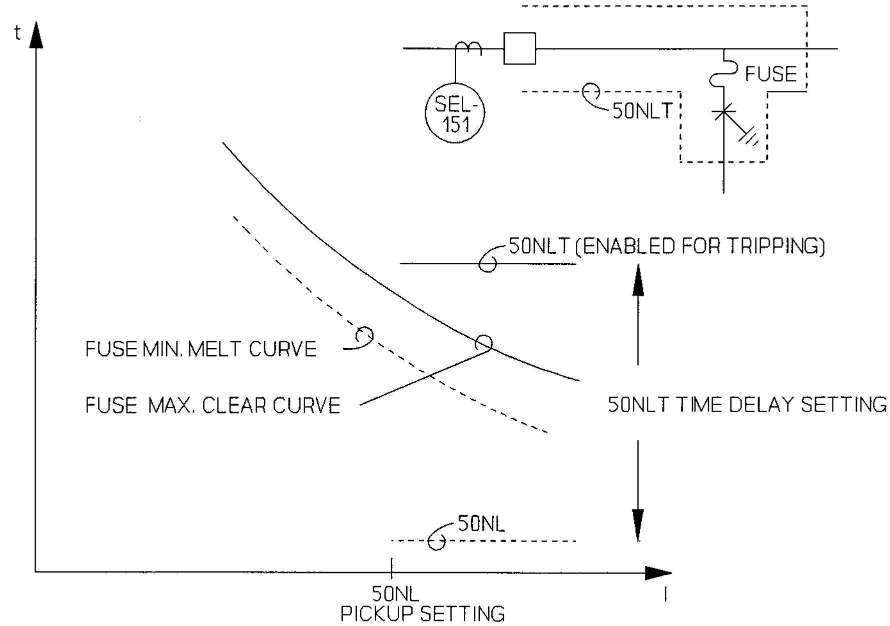


Figure 5.4: Trip Saving Using Ground/Residual Elements

The benefits of trip saving schemes are:

- The substation circuit breaker does not trip for faults beyond other protective devices (assuming proper coordination); faults are isolated locally, minimizing the number of customers affected by the outage.
- Damage to underground cable and other line equipment is minimized by not reclosing into faults beyond other protective devices (the substation circuit breaker doesn't trip in the first place).
- Other distribution circuits fed from the same substation transformer bank see fewer voltage distortions due to magnetizing inrush or fault current upon reclosure. Fewer trips means fewer consequent reclosures, resulting in fewer voltage distortions to other distribution circuits.

Utilities have written papers about converting from fuse to trip saving on many distribution feeder protection schemes:

> "Distribution Overcurrent Protection Philosophy Used at Duke Power Company," R.D. Melchior, B.W. Jackson, Georgia Tech Relay Conference, Atlanta, Georgia, April 29 - May 1, 1987.

"Relaying Changes That Will Reduce Blinks," Neil G. Engelman, P.E., Lincoln Electric System, Lincoln, Nebraska, 33rd Annual American Public Power Association Engineering and Operations Workshop, Washington, D.C., March 15, 1989.

"Relaying Changes Improve Distribution Power Quality," Neil G. Engelman, P.E., Lincoln Electric System, Lincoln, Nebraska, *Transmission & Distribution*, May 1990, pp. 72-76.

In these papers, trip saving implementations required extra timers for the instantaneous relays to realize definite-time overcurrent elements. Definite-time overcurrent elements are already available in the SEL-151 relay, eliminating the need for external timers.

BLOCKING SCHEMES FOR COLD LOAD INRUSH

Overcurrent elements with low pickup and low time delay settings can operate unintentionally on cold load inrush. These overcurrent elements need to be blocked from initiating tripping for a time period after circuit breaker closure if the potential for cold load inrush current exists.

Two overcurrent element blocking scheme implementations are possible. One scheme uses the **50C** Relay Word bit; the other uses the **52AT** Relay Word bit.

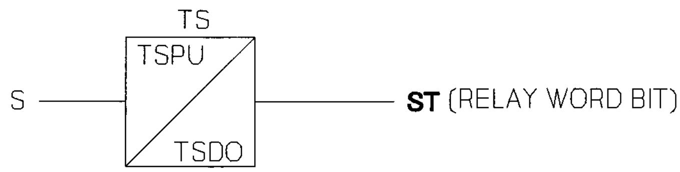
Blocking Scheme for Cold Load Inrush Using the 50C Bit

50C is a phase instantaneous overcurrent element that is not used in the reclosing relay reset inhibit function. Thus it can be set below load levels for a blocking scheme for cold load inrush. **50C** can assert with the presence of load current or deassert in its absence. With this setting, **50C** indicates whether the circuit breaker is closed or open. This scheme is not 52A dependent. To block an overcurrent element for cold load inrush for a time period after circuit breaker closure, supervise the element with a time delayed pickup **50C** condition.

If **50C** is used in this blocking scheme, it cannot be used in the internal torque control settings. The **50C** pickup setting would be too low.

Using SELogic Control Equations:

S(123) = **50C**



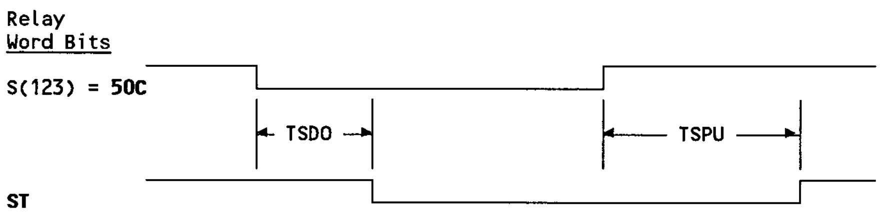


Figure 5.5: 50C Delayed by TSPU Time

If **50L** is supervised by **ST**, **50L** continues to be disabled for time period TSPU after the circuit breaker closes and load is picked up. Set TSPU slightly greater than the potential cold load inrush time.

Continuing with SELogic Control Equations:

B(12)	= **50L**	
E(34)	= **ST**	(time delayed **50C**)
V(56)	= **B*E**	
TR(1246)	= **V+...**	(TR is the programmable trip condition)

effectively, TR(1246) = **50L*ST+...**

close TRIP output contacts = TR + ...

If the TSDO setting exceeds the longest reclosing relay open interval time setting (79OI1, 79OI2, etc.), **ST** will not drop out during the reclose cycle. Thus, **50L** remains enabled throughout the cycle. **ST** drops out when TSDO expires after the recloser goes to lockout (the circuit breaker is open and **50C** = 0). This may be desirable since typical open interval times are not long enough to warrant concern about cold load inrush. Thus, **50L** is disabled for TSPU time only after the circuit breaker closes from the lockout state.

To disable **50L** only after the circuit breaker closes from the lockout state, make the following settings.

Using SELogic Control Equations:

S(123)	= **50C**	
B(12)	= **50L**	
E(34)	= **79RS+79CY+ST**	
V(56)	= **B*E**	
TR(1246)	= **V+...**	(TR is the programmable trip condition)

effectively, TR(1246) = **50L***(**79RS**+**79CY**+**ST**)+...

close TRIP output contacts = TR + ...

79RS = **79CY** = 0 when the relay is in the lockout state. **79RS** + **79CY** = 1 when the relay is not in the lockout state. Thus, **ST** effectively supervises **50L** only when the relay is in the lockout state. TSDO can be set to any value. **50L** is enabled while the reclosing relay is cycling. The 79RST setting should be greater than the TSPU setting.

If setting 50C is greater than minimum load levels, **50L** is disabled from initiating tripping during minimum load times. If a fault occurred during minimum load times, **50L** would be delayed from operating for the fault for TSPU time.

Blocking Scheme for Cold Load Inrush Using the 52AT Bit

The 52APU and 52ADO settings affect Relay Word bits **52AT** and **52BT** as follows:

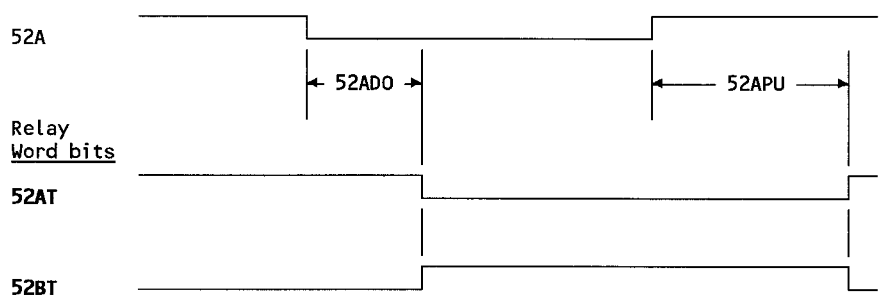


Figure 5.6: Effect of 52APU and 52ADO Settings on Relay Word Bits 52AT and 52BT

Note that **52BT** is the inverse of **52AT**. This discussion involves only **52AT**.

If **52AT** supervises **50L**, **50L** continues to be disabled for 52APU time after circuit breaker closure. Set 52APU slightly greater than the potential cold load inrush time.

Using SELogic Control Equations:

B(12)	= **50L**	
E(34)	= **52AT**	
V(56)	= **B*E**	
TR(1246)	= **V**+...	(TR is the programmable trip condition)

effectively, TR(1246) = **50L***52AT**+...

close TRIP output contacts = TR + ...

If setting 52ADO exceeds all reclosing relay open interval time settings (79OI1, 79OI2, etc.), **52AT** will not drop out during the reclose cycle, leaving **50L** enabled throughout the reclose cycle. **52AT** drops out when 52ADO time expires after the recloser goes to lockout (the circuit breaker is open and 52A = 0). This may be desirable since open interval times are not long enough to warrant concern about cold load inrush. Thus, **50L** continues to be disabled for 52APU time only after the circuit breaker closes from the lockout state.

To disable **50L** only after the circuit breaker closes from the lockout state, make the following settings.

Using SELOGIC Control Equations:

B(12) = **50L**
E(34) = **79RS+79CY+52AT**
V(56) = **B*E**
TR(1246) = **V**+... (TR is the programmable trip condition)

effectively, TR(1246) = **50L*(79RS+79CY+52AT)**+...

close TRIP output contacts = TR + ...

79RS = **79CY** = 0 when the relay is in the lockout state. **79RS** + **79CY** = 1 when the relay is not in the lockout state. Thus, **52AT** effectively supervises **50L** only when the relay is in the lockout state. 52ADO can be set to any value. **50L** is enabled while the reclosing relay is cycling. The 79RST setting should be greater than the 52APU setting.

DISABLE GROUND/RESIDUAL OVERCURRENT ELEMENTS

Ground relays are often temporarily disabled during distribution circuit paralleling operations. This is done to avoid ground relay trips resulting from residual current unbalance. This unbalance results from line switches not closing or opening all phases in unison when making or breaking parallel, respectively. Ground/residual overcurrent elements in the SEL-151 relay can be disabled by inputs functioning as permissive trip, block trip, or torque control inputs. You can apply the principles in the following examples to other elements.

Disable Ground/Residual Overcurrent Elements with Permissive Trip Input

When a permissive trip input is energized, selected overcurrent elements are enabled for tripping. When a permissive trip input is de-energized, selected overcurrent elements are disabled for tripping.

Inputs IN5 and IN6 are available in the Relay Word and can be effectively used as permissive trip inputs.

Using SELogic Control Equations:

A(12)	= **51NT**	(ground/residual time-overcurrent element)
F(34)	= **IN5**	(input IN5 to function as a permissive trip input)
V(56)	= **A*F**	
TR(1246)	= **V**+...	(TR is the programmable trip condition)

effectively, TR(1246) = **51NT*IN5**+...

close TRIP output contacts = TR + ...

Some applications may require that the permissive trip input supervise a low-set ground residual instantaneous overcurrent element. In the following example, 79SH also supervises the low-set ground/residual instantaneous overcurrent element **50NL** in a fuse saving scheme.

Using SELogic Control Equations:

A(12)	= **51NT**	(ground/residual time-overcurrent element)
B(12)	= **50NL**	(low-set ground residual instantaneous overcurrent element)
E(34)	= **79SH**	
F(34)	= **IN5**	(input IN5 will function as a permissive trip input)
V(56)	= **A*F**	
W(56)	= **B*E*F**	
TR(1246)	= **V**+**W**+...	(TR is the programmable trip condition)

effectively, TR(1246) = (**51NT*IN5**)+(**50NL*79SH*IN5**)+...
which reduces to: TR(1246) = [**51NT**+(**50NL*79SH**)]***IN5**+...

close TRIP output contacts = TR + ...

Disable Ground/Residual Overcurrent Elements with Block Trip Input

When a block trip input is energized, selected overcurrent elements are disabled for tripping. When a block trip input is de-energized, selected overcurrent elements are enabled for tripping. This function is the opposite of a permissive trip input.

Inputs IN5 and IN6 are available in the Relay Word and can be effectively used as block trip inputs.

Using SELogic Control Equations:

A(12)	= **51NT**	(ground/residual time-overcurrent element)
L(1234)	= **IN5**	(input IN5 to function as a block trip input)
V(56)	= **A*!L**	(**!L**=NOT(L) = NOT(**IN5**))
TR(1246)	= **V**+...	(TR is the programmable trip condition)

effectively, TR(1246) = **51NT***NOT(**IN5**)+...

close TRIP output contacts = TR + ...

Some applications may require that the block trip input supervise a low-set ground residual instantaneous overcurrent element. In the following example, **52AT** also supervises the low-set ground/residual instantaneous overcurrent element **50NL** in a fuse saving scheme.

Using SELOGIC Control Equations:

A(12)	= **51NT**	(ground/residual time-overcurrent element)
B(12)	= **50NL**	(low-set ground residual instantaneous overcurrent element)
E(34)	= **52AT**	
L(1234)	= **IN5**	(input IN5 will function as a block trip input)
V(56)	= **A*!L**	(**!L**=NOT(L) = NOT(**IN5**))
W(56)	= **B*E*!L**	
TR(1246)	= **V+W+...**	(TR is the programmable trip condition)

effectively, TR(1246) = [**51NT***NOT(**IN5**)]+[**50NL***52AT*NOT(**IN5**)]+...
which reduces to: TR(1246) = [**51NT**+(**50NL***52AT)]*NOT(**IN5**)+...

close TRIP output contacts = TR + ...

If the control wiring into input IN5 is accidently open circuited (IN5 is de-energized; IN5=0), elements supervised by IN5 are still enabled, enhancing dependability.

Disable Ground/Residual Overcurrent Elements with Torque Control Input

When a torque control input is energized, selected overcurrent elements are enabled for operation.

When a torque control input is de-energized, selected overcurrent elements are disabled from operation. In such a state, selected instantaneous overcurrent elements do not pick up if current exceeds their pickup settings. Selected definite-time overcurrent and time-overcurrent elements do not start timing when current exceeds pickup settings.

For example, assign input IN4 to function as the ground/residual overcurrent element torque control input. Using the SET G command (global settings):

IN4	= TCG	(external torque control input for ground/residual elements)

Then externally torque control the ground/residual time-overcurrent element **51NT**.

Using SELOGIC Control Equations:

TR(1246)	= **51NT**+...	(TR is the programmable trip condition)
ETC(1)	= **51NP**	(choose elements to be externally torque controlled)

close TRIP output contacts = TR + ...

Setting ETC(1) lists overcurrent pickups to be externally torque controlled. Element **51NP** is the pickup for **51NT**. If **51NP** is torque controlled, **51NT** is also torque controlled. This is how the relay achieves torque controlling for time-overcurrent and definite-time overcurrent elements via pickups.

In this example, energizing input IN4 enables the **51NT** element; de-energizing input IN4 disables the **51NT** element.

If IN4 = !TCG, the opposite sense is on the input. De-energizing input IN4 enables the **51NT** element; energizing input IN4 disables the **51NT** element.

Implementation of this scheme using the external torque control function is much more efficient than the previous two examples. You can use the SELOGIC Control Equations variables saved to implement other schemes as needed.

MINIMUM RESPONSE TIME FOR TIME-OVERCURRENT ELEMENTS

For time-overcurrent element coordination problems at higher fault current levels, you can incorporate a minimum response time into the time-overcurrent element. Such a time-overcurrent element cannot operate until a set minimum time passes. A ground/residual time-overcurrent element example appears below.

To implement this scheme, set **51NT** and **50NLT** with the same magnitude pickup setting (51NP = 50NL). Set the 50NLT setting with the desired minimum response time.

Using SELOGIC Control Equations:

A(12)	= **51NT**	(ground/residual time-overcurrent element)
B(12)	= **50NLT**	(ground residual definite-time overcurrent element)
V(56)	= **A*B**	
TR(1246)	= **V**+...	(TR is the programmable trip condition)

effectively, TR(1246) = **51NT*50NLT**+...

close TRIP output contacts = TR + ...

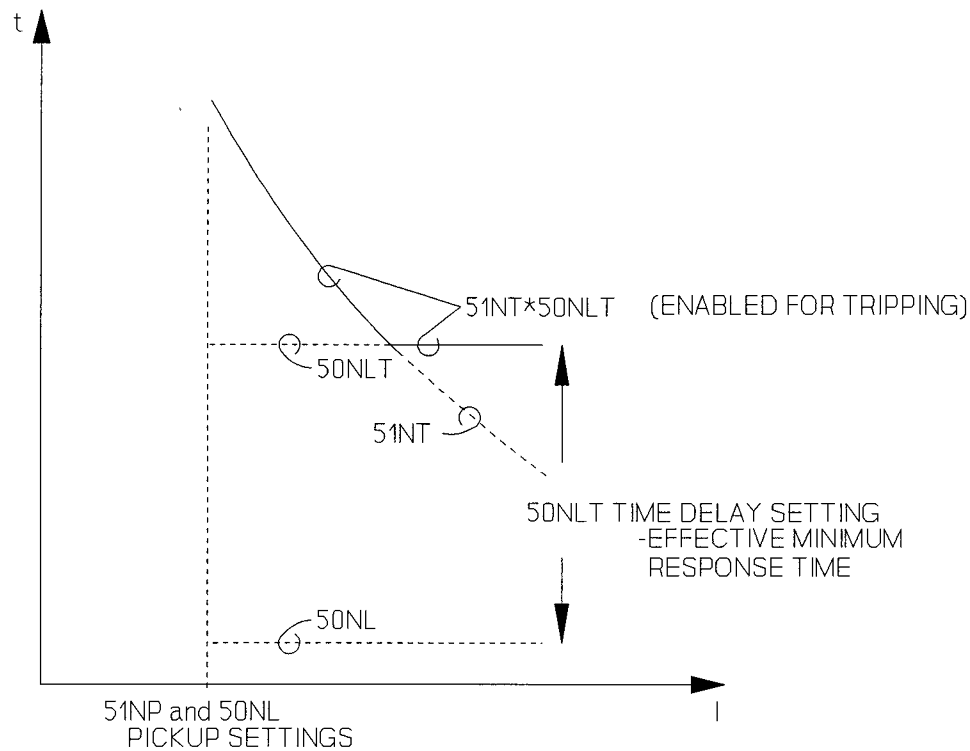


Figure 5.7: Minimum Response Time Using Ground/Residual Elements

NEGATIVE-SEQUENCE ELEMENTS PROTECT FOR PHASE FAULTS

Table 5.1 shows different system conditions and the currents generated by each.

Table 5.1: System Conditions and Currents Generated

System Condition	Phase Current (I_P)	Negative-sequence Current (I_2)	Zero-sequence Current (I_0)
LG Fault	X	X	X
LLG Fault	X	X	X
LL Fault	X	X	
3-Phase Fault	X		
Balanced Load	X		

In traditional distribution feeder protection, residually connected ground overcurrent relays operate on $3xI_0$ current and cover LG and LLG faults. Phase overcurrent relays operate on I_P current and cover LL faults and three-phase faults. Phase overcurrent relays are sensitive to load current; their pickup settings must exceed load current levels.

Negative-sequence overcurrent relay elements in the SEL-151 relay respond to $3xI_2$ current. These elements can be set to cover LL faults more sensitively than phase overcurrent elements. This is because negative-sequence overcurrent elements do not respond to balanced load current. For an LL fault (current magnitudes only):

$$I_2 = (\sqrt{3}/3) \text{ x } I_P$$

$$3xI_2 = \sqrt{3} \text{ x } I_P$$

$$= 1.73 \text{ x } I_P$$

Thus, a negative-sequence overcurrent element has the same sensitivity for LL faults as a phase overcurrent element if negative-sequence overcurrent element pickup value is a factor of 1.73 times the phase overcurrent element pickup value.

The following negative-sequence overcurrent elements (with respective settings) are available in the SEL-151 relay:

51QP Negative-sequence time-overcurrent element pickup
51QT Negative-sequence time-overcurrent element
Settings: 51QP pickup (secondary amps)
51QTD time dial
51QC curve
51QRS time delay or one cycle delay reset

The 51QRS setting activates time delay reset. During the setting procedure, the relay sends the message: "Dly Reset Y/N?" If you press **Y <ENTER>**, the negative-sequence time-overcurrent element emulates an induction disc, rotating back to reset after the $3xI_2$ current drops below 51QP (time delay reset). If you press **N <ENTER>**, the negative-sequence time-overcurrent element resets completely when the $3xI_2$ current drops below 51QP for one cycle (one cycle delay reset).

The other negative-sequence overcurrent elements and settings are:

50Q Negative-sequence definite-time overcurrent element pickup
50QT Negative-sequence definite-time overcurrent element
Settings: 50Q pickup (secondary amps)
50QT time delay

The SEL-151 relay phase and ground overcurrent elements have similar element types and settings.

If you coordinate the negative-sequence time-overcurrent element (**51QT**) with the phase time-overcurrent element of a line recloser, settings can be as sensitive as the line recloser phase time-overcurrent element pickup for LL faults. This is possible because **51QT** does not respond to balanced load. The relay requires proper coordination time between **51QT** and the line recloser phase time-overcurrent element.

If you coordinate **51QT** with a phase time-overcurrent element for LL faults, it should have no coordination problems with ground time-overcurrent elements. Ground time-overcurrent elements usually have pickup values one-third or one-fourth the magnitude of phase time-overcurrent relay pickups in their respective protection zones. Ground time-overcurrent relays also have shorter time dials than phase time-overcurrent relays in their respective protection zones. For an LG fault, **51QT** sees the same current magnitude as a ground time-overcurrent relay:

$$I_2 = I_0, \text{ for a LG fault}$$

$$3 \times I_2 = 3 \times I_0$$

Negative-Sequence Overcurrent Elements and Delta-Wye Transformers

Phase-to-ground and phase-to-phase faults on the secondary side of delta-wye transformers can generate negative-sequence currents on the primary system. This should be considered when entering negative-sequence element settings, especially if the delta-wye transformer bank is a large kVA transformer (small impedance). Ground/residual elements are not affected by such phase-to-ground faults because the delta winding does not allow zero-sequence generation in the primary system. See Figures 5.8 and 5.9.

Summary of Figure 5.8

In general, for a phase-to-ground fault on the secondary side of a delta-wye transformer, the following primary current relationship is true:

$$I_P = 1.73 \text{ x } I_2$$

$$1.73 \text{ x } I_P = 3 \text{ x } I_2$$

Thus, for this case, the negative-sequence overcurrent elements have the same sensitivity as a primary phase overcurrent element (e.g., the fuses for the delta-wye transformer) if the negative-sequence overcurrent element pickup value is a factor of 1.73 times the primary phase overcurrent element pickup value.

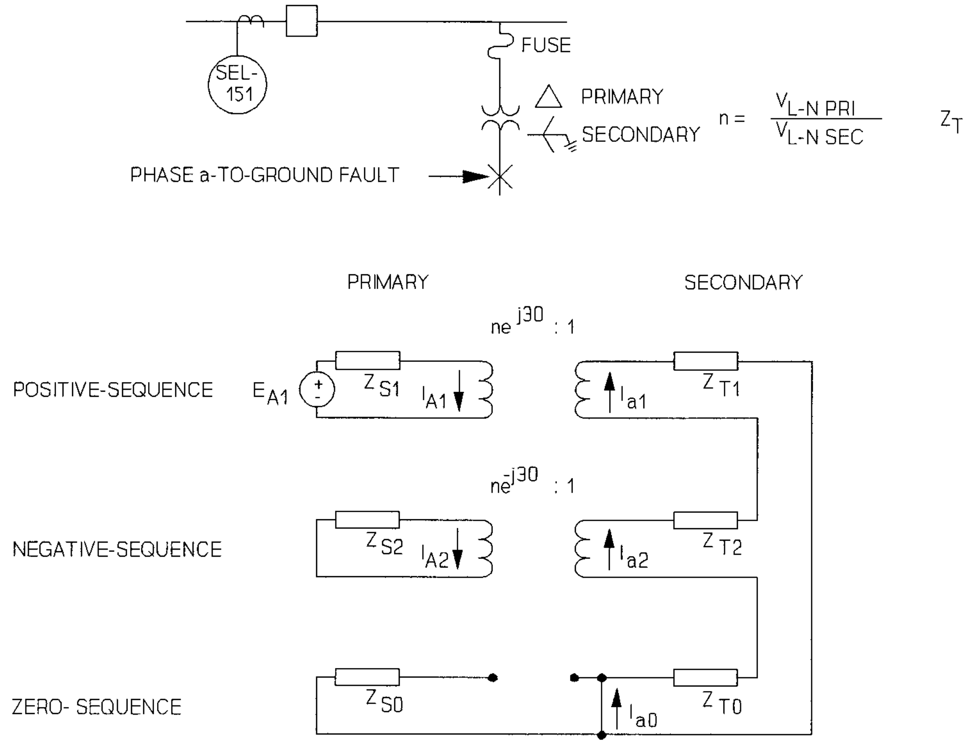
Summary of Figure 5.9

In general, for a phase-to-phase fault on the secondary side of a delta-wye transformer, the following primary current relationship is true:

$$I_P = 2 \text{ x } I_2$$

$$1.5 \text{ x } I_P = 3 \text{ x } I_2$$

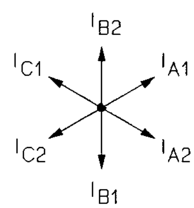
Thus, for this case, the negative-sequence overcurrent elements have the same sensitivity as a primary phase overcurrent element (e.g., the fuses for the delta-wye transformer) if the negative-sequence overcurrent element pickup value is a factor of 1.5 times the primary phase overcurrent element pickup value.



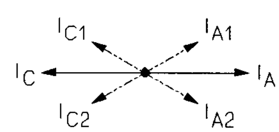
$$|I_{A1}| = |I_{A2}|$$

$$I_{a1} = I_{a2} = I_{a0}$$

$$I_A = I_{A1} + I_{A2}$$
$$I_B = I_{B1} + I_{B2} = 0$$
$$I_C = I_{C1} + I_{C2}$$



$$\sqrt{3}\,|I_{A2}| = |I_A|$$
$$\sqrt{3}\,|I_{C2}| = |I_C|$$



$$\sqrt{3}\ I_2 = I_P$$
$$3\ I_2 = \sqrt{3}\ I_P$$
$$\therefore \boxed{\frac{3\ I_2}{I_P} = \sqrt{3}}$$

Figure 5.8: Phase-To-Ground Fault on Delta-Wye Transformer Secondary

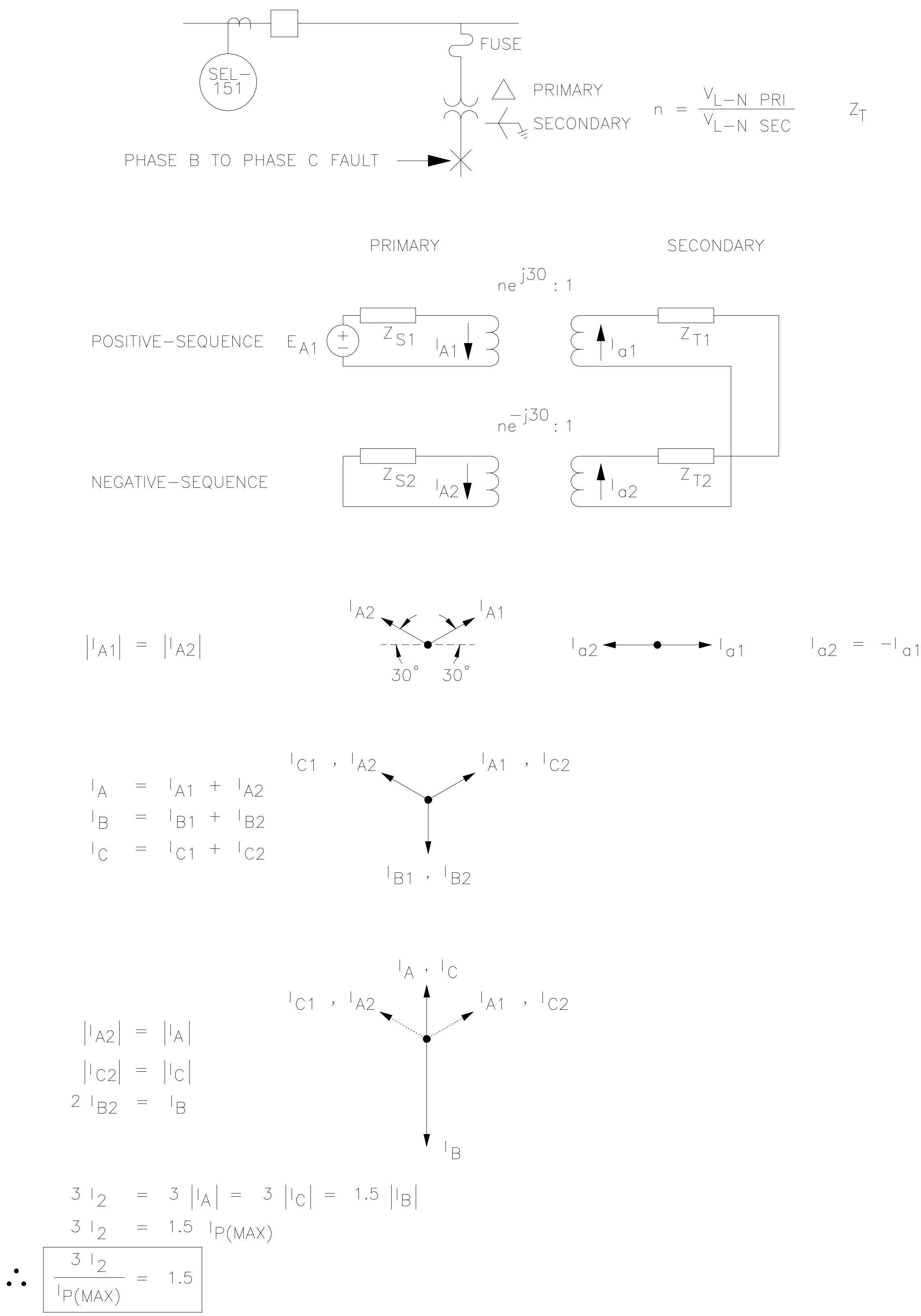


Figure 5.9: Phase-To-Phase Fault on Delta-Wye Transformer Secondary

UNDERFREQUENCY LOAD-SHEDDING INPUT

Relay Word inputs IN5 and IN6 can be used as time-qualified underfrequency load-shedding inputs. The output of an underfrequency relay is wired into IN5 or IN6.

Using SELOGIC Control Equations:

K(1234) = **IN5**

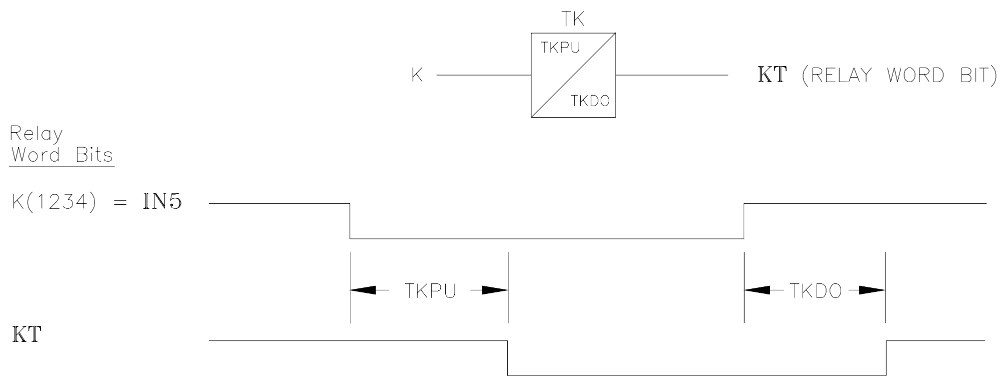


Figure 5.10: Input IN5 Qualified by Time TKPU

Time TKPU qualifies the underfrequency input condition.

Continuing with SELOGIC Control Equations:

TR(1246) = **KT**+... (TR is the programmable trip condition)

close TRIP output contacts = TR + ...

Relays on different feeders can have different TKPU time delay pickup settings so certain feeders are tripped before others during a system underfrequency condition.

UNDERVOLTAGE LOAD-SHEDDING

An undervoltage load-shedding condition is possible by time qualifying the **27** Relay Word bit.

Using SELogic Control Equations:

K(1234) = **27**

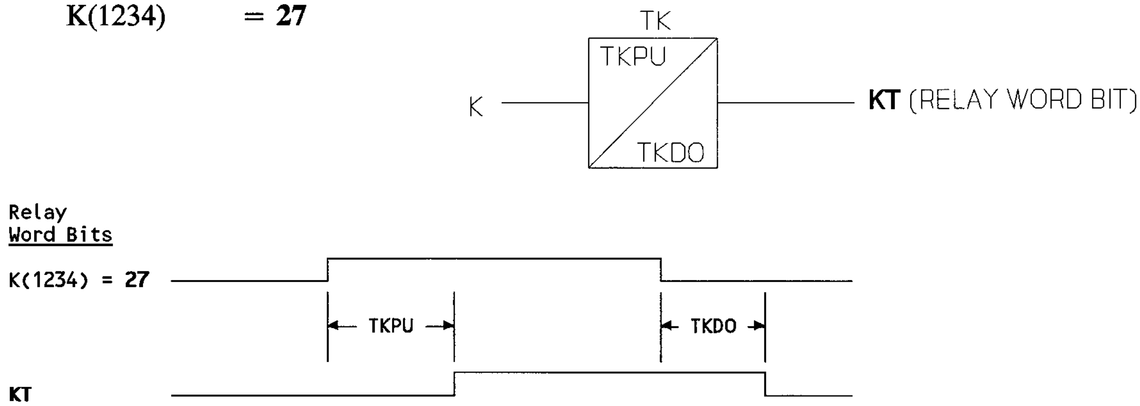


Figure 5.11: Element 27 Qualified by Time TKPU

The TKPU time qualifies the undervoltage condition.

Continuing with SELogic Control Equations:

TR(1246) = **KT**+... (TR is the programmable trip condition)

close TRIP output contacts = TR + ...

A system undervoltage condition is a three-phase phenomenon, so the **27** element should be set three-phase sensitive (setting 27C = 3). Set high- and low-set limits for **27** (27H and 27L), according to system conditions. The input voltage to the SEL-151 relay needs to be to the source-side of the circuit breaker the relay is controlling.

BREAKER FAILURE

Use the **TF** bit in the Relay Word to create a breaker failure scheme.

Using SELogic Control Equations:

A1(1234)	= **TF**

Output contact A1 operates as a breaker failure output. Breaker failure applications need the following setting relationship.

TFT (Trip Failure Time) > TDUR (Trip Duration Time)

Breaker Failure Implementation Notes

The "close TRIP output contacts" condition drives the trip failure timer. This condition ends if all trip conditions vanish and all overcurrent element pickups in Relay Word row R1 drop out. For more information, see Figure 2.22.

Even if a circuit breaker trips successfully and all overcurrent element pickups in Relay Word row R1 drop out, a trip condition can still be present.

For example, TR(1246) = **KT**+..., from the previous underfrequency or undervoltage load-shedding applications.

close TRIP output contacts = TR(1246) +...

In this example, a false breaker failure operation can occur if **KT** remains asserted long enough for the trip failure timer to expire. This problem can be overcome if trip condition **KT** is qualified by the presence of load current or limited in duration.

Qualify Trip Condition with Presence of Load Current

Phase instantaneous overcurrent element **50C** is not used in the reclosing relay reset inhibit function and can be set below load levels. **50C** can assert with the presence of load current or deassert in its absence. With this low setting **50C** can indicate whether the circuit breaker is closed or open. There is no 52A dependence.

Using SELogic Control Equations to qualify **KT**:

A(12)	= **50C**	
K(1234)	= **IN5** or **27**	(underfrequency or undervoltage application)
V(56)	= **A*KT**	
TR(1246)	= **V**+...	(TR is the programmable trip condition)

close TRIP output contacts = TR + ...

Limit Trip Condition Time Duration

Limiting the **KT** trip condition duration to a time shorter than TFT prevents false breaker failure operation.

Using SELogic Control Equations to effectively limit the duration of **KT**:

S(123)	= **IN5** or **27**	(underfrequency or undervoltage application)
L(1234)	= **ST**	
K(1234)	= **IN5** or **27**	(underfrequency or undervoltage application)
V(56)	= **KT*!L**	(**!L** limits the duration of **KT**)
TR(1246)	= V+...	(TR is the programmable trip condition)

close TRIP output contacts = TR + ...

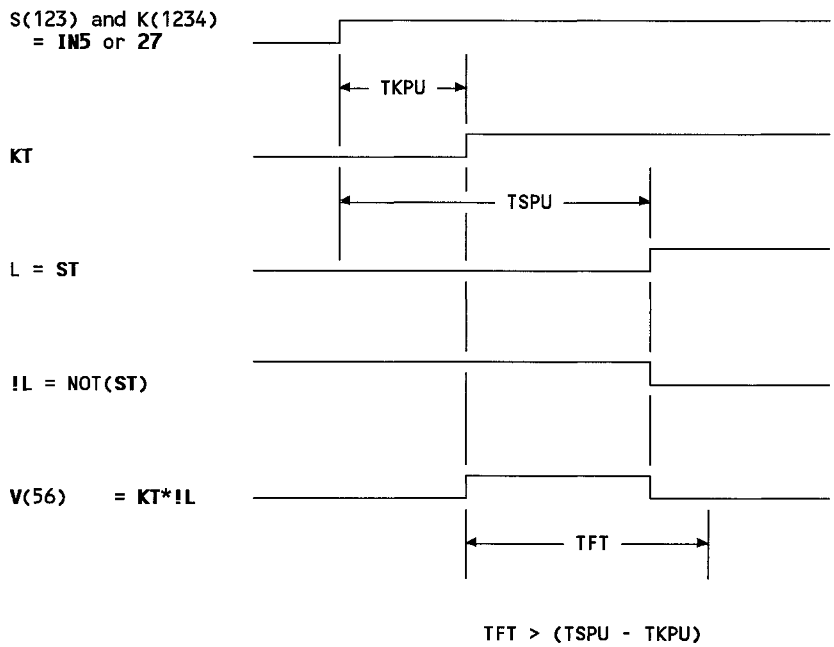


Figure 5.12: Underfrequency or Undervoltage Trip Condition Time Duration Limit

RESIDUAL CURRENT UNBALANCE ALARM

The **NDEM** bit asserts when current exceeds ground/residual demand threshold setting NDEM.

Using SELOGIC Control Equations:

A2(1234) = **NDEM**

Output contact A2 asserts for residual current unbalance. It can also warn of impending ground/residual overcurrent relay pickup due to residual current unbalance.

All demand ammeters use the same time constant (DATC = 15 or 60 minutes).

BLOCK VOLTAGE REGULATING LOAD-TAP-CHANGER OPERATION

Load-tap-changers should not operate when a reclosing cycle is in progress because fault current should not pass through a tap-changer in motion. Also, if the voltage input to the load-tap-changer is on the load side of the feeder circuit breaker, the load-tap-changer will see zero voltage during the reclosing relay open intervals and will erroneously start to move toward the highest tap possible in an attempt to raise the voltage.

The **79CY** bit asserts when the reclosing relay is in the reclose cycle state.

Using SELOGIC Control Equations:

A3(1346) = **79CY** (Output contact A3 should be configured as a "b" contact)

The A3 output contact is wired in series with the load-tap-changer control. The A3 output contact open circuits the control when the reclosing relay is in the reclosing cycle. This prevents load-tap-changer operation.

EXTRA ALARM OUTPUT CONTACTS

If an input is assigned to the 52A or !52A function, the reclosing relay states in the Relay Word are functional:

79RS = reclosing relay in the reset state
79CY = reclosing relay in the reclose cycle state
79LO = reclosing relay in the lockout state

Only one state is asserted at a time; one state is always asserted if they are functional (as determined by the above criteria).

Using SELogic Control Equations:

A4(2346) = **79RS+79CY+79LO**

The A4 output contact is always asserted. If A4 is a "b" output contact, it is always in the "open" position.

If a relay self test fails, output contacts are inoperative. In this situation, the A4 output contacts close. The A4 output contacts also close if the relay loses power. Thus, A4 performs alarming functions much like the dedicated ALARM output contacts.

With this setting the A4 output contacts do not close for access level changes, but pulse closed when you make setting changes to the active setting group with the COPY, GROUP, or SET commands.

Extra alarm contacts can be used to notify backup protective relays of the primary relay failure condition so that protection adjustments can be made. Extra alarm contacts can also be used for local annunciation, SCADA input, trip supervision, etc.

The same result can be achieved using **52AT** and **52BT** (**52BT** = NOT(**52AT**)):

A4(2346) = **52AT** + **52BT**

BACKUP FEEDER RELAYS WITH A BUS RELAY

Use one SEL-151C relay to backup the SEL-151 relays installed on individual feeders. The feeder relay ALARM contact can supervise a trip from the bus relay because backup is required only when the feeder relay fails. Because of this supervision, the bus relay TRIP output contacts can be set to operate simultaneously with feeder relay TRIP output contacts, both attempting to trip the feeder circuit breaker.

Time delayed trips from the feeder relays (for feeder circuit breaker failures) and the bus relay can trip the bus breaker. These time delayed trips are possible using the trip failure logic available in the SEL-151 and SEL-151C relays.

Using SELogic Control Equations (for SEL-151 and SEL-151C relays):

A1(1234) = **TF**

The TFT (trip failure time) settings provide the time delay for the A1 output contacts.

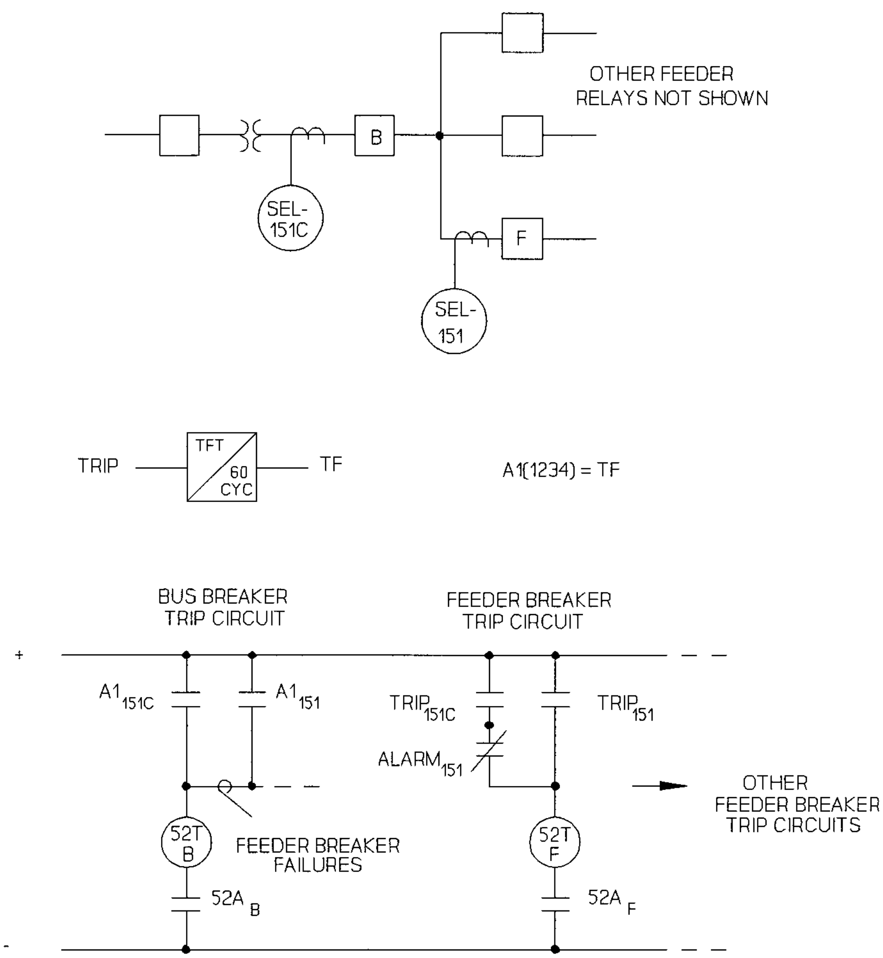


Figure 5.13: Distribution Feeder Relay Backup Scheme

FEEDER RELAY SETTING CHANGES

When a faulted feeder section is isolated and customers beyond the fault are backfed, the feeder configurations are different. One is shorter with less load, while the other is longer with more load. Save setting groups for different feeder configurations to optimize protection.

You can parallel one feeder with another for breaker maintenance. Program setting groups for normal or parallel operation.

BUS-TIE RELAY SETTING CHANGES

In stations where bus-tie breakers substitute for feeder breakers during maintenance, the bus-tie breaker relay can have a setting group for each feeder it protects.

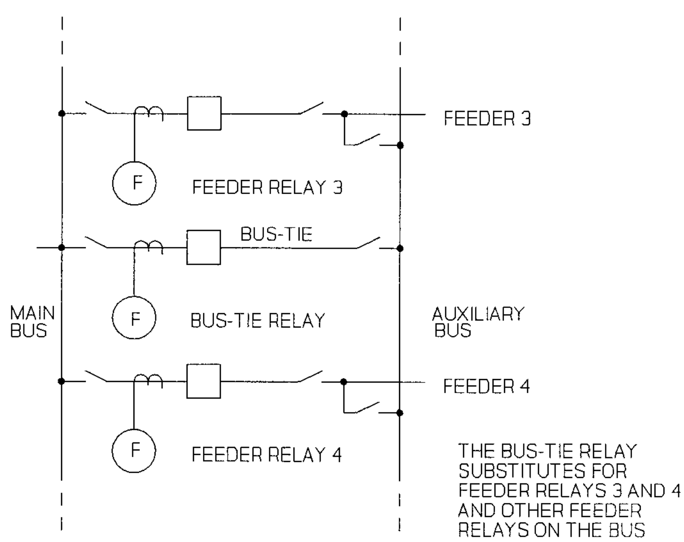


Figure 5.14: Main/Auxiliary Bus with Bus-Tie Circuit Breaker

CLOCK-DRIVEN SETTING GROUP SELECTION

Consider seasonal, weekend/weekday, and daily system changes. Develop optimum settings for various times, and use clock contacts to select appropriate settings.

DEMAND-DRIVEN SETTING GROUP SELECTION

Trigger a change to less sensitive settings when demand (phase, negative-sequence or ground/residual) encroaches on relay settings, thus avoiding nuisance trips. Set an alarm so problems can be investigated.

SYSTEM RESTORATION AFTER UNDERFREQUENCY LOADSHEDDING

After a feeder circuit breaker has been tripped by an underfrequency relay, the reclosing relay in the SEL-151 relay can reclose the breaker, after system frequency returns to normal. Manual or SCADA closing of the breaker is not necessary. This can be of benefit in remote substations that are not readily accessible by utility personnel or do not have SCADA-type control. This reclosing function is realized in the following example (see Figures 5.15 and 5.16):

IN6 = !52AR	Circuit Breaker Status (52B contact input)/Reclose Initiate

If input IN6 is de-energized and then energized, circuit breaker status is interpreted to be a breaker in the process of opening ($52B_F$ contacts assert for opening breakers) and this initiates reclosing.

When an underfrequency condition is present, the underfrequency relay contacts (81U) close, tripping the feeder circuit breaker and energizing the auxiliary relay (AUX). In the feeder relay circuit breaker status input circuit, the AUX contact ("b" seal) opens to prevent reclose initiation by the assertion of the $52B_F$ contact (continue to keep input IN6 de-energized during the underfrequency condition).

There can be a possible contact race between the $52B_F$ and AUX contacts in the feeder relay circuit breaker status input circuit. If the $52B_F$ contact closes before the AUX contact opens, input IN6 will be energized and reclosing will be initiated for an underfrequency trip.

To avoid this problem, the circuit breaker status function internal to the relay has a 10 cycle delay to qualify circuit breaker opening, when 52AR or !52AR is assigned to an input. For this application, if the AUX contact opens in less than 10 cycles after the $52B_F$ contact closes, the circuit breaker status function deems the circuit breaker still closed and reclosing is not initiated.

When system frequency returns to normal, the 81U contacts open, de-energizing the AUX relay. The $52B_F$ contact is already closed, so the closing of the AUX contact energizes input IN6. After the 10 cycle delay to qualify circuit breaker opening, the circuit breaker is deemed to have opened and reclosing is initiated (the reclose cycle starts).

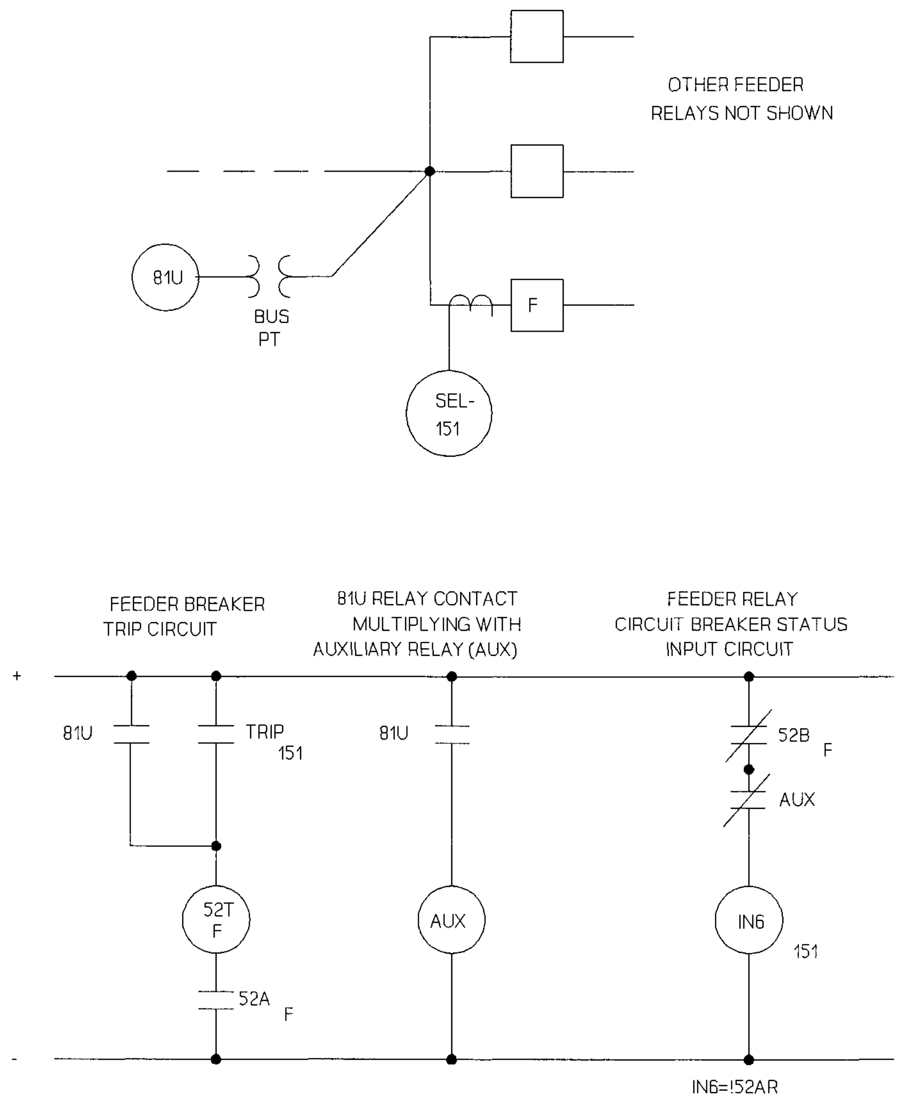


Figure 5.15: Underfrequency Loadshedding and Reclose Initiate Supervision

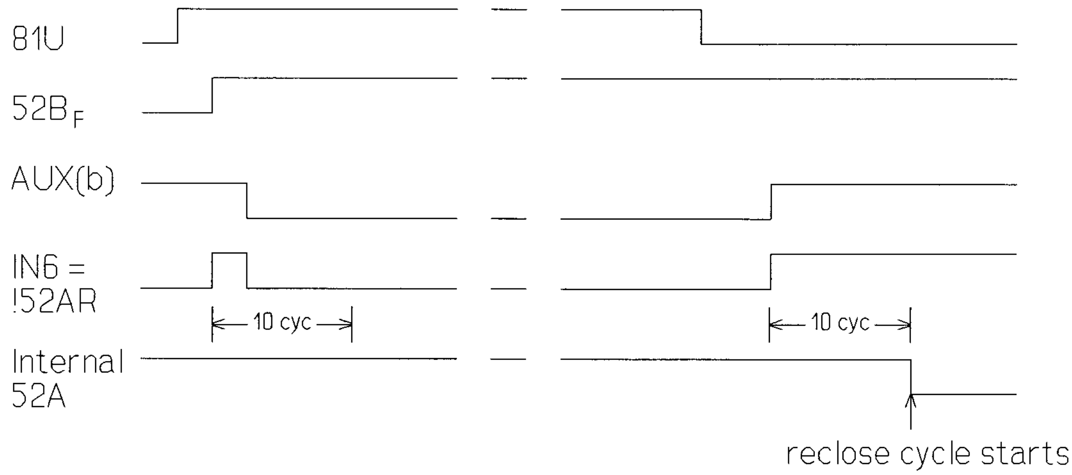


Figure 5.16: Timing for Reclose Initiation

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INSTALLATION

INSTALLATION

Mounting

The relay is designed for mounting by its front vertical flanges in a 19" vertical relay rack. It may also be mounted semi-flush in a switchboard panel. Use four #10 screws for mounting. This section includes front and rear panel drawings.

Frame Ground Connection

Terminal 35 or 36 on the rear panel must be connected to frame ground for safety and performance. These terminals connect directly to the chassis ground of the instrument.

Power Connections

Terminals 37 and 38 on the rear panel must be connected to a source of control voltage. Control power passes through these terminals to the fuse(s) and a toggle switch, if installed. The power continues through a surge filter and connects to the switching power supply. The control power circuitry is isolated from the frame ground.

Secondary Circuits

The relay presents a very low burden to the secondary potential and current circuits. It requires three currents from the power system current transformer secondaries.

The four-wire wye potential from potential transformer secondaries is optional. It is used for fault locating, voltage and MW/MVAR metering, and undervoltage torque control.

Control Circuits

The control inputs are dry. For example, to assert the IN5 input, you must apply control voltage to the IN5 input terminals. Each input is individually isolated, and a terminal pair is brought out for each input. There are no internal connections between control inputs.

Control outputs are dry relay contacts rated for tripping duty. A metal-oxide varistor protects each contact. Each control circuit input and output point is bypassed to chassis ground via a 0.0047 uF, 3000 Vdc disc ceramic capacitor.

Communications Circuits

Connections to the two EIA RS-232-C serial communications ports are made via the two nine-pin connectors labelled PORT 1 and PORT 2 on the rear panel. Pins 1 and 9 connect directly to frame (chassis) ground.

Warning: Do not rely upon pins 1 and 9 for safety grounding, since their current-carrying capacity is less than control-power short circuit current and protection levels.

The communications circuits are protected by low-energy, low-voltage MOVs and passive RC filters. You can minimize communications-circuit difficulties by keeping the length of the EIA RS-232-C cables as short as possible. Lengths of twelve feet or less are recommended, and the cable length should never exceed 100 feet. Use shielded communications cable for lengths greater than ten feet. Modems are required for communications over long distances.

Route the communications cables well away from the secondary and control circuits. Do not bundle the communications wiring with secondary or control circuit wiring. If these wires are bundled, switching spikes and surges can cause noise in the communications wiring. This noise may exceed the communications logic thresholds and introduce errors. The IRIG-B clock cable should also be routed away from the control wiring and secondary circuits.

Jumper Selection

All jumpers are on the front edge of the main board. They are easily accessed by removing the top cover or front panel.

EIA RS-232-C Jumpers

JMP105 provides EIA RS-232-C baud rate selection. Available baud rates are 300, 600, 1200, 2400, 4800, and 9600. To select a baud rate for a particular port, place the jumper so it connects a pin labeled with the desired port to a pin labeled with the desired baud rate.

Caution: Do not select two baud rates for the same port. This can damage the baud rate generator.

Password Protection Jumper

Put JMP103 in place to disable password protection. This feature is useful if passwords are not required or when passwords are forgotten.

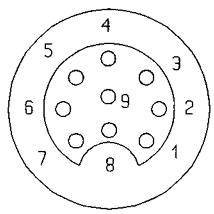
OPEN/CLOSE Command Enable Jumper

With jumper JMP104 in place, the OPEN and CLOSE commands are enabled. If you remove jumper JMP104, OPEN and CLOSE command execution results in the message: "Aborted."

EIA RS-232-C and IRIG-B Installation

This section contains specific information concerning pinouts of the communications ports.

A pin definition of the nine-pin port connectors and cabling information for the EIA RS-232-C ports appears below in Figure 6.1. The following cable listings show several types of EIA RS-232-C cables. These and other cables are available from SEL. Cable configuration sheets are also available at no charge for a large number of devices. Contact the factory for more information.



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

Figure 6.1: Nine-Pin Connector Pin Number Convention

EIA RS-232-C Cables

```
SEL Relay           25-Pin *DTE DEVICE

GND  1 ---------------- 7   GND
TXD  2 ---------------- 3   RXD
RTS  3 ---------------- 5   CTS
RXD  4 ---------------- 2   TXD        (SEL  CABLE 123)
CTS  5 ---------------- 4   RTS
+5   6
+12  7
-12  8
GND  9 ---------------- 1   GND
                        6-┐ DSR
                        8-┤ DCD
                       20-┘ DTR
```

```
SEL Relay           25-Pin **DCE DEVICE

GND   1 --------------- 7   GND
TXD   2 --------------- 2   RXD
RTS   3 --------------- 20  DTR        (SEL  CABLE 422)
RXD   4 --------------- 3   TXD
CTS   5 --------------- 8   CD
GND   9 --------------- 1   GND
```

```
SEL Relay                    9-Pin *DTE DEVICE

GND  1 ------------------- 5   GND
TXD  2 ------------------- 2   RXD
RTS  3 ------------------- 8   CTS
RXD  4 ------------------- 3   TXD          (SEL  CABLE 134)
CTS  5 ------------------- 7   RTS
                           1-┐ DCD
                           4-┤ DIR
                           6-┘ DSR
                           9   RI
```

```
SEL Relay                      PRTU

GND   1 ------------------ 1   GND
TXD   2 ------------------ 4   RXD
RXD   4 ------------------ 2   TXD          (SEL  CABLE 331A - 338A)
CTS   5 ------------------ 7   +12
+12   7 ------------------ 5   CTS
GND   9 ------------------ 9   GND
```

* DTE = Data Terminal Equipment (terminals, printers, computers, etc.)
** DCE = Data Communications Equipment (modems, etc.)

IRIG-B Input Description

The port labelled J201/AUX INPUT receives demodulated IRIG-B input. Pin definitions appear in Table 6.1.

Table 6.1: AUX INPUT Pin Definition

Pin	Name	Description
2	IRIGIN HI	Positive IRIGB input
3	IRIGIN LOW	Negative IRIGB input
6	+5 *	
7	+12 *	
8	-12 *	
1,5,9	GND	Ground

* Consult the factory before using these power supply outputs

The actual IRIG-B input circuit is a 56 ohm resistor in series with an optocoupler input diode. The input diode has a forward drop of about 1.5 volts. Driver circuits should put approximately 10 mA through the diode when "on."

The IRIG-B serial data format consists of a one second frame containing 100 pulses and divided into fields. The relay decodes the second, minute, hour, and day fields and sets the internal relay clock accordingly.

When IRIG-B data acquisition is activated either manually (with the IRIG command) or automatically, two consecutive frames are taken. The older frame is updated by one second and the two frames are compared. If they do not agree, the relay considers the data erroneous and discards it.

The relay reads the time code automatically about once every five minutes. The relay stops IRIG-B data acquisition ten minutes before midnight on New Year's Eve so the relay clock may implement the year change without interference from the IRIG-B clock. Ten minutes later, the relay restarts IRIG-B data acquisition.

INSTALLATION CHECKOUT

You may follow the suggestions below or combine them with your normal practice. Never implement recommendations prohibited by the rules of your normal practice. The checkout procedure recommends various settings for ease of testing. These settings may not be applicable to an in-service installation.

The following equipment is required for initial checkout:

- Portable terminal or computer with interconnecting cable (connect to PORT 2)
- Control power to the relay power connections
- Source of three-phase voltages and at least one current source
- Ohmmeter or contact opening/closing device

1. Apply control power and make sure the terminal displays the startup message. If not, set AUTO = 2 with the SET G command in Access Level 2. Check the settings with the ACCESS and SHOWSET commands. Use the TIME command to set the clock.

2. Apply three-phase voltages. Execute the METER command and make sure the readings are accurate. If they are not, be sure the correct PT ratio was entered. Remember that displayed values are in primary line-to-neutral and line-to-line volts.

3. Use the TRIGGER command to generate an event record. Type **EVENT 1 <ENTER>** and examine the event record. Refer to the top row of data as the "Y" components and the next row as the "X" components. Using the SEL Direction and Polarity Check Form at the end of this section, plot the three voltage phasors to ensure that they are 120° apart, of reasonable magnitudes, and rotating in the positive-sequence direction. The zero-sequence voltage Y and X components (times a factor of three) are the totals of the three Y components and the three X components. These sums should be near zero if balanced three-phase potentials are present.

4. Use the TARGET command to check all inputs (IN1-IN6). Type **TAR 7 <ENTER>** and the front panel target LEDs display input states. Corresponding targets and inputs appear below:

INST	A	B	C	Q	N	RS	LO	Front Panel Targets
		IN6	IN5	IN4	IN3	IN2	IN1	Inputs

   An LED illuminates when a corresponding input is energized with nominal control voltage. Apply nominal control voltage to each input and make sure the corresponding LED illuminates. When the test is complete, type **TAR R <ENTER>** to reset and clear the front panel target LEDs.

5. Proceed to Access Level 2 with the 2ACCESS command and second password. Be sure the ALARM relay contacts close and open when the relay executes the 2ACCESS command. The ALARM pulse will not be detectable if the ALARM contacts are closed due to an alarm condition.

6. Test the TRIP output contacts by executing the OPEN command (The OPEN/CLOSE command enable jumper JMP104 must be in place). The TRIP output contacts remain asserted for at least the length of the TDUR (trip duration) setting and will not deassert until all overcurrent elements in Relay Word row R1 drop out or you press the front panel TARGET RESET button.

7. Test the CLOSE output contact by executing the CLOSE command (the OPEN/ CLOSE command enable jumper JMP104 must be in place). CLOSE output contact operation requires that a 52A, !52A, 52AR, or !52AR function be assigned to an input (for example, IN6=52A). With IN6 de-energized (circuit breaker open), execute the CLOSE command.

   The CLOSE contacts remain asserted for as long as the CFT (close failure time) setting unless the TRIP output contact is asserted or IN6 is energized (circuit breaker apparently closed). If CFT = 0, CLOSE remains asserted indefinitely unless TRIP is asserted or IN6 is energized (circuit breaker closed).

8. Test the programmable output contacts A1, A2, A3, and A4. Using the SET command, set these contacts to assert when input IN5 is energized. **IN5** is in Relay Word row R3 and accessible by A1, A2, A3, and A4 output contact settings:

   A1(1234) = IN5
   A2(1234) = IN5
   A3(1346) = IN5
   A4(2346) = IN5

   After entering the previous settings, apply nominal control voltage to input IN5 and observe A1, A2, A3, and A4 output contact assertion.

9. Use the STATUS command to inspect the self test status. You may wish to save the reading as part of an as-left record.

When local checkout is complete, check communications with the instrument via a remote interface (if used). Make sure the automatic port is properly assigned and that desired timeout intervals are selected for each port. Also, be sure to record password settings.

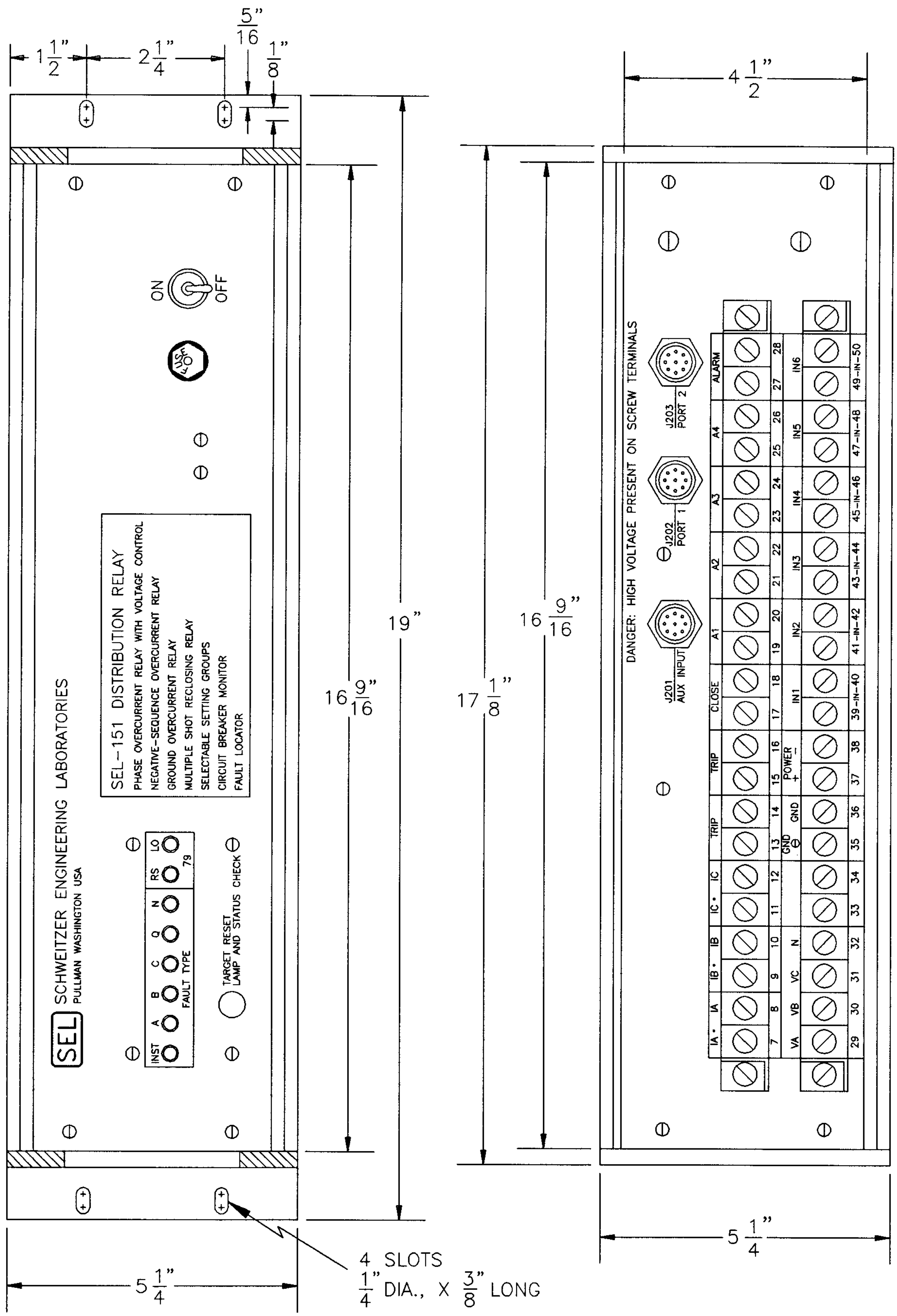
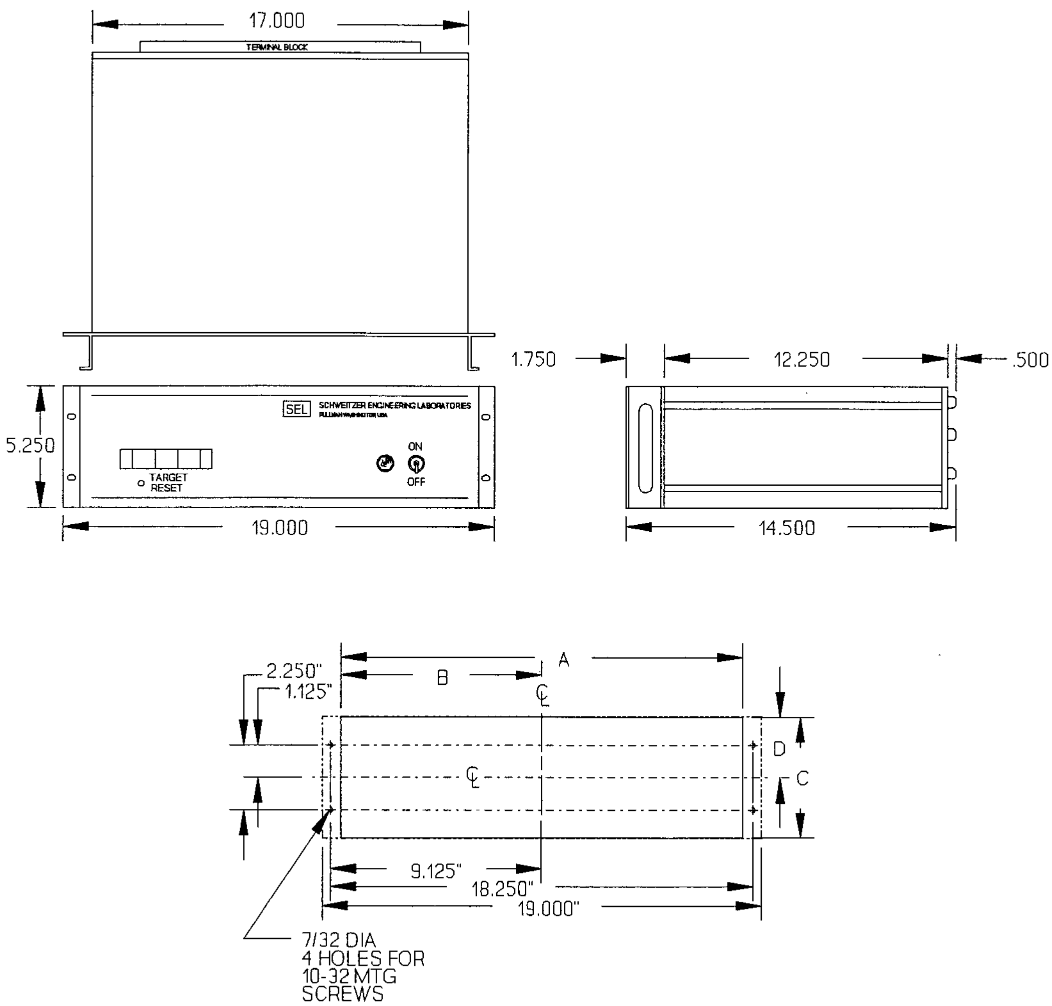


Figure 6.2: SEL-151 Relay Horizontal Front and Rear Panel Drawings



DIMENSION A:
CUT OUT: 17.250" - 17.875"
17.375" PREFERRED
DIMENSION B:
CUT OUT: 8.625" - 8.9375"
8.688" PREFERRED
DIMENSION C:
CUT OUT: 5.350" - 5.450"
DIMENSION D:
CUT OUT: 2.675" - 2.725"

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

PANEL CUTOUT AND DRILL FOR SEMI-FLUSH MOUNTING OF 5.250 INCH HIGH CASE.

Figure 6.3: Relay Dimensions, Panel Cutout, and Drill Diagrams

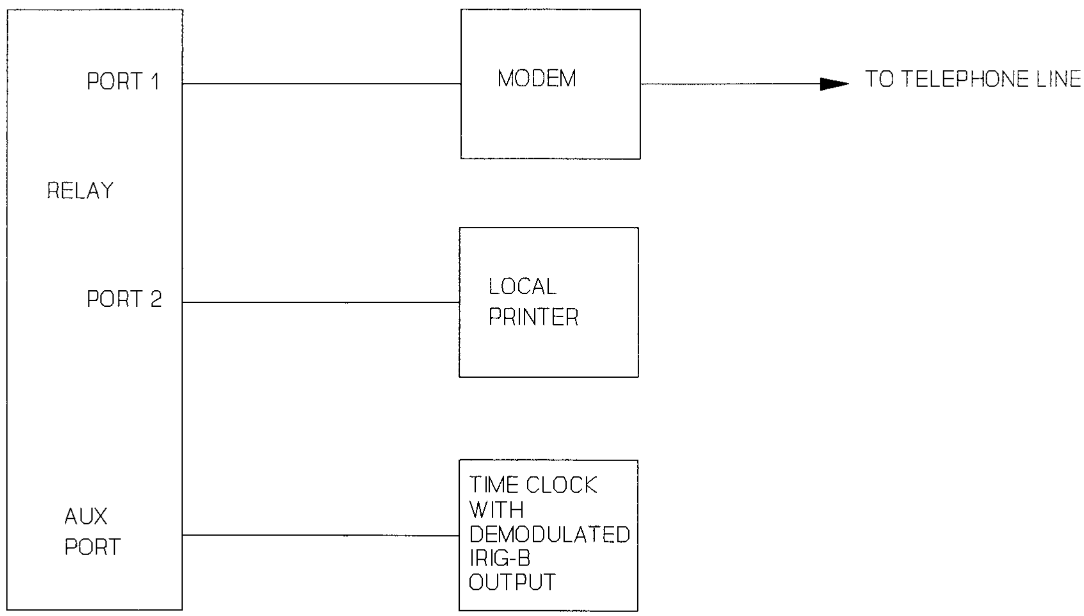


Figure 6.4: Communications and Clock Connections - One Unit at One Location

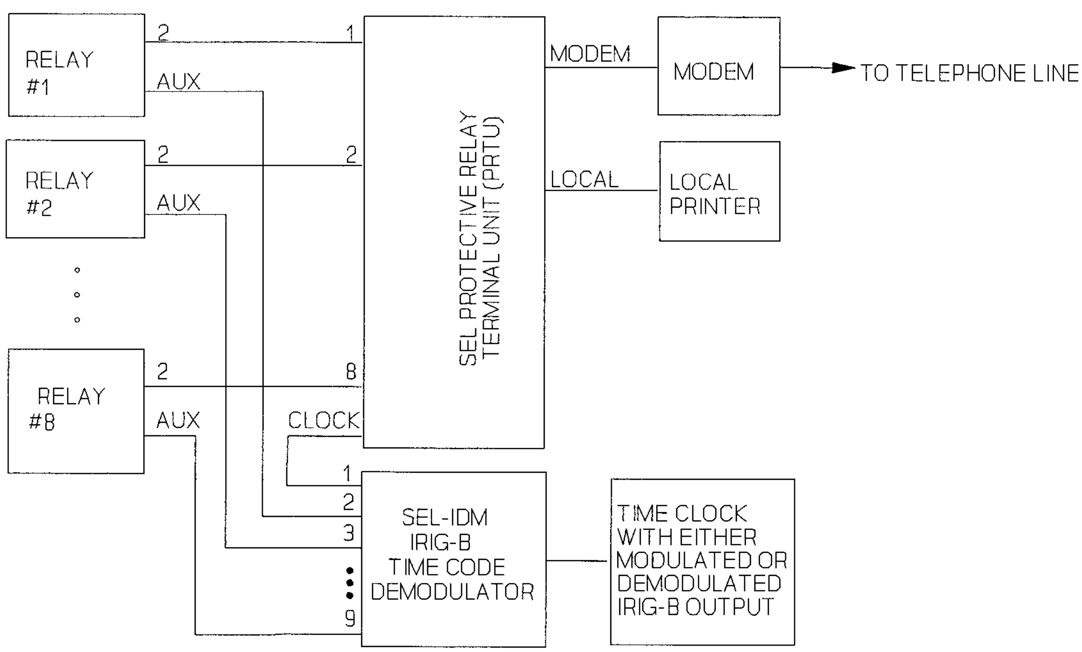


Figure 6.5: Remote Communications, Local Display, and Clock Connections - Multiple Relay Units at One Location

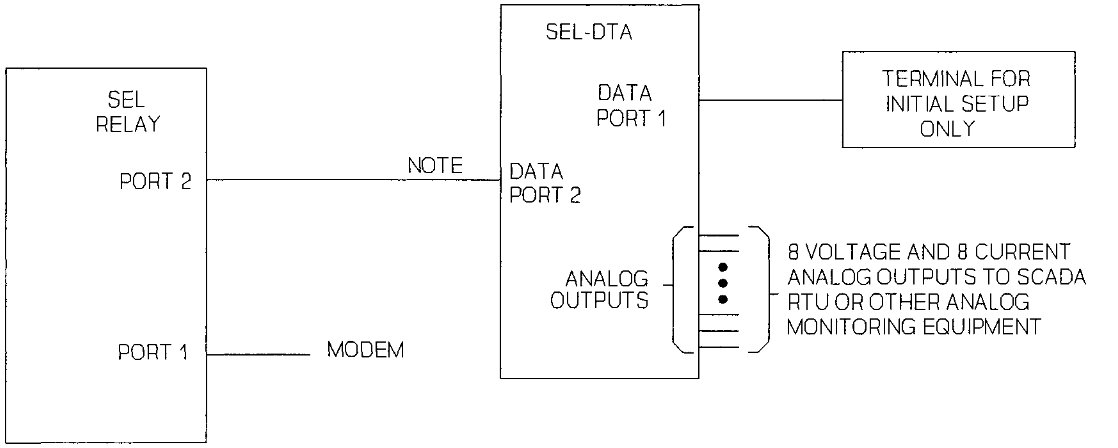


Figure 6.6: SEL Relay Communications Diagram for Connection to the SEL-DTA

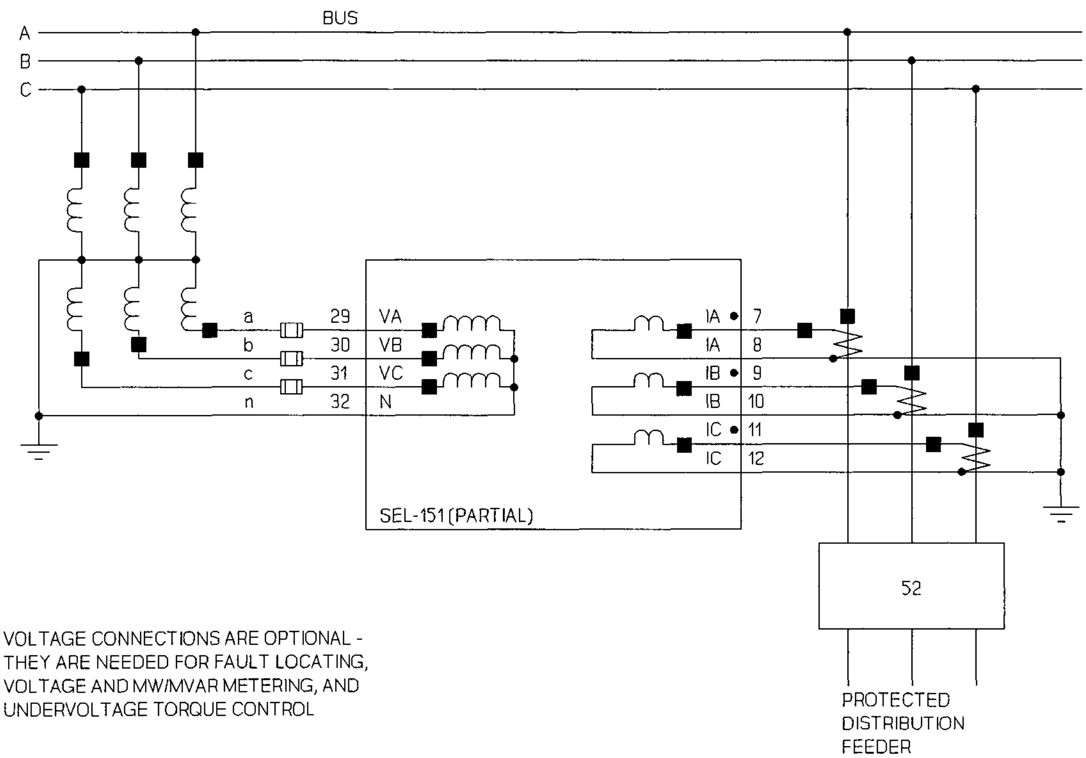


Figure 6.7: SEL-151 Relay Typical AC External Current and Voltage Connections

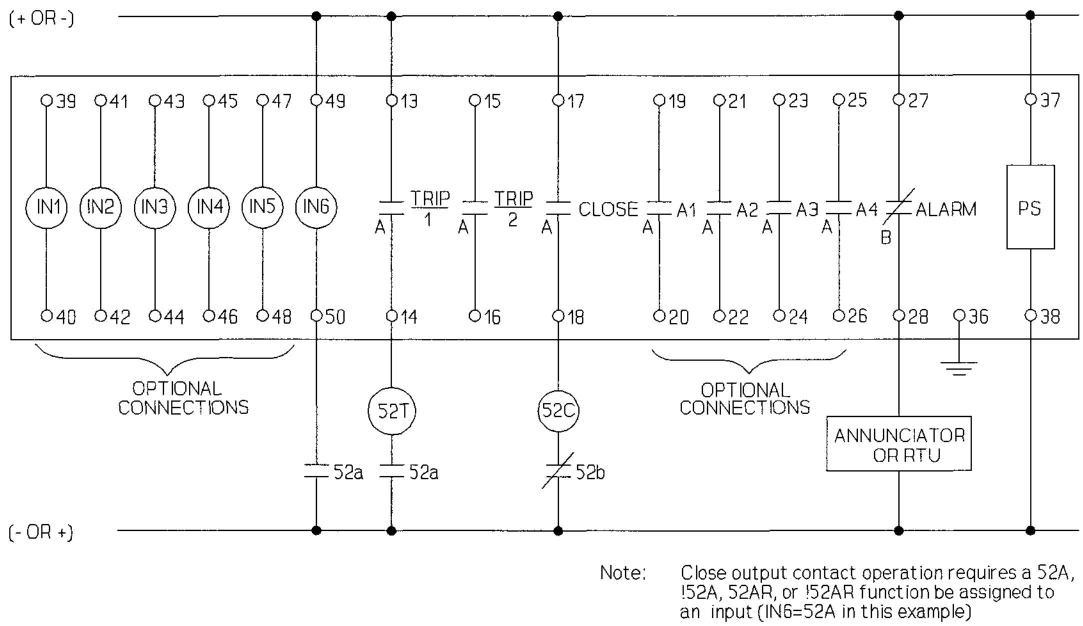


Figure 6.8: SEL-151 Relay Typical DC External Connections

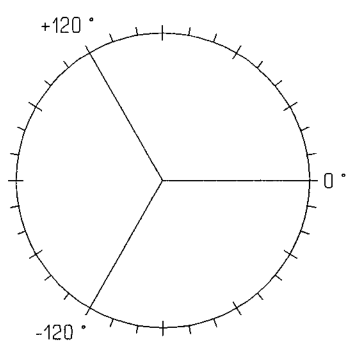
SEL DIRECTION AND POLARITY CHECK FORM

STATION ______________________ DATE: ___/___/___ TESTED BY ______________
SWITCH NO. ______________ EQUIPMENT ______________________________
INSTALLATION ________ ROUTINE ________ OTHER ______________________

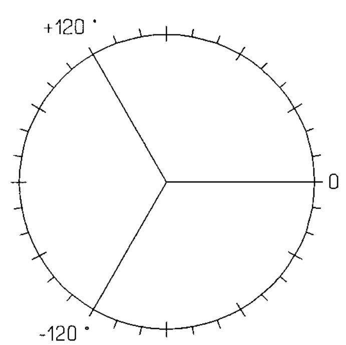
LOAD CONDITIONS:
STATION READINGS: ________ MW (OUT)(IN) ________ MVAR (OUT)(IN) ________ VOLTS ________ AMPS
SEL READINGS: ________ MW (+)(-) ________ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I( )	I( )	I( )	V( )	V( )	V( )	
1st LINE CHOSEN (Y COMPONENT)							
2nd LINE CHOSEN (X COMPONENT)							
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$							ROW 1
ANGLE IN DEGREES ARCTAN Y/X							
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0							
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM							ROW 2

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



CURRENTS



VOLTAGES

SEL DIRECTION AND POLARITY CHECK FORM

STATION ______________________________ DATE: ___/___/___ TESTED BY ____________________

SWITCH NO. ____________________ EQUIPMENT ______________________________________

INSTALLATION ________ ROUTINE _______ OTHER ____________________________________

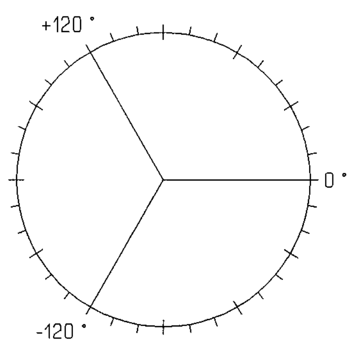
LOAD CONDITIONS:

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

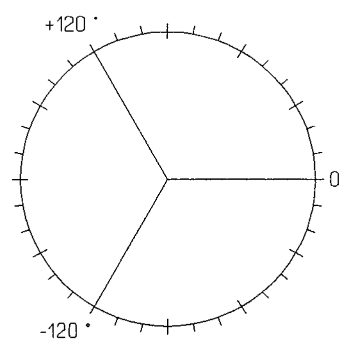
SEL READINGS: ________ MW (+)(-) ________ MVAR (+)(-)

AS SEEN ON SCREEN	Ia	Ib	Ic	Va	Vb	Vc	
COMPANY NOTATION	I( )	I( )	I( )	V( )	V( )	V( )	
1st LINE CHOSEN (Y COMPONENT)							
2nd LINE CHOSEN (X COMPONENT)							
CALCULATED MAGNITUDE $\sqrt{X^2 + Y^2}$							ROW 1
ANGLE IN DEGREES ARCTAN Y/X							
VALUE OF Va DEGREES TO SUBTRACT TO OBTAIN Va DEGREES = 0							
@ Va DEGREES = 0, ANGLE USED TO DRAW PHASOR DIAGRAM							ROW 2

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



CURRENTS



VOLTAGES

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MAINTENANCE & TESTING

TEST PROCEDURES

Test Aids Provided by the Relay

The following features assist you during relay testing and calibration.

METER Command

The METER command shows the voltages and currents presented to the relay in primary values. The relay calculates megawatts (MW) and megavars (MVAR) from these voltages and currents. These quantities are useful for comparing relay calibration against other meters of known accuracy.

When testing the relay, first verify relay calibration. Consider all tests invalid if you determine that the relay is out of calibration. Each relay is calibrated at the factory prior to shipment and should not require further adjustment. If calibration is necessary, refer to Calibration in this section.

TARGET Command

The relay allows you to reassign front panel targets to indicate elements and intermediate logic results in the Relay Word as well as input and output contact status. Use the TARGET command to reassign the front panel LEDs. Once target LEDs are reassigned from the default targets, the front panel targets are no longer latching. This means the targets follow the pickup and dropout condition in much the same manner as an output contact. See Section 3: COMMUNICATIONS for more information about the TARGET command.

By employing the target LEDs for testing, you need not change the relay settings for testing purposes.

Event Reporting

The relay generates an eleven-cycle event report in response to a trip condition or other user selected conditions. Each event report contains voltage and current information, relay element states, and input/output contact information in ¼ cycle resolution. If you question the relay response or your test method, use the event report for assistance.

Each event report is date and time tagged relative to the sixteenth quarter-cycle of the event report. Each report is triggered upon assertion of designated relay elements and/or contact inputs and outputs. If the time-out of a protective element results in TRIP output contact closure, the trip generates a second event report. Thus, the relay generates two event reports: the first when the designated instantaneous element asserts, the second when the TRIP output contact closes. Where time delayed pickup (TDPU) timers are concerned, use the event report time tag to determine the validity of a TDPU timer setting. Simply subtract the latest event report time tag from the previous event report time tag. Section 2: SPECIFICATIONS has further details concerning event report generation.

SELOGIC™ Control Equations

SELOGIC Control Equations allow you to isolate individual relay elements. See the SET n p command description in Section 3: COMMUNICATIONS for more information.

Test Methods

There are two means of determining the pickup and dropout of relay elements: target lamp illumination and output contact closure.

Testing Via Target LED Illumination

During testing you can use target lamp illumination to determine relay element status. Using the TARGET command, set the front panel targets to display the element under test. For example, the overcurrent element pickups appear in Relay Word row 1. When you type the command **TARGET 1 <ENTER>**, the LEDs display the status of the elements in Relay Word row 1. Thus, with Target 1 displayed, if the phase time-overcurrent element pickup (**51P**) asserts, the left most LED illuminates. Using LED illumination as an indicator, you can measure the element operating characteristics.

When the TARGET command sets target LED output to a level other than 0 (Relay Targets), the front panel target markings no longer correspond to illuminated LEDs and the LEDs do not latch.

If you place the relay in service with a target level other than Level 0, it automatically returns to Level 0 when an automatic message transmits to a timed out port. While this feature prevents confusion among station operators and readers, it can be inconvenient if the relay tester does not want targets to revert to Level 0.

To simplify testing using targets, set the relay AUTO setting equal to the port which you intend to use. Also, set that port TIME setting equal to zero. This prevents automatic message transmission to a port which may be timed out. Remember to reset these settings and the target level before returning the relay to service following tests.

Testing Via Output Contact Assertion

To test using this method, set one programmable output contact to assert when the element under test picks up. With the SET n p command, set an output contact equal to the element under test.

For an "a" contact, when the condition asserts, the output contact closes; when the condition deasserts, the output contact opens.

For a "b" contact, when the condition asserts, the output contact opens. When the condition deasserts, the output contact closes. Programmable contacts can be specified at the factory as "a" or "b." Using contact operation as an indicator, you can measure element operating characteristics, stop timers, etc.

Tests in this chapter use the output contact method and assume an "a" output contact.

Using a Breaker Simulator

Because much of the relay logic depends on whether the breaker is open or closed, it is important to use a breaker simulator. The following logic depends on the state of the circuit breaker status input:

- Reclosing Relay Logic
- Close Function Logic
- Trip Circuit Monitor Logic
- 52AT and 52BT Functions
- Circuit Breaker Monitor Logic

We recommend testing the SEL-151 relay with a latching relay to simulate line breaker auxiliary contact action. This ensures proper assertion and deassertion of the circuit breaker status function assigned to an input on the back panel.

INITIAL CHECKOUT

The initial checkout procedure should familiarize you with the relay and ensure that all functions are operational. Study Functional Specification and Description in Section 2: SPECIFICATIONS, command descriptions in Section 3: COMMUNICATIONS, and Section 4: EVENT REPORTING for a complete understanding of the relay capabilities.

Equipment Required

The following equipment is necessary for initial checkout.

1. Terminal with EIA RS-232-C serial interface
2. Interconnecting cable between terminal and relay
3. Source of control power
4. Source of three-phase voltages and currents
5. Ohmmeter or contact opening/closing sensing device

Checkout Procedure

In the procedure below, you will use several relay commands. Section 3: COMMUNICATIONS provides a full explanation of all commands. The following information should allow you to complete the checkout without referring to the detailed descriptions.

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

Relay output appears in the following format:

```
Example 21.6 kV distribution feeder          Date: 7/1/92        Time: 01:01:01
```

- **Step 1**

Purpose: Be sure you received the relay in satisfactory condition.

Method: Inspect the instrument for physical damage such as dents or rattles.

- **Step 2**

Purpose: Verify the requirements for the relay logic inputs, control power voltage level, and voltage and current inputs.

Method: Refer to the information sticker on the rear panel of the relay. Figure 7.1 provides an example. Please read the information on this sticker before applying power to the relay or starting tests. Be sure your dc supply is correctly adjusted for the control and logic input requirements.

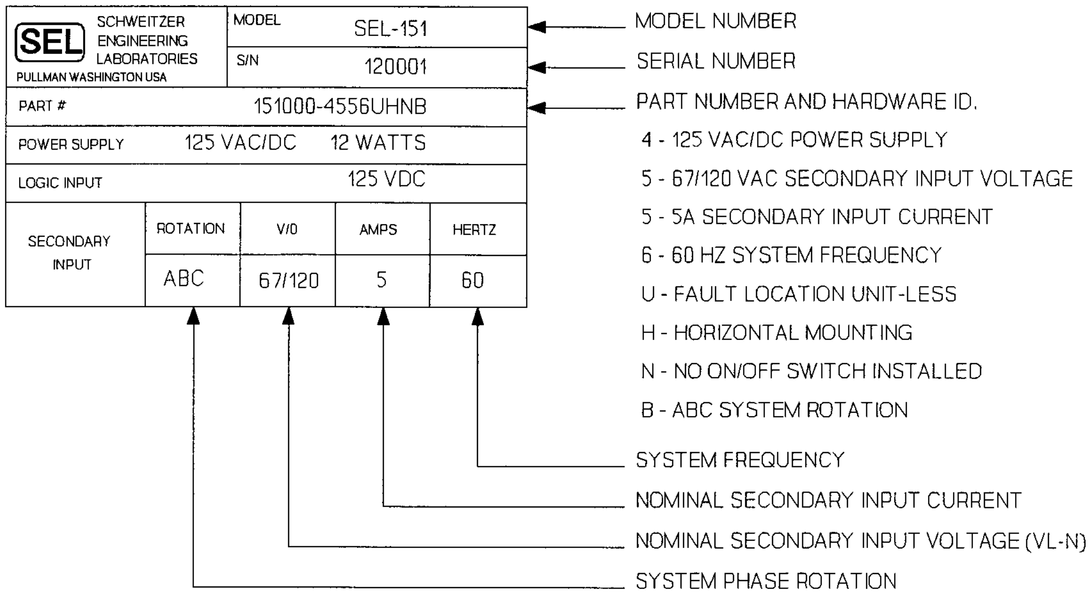


Figure 7.1: Relay Part Number and Hardware Identification Sticker

- **Step 3**

Purpose: Verify the communications interface setup.

Method: Connect a computer terminal to PORT 2 on the relay rear panel. The terminal should be configured to 2400 baud, eight data bits, two stop bits, and no parity. The relay is shipped from the factory with Port 2 set to 2400 baud and Port 1 set to 300 baud. Section 3: COMMUNICATIONS provides additional details on port configuration. Baud rate selection is described under Jumper Selection in Section 6: INSTALLATION. Figure 7.2 shows the typical communication interface setup for testing purposes.

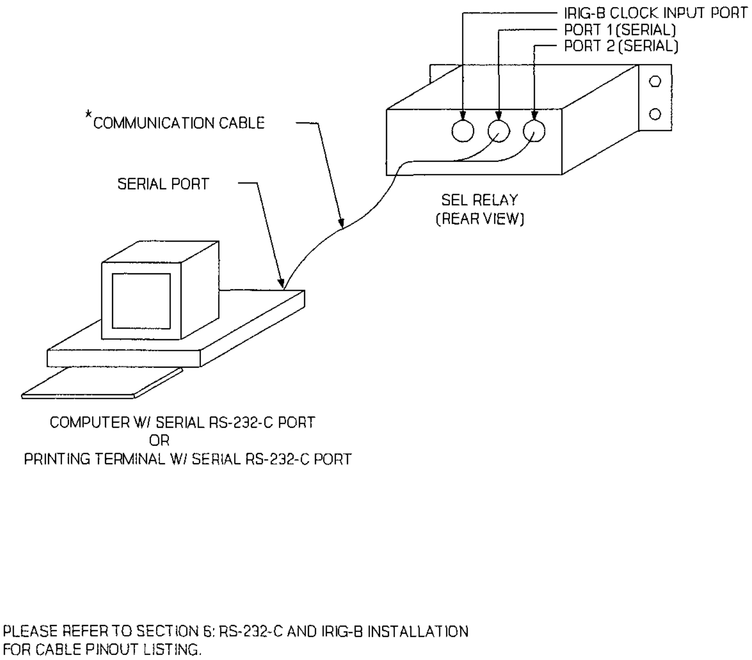


Figure 7.2: Communication Interface Setup

- **Step 4**

Purpose: Establish control power connections.

Method: Connect a frame ground to terminal 36 on the rear panel and connect rated control power to terminals 37 and 38. Polarity is unimportant. Relays supplied with 125 or 250 V power supplies may be powered from a 115 V ac wall receptacle for testing. In the final installation, we recommend that the relay receive control power from the station dc battery to avoid losing events stored in volatile memory if station service is lost.

- **Step 5**

Purpose: Apply control voltage to the relay and start Access Level 0 communications.

Method: Turn on the relay power. All front panel targets should illuminate when you press the TARGET RESET button. If not, be sure that power is present and check the fuse or fuses. The following message should appear on the terminal:

```
Example 21.6 kV distribution feeder        Date: 7/1/92      Time: 01:01:01

SEL-151
=
```

The ALARM relay should pull in, holding its "b" contacts (terminals 27,28) open. If the relay pulls in but no message is received, check the terminal configuration. If neither occurs, turn off the power and refer to Troubleshooting later in this section.

The = prompt indicates that communications with the relay are at Access Level 0, the first of three levels. The only command accepted at this level is ACCESS, which opens communications on Access Level 1.

Note: If you are using a battery simulator, be sure the simulator voltage level is stabilized before turning the relay on.

- **Step 6**

Purpose: Establish Access Level 1 communications.

Method: Type **ACCESS** and press **<ENTER>**. At the prompt, enter the Access Level 1 password **OTTER** and press **<ENTER>**. The => prompt should appear, indicating that you have established communications at Access Level 1.

- **Step 7**

Purpose: Verify relay self test status.

Method: Type **STATUS** and press **<ENTER>**. The following display should appear on the terminal:

```
Example 21.6 kV distribution feeder        Date: 7/1/92      Time: 01:04:56

SELF-TESTS

W=Warn   F=Fail

      IR   IA   IB   IC   VA   VB   VC
OS    0    0    0    0    0    0    0
PS     5.08      14.92      -14.99
RAM    ROM    A/D     MOF    SET
OK     OK     OK      OK     OK

=>
```

■ **Step 8**

Purpose: View the demonstration settings entered before shipment.

Method: The relay is shipped with demonstration settings; type **SHOWSET 1 <ENTER>** to view them. The terminal should display the following:

```
=>SHOWSET 1 <ENTER>
Settings for group 1

Example 21.6 kV distribution feeder
CTR  =120.00  PTR  =180.00
R1   =0.58    X1   =1.50    R0   =1.44    X0   =4.56
RS   =0.00    XS   =0.00    LL   =2.42
DATC =15      PDEM =12.00   QDEM =12.00   NDEM =0.99
79OI1=60      79OI2=600     79OI3=900     79OI4=0
79RST=1800    M79SH=00000
50C  =99.99   27L  =0.00    27H  =0.00    27C  =2      TCI  =0
50Q  =99.99   50QT =0
51QP =6.00    51QTD=15.00   51QC =3       51QRS=N
50NL =19.99   50NLT=2       50NH =100.00
51NP =1.50    51NTD=2.00    51NC =3       51NRS=N
50L  =99.99   50LT =0       50H  =40.00
51P  =6.00    51TD =6.00    51C  =3       51RS =N
52APU=1200    52ADO=0       TSPU =0       TSDO =0
TKPU =0       TKDO =0       TZPU =0       TZDO =0

PRESS RETURN ? <ENTER>
SELogic Equations

S(123)   =
A(12)    =
B(12)    =50NLT
C(12)    =50NL
D(12)    =
E(34)    =79RS+79CY+52AT
F(34)    =IN6
G(34)    =
H(34)    =
J(1234)  =
K(1234)  =
L(1234)  =
A1(1234)=TF
A2(1234)=NDEM

PRESS RETURN ? <ENTER>

V(56)    =B*E*F
W(56)    =C*E*F
X(56)    =
Y(56)    =
Z(56)    =
A3(1346)=79CY
A4(2346)=
TR(1246)=50H+51T+51NT+V
RC(1246)=50H+TF
ER(1246)=TF+W
SEQ(1)   =
ETC(1)   =
ITC(1)   =

Global settings
DEMR =Y       CFT  =60      TDUR =4       TFT  =30     TGR  =180
ITT  =5       TIME1=15      TIME2=0       AUTO =2      RINGS=3
IN1  =SS1     IN2  =DT      IN3  =RE      IN4  =
IN5  =52A     IN6  =

=>
```

The SET command descriptions in Section 3: COMMUNICATIONS include a complete explanation of the settings.

- **Step 9**

Purpose: Connect voltage and current sources to the relay.

Method: Turn power off and connect the sources of voltage and current to the rear panel terminals of the relay as shown in Figure 7.3. Apply 69 volts per phase (line-to-neutral) in positive-sequence rotation.

Set the A-phase current source to 2 amperes, at the same angle as the A-phase voltage. Set the B-phase current source to 2 amperes, at the same angle as the B-phase voltage. Set the C-phase current source to 2 amperes, at the same angle as the C-phase voltage.

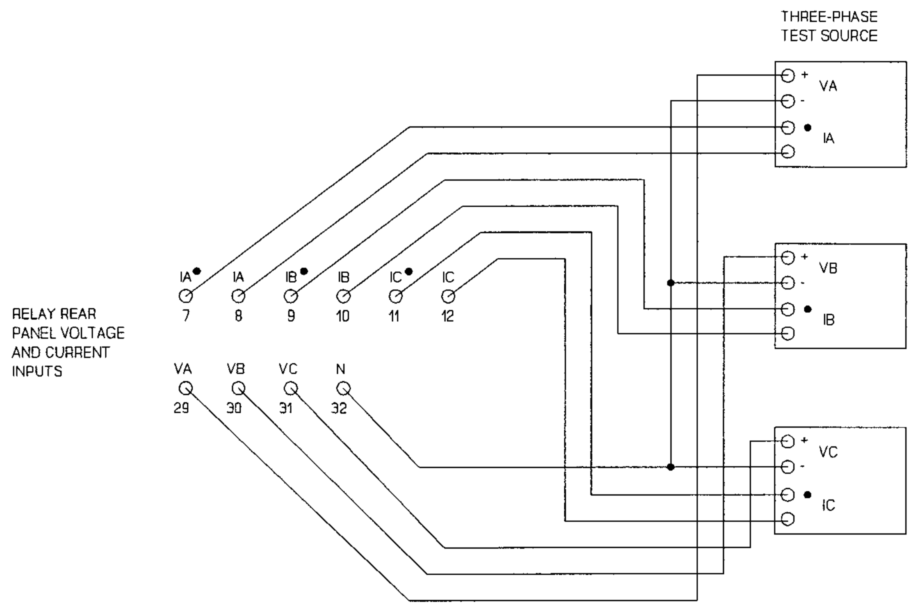


Figure 7.3: Three-Phase Voltage and Current Source Test Connections

- **Step 10**

Purpose: Verify correct voltage and current connections and levels.

Method: Use the METER command to measure the voltages and currents applied in Step 9. With applied voltages of 69 volts per phase and a potential transformer ratio of 180:1, the displayed line-to-neutral voltages should be 12420 V. With applied currents of 2.0 amperes per phase and a current transformer ratio of 120:1, the displayed line-to-neutral currents should be 240 amperes. All line-to-line quantities should be balanced, differing from the line-to-neutral measurements by a factor of 1.73. Real power P should be approximately 8.94 MW; reactive power Q should be approximately 0 MVAR.

```
=>METER <ENTER>

Example 21.6 kV distribution feeder        Date: 7/1/92      Time: 09:12:49


MET IA=240     B=239    C=242    R=6
   3I2=5      P=8.942      Q=0.054

VA=12408  VB=12419  VC=12421  3V0=20
AB=21501  BC=21512  CA=21513  3V2=17

=>
```

If you inadvertently switched a pair of voltages or currents, the MW reading should be incorrect. It is important to remember this when commissioning the relay using system voltages and currents.

■ Step 11

Purpose: Establish Access Level 2 communications.

Method: Type **2ACCESS** and press **<ENTER>**. At the prompt, enter the Access Level 2 password **TAIL** and press **<ENTER>**. The =>> prompt should appear, indicating that you have established communications at Access Level 2.

■ Step 12

Purpose: Test the fault locator.

Method: Test the fault locator using the voltages and currents in Table 7.1. These voltages and currents were obtained for AG and BC fault types assuming a radial line with a source impedance of $Z1 = 0.25 + j2.50\ \Omega$ and $Z0 = 0.05 + j0.53\ \Omega$ (21.6 kV).

Use the following settings:

CTR = 120
PTR = 180
R1 = 0.58
X1 = 1.50
R0 = 1.44
X0 = 4.56
RS = 0
XS = 0
LL = 2.42

Set one of the phase pickups (51P, 50L, or 50H) below 10.00 A secondary and enable this same pickup to generate an event report [ER(1246) setting]. Remember that the line length (LL) setting is unit-less.

Table 7.1: Fault Locator Test Values

LOCATION	TYPE	VA	VB	VC	IA	IB	IC	UNITS
7.26	AG	56.49	66.33	67.88	10.60	0.00	0.00	V or A
		-2.5	-116.9	116.3	-73.5	0.00	0.00	Degrees
7.26	BC	69.28	55.09	50.29	0.00	12.38	12.38	V or A
		0.00	-134.0	128.1	0.00	-164.2	15.81	Degrees

To view the full event report for the last fault, type **EVENT 1** and press **<ENTER>**. Each event report provides an eleven cycle record of the currents, voltages, relay element states, and all contact input and output states. The relay saves the twelve newest reports.

This checkout procedure demonstrates only a few relay features. For a complete understanding of relay capabilities, study Functional Description in Section 2: SPECIFICATIONS, the command descriptions in Section 3: COMMUNICATIONS, and Section 4: EVENT REPORTING. For more test procedures, see the Full Functional Test portion of this section.

FULL FUNCTIONAL TEST

This procedure allows you to test the protective and control functions of the relay more fully than the initial checkout procedure does.

Equipment Required

The following equipment is necessary to complete a full functional test:

1. Communications terminal with EIA RS-232-C serial interface
2. Data cable to connect terminal and relay
3. Source of relay control power
4. Source of synchronized three-phase voltages and at least two currents
5. Ohmmeter or contact opening/closing sensing device
6. Timer with contact inputs for start and stop

What Should Be Tested

A full functional test includes the initial checkout procedure and the additional steps described below. In general, these tests assure that the relay settings match your application rather than checking relay performance. For commissioning purposes, your company policy may require you to perform the full functional test. For maintenance purposes, a quick test of selected fault types and elements should suffice.

SETTING TEST

Purpose: Ensure that the relay accepts settings.

Method:

1. Gain Level 2 Access (see ACCESS and 2ACCESS commands in Section 3: COMMUNICATIONS).

2. Change one setting in setting group 1. For example, change the ground/residual time-overcurrent element pickup from 1.5 amperes secondary to 2.0 amperes secondary.

   Type **SET 1 51NP** and press **<ENTER>**.

   Following the 51NP prompt, type **2.0** and press **<ENTER>**.

3. To complete the setting procedure, type **END** and press **<ENTER>**. Type **Y <ENTER>** at the prompt: "OK (Y or N) ?" The relay computes internal settings and compares them against fixed limits. If all settings are within acceptable ranges, the ALARM contact closes momentarily as the new settings are enabled unless an alarm condition already exists (e.g., self test failure).

4. Use the SHOWSET command to inspect settings. Make sure your change was accepted.

   Type **SHOWSET 1** and press **<ENTER>**.

5. Use SET and SHOWSET again to restore the initial values and check the settings.

METER TEST

Purpose: Verify the magnitude accuracy and phase balance. This test only requires a single voltage and current test source.

Method:

1. Parallel all voltage inputs by connecting terminals 29, 30, and 31 with a jumper. See Figure 7.4 for the test connections.

2. Series all current inputs as shown in Figure 7.4.

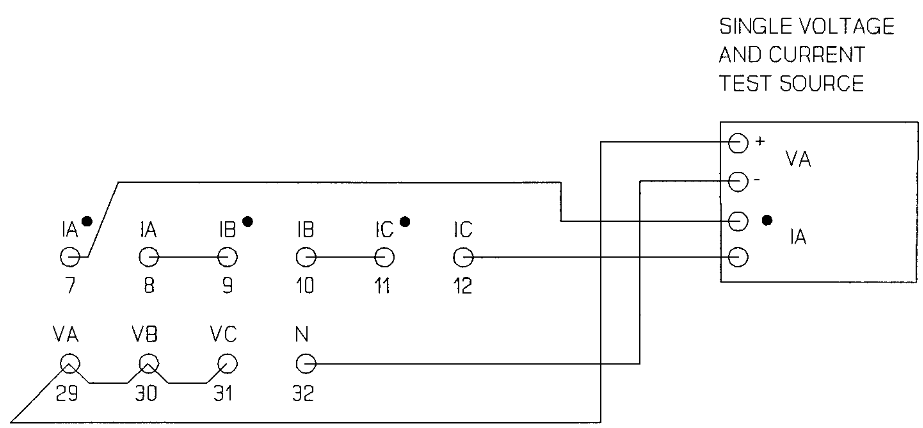


Figure 7.4: METER Test Connections

3. Apply a voltage of 50 Vac between the paralleled voltage inputs to the neutral point and a current of five amperes through the three inputs. The phase angle of the voltage and current source should be set to 0°.

4. Use the METER command to inspect measured voltages, currents, and power. Voltages VA, VB, and VC should equal the applied voltage times the potential transformer ratio setting. With the Example 21.6 kV distribution feeder settings, you should obtain:

$$VA = VB = VC = (50\ V)(180) = 9000\ V\ (\pm 0.5\%).$$

Voltages VAB, VBC, and VCA should read less than 135 V primary.

Similarly, currents IA, IB, and IC should equal the applied current times the current transformer ratio. With the Example 21.6 kV distribution feeder settings, you should obtain:

$$IA = IB = IC = (5\ A)(120) = 600\ A\ (\pm 1\%).$$

Difference currents IAB, IBC, and ICA should be less than 12 amperes.

The power reading, P (MW), should read:

$$(VA)(IA) + (VB)(IB) + (VC)(IC) = 16.20\ MW.$$

The reactive power reading Q (MVAR) should be less than 0.3 MVAR.

OVERCURRENT ELEMENT PICKUP TESTS

Purpose: Verify the pickup thresholds of the following overcurrent elements:

51P Phase time-overcurrent element pickup
50L Phase definite-time overcurrent element pickup
50H Phase instantaneous overcurrent element
51QP Negative-sequence time-overcurrent element pickup
50Q Negative-sequence definite-time overcurrent element pickup
51NP Ground/Residual time-overcurrent element pickup
50NL Ground/Residual definite-time overcurrent element pickup
50NH Ground/Residual instantaneous overcurrent element

Method: 1. Using the SET command, set the desired programmable output (A1-A4) to follow the appropriate overcurrent element. Select one of the overcurrent elements from the first row of the Relay Word listed above.

2. Disable all external and internal torque control on the overcurrent elements. Using the SET command, enter NA for the ETC(1) and ITC(1) settings. These settings specify the overcurrent elements in Relay Word row R1 you want externally and internally torque controlled (none in this case).

3. Apply current to one phase and observe the pickup and dropout of each element. Record the results.

Note: With current applied to only one phase (e.g., $I_A = 6$ A, $I_B = I_C = 0$), the following sequence currents result:

$$
\begin{aligned}
I_0 &= \tfrac{1}{3}[I_A + I_B + I_C] \\
&= \tfrac{1}{3}[6\text{ A} \angle 0° + 0\text{ A} \angle 0° + 0\text{ A} \angle 0°] \\
&= 2\text{ A} \angle 0°
\end{aligned}
$$

$$I_2 = \tfrac{1}{3}[I_A + a^2(I_B) + a(I_C)]$$

Where: $a \equiv 1 \angle 120°$ and $a^2 \equiv 1 \angle 240°$

$$
\begin{aligned}
I_2 &= \tfrac{1}{3}[6\text{ A} \angle 0° + 0\text{ A} \angle (0° + 240°) + 0\text{ A} \angle (0+120°)] \\
&= \tfrac{1}{3}[6\text{ A} \angle 0° + 0\text{ A} \angle -120° + 0\text{ A} \angle 120°] \\
&= 2\text{ A} \angle 0°
\end{aligned}
$$

The negative-sequence and ground/residual overcurrent elements respond to $3xI_2$ and $3xI_0$ currents, respectively. Thus, for this test all overcurrent elements see 6 A.

You can also test the following element in Relay Word row R2 using the above method (bypass step 2 because **50C** cannot be torque controlled).

50C Phase instantaneous overcurrent element (**50C** overrides internal torque control element **27**)

DEFINITE-TIME OVERCURRENT ELEMENT TIMING TESTS

Purpose: Verify operating times for the following definite-time overcurrent elements.

50LT Phase definite-time overcurrent element
50QT Negative-sequence definite-time overcurrent element
50NLT Ground/Residual definite-time overcurrent element

Method: 1. Disable all external and internal torque control on the definite-time overcurrent element pickups in Relay Word row R1. The above definite-time overcurrent elements are derived from their respective pickups in Relay Word row R1. If one of these pickups in Relay Word row R1 is torque controlled, the respective definite-time overcurrent element it drives in Relay Word row R2 is also torque controlled.

Using the SET command, enter **NA** for the ETC(1) and ITC(1) settings. These settings specify the overcurrent elements in Relay Word row R1 you want externally and internally torque controlled, respectively (none in this case).

2. Set a programmable output (A1-A4) to follow a definite-time overcurrent element pickup (e.g., **50NL**). Use the assertion of this output (open to close) to start an external timer.

3. Set another programmable output to follow definite-time overcurrent element timeout via Relay Word bit 50NLT (**50NL** drives **50NLT**). Use the assertion of this output to stop the external timer.

4. Apply current to one phase over the 50NL pickup setting. The time shown on the timer should match the 50NLT time delay setting.

Note: With current applied to only one phase (e.g., $I_A = 6$ A, $I_B = I_C = 0$), the following sequence currents result:

$$\begin{aligned} I_0 &= \tfrac{1}{3}[I_A + I_B + I_C] \\ &= \tfrac{1}{3}[6\text{ A} \angle 0° + 0\text{ A} \angle 0° + 0\text{ A} \angle 0°] \\ &= 2\text{ A} \angle 0° \end{aligned}$$

$$I_2 = \tfrac{1}{3}[I_A + a^2(I_B) + a(I_C)]$$

Where: $a \equiv 1 \angle 120°$ and $a^2 \equiv 1 \angle 240°$

$$\begin{aligned} I_2 &= \tfrac{1}{3}[6\text{ A} \angle 0° + 0\text{ A} \angle(0° + 240°) + 0\text{ A} \angle(0+120°)] \\ &= \tfrac{1}{3}[6\text{ A} \angle 0° + 0\text{ A} \angle -120° + 0\text{ A} \angle 120°] \\ &= 2\text{ A} \angle 0° \end{aligned}$$

The negative-sequence and ground/residual overcurrent elements respond to $3xI_2$ and $3xI_0$ currents, respectively. Thus, for this test all overcurrent elements see 6 A.

5. Repeat these tests for the phase- and negative-sequence definite-time overcurrent elements (**50LT** and **50QT**).

TIME-OVERCURRENT ELEMENT TIMING TESTS

Purpose: Verify the operating times of the following time-overcurrent elements.

51T Phase time-overcurrent element
51QT Negative-sequence time-overcurrent element
51NT Ground/Residual time-overcurrent element

Method:

1. Disable all external and internal torque control on the time-overcurrent element pickups in Relay Word row R1. The above time-overcurrent elements are derived from their respective pickups in Relay Word row R1. If a time-overcurrent element pickup in row R1 is torque controlled, the respective time-overcurrent element it drives in Relay Word row R2 is also torque controlled.

   Using the SET command, enter **NA** for the ETC(1) and ITC(1) settings. These settings specify the overcurrent elements in Relay Word row R1 you want externally and internally torque controlled, respectively (none in this case).

2. Set a programmable output (A1-A4) to follow a time-overcurrent element pickup (e.g., **51NP**). Use the assertion of this output (open to close) to start an external timer.

3. Set another programmable output to follow time-overcurrent element timeout via the **51NT** bit in the Relay Word (**51NP** drives **51NT**). Use the assertion of this output to stop the external timer.

4. Calculate the expected operating time of **51NT** using the appropriate equation for the curve number (see Time-Overcurrent Curve-Timing and Time Delay Reset Equations in Section 2: SPECIFICATIONS). This is dictated by the 51NC setting. TD is the 51NTD time dial setting. M is the multiple of pickup current to be applied to the relay. Using example relay settings and a current multiple of pickup equal to three, the equation for the very inverse curve (51NC = 3) is:

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

   Where M = Multiples of Pickup = 3
   TD = Time Dial =4

$$t_M = 2.33 \text{ seconds}$$

   For example, if the relay measures 3.45 amperes of residual current, the 51NT bit in the Relay Word asserts 2.33 seconds after 51NP assertion (51NP = 1.15 A; 3x1.15 = 3.45). Table 7.2 shows current quantities for the previous example.

Table 7.2: Current Quantities for 51NT Timing Test Example

IA	IB	IC	
3.45	0.00	0.00	Amperes
0.0°	0.0°	0.0°	Degrees

5. Apply a multiple of pickup current to one phase. Record the **51NT** element operating time and compare it to the calculated time.

Note: With current applied to only one phase (e.g., $I_A = 3.45$ A, $I_B = I_C = 0$), the following sequence currents result:

$$\begin{aligned} I_0 &= \tfrac{1}{3}[I_A + I_B + I_C] \\ &= \tfrac{1}{3}[3.45\ \text{A} \angle 0° + 0\ \text{A} \angle 0° + 0\ \text{A} \angle 0°] \\ &= 1.15\ \text{A} \angle 0° \end{aligned}$$

$$I_2 = \tfrac{1}{3}[I_A + a^2(I_B) + a(I_C)]$$

Where: $a \equiv 1 \angle 120°$ and $a^2 \equiv 1 \angle 240°$

$$\begin{aligned} I_2 &= \tfrac{1}{3}[3.45\ \text{A} \angle 0° + 0\ \text{A} \angle (0° + 240°) \\ &\quad + 0\ \text{A} \angle (0+120°)] \\ &= \tfrac{1}{3}[3.45\ \text{A} \angle 0° + 0\ \text{A} \angle \text{-}120° + 0\ \text{A} \angle 120°] \\ &= 1.15\ \text{A} \angle 0° \end{aligned}$$

The negative-sequence and ground/residual overcurrent elements respond to $3xI_2$ and $3xI_0$ currents, respectively. Thus, for this test all overcurrent elements see 3.45 A.

6. Optional: You may want to repeat this test with various multiples of pickup current (e.g., M = 3, 5, and 7) and various time dial settings (e.g., TD = 1, 5, and 10) for each of the four curve indexes.

7. Repeat these tests for the phase- and negative-sequence time-overcurrent elements (**51T** and **51QT**).

DEMAND AMMETER TIMING TESTS

Purpose: Verify the operating time of the following demand ammeter thresholds.

PDEM Phase demand current threshold exceeded
QDEM Negative-sequence demand current threshold exceeded
NDEM Residual demand current threshold exceeded

Method:

1. Using the SET command, set a programmable output contact (A1-A4) to follow one of the demand ammeter threshold alarms from Relay Word row R4 (e.g., **NDEM**). Also, set the respective demand threshold to some secondary current value level and DATC (Demand Ammeter Time Constant) to a value from 5 to 60 minutes (e.g., NDEM = 4.50 and DATC = 15).

2. Using the METER RD command, reset demand ammeters to zero.

3. Note the time and apply a constant current to one phase. The current should be a factor of 10/9 = 1.11 times greater than the NDEM setting (constant current = 1.11 x 4.50 A = 5.00 A). See Demand Ammeter in Section 2: SPECIFICATIONS for background on the 1.11 factor.

   Note: With current applied to only one phase (e.g., I_A = 5 A, $I_B = I_C$ = 0), the following sequence currents result:

   $$\begin{aligned} I_0 &= \tfrac{1}{3}[I_A + I_B + I_C] \\ &= \tfrac{1}{3}[5\text{ A } \angle 0^\circ + 0\text{ A } \angle 0^\circ + 0\text{ A } \angle 0^\circ] \\ &= 1.67\text{ A } \angle 0^\circ \end{aligned}$$

   $$I_2 = \tfrac{1}{3}[I_A + a^2(I_B) + a(I_C)]$$

   Where: $a \equiv 1 \angle 120^\circ$ and $a^2 \equiv 1 \angle 240^\circ$

   $$\begin{aligned} I_2 &= \tfrac{1}{3}[5\text{ A } \angle 0^\circ + 0\text{ A } \angle(0^\circ + 240^\circ) + 0\text{ A } \angle(0+120^\circ)] \\ &= \tfrac{1}{3}[5\text{ A } \angle 0^\circ + 0\text{ A } \angle -120^\circ + 0\text{ A } \angle 120^\circ] \\ &= 1.67\text{ A } \angle 0^\circ \end{aligned}$$

   The negative-sequence and residual demand threshold elements respond to $3xI_2$ and $3xI_0$ currents, respectively. Thus, for this test all demand threshold elements see 5 A.

4. If the current remains constant at 5.00 A, the programmable output contact assigned to the **NDEM** element asserts 15 minutes after you apply current when DATC = 15.

5. Repeat these tests for the phase- and negative-sequence demand threshold alarms (**PDEM** and **QDEM**).

RECLOSING RELAY TESTS SETUP

Purpose: Make settings for subsequent reclosing relay tests.

Note: These tests should be performed using a circuit breaker simulator to simulate the action of the circuit breaker auxiliary contacts. A simple latching relay works well as a circuit breaker simulator.

Connect the SEL-151 relay TRIP and CLOSE output contacts to the circuit breaker simulator to trip and close the simulator. Connect the simulator output to a relay input assigned to the circuit breaker status function (IN5 = 52A in the following example).

Method: 1. Using the SET n command (n is the active setting group), enter the following settings:

```
           .
           .
           .
79OI1   = 60          open interval times (cycles)
79OI2   = 600
79OI3   = 900
79OI4   = 0           no fourth open interval

79RST   = 1800        reset interval time (cycles)
M79SH   = 01010
           .
           .
           .
50L     = 4.00        amps, secondary
           .
           .
           .
A1(1234) = 79RS       reset state
A2(1234) = 79CY       reclose cycle state
           .
           .
           .
A3(1346) = 79LO       lockout state
A4(2346) = 79SH       shot "bit"; asserts per M79SH setting
TR(1246)              = 50Lprogrammable trip conditions
RC(1246)              = NAno reclose cancel conditions
```

	.	
SEQ(1)	= NA	no sequence coordination
ETC(1)	= NA	no externally torque controlled overcurrent elements
ITC(1)	= NA	no internally torque controlled phase overcurrent elements

The setting entry NA (not applicable) leaves the designated variable blank when the settings are shown.

2. Using the SET G command (G signifies the global setting group: settings common to all groups), enter additional example settings:

	.	
	.	
	.	
TDUR	= 4	trip duration timer (cycles)
	.	
	.	
	.	
IN3	= RE	reclose enable
IN4	= DC	direct close
IN5	= 52A	circuit breaker auxiliary

The choice of inputs IN3, IN4, and IN5 is for demonstration purposes only.

3. After the settings are made, energize IN3 (IN3 = RE) to enable the reclosing relay.

   Note that if IN3 is de-energized, the reclosing relay goes to lockout. The relay illuminates the front panel LO (lockout) LED and asserts the A3 output contact (A3 = **79LO**).

4. Note that the front panel RS (reset) and LO (lockout) LEDs follow the **79RS** and **79LO** Relay Word bits, respectively.

RECLOSING RELAY RESET INTERVAL TIMER TEST

Purpose: Verify the reclosing relay reset interval timer accuracy.

Method: 1. Enter the settings in the preceding RECLOSING RELAY TESTS SETUP if you haven't already.

2. Open the circuit breaker simulator manually or via the OPEN command. With the circuit breaker simulator open, IN5 is de-energized (IN5 = 52A), the front panel LO (lockout) LED is illuminated, and the A3 output contact is asserted (A3 = **79LO**).

3. Connect the circuit breaker simulator output to an external timer. When the circuit breaker simulator output is asserted (indicating that the circuit breaker has closed), the external timer starts.

4. Connect the A1 output contact to stop the same external timer. The external timer should stop when the A1 output contact asserts (A1 = **79RS**), indicating that the reclosing relay is in the reset state. When the circuit breaker remains closed for the duration of the reset interval time (79RST = 1800 cycles), the reclosing relay goes into the reset state.

5. Execute the CLOSE Command or energize the IN4 input (IN4 = DC; direct close) to cause CLOSE output contact assertion. When the circuit breaker simulator output asserts (IN5 = 52A energized), the external and reset interval timers start. The front panel LO (lockout) LED remains lit and the A3 output contact is still asserted (A3 = **79LO**).

   When the reset interval timer expires, the reclosing relay is in the reset state, the A1 output contact asserts (A1 = **79RS**), and the A3 output contact deasserts (A3 = **79LO**). The front panel LO (lockout) LED turns off and the RS (reset) LED is illuminated.

   A1 output contact assertion stops the external timer. Compare the external timer reading to the reset interval time setting (in this example 79RST = 1800 cycles).

RECLOSING RELAY OPEN INTERVAL TIMER TEST

Purpose: Verify the reclosing relay open interval timer accuracy.

Method: 1. Enter the settings in RECLOSING RELAY TESTS SETUP if you haven't already.

In this example there are only three set open interval times:

79OI1	= 60	open interval times (cycles)
79OI2	= 600	
79OI3	= 900	
79OI4	= 0	no fourth open interval

2. Execute the CLOSE Command or energize the IN4 input (IN4 = DC; direct close) to cause the relay to assert the CLOSE output contact. With the circuit breaker simulator closed, IN5 is energized (IN5 = 52A) and the front panel RS (reset) LED illuminates after the reset interval timer expires (79RST = 1800 cycles). The A1 output contact asserts (A1 = **79RS**).

3. If you just performed the preceding RECLOSING RELAY RESET INTERVAL TIMER TEST:

   The circuit breaker simulator is already closed and the reclosing relay is in the reset state. The front panel RS (reset) LED is illuminated and the A1 output contact is asserted (A1 = **79RS**).

   Detach the connections to the external timer and reset the timer.

4. Connect the circuit breaker simulator output and a relay TRIP output contact to an external timer so that when the simulator output **and** relay TRIP output contact deassert, the external timer starts. Deassertion of both outputs indicates that the circuit breaker is open and the TRIP condition is gone. If any open interval times remain in the reclosing cycle, the recloser open interval timer also starts.

5. Connect the CLOSE output contact to the same external timer so it stops when the CLOSE output contact asserts. CLOSE output contact assertion indicates that the open interval timer has expired on a particular open interval time period and the relay subsequently asserted the CLOSE output contact.

6. Apply 5 amps of current to only one phase of the relay. The TRIP output contacts immediately assert (5 A > 50L = 4.00 A; TR = **50L**) and the circuit breaker simulator trips open (IN5 = 52A is de-energized).

7. Turn off the current and the TRIP output contact deasserts. Then the external and reclosing relay open interval timers start.

   After the open interval timer expires, the CLOSE output contact asserts. This stops the external timer and closes the circuit breaker simulator (IN5 = 52A is energized).

8. Record the time on the external timer and reset it. With the circuit breaker simulator closed, the reclosing relay reset interval timer runs.

   The reset interval timer is set for 1800 cycles, so to check the next open interval timer, reapply 5 amps of current to only one phase of the relay before the reset interval expires. Repeat the sequence starting at number 6.

9. Compare the recorded times to the respective open interval times you monitored. You should expect consecutive open intervals of 60, 600, and 900 cycles. The relay should go to lockout after the fourth trip.

RECLOSING RELAY STATES TEST

Purpose: Verify reclosing relay states (**79RS**, **79CY**, **79LO**).

Method: 1. Enter the settings in RECLOSING RELAY TESTS SETUP if you haven't already.

You can observe the reclosing relay states while performing the preceding RECLOSING RELAY OPEN INTERVAL TIMING TEST.

2. When you first trip the circuit breaker simulator while in the reset state, the front panel RS (reset) LED extinguishes and the A1 output contact deasserts (A1 = **79RS**). The reclosing relay is no longer in the reset state. The A2 output contact asserts (A2 = **79CY**), and the reclosing relay is in the reclose cycle state. The reclosing relay remains in the reclose cycle state until one of the following occurs:

> The circuit breaker remains closed throughout the reset interval time (79RST = 1800 cycles) so the reclosing relay goes to the reset state. The front panel RS (reset) LED illuminates, the A1 output contact asserts (A1 = **79RS**), and the A2 output contact deasserts (A2 = **79CY**).
>
> or
>
> All open intervals are exhausted and the circuit breaker remains open, so the reclosing relay goes to the lockout state. The front panel LO (lockout) LED illuminates, the A3 output contact asserts (A3 = **79LO**), and the A2 output contact deasserts (A2 = **79CY**).

RECLOSING RELAY SHOT BIT TEST

Purpose: Verify the operation of the reclosing relay shot bit (**79SH**) according to the M79SH setting.

Method: 1. Enter the settings in RECLOSING RELAY TESTS SETUP if you haven't already.

The **79SH** Relay Word bit monitors any desired state of the shot counter. In this example, it is assigned to the A4 output contact (A4 = **79SH**).

This test does not require an external timer.

2. Execute the CLOSE command or energize the IN4 input (IN4 = DC; direct close) to cause CLOSE output contact assertion. With the circuit breaker simulator closed, IN5 is energized (IN5 = 52A) and the front panel RS (reset) LED illuminates after the reset interval timer expires (79RST = 1800 cycles). The A1 output contact asserts (A1 = **79RS**).

3. You can test the reclosing relay shot bit **79SH** using RECLOSING RELAY OPEN INTERVAL TIMER TEST steps 6 through 8 without monitoring open interval times.

   The number of reclosing shots (automatic reclosures) depends on the number of set open interval times. In this example there are three open intervals, so there are three shots. Every time the open interval timer expires, the shot counter is incremented and an automatic reclosure is initiated (CLOSE output contact is asserted).

   When the reclosing relay is in the reset state, shot = 0. The front panel RS (reset) LED is illuminated and the A1 output contact is asserted (A1 = **79RS**).

   79SH asserts according to the M79SH setting. M79SH can be set for any combination of shots 0, 1, 2, 3, and 4. As previously mentioned, the number of shots depends on the number of set open interval times; this example uses three set open interval times. M79SH is set for only shot = 1 and shot = 3:

   M79SH = 01010

   Thus, **79SH** will assert only when shot = 1 or shot = 3.

   The shot = 4 position in the M79SH setting (right most position) is not applicable in this example because there are no more than three shots.

4. Use the procedure in RECLOSING RELAY OPEN INTERVAL TIMER TEST steps 6 through 8. After the first open interval expires, the shot counter increments (shot counter increments from shot = 0 to shot = 1) and the CLOSE output contact is then asserted. Because of the M79SH setting (M79SH = 01010), the A4 output contact also asserts (A4 = **79SH**). The shot counter remains at shot = 1 and the A4 output contact remains asserted until:

   > The circuit breaker remains closed throughout reset interval time (79RST = 1800 cycles), so the reclosing relay goes to the reset state. The front panel RS (reset) LED illuminates, the A1 output contact asserts (A1 = **79RS**), the A2 output contact deasserts (A2 = **79CY**), the shot counter reverts back to shot = 0, and the A4 output contact deasserts (A4 = **79SH**).

   or

Current is reapplied to the relay and trips the circuit breaker simulator again before the reset interval timer expires. The shot counter is incremented to shot = 2 and the A4 output contact deasserts (A4 = **79SH**). The A2 output contact remains asserted (A2 = **79CY**).

If you follow RECLOSING RELAY OPEN INTERVAL TIMER TEST steps 6 through 8, the relay trips again before the reset interval expires. The shot counter is then incremented to the next shot.

5. If you repeat these steps, the reclosing relay shot counter will increment until shot = 3. Because of the M79SH setting (M79SH = 01010), the A4 output contact will assert again for shot = 3 (A4 = **79SH**).

   The reclosing relay will go to lockout on the next trip because shot = 3 is the last shot. The front panel LO (lockout) LED illuminates, the A3 output contact asserts (A3 = **79LO**) and the A2 output contact deasserts (A2 = **79CY**). The shot counter remains at shot = 3 (last shot) and the A4 output contact remains asserted (A4 = **79SH**).

RECLOSING RELAY SEQUENCE COORDINATION TEST

Purpose: Verify the operation of the reclosing relay sequence coordination feature.

Method: 1. Enter the settings in RECLOSING RELAY TESTS SETUP if you haven't already. Make the following changes to these settings:

```
        .
        .
        .
TR(1246)                    = NAno programmable trip conditions
        .
        .
SEQ(1)  = 50L               sequence coordination control
                            condition
```

The **79SH** Relay Word bit monitors any desired state of the shot counter. In this example, it is assigned to the A4 output contact (A4 = **79SH**).

This test does not require an external timer.

2. Execute the CLOSE command or energize the IN4 input (IN4 = DC; direct close) to cause CLOSE output contact assertion. With the circuit breaker simulator closed, IN5 is energized (IN5 = 52A) and the front panel RS (reset) LED illuminates after the reset interval timer expires (79RST = 1800 cycles). The A1 output contact asserts (A1 = **79RS**) and shot = 0.

3. You can test the reclosing relay sequence coordination feature using the same procedure in RECLOSING RELAY OPEN INTERVAL TIMER TEST steps 6 through 8 without monitoring open interval times. Since no overcurrent trip condition is given (TR = 0), the relay does not trip when you apply current. It remains in the reset state with the circuit breaker closed.

   However, SEQ = **50L**, so the shot counter is incremented every time the circuit breaker is closed (IN5 = 52A is asserted), you apply and turn off current above the 50L level (4.00 A), and no TRIP output contact asserts. Every time the shot counter is incremented by SEQ pickup and dropout, the reset interval timer is reinitialized and starts timing. The reclosing relay remains in the reset state (A1 = **79RS** remains asserted).

   In application, sequence coordination advances the shot counter, keeping the SEL-151 relay in step with line reclosers (see Multiple Shot Reclosing Relay in Section 2: SPECIFICATIONS). If the reset interval timer expires before current rises above and falls below the 50L level again, the shot counter resets to shot = 0.

   The number of reclosing shots (automatic reclosures) depends on the number of set open interval times. In this example there are three open intervals, so there are three shots.

   79SH asserts according to the M79SH setting. M79SH can be set for any combination of shots 0, 1, 2, 3, and 4. As previously mentioned, the number of shots depends on the number of set open interval times; this example uses three set open interval times. M79SH is set for shot = 1 and shot = 3:

   M79SH = 01010

   Thus, **79SH** will assert only when shot = 1 or shot = 3.

   The shot = 4 position in the M79SH setting (right most position) is not applicable in this example because there are only three shots.

   The A4 output contact is used to monitor shot counter increments (A4 = **79SH**).

4. Follow the procedure in RECLOSING RELAY OPEN INTERVAL TIMER TEST steps 6 through 8 (remember that the relay will not trip). When the applied current is removed, the shot counter increments from shot = 0 to shot = 1 and the reset interval timer is reinitialized. Because of the M79SH setting (M79SH = 01010), the A4 output contact also asserts (A4 = **79SH**).

The shot counter remains at shot = 1 and the A4 output contact remains asserted until:

> The circuit breaker remains closed throughout reset interval time (79RST = 1800 cycles), the shot counter reverts back to shot = 0, and the A4 output contact deasserts (A4 = **79SH**). The front panel RS (reset) LED remains illuminated and the A1 output contact remains asserted (A1 = **79RS**).
>
> or
>
> Current is reapplied to the relay and taken away before the reset interval timer expires. The shot counter is then incremented to shot = 2 and the A4 output contact deasserts (A4 = **79SH**). The front panel RS (reset) LED remains illuminated and the A1 output contact remains asserted (A1 = **79RS**).

If you complete RECLOSING RELAY OPEN INTERVAL TIMER TEST steps 6 through 8 you apply current to the relay and remove it before the reset interval expires. The shot counter is then incremented to the next shot.

5. If you repeat these steps, the reclosing relay shot counter will increment until shot = 3. Because of the M79SH setting (M79SH = 01010), the A4 output contact asserts again for shot = 3 (A4 = **79SH**). The front panel RS (reset) LED remains illuminated and the A1 output contact remains asserted (A1 = **79RS**).

   The shot counter remains at shot = 3 if you reapply current to the relay and remove it before the reset interval expires, because shot = 3 is the last shot. The A4 output contact remains asserted (A4 = **79SH**). The front panel RS (reset) LED remains illuminated and the A1 output contact remains asserted (A1 = **79RS**).

   During this entire sequence coordination test, the reclosing relay remained in the reset state. The front panel RS (reset) LED remained illuminated and the A1 output contact was asserted (A1 = **79RS**), even though the shot counter was being incremented and the reset interval timer reinitialized. The reset interval timer was only used to bring the shot counter back to shot = 0 after a time equal to the reset interval.

CLOSE FAILURE TIMER TEST

Purpose: Verify the operating time of the close failure timer.

Method: 1. Using the SET n command (n is the active setting group), enter the following example setting:

.
.
.

A4(2346)	= **CF**	close failure condition

.
.
.

2. Using the SET G command (G signifies the global setting group: settings common to all groups), enter these settings:

.
.
.

CFT	= 120	close failure time (cycles)

.
.
.

IN4	= DC	direct close
IN5	= 52A	circuit breaker auxiliary

The choice of inputs IN4 and IN5 is for demonstration purposes only.

Connect the CLOSE output contact to an external timer so the timer starts upon CLOSE output contact assertion. The close failure timer in the relay also starts at CLOSE output contact assertion.

The CLOSE output contact remains asserted until the close failure timer expires or the circuit breaker auxiliary contact input to the relay (IN5 = 52A) is energized (circuit breaker successfully closed). In this test, no circuit breaker simulator is connected to either the IN5 input (IN5 = 52A) or the CLOSE output contact. IN5 remains de-energized and the relay considers that the circuit breaker is open.

Connect the A4 output contact to the same external timer to stop the timer when the A4 output contact asserts. A4 contact assertion indicates that the relay failed to close the circuit breaker within the time allotted by the CFT setting; CFT = 120 cycles; A4 = **CF**, close failure condition.

Assert the relay CLOSE output contact using the CLOSE Command or by energizing the IN4 input (IN4 = DC) function. The external and close failure timers start. Input IN5 must remain de-energized (IN5 = 52A).

When the close failure timer expires, close failure condition **CF** asserts for 60 cycles and the A4 output contact asserts (A4 = **CF**). A4 output contact assertion stops the external timer. The CLOSE output contact deasserts when the **CF** bit asserts and the A4 output contact deasserts 60 cycles after asserting. Compare the external timer reading to the close failure time setting (in this example CFT = 120 cycles).

TRIP FAILURE TIMER TEST

Purpose: Verify the operating time of the trip failure timer.

Method: 1. Using the SET n command (n is the active setting group), program an element (e.g., **50L**, phase overcurrent pickup) for tripping via the programmable tripping variable TR:

close TRIP output contacts = TR + ...

50L should not be internally or externally torque controlled (via ITC and ETC). Enter the following example settings:

	.	
	.	
	.	
50L	= 4.00	amps secondary
	.	
	.	
	.	
A4(2346)	= **TF**	trip failure condition
TR(1246)		= **50L**
	.	
	.	
	.	
ETC(1)	= NA	
ITC(1)	= NA	

The setting entry NA (not applicable) leaves the designated variable blank [e.g., ETC=].

2. Using the SET G command (G signifies the global setting group - settings common to all setting groups), enter the example settings:

.
.
.

TDUR	= 5	trip duration time (cycles)
TFT	= 30	trip failure time (cycles)

.
.
.

Connect a TRIP output contact to an external timer so that TRIP output contact assertion starts the external timer. The trip failure timer in the relay also starts when the TRIP output contact asserts.

The TRIP output contact remains asserted until the trip duration timer (TDUR) expires and all programmable trip conditions (TR) go away. Additionally, all overcurrent element pickups have to drop out or TARGET RESET must be pushed to unlatch the TRIP output contact.

Connect the A4 output contact to the same external timer so that it stops timing when A4 asserts. This indicates that the relay has failed to trip the circuit breaker and interrupt the fault current within the time allotted by the TFT setting (TFT = 30 cycles; A4 = **TF**, trip failure condition).

Apply 5 amps of current to one phase of the relay. The TRIP output contacts will immediately assert (5 A > **50L** = 4.00 A). The external and trip failure timers start immediately.

When the trip failure timer expires, trip failure condition bit **TF** and the A4 output contact assert (A4 = **TF**). A4 output contact assertion stops the external timer. Compare the external timer reading to the trip failure time setting (TFT = 30 cycles in this example). The **TF** bit deasserts 60 cycles after you turn the current off.

INPUT CIRCUITS TEST

Purpose: Verify that logic inputs assert when you apply control voltage across respective terminal pairs.

Method : 1. Set the target LEDs to display the contact inputs by typing **TAR 7 <ENTER>**. The front panel LEDs should now follow contact inputs.

2. Apply control voltage to each input and make sure the corresponding target LED turns on. Energizing the DT and ET inputs should trigger an event report. Table 7.3 lists contact inputs and terminal numbers.

Table 7.3: Contact Inputs and Terminal Numbers

IN1	39, 40
IN2	41, 42
IN3	43, 44
IN4	45, 46
IN5	47, 48
IN6	49, 50

SERIAL PORTS TEST

Purpose: Verify operation of serial PORT 1.

Method : The initial checkout procedure assumes you connected a terminal to PORT 2. Set the baud rate of PORT 1 to match that of PORT 2 and switch your terminal from PORT 2 to PORT 1. Be sure you can communicate through this port.

IRIG-B TIME CODE INPUT TEST

Purpose: Verify operation of the IRIG-B clock input port.

Method:

1. Connect a source of demodulated IRIG-B time code to the relay Auxiliary Port in series with a resistor to monitor the current. Adjust the source to obtain an "ON" current of about 10 mA.

2. Execute the IRIG command. Make sure the relay clock displays the correct date and time.

Note: A recording of the IRIG-B signal passed through a simple demodulator provides a convenient, inexpensive test of the IRIG-B port. Please contact the factory for further details.

POWER SUPPLY VOLTAGES TEST

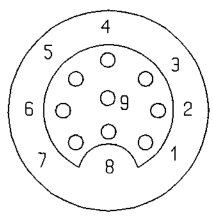
Purpose: Verify that correct output voltages are presented to PORT 1, PORT 2, and the auxiliary port. These voltages are required by external devices including a dc powered modem or the SEL-DTA unit.

Method:

1. Execute the STATUS command and inspect the voltage readings for the +5 and ±15 volt supplies.

2. At the Auxiliary Port, use a voltmeter to read the +5 and ±12 volt outputs. The 12 volt outputs are derived from the 15 volt supplies using three-terminal regulators. The following pins are the read points:

   Pin 1: Ground
   Pin 9: Ground
   Pin 6: +5 Vdc
   Pin 7: +12 Vdc
   Pin 8: -12 Vdc



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

Figure 7.5: Nine-Pin Connector Pin Number Convention

3. Compare the +5 volt readings from the status report and voltmeter. The voltage difference should be less than 50 mV, and both readings should be within 0.15 volts of five volts.

   The 12 volt supplies should be within 0.5 volts of their nominal values.

CALIBRATION

When testing this relay, first verify relay calibration. Consider all tests invalid if you determine that the relay is out of calibration. System calibration requires trimming analog channel gains and offsets.

Each SEL relay is fully tested and calibrated before it leaves the factory. Although periodic calibration is unnecessary, you should consider calibrating the relay for the conditions listed below:

1. Replacement of any analog components in the system, such as operational amplifiers, the A/D converter, or sample/hold amplifiers.

2. Replacement of input transformers or their secondary burden resistors.

3. Out-of-tolerance indication of analog voltages or currents (STATUS command).

Equipment Required

1. Calibrated ac digital voltmeter
2. One calibrated voltage and current source
3. Computer terminal

Calibration Procedures

Offset Adjustments

1. Be sure voltage and current inputs are zero at the rear panel and remove the top cover of the relay.

2. Turn the system power on.

3. Execute the STATUS command to observe the offsets while adjusting potentiometers R128 - R133 and R138 for indications of 5 mV or less (clockwise rotation results in positive offset). Note that the STATUS command is updated approximately every 30 seconds. One full revolution will change measurement by approximately 1 to 2 mV.

Gain Adjustments

The procedure below uses an ac voltage and current source at the relay inputs. This allows gain adjustments to accommodate ratio error in the input transformers and error in the burden resistors at the input CT secondaries.

1. Connect a 50 volt, 60 Hz source to all three voltage inputs. Connect a 2 ampere, 60 Hz source to all three current inputs. Both voltages and currents should have phase angles equal to 0°.

2. Turn on the system power.

3. Type **METER 222 <ENTER>** to repeat the METER command and display 222 times (you may cancel any command using the **<CTRL>X** key sequence). Keep in mind that the CTR and PTR settings cause the relay to display primary values.

4. Adjust R109-R114 for correct indication (counterclockwise increases gain).

5. Replace the relay cover.

TROUBLESHOOTING

Inspection Procedure

Complete the following procedure before disturbing the system. After you finish the inspection, proceed to the Troubleshooting Table.

1. Measure and record control power voltage at terminals 37 and 38.

2. Check to see that the power is on, but do not turn system off if it is on.

3. Measure and record the voltage at all control inputs.

4. Measure and record the state of all output relays.

5. Inspect the cabling to the serial communications ports and be sure a communications device is connected to at least one communications port.

Troubleshooting Table

All Front Panel LEDs Dark

1. Power is off.

2. Blown fuse.

3. Input power not present.

4. Self test failure.

5. Target command improperly set.

Note: For 1, 2, 3, and 4 the ALARM relay contacts should be closed.

System Does Not Respond to Commands

1. Communications device not connected to system.
2. Relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.
3. Internal ribbon cable connector loose or disconnected.
4. System is processing event record. Wait several seconds.
5. System is attempting to transmit information, but cannot due to handshake line conflict. Check communications cabling.
6. System is in the XOFF state, halting communications. Type **<CTRL>Q** to put system in XON state.

Tripping Output Relay Remains Closed Following Fault

1. Auxiliary contact inputs improperly wired.
2. Output relay contacts burned closed.
3. Interface board failure.

No Prompting Message Issued to Terminal upon Power-Up

1. Terminal not connected to system.
2. Wrong baud rate.
3. Terminal improperly connected to system.
4. Other port designated AUTO in the relay settings.
5. Port timeout interval set to a value other than zero.
6. Main board or interface board failure.

System Does Not Respond to Faults

1. Relay improperly set. Review your settings with the SHOWSET command.
2. Improper test settings.
3. PT or CT input cable wiring error.

4. Analog input cable between transformer-termination and main board loose or defective.

5. Check self test status with STATUS command.

6. Check input voltages and currents with METER command and TRIGGER and EVENT sequence.

Terminal Displays Meaningless Characters

1. Baud rate set incorrectly. Check terminal configuration. See Section 3: COMMUNICATIONS.

Self Test Failure: +5 Volts

1. Power supply +5 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self Test Failure: +15 Volts

1. Power supply +15 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self Test Failure: -15 Volts

1. Power supply -15 volt output out of tolerance. See STATUS command.

2. A/D converter failure.

Self Test Failure: Offset

1. Offset drift. Adjust offsets.

2. A/D converter drift.

3. Loose ribbon cable between transformers and main board.

Self Test Failure: ROM Checksum

1. EPROM failure. Replace EPROM(s).

Self Test Failure: RAM

1. Static RAM IC failure. Replace RAM(s).

Self Test Failure: A/D Converter

1. A/D converter failure.
2. RAM error not detected by RAM test.

Alarm Contact Closed

1. Power is off.
2. Blown fuse.
3. Power supply failure.
4. Improper EPROMs or EPROM failure.
5. Main board or interface board failure.

FIRMWARE UPGRADE INSTRUCTIONS

SEL may occasionally offer firmware upgrades to improve the performance of your relay. These instructions explain how to install new firmware.

The modifications require that you power down the relay, remove its front panel, pull out the drawout unit, exchange several integrated circuit chips, and reassemble the relay. If you do not wish to perform the modifications yourself, we can assist you. Simply return the relay and integrated circuit chips to us. We will install the new chips and return the unit to you within a few days.

Warning: This procedure requires that you handle electrostatic discharge sensitive components. If your facility is not equipped to work with these components, we recommend that you return the relay to SEL for firmware installation.

Upgrade Instructions

1. If the relay is in service, disable its control functions.
2. Turn off control power to the relay.

3. Remove the front panel by unscrewing the four pan-head screws from the front panel (one in each corner).

4. With the front panel leaning forward, you can see the aluminum drawout chassis. The main board is attached to the top of the drawout chassis. The power supply and interface board are attached to the bottom of the drawout chassis. Several ribbon cables connect the boards to each other and to other portions of the relay.

5. Disconnect the analog input ribbon cable (the right most cable) from the main board.

6. The front panel display cable connects the relay interface board to the front panel display board. It is located on the left side of the front panel. Disconnect this cable from the display board.

7. Two hex head screws hold the drawout chassis in place. These screws are on the bottom of the chassis in each front corner. Remove both screws.

8. Remove the drawout assembly by pulling the spacers on the bottom of the drawout chassis. You should be able to remove the assembly with your fingers.

9. Because steps 10 through 12 involve handling electrostatic discharge (ESD) sensitive devices and assemblies, perform these steps at an ESD safe work station. This will help prevent possible damage by electrostatic discharge.

10. Note the orientation of the ICs to be replaced. Use a small screwdriver to pry the indicated ICs free from their sockets. Be careful not to bend the IC pins or damage adjacent components.

11. Carefully place the new ICs in the appropriate sockets.

12. Check the orientation of the ICs. Be sure that each IC is in its corresponding socket. Look for IC pins that bent under or did not enter a socket hole.

13. Slide the drawout assembly back into the relay chassis. Using your fingers, push the assembly in until the retaining screw holes in the drawout assembly align with corresponding holes in the relay chassis.

14. Install the retaining screws and reconnect the two ribbon cables. Install the front panel.

15. With breaker control disabled, turn relay power back on and enter your settings. Execute the STATUS, METER, and TRIGGER commands to ensure that all functions are operational. Set and record your Access Level 1 and 2 passwords and the date and time. The relay is now ready to resume protective functions.

16. Please return the old ICs to the factory in the same packing materials. New chips are shipped with a mailing label to simplify this process. When we receive the old parts, we will record a firmware upgrade for each of your relays.

FACTORY ASSISTANCE

If you have any questions regarding the performance, application, or repair of this or any other SEL product, do not hesitate to contact the factory. Our staff is always happy to assist you.

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603
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FAX: (509)332-7990

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2350 NE HOPKINS COURT • PULLMAN, WA 99163-5603 • TEL: (509) 332-1890

PROGRAM TO COMPUTE TEST SET SETTINGS FOR TESTING DISTANCE RELAYS

The BASIC program in this note determines voltages and currents which would appear on distance relay terminals for ground and phase faults on a radial system with source impedance at the same angle as line impedance. It is useful in determining test settings for SEL distance relays and fault locating equipment.

The program was initially designed to run on a TRS-80 Model 100 briefcase computer but may be installed on virtually any personal computer or laptop.

It first prompts you for the positive and zero-sequence impedances of the transmission line. Enter the data in secondary ohms for the entire length of the protected line.

Next, you may enter fault resistance, which is used in the ground-fault computations.

Enter source impedance as a per-unit value with a base of the previously-entered transmission line data. For example, if the radial system has a source impedance of about ten percent of the entered line impedance, enter 0.1 for the per-unit distance from the source to the bus.

Specify the distance from the bus to the fault as a fraction of the total line length. To obtain the voltages and currents for a fault one-half the way down the line from the bus, enter 0.5 for the distance from the bus to the fault.

After you enter this data, the program begins computations. The display then shows voltages and currents for both an AG and BC fault. These data can be entered into any active test source.

The bottom line of the display offers you a choice of entering a new impedance data (I), changing the distance from the source to the bus (B), specifying a new fault location (F), or quitting (Q).

TWX: 5106012265 (SCHWEITZER SEL) FACSIMILE: (509) 332-7990

```
1     REM SCHWEITZER ENGINEERING LABORATORIES, INC.
2     REM 2350 NE Hopkins Court
3     REM Pullman, WA  99163-5603
4     REM
10    REM COMPUTE DOBLE SETTINGS FOR A ONE-BUS SYSTEM
20    REM HOMOGENEOUS SYSTEM
30    REM SOURCE VOLTS= 67 L-N
40    REM
50    REM ENTER IMPEDANCES FOR 100% OF LINE
60    INPUT "ENTER Z1: R,X";R1,S1
70    INPUT "ENTER Z0: R,X";R0,S0
75    INPUT "ENTER RF FOR GND FLTS";RF
80    REM
90    REM ENTER BUS LOC. FROM SOURCE
100   INPUT "DIST SOURCE TO BUS (PU OF LINE)";S
120   INPUT "DIST BUS TO FAULT (PU OF LINE)";F
130   REM
140   REM  PHASE A TO GROUND
150   REM COMPUTE POS SEQ CURRENT
160   X = R0+2*R1: Y = S0+2*S1
170   R3 = R1-R0:   S3 = S1-S0
180   AR=1/(S+F):  AI=0
190   BR=X      :  BI=Y
195   BR=BR+3*RF/(S+F)
200   GOSUB 2000
210   I = RR    :   J = RI
220   IA = 3*67*I:  JA=3*67*J
225   IB=0:JB=0:IC=0:JC=0
230   AR=X:AI=Y:BR=I:BI=J
232   GOSUB 1000
234   UA=67*(1-S*RR):VA=67*(-S*RI)
240   AR=R3       :AI=S3
250   BR=I        :BI=J
260   GOSUB 1000
270   TR=S*RR    :TS=S*RI
280   UB=67*(-0.5+TR)
290   VB=67*(-SQR(3)/2+TS)
300   UC=67*(-0.5+TR)
310   VC=67*(SQR(3)/2+TS)
315   FF$="A-G"
320   GOSUB 4041
500   REM  B-C FAULT
510   AR=1: AI=0
520   BR=2*R1*(S+F):BI=2*S1*(S+F)
530   GOSUB 2000
540   I=RR:J=RI
550   IA=0:JA=0
560   AR=I:AI=J:BR=0:BI=-67*SQR(3)
570   GOSUB 1000
580   IB=RR:JB=RI:IC=-IB:JC=-JB
590   UA=67:VA=0
600   AR=I:AI=J:BR=S*RI:BI=S*S1
610   GOSUB 1000
620   AR=RR:AI=RI:BR=0:BI=SQR(3)
630   GOSUB 1000
635   TR=RR:TS=RI
640   UB=67*(-0.5+TR)
650   VB=67*(-SQR(3)/2+TS)
660   UC=67*(-0.5-TR)
670   VC=67*(0.5*SQR(3)-TS)
675   FF$="B-C"
680   GOSUB 4041
900   INPUT "IMP BUS FAULT OR QUIT (I,B,F,Q)";A$
910   IF A$ = "I" THEN GOTO 50
920   IF A$ = "B" THEN GOTO  75
930   IF A$ = "F" THEN GOTO 120 ELSE GOTO 999
999   END
1000  REM MULT SUBROUTINE
1010  REM AR,AI * BR,BI = RR,RI
1020  RR=AR*BR-AI*BI
1030  RI=AI*BR+AR*BI
1040  RETURN
2000  REM DIVISION SUBROUTINE
2010  REM AR,AI / BR,BI = RR,RI
2020  D = BR*BR + BI*BI
2030  RR = AR*BR + AI*BI
2040  RR = RR/D
2050  RI = BR*AI - AR*BI
2060  RI = RI/D
2070  RETURN
3000  REM RECT TO POLAR CONV
3010  REM AR,AI, TO RH, TH
3020  PI = 3.14159265358
3030  IF (AR=0 AND AI=0) THEN    RH=0: TH=0: RETURN
3040  IF (AR=0 AND AI>0) THEN    RH=AI: TH=90:RETURN
3050  IF (AR=0 AND AI<0) THEN RH=-AI: TH=-90: RETURN
3060  IF (AR>0) THEN TH=(180/PI)*ATN(AI/AR)
3070  IF (AR<0) THEN TH=(180/PI)*ATN(AI/AR)+180
3080  IF TH>180 THEN TH = TH-360
3090  RH=SQR(AR*AR+AI*AI)
3100  RETURN
4041  AR=UA:AI=VA:GOSUB 3000
4042  UA=RH:VA=TH
4043  AR=UB:AI=VB:GOSUB 3000
4044  UB=RH:VB=TH-VA
4045  AR=UC:AI=VC:GOSUB 3000
4046  UC=RH:VC=TH-VA
4047  AR=IA:AI=JA:GOSUB 3000
4048  IA=RH:JA=TH-VA
4049  AR=IB:AI=JB:GOSUB 3000
4050  IB=RH:JB=TH-VA
4055  AR=IC:AI=JC:GOSUB 3000
4060  IC=RH:JC=TH-VA
4061  VA=0
4100  PRINT " VA   VB   VC   IA   IB   IC"
4130  PRINT USING"##.# ";UA;UB;UC;IA;IB;IC,
4132  PRINT FF$
4140  PRINT USING"#### ";VA;VB;VC;JA;JB;JC
4150  RETURN
```

APPENDICES
TABLE OF CONTENTS

Appendix A - Firmware Versions
Appendix B - Parts Placement Diagrams

APPENDIX A: FIRMWARE VERSIONS

The firmware versions are listed in chronological order (most recent firmware at top). Firmware enhancements are listed at the time they were incorporated into the firmware [firmware versions listed above the enhancement(s), incorporate the enhancement(s)].

Firmware Part/Revision No.	Description of Firmware
	This firmware differs from the previous versions as follows: – Initialized analog gain on unused channel.
SEL-151C-R612	151C 60 Hz 5 A ACB rotation
SEL-151C-R564	151C 50 Hz 1 A
SEL-151C-R514	151C 60 Hz 1 A
SEL-151C-R465	151C 50 Hz 5 A
SEL-151C-R419	151C 60 Hz 5 A
	This firmware differs from the previous versions as follows: – INST target is now independent of phase targets.
SEL-151C-R611	151C 60 Hz 5 A ACB rotation
SEL-151C-R563	151C 50 Hz 1 A
SEL-151C-R513	151C 60 Hz 1 A
SEL-151C-R464	151C 50 Hz 5 A
SEL-151C-R418	151C 60 Hz 5 A
	This firmware differs from the previous versions as follows: – Debounce all control inputs. – Enhance 2020 compatibility.
SEL-151C-R610	151C 60 Hz 5 A ACB rotation
SEL-151C-R562	151C 50 Hz 1 A
SEL-151C-R512	151C 60 Hz 1 A
SEL-151C-R463	151C 50 Hz 5 A
SEL-151C-R417	151C 60 Hz 5 A
	This firmware differs from the previous versions as follows: – Changed the RINGS prompt to "RINGS 1-30."
SEL-151C-R609	151C 60 Hz 5 A ACB rotation
SEL-151C-R561	151C 50 Hz 1 A
SEL-151C-R511	151C 60 Hz 1 A
SEL-151C-R462	151C 50 Hz 5 A
SEL-151C-R416	151C 60 Hz 5 A
	This firmware differs from the previous versions as follows: – Added high-side blown-fuse logic with new 27C setting option.
SEL-151C-R608	151C 60 Hz 5 A ACB rotation
SEL-151C-R560	151C 50 Hz 1 A
SEL-151C-R510	151C 60 Hz 1 A
SEL-151C-R461	151C 50 Hz 5 A
SEL-151C-R45	151C 60 Hz 5 A

Firmware Part/Revision No.	Description of Firmware
SEL-151C-R606 SEL-151C-R558 SEL-151C-R508 SEL-151C-R459 SEL-151C-R413	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
SEL-151C-R605 SEL-151C-R557 SEL-151C-R507 SEL-151C-R458 SEL-151C-R412	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
SEL-151C-R604 SEL-151C-R556 SEL-151C-R506 SEL-151C-R457 SEL-151C-R411	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
SEL-151C-R603 SEL-151C-R555 SEL-151C-R505 SEL-151C-R456 SEL-151C-R410	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
SEL-151C-R602 SEL-151C-R554 SEL-151C-R504 SEL-151C-R455 SEL-151C-R409	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
SEL-151C-R601 SEL-151C-R553 SEL-151C-R503 SEL-151C-R454 SEL-151C-R408	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
SEL-151C-R600 SEL-151C-R552 SEL-151C-R502 SEL-151C-R453 SEL-151C-R407	151C 60 Hz 5 A ACB rotation 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
  SEL-151C-R551 SEL-151C-R501 SEL-151C-R452 SEL-151C-R406	This firmware differs from the previous versions as follows: – Added STX, ETX consistently. 151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A

Firmware Part/Revision No.	Description of Firmware
SEL-151C-R550 SEL-151C-R500 SEL-151C-R451 SEL-151C-R405	151C 50 Hz 1 A 151C 60 Hz 1 A 151C 50 Hz 5 A 151C 60 Hz 5 A
	This firmware differs from the previous versions as follows: – Added TRIP bit to Relay Word. – Expanded DATC setting range. – 1 or 2 stop bit communications protocol options (previously just 2 stop bits available).
SEL-151C-R450 SEL-151C-R404	151C 50 Hz 5 A 151C 60 Hz 5 A

The following table shows firmware that does not precisely match this manual. An explanation of the differences between firmware versions is in the heading for each group of firmware in the table.

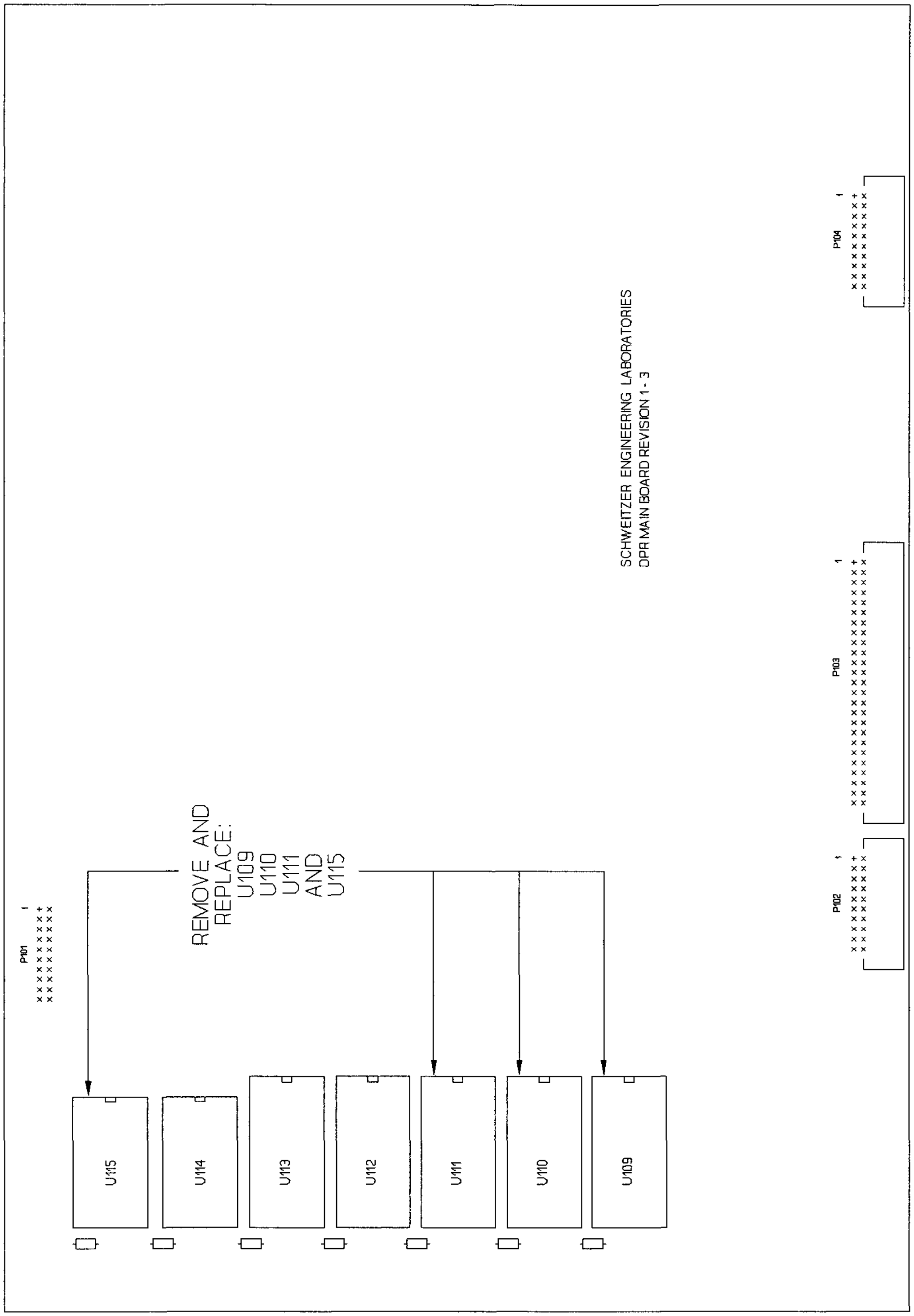
Firmware Part/Revision No.	Description of Firmware
SEL-151C-R403 SEL-151C-R402 SEL-151C-R401 SEL-151C-R400	151C 60 Hz 5 A 151C 60 Hz 5 A 151C 60 Hz 5 A 151C 60 Hz 5 A

To find the firmware revision number in your relay, obtain an event report (which identifies the firmware) using the EVENT command. This is an FID number with the Part/Revision number in bold:

FID=**SEL-151C-R405**-V656rplr-D921102

For a detailed explanation of the Firmware Identification Number (FID) refer to Section 4: EVENT REPORTING.

APPENDIX B - INTERNAL DIAGRAM



SEL-100 Series Relay Main Board Troubleshooting Test Points and Jumper Locations

SEL-151 RELAY COMMAND SUMMARY

Access Level 0

ACCESS	Answer password prompt (if password protection is enabled) to enter Access Level 1. Third unsuccessful attempt pulses 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.
BREAKER	Display running sum of circuit breaker trips for relay and external trips (circuit breaker trip counters). Also display running sum of interrupted current in each circuit breaker pole for relay and external trips.
BREAKER R	Reset circuit breaker trip counters and interrupted current sums to zero for both relay and external trips. Relay stores reset date and time.
DATE m/d/y	Set or display date. DAT 6/1/92 sets date to June 1, 1992. IRIG-B time code input overrides existing month and day settings. DATE pulses ALARM contacts when year entered differs from year stored. To display the date only, enter DATE.
EVENT n	Show event record. EVE or EVE 1 shows newest event; EVE 12 shows oldest (n=1, 2, 3,...,11, or 12).
HISTORY	Show DATE, TIME, EVENT, LOCAT (location), SHOT, TARGETS, 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 present phase, residual, and negative-sequence current values; present real and reactive power values; present line-to-neutral, line-to-line, zero-sequence, and negative-sequence voltage values. Optional n displays METER data n times.
METER D	Display demand and peak demand values of phase, residual, and negative-sequence current values and real and reactive power values.
METER RD	Reset demand values.
METER RP	Reset peak demand values.
QUIT	Return control to Access Level 0; return target display to Relay Targets.
SHOWSET n	Display settings of setting group n without affecting them (n = 1, 2, 3, 4, 5, or 6).
STATUS	Show self test status.

Access Level 1 Continued

TARGET n k	Show data and set target LEDs as follows (n = 0, 1, 2, . . . 7, or 8): TAR 0: Front Panel Targets — TAR 1: Relay Word row R1 TAR 2: Relay Word row R2 — TAR 3: Relay Word row R3 TAR 4: Relay Word row R4 — TAR 5: Relay Word row R5 TAR 6: Relay Word row R6 — TAR 7: Input States TAR 8: Output Contact States — Optional k displays target data k times.
TARGET R	Clears targets and returns to TAR 0
TIME h/m/s	Set or display time. TIM 13/32/00 sets clock to 1:32:00 PM. IRIG-B synchronization overrides this setting. To display the time only, enter TIME.
TRIGGER	Trigger and save an event record (event type is EXT).

Access Level 2

CLOSE	Close circuit breaker, if allowed by jumper setting.
COPY m n	Copy setting group m to setting group n (m and n equal any combination of 1, 2, 3, 4, 5, or 6). Clears buffers. If n is the active setting group, the ALARM output contacts pulse closed.
GROUP n	Designate the active setting group when no Setting Group Selection Inputs are assigned to inputs or all Setting Group Selection Inputs assigned to inputs are deasserted (n = 1, 2, 3, 4, 5, or 6). The ALARM output contacts pulse closed when the active group changes. GROUP n command execution does not clear the event buffer.
OPEN	Open circuit breaker, if allowed by jumper setting.
PASSWORD	Show or set passwords. ALARM contacts pulse closed after password entry. PAS 1 OTTER sets Level 1 password to OTTER. PAS 2 TAIL sets Level 2 password to TAIL.
SET n p	Initiate setting procedure for setting group n (n = 1, 2, 3, 4, 5, or 6). Option p directs the relay to begin the setting procedure for setting group n at setting p (if p = 51P, the setting procedure starts at setting 51P, bypassing all settings before 51P). If no optional p is entered, the setting procedure starts at the beginning. The relay clears event buffers when new settings are stored. If n is the active setting group, the ALARM output contact pulses closed.
SET G p	Initiate setting procedure for the global setting group. Option p directs the relay to begin the setting procedure for the global setting group at setting p (if p = TDUR, the setting procedure starts at setting TDUR, bypassing all settings before TDUR). If optional p is not used, the setting procedure starts at the beginning. The SET G command pulses ALARM contacts closed and clears event buffers when new settings are stored.

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SEL-151 RELAY COMMAND SUMMARY

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Access Level 1

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Access Level 2

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