SEL Underground AutoRANGER®
Instruction Manual

Purpose of the SEL Underground AutoRANGER

The SEL Underground AutoRANGER (SEL-ARU) fault indicator points line crews to faulted sections of underground cable. It indicates the passage of current that results from a fault on the cable on which it is installed. The SEL-ARU uses a red target, LED, auxiliary contact (as part of a SCADA system) or radio signal to indicate a fault.

The SEL-ARU, and fault indicators in general, improve distribution circuit reliability, improve the safety of line crews and the public, and reduce costs associated with power system downtime, equipment, and regulation. SEL-ARU fault indicators can lead line crews directly to the location of a fault, as shown in *Figure 1*. The resulting shorter outage times mean reduced outages for electricity customers and less lost revenue for electricity providers. Line crews spend less time searching for the location of the fault and are able to isolate and repair faulted sections faster, which further increases cost savings.

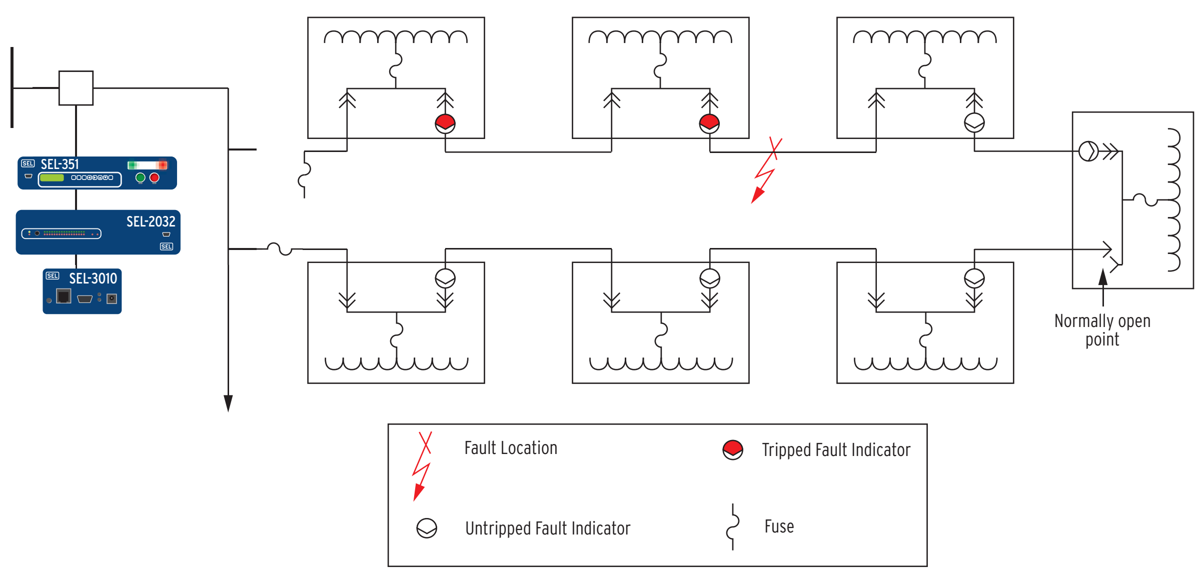


Figure 1 Example System With SEL-ARU Fault Indicators

Basic Functionality

The SEL-ARU is a simple and robust fault indicator with application flexibility that makes it appropriate for many underground distribution systems. The SEL-ARU automatically configures its fault threshold and protection timing, simplifying correct application and installation and making human judgment calls unnecessary.

Line Powered

The SEL-ARU uses inductively coupled power line energy to operate its internal circuitry, as well as to monitor the current in the conductor. Two types of circuits are used to monitor the conductor current: an averaging circuit to monitor the normal load current of the power line, and a comparator circuit to indicate when the instantaneous current is above the fault threshold. *Figure 2* illustrates the functional operation of the SEL-ARU.

Autoranging

The SEL-ARU automatically configures its fault current threshold or trip level, the level of fault current that causes the device to trip. (Unless noted, all currents are rms current values.) The fault threshold is based on the normal measured cable current load on the cable. Measuring the load current and automatically setting the fault threshold ensures that the fault threshold is appropriate for the cable and circuit on which the SEL-ARU is installed.

The SEL-ARU has a limited number of fixed fault thresholds. It periodically measures the load current on the circuit, and then uses an internal algorithm to choose the appropriate threshold for the fault threshold. Measuring the load current and choosing a fixed fault threshold can be described as autoranging.

Dynamic Trip Response (DTR)

Because it incorporates a Dynamic Trip Response (DTR) time feature, the SEL-ARU coordinates well with upstream protection. DTR ensures that fault current detected by the SEL-ARU is sustained for a period of time before the unit indicates a fault. By doing so, DTR prevents the SEL-ARU from falsely indicating fault conditions based on short bursts of high current that might occur normally and do not indicate a fault. The period of time that the fault current is sustained before the SEL-ARU indicates a fault varies with the magnitude of the fault current. The combination of automatic fault threshold selection and DTR allows integration of the SEL-ARU into almost any circuit protection scheme.

See *Fault Indication on page 16* for details about DTR.

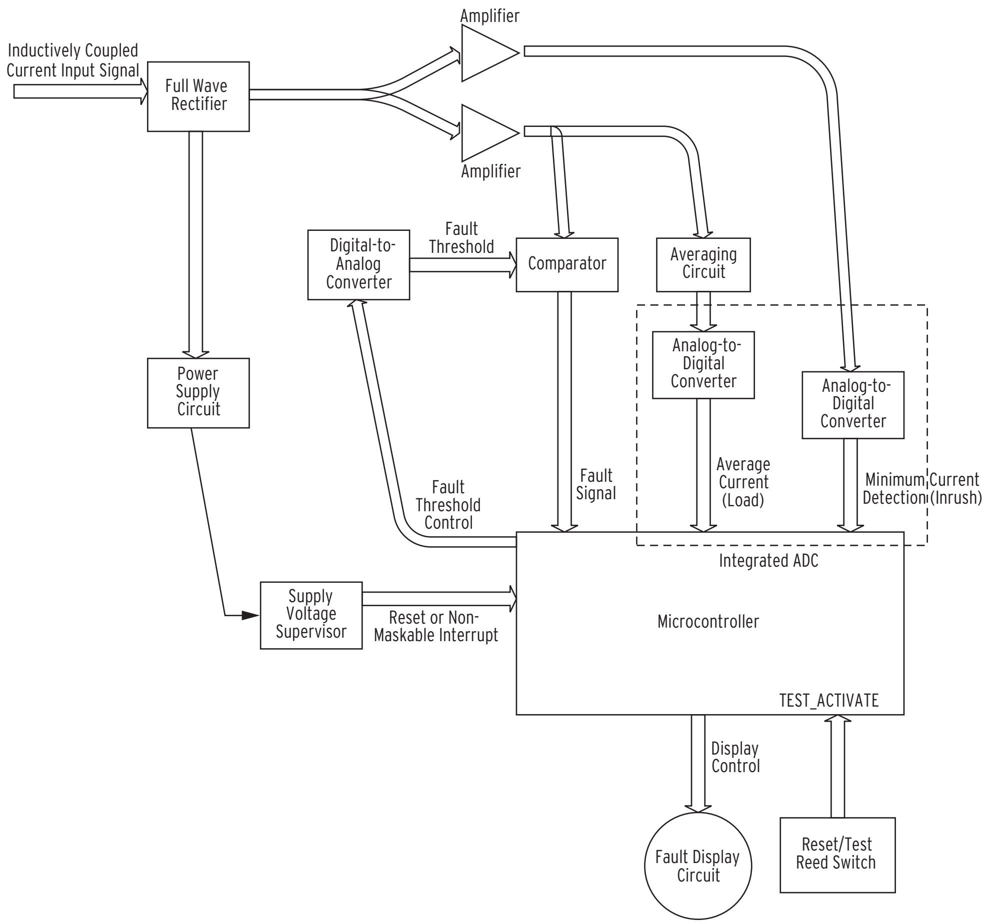


Figure 2 SEL-ARU Functional Block Diagram

Physical Design

The SEL-ARU is designed for simple installation and resistance to elements such as water and dirt. SEL-ARU fault indicators are waterproof, operate from –40° to +85°C (–40° to +185°F), and meet an IP rating of IP68.

Figure 3 SEL-ARU With Integrated Target Display

Transformer Core

The SEL-ARU is applicable on cables with outer diameters ranging from 19.1 mm to 53.3 mm (0.75 inches to 2.1 inches). Large-core models are available to fit larger conductor cable diameters. The fault indicator's split-core current transformer monitors the current magnitude of the cable on which it is installed.

In addition to measuring the cable's current magnitude, the split-core transformer provides power to the internal electronic components of the SEL-ARU, making it a line-powered fault indicator. The SEL-ARU is designed so that its electrical components draw a minimum amount of power from the line. Low power consumption minimizes the burden on the current transformer, allowing the fault indicator to operate at relatively low load currents and maintain accurate current monitoring. In the absence of cable current, the SEL-ARU fault indicator's microcontroller can function for five seconds on capacitive stored energy. This feature allows the SEL-ARU to sense that the conductor current has ceased and to prepare for the loss of its power supply, as described in the following paragraph.

To maintain consistent operation, the SEL-ARU saves its automatically configured fault threshold, the state of its fault display (tripped or reset), and the amount of current-activated timed reset (CATR) time remaining for the fault display in its internal memory. By saving this information, the SEL-ARU can begin operating in the same configuration that it was in prior to loss of its power supply. Indeed, this information must be saved to ensure proper CATR and normalization current operation. See *Operation on page 6* and *Fault Indication on page 16* for details on CATR and normalization current.

Remote Display, Auxiliary Contact, and Junction Box (Some Models)

Remote Displays

SEL-ARU fault indicators with remote displays have targets visible from the exterior of the cabinet or enclosure in which they are installed.

Figure 4 Remote "V" Display

Figure 5 Remote Large "L" Display

Figure 6 Three-Phase Display

Auxiliary Contacts

SEL-ARU fault indicators' auxiliary contacts are normally open relay contacts that allow for integration into a SCADA system. When a fault occurs, the auxiliary contact closes, sending a signal via SCADA or to an alarm contact or RTU.

Junction Box

Some SEL-ARU fault indicators, such as those with auxiliary contacts or LED displays, require batteries. In these cases, an accompanying junction box houses a battery.

The auxiliary contact is provided as a normally open relay contact.

The BEACON Bolt® LED displays operate with a 3.6 V high-capacity lithium battery.

Figure 7 Remote BEACON Bolt Display

Operation

The SEL-ARU derives operating power from the current it monitors. However, the SEL-ARU will only operate at a current level above or equal to the Minimum Operating Current (MOC) of 3 A. The electronic circuitry in the SEL-ARU cannot detect and indicate faults immediately after sensing MOC. The SEL-ARU has a power-up period that allows this circuitry to accumulate the charge needed to operate mechanical target displays. When current greater than or equal to MOC is present on the monitored conductor for four minutes (or less if the current is significantly above MOC), the SEL-ARU will turn on and begin operating in the System Detect state (see *Table 1*). After three minutes of System Detect, the SEL-ARU is armed and ready to detect faults. The SEL-ARU will autorange before becoming active.

State Machine Operation

The SEL-ARU operates as a state machine. A state machine has different responses to its inputs based on its current state. *Figure 8* shows the states and transitions of the SEL-ARU. Most of the state transitions are governed by time-outs that occur when the device has been in that state for a specified time. The state machine is very limited and consists of only three states, as shown in *Table 1*.

Table 1 SEL-ARU Operating States

State	Description
SYSTEM_DETECT	Detecting stable system current
ARMED	Armed for fault detection and autoranging
INTERMEDIATE_FAULT	Delay after fault current detection to check for sustained increase in load or momentary fault condition

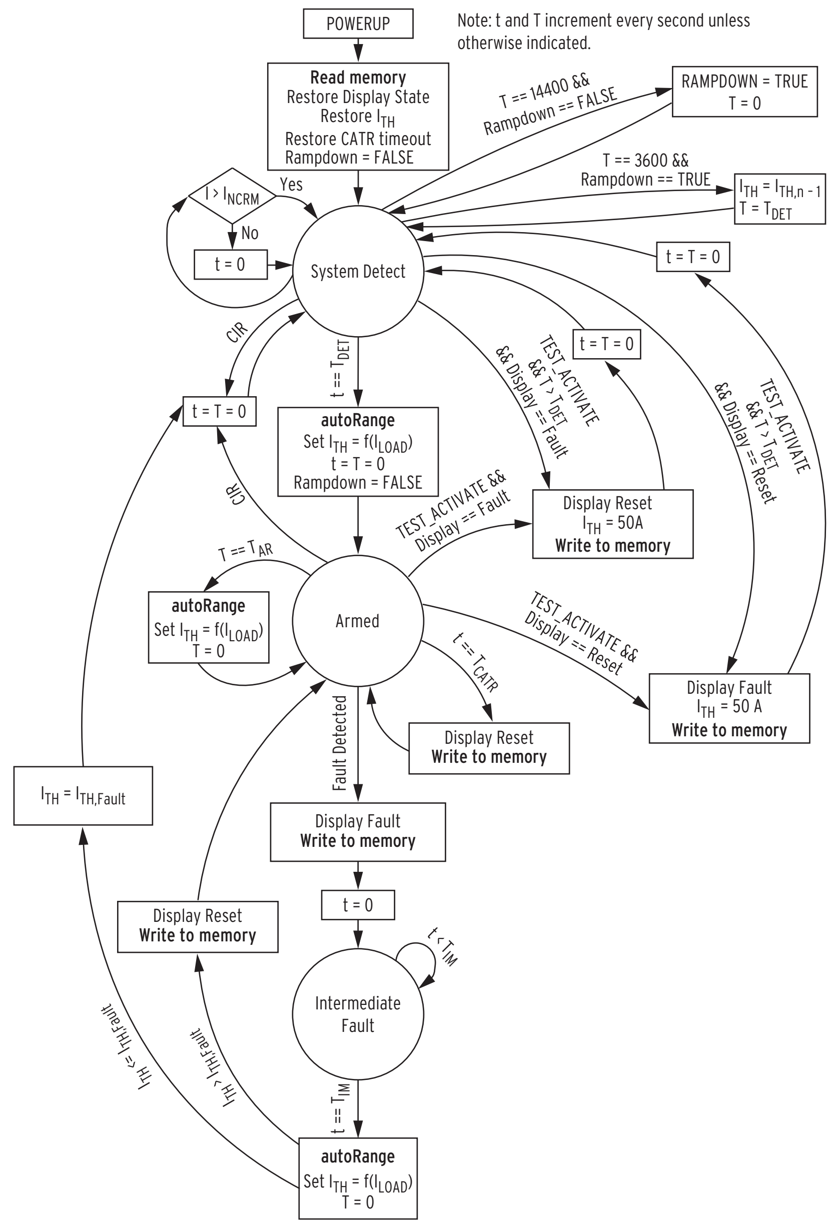


Figure 8 SEL-ARU State Diagram

System Detect State

The System Detect state feature detects normal system operation for a period of time before responding to fault conditions. Normal system operation is defined as continuous sensing of current for a duration T_{DET} = 3 minutes. The level of current that defines normal system activity depends on the fault threshold before the inrush or fault event. To exit the System Detect state, the SEL-ARU must sense a constant current greater than or equal to I_{NORM} (normalization current) for three minutes.

Please see *Fault Indication on page 16* for a complete description of I_{NORM}.

Armed State

Armed state is the primary state of operation for the SEL-ARU. After detecting stable system current for the required T_{DET} period, the SEL-ARU is ready to respond to system faults. Detection of fault current will send the SEL-ARU into Intermediate Fault state (see *Fault Indication on page 16* for details on fault detection). The SEL-ARU device will also measure system load current periodically every 30 seconds, using these measurements to configure its fault threshold automatically.

While in the Armed state and indicating a fault, the SEL-ARU waits a defined period of time before it resets automatically. This timed reset period is defined by the Current Activated Timed Reset (CATR) option. Customers select the CATR duration when ordering; the duration is set in the factory. If they choose a CATR duration of zero, the device will reset its fault display immediately upon entering the Armed state. Although the duration of CATR is factory set, it is also affected by inrush restraint events during the CATR period.

SEL-ARU Models and Configurations on page 23 details the SEL-ARU fault indicator's CATR feature. The end of the CATR period (or a line crew performing a field test) causes the SEL-ARU to exit the Armed state.

Intermediate Fault State

The Intermediate Fault state directs SEL-ARU operation after the device senses a fault current event. The SEL-ARU will immediately indicate the detection of the fault event before entering the Intermediate Fault state. However, it is possible that the condition the SEL-ARU detected was the result of a large, sustained increase in the load current or load pickup. Load pickup is caused by a sustained load increase on a distribution system, often as a result of a large switched load or system reconfiguration. If the fault threshold that the SEL-ARU selects automatically, I_{TH}, is greater when the load current is measured at the expiration of the Intermediate Fault (T_{IM} = 2 minutes) state than it was when the SEL-ARU sensed the fault event, load pickup has occurred. Load pickup is considered a normal and temporary system transient, so the SEL-ARU returns to Armed state with the newly configured fault threshold and resets the fault indication display. If the measured load current at the end of the Intermediate Fault state duration, T_{IM}, does not result in a greater fault threshold, the SEL-ARU returns to System Detect state and the fault display continues to indicate the detected fault event.

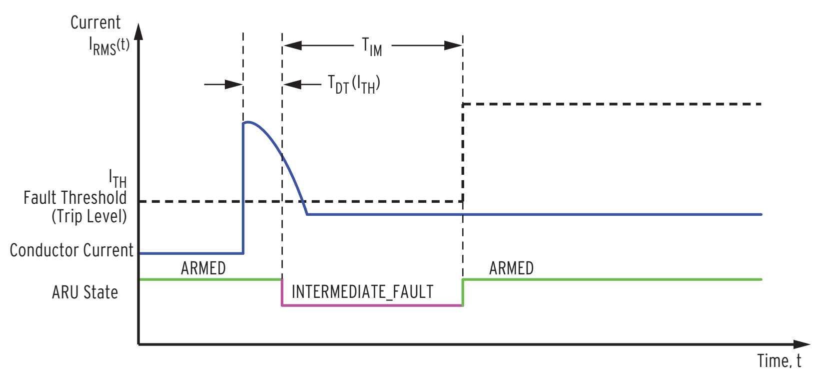


Figure 9 Example Sustained Increase in Load

Autoranging

The SEL-ARU has eight distinct fault thresholds: 50 A, 100 A, 200 A, 300 A, 450 A, 600 A, 900 A, and 1200 A. The SEL-ARU chooses one of these fault thresholds automatically. This threshold will be at least twice the load current sensed by the fault indicator.

By measuring normal load current, the SEL-ARU selects automatically, or autoranges to one of the eight fault thresholds listed previously. Because of the SEL-ARU fault locator's split-core transformer design, the effect of trip level versus cable diameter is minimal. Each fault threshold has an associated range of load current (see *Table 2*). *Equation 1* and *Equation 2* show the relationship between measured load current and the resulting trip level. *Equation 1* shows how the SEL-ARU will increase its fault threshold when the load reaches 50 percent of its present value. *Equation 2* is chosen to provide hysteresis between load currents, resulting in an increase or decrease of the fault threshold.

$$I_{LOAD,max}(I_{TH,n}) = \begin{cases} \frac{1}{2} I_{TH,n} & : I_{TH,n} < 1200\ A \\ (0.90 \bullet\ I_{T,n}) & : I_{TH,n} = 1200\ A \end{cases}$$

Equation 1

$$I_{LOAD,min}(I_{TH,n}) = \begin{cases} 3\ A & : I_{TH,n} = 50\ A \\ \left(\frac{1}{2} I_{LOAD,max}(I_{TH,n-1})\right)^{1.1} & : I_{TH,n} > 50\ A \end{cases}$$

Equation 2

The fault indicator measures system load current every 30 seconds while in armed state and, based on this measurement, either remains at its existing fault threshold or autoranges to a different fault threshold. This feature enables the SEL-ARU to handle variable loads, including seasonal and time-of-day fluctuations, making specification, application, stocking, and use as simple as possible. *Table 2* lists the measured load current (I_{LOAD}) minimum and maximum values associated with the SEL-ARU fault threshold, $I_{TH,n}$.

The period between load current measurements and fault threshold adjustments is T_{AR} = 30 seconds. The autorange measurement is taken from an RC (resistor-capacitor) circuit with the following time constant:

$\tau = 1.5$ s

Because the time constant for the autorange circuit is only 1.5 s, transients that last for this amount of time can influence the voltage on the autorange circuit and can influence the autorange behavior if the transient coincides with the microcontroller sampling of this circuit. If the load current transient and the microcontroller sampling are synchronous, there can be sustained load current increases for approximately 1 s or more that can cause the SEL-ARU to increase its trip level. Very large changes (more than double) in load current could cause the SEL-ARU to increase its trip level on a time scale even smaller than 1 second. If the fault threshold increases as a result of a transient load current, it will correct itself with the next measurement 30 seconds later.

Table 2 Fault Thresholds for Measured Load Current Ranges

n	$I_{TH,n}$ (A)	$I_{LOAD,min}$ (A)	$I_{LOAD,max}$ (A)
0	50	3	25
1	100	16.1	50
2	200	34.5	100
3	300	73.9	150
4	450	115.5	225
5	600	180.4	300
6	900	247.6	450
7	1200	386.7	600

Figure 10 shows a graphical representation of how load currents result in autorange fault thresholds.

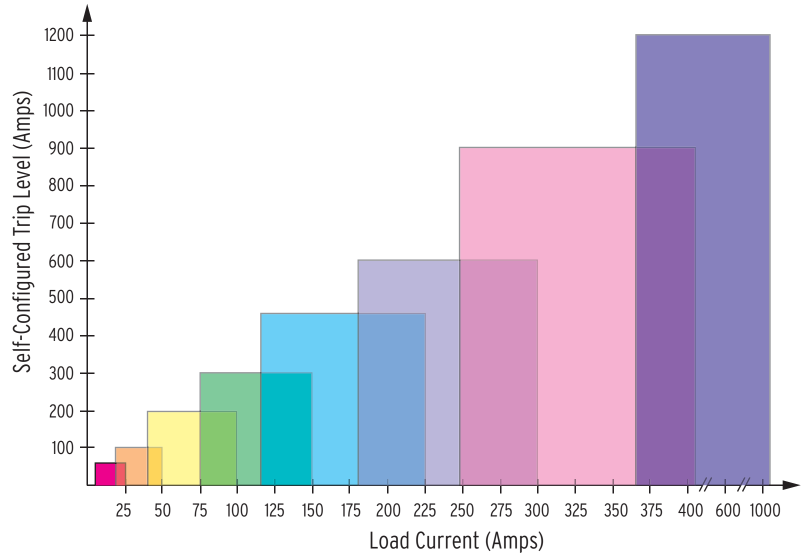


Figure 10 SEL-ARU Self-Configured Trip Value as a Function of Load Current

The load current ranges overlap for each fault threshold. This provides hysteresis to the autoranging algorithm and prevents the SEL-ARU from oscillating between fault thresholds. (If the load current ranges did not overlap, small fluctuations in load current would cause the SEL-ARU to oscillate between two fault thresholds, creating a risk of inaccurate fault detection and indication.)

Figure 11 illustrates how the fault threshold would oscillate if autoranging thresholds were too close to one another (for example, 44 A and 45 A). *Figure 12* illustrates how overlapping load current cutoffs for adjacent fault thresholds stabilize the fault threshold, allowing the SEL-ARU to select a single fault threshold.

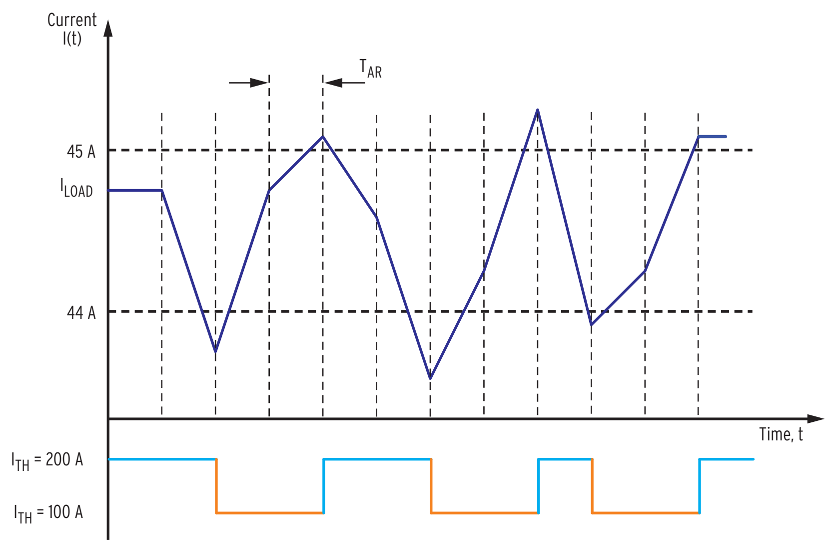


Figure 11 Oscillating Trip Threshold With Small Hysteresis (Unwanted)

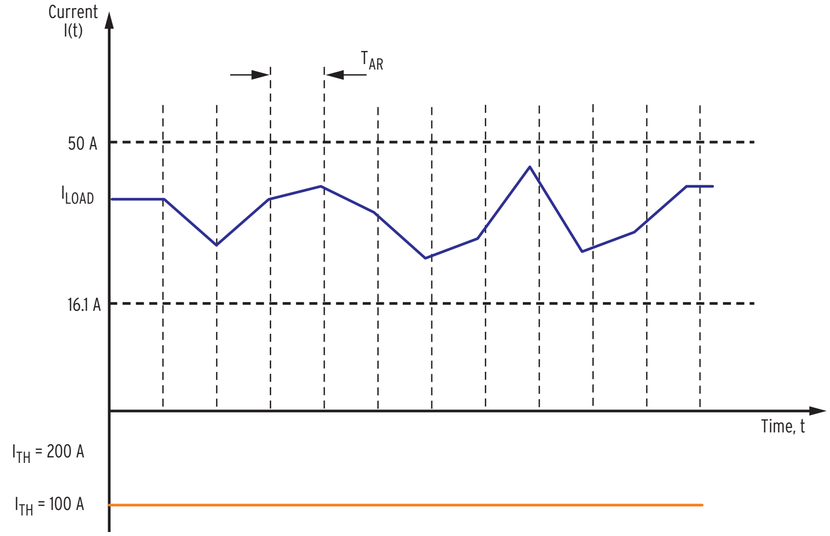


Figure 12 Stable Autoranging Algorithm

Dynamic Current Inrush Restraint (IR)

The SEL-ARU will not trip after detecting loss-of-current. The trip prevention feature of the SEL-ARU is referred to as loss-of-current activated inrush restraint, or current Inrush Restraint (IR). The IR feature differentiates between the opening of upstream interrupting devices (e.g., reclosers or load transfer switches) and actual fault current, preventing false indication of faults. Without the IR feature, the SEL-ARU could detect fault-level currents from the inrush of current resulting from the recloser performing its closing action. The SEL-ARU constantly monitors the load current for IR events, and it uses the detection of such an event to direct the state of operation, as shown in *Figure 13*.

IR events that occur while the SEL-ARU is armed to detect and indicate a fault will return the fault indicator to the System Detect state. IR events that occur during the System Detect state will reset the timebase for that state. IR events are ignored in Intermediate Fault state.

Figure 13 shows an IR event, followed by current that exceeds the fault threshold for a period long enough to satisfy the dynamic trip (DT) feature. The SEL-ARU, however, ignores the inrush current and continues with System Detection.

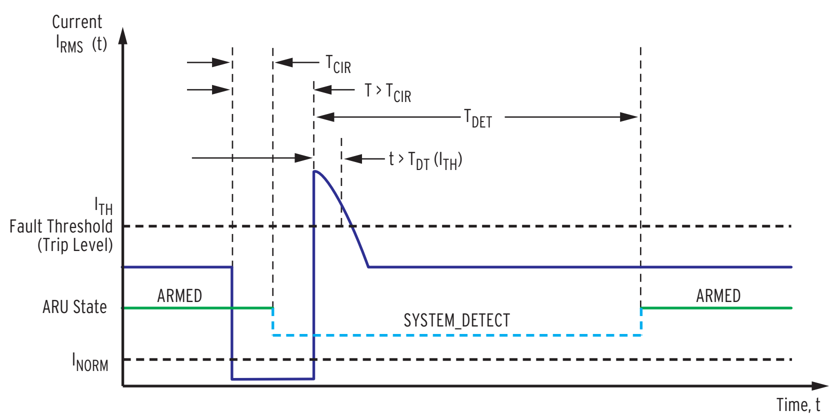


Figure 13 Loss-of-Current Inrush Lockout Example

Each of the SEL-ARU fault indicator's fault thresholds has an associated current below which IR events will be detected. The current threshold that defines the loss-of-current condition for any given fault threshold is known as normalization current, or I_{NORM}. Normalization current is equal to onetwentieth, or 5 percent, of the fault threshold. (The normalization current for the 1200 A trip level is slightly lower than the normal 5 percent level and is nominally 55 A.)

$$I_{NORM} = 0.05 \cdot I_{TH} \quad \textbf{Equation 3}$$

If current falls below I_{NORM} for a period, T_{IR} = 83.3 ms (five 60 Hz cycles), the SEL-ARU detects an IR event. *Table 3* lists the minimum current necessary to prevent inrush restraint for each fault threshold.

Table 3 Normalization Current vs. Fault Threshold

I_{TH}	I_{NORM} (Ignored Backfeed Level)
50 A	2.5 A
100 A	5 A
200 A	10 A
300 A	15 A
450 A	22.5 A
600 A	30 A
900 A	45 A
1200 A	55 A

Associating a minimum inrush restraint current for each fault threshold provides the SEL-ARU with a method for ignoring feedback currents induced by single-phase sectionalizing of a three-phase system (see *Backfeed Restraint* for details) that can prevent it from detecting IR events accurately. Current backfeed can come from delta-connected loads or large stored-energy devices (e.g., a very large motor). Distribution systems with higher load currents can usually sustain higher current levels that backfeed into the system. In this case, the SEL-ARU ignores higher backfeed currents on systems with larger measured load currents, preventing false detection of faults as a result of undetected IR events.

Backfeed Restraint

Backfeed current can emanate from many sources on a distribution circuit, such as stored-energy devices, inductive coupling to adjacent circuits, and residual current flow during single phasing. Depending on the magnitude and duration, backfeed can cause SEL-ARU fault indicators to falsely trip or reset, leading to confusion in the field.

One method to prevent false faulted circuit indicator (FCI) reset or trip operations because of backfeed current is to apply a time delay to the reset function. Once a fault has occurred, a timed reset FCI would remain in its tripped state until its set time period has expired. While beneficial in eliminating false reset, timed-reset devices might not be able to reset automatically upon circuit restoration. Additionally, timed reset functionality does not address the problem of downstream stored energy discharging into a fault, causing fault indicators to trip beyond the fault. The SEL-ARU uses the I_{NORM} threshold to prevent false operations resulting from backfeed current.

The SEL-ARU is a current-reset device, but current must exceed the normalization current (I_{NORM}) threshold before the SEL-ARU resets. As a result, the SEL-ARU will not reset falsely because of backfeed current as long as this current does not exceed I_{NORM}.

The normalization current threshold moves in tandem with the self-configured trip threshold and represents a dynamic reset current threshold. Backfeed currents are typically below this threshold for a given load current range. Systems with higher load currents can generally sustain higher backfeed current levels. Self-adjusting normalization current thresholds allow the

SEL-ARU to ignore large backfeed currents on systems with large measured load currents.

Rampdown Restraint

The SEL-ARU will not lower its fault threshold (“autorange down”) unless it detects sufficient (normal) load current. If the load current is below I_{NORM}, the SEL-ARU regards the current as backfeed and does not adjust its fault threshold lower. I_{NORM} provides rampdown restraint, which prevents the SEL-ARU from lowering its fault threshold because of backfeed current. As a result, SEL-ARU will not autorange down to the minimum fault threshold when the conductor is de-energized because of a fault. If load current is greater than I_{NORM} upon system restoration, the SEL-ARU will autorange to the appropriate fault threshold given the new load current.

Rampdown restraint has an associated time-out, or T_{RDR}, equal to four hours. If a current greater than 3 A is present on the monitored conductor for a period greater than T_{RDR}, the SEL-ARU will lower its trip threshold. This is necessary to ensure that the SEL-ARU operates properly if the load current falls below I_{NORM} unexpectedly, for example because of system reconfiguration or the relocation of an SEL-ARU from a heavily loaded conductor to a very lightly loaded conductor. Without the rampdown restraint time-out, the device may never lower its trip threshold and operate properly at its new installation location.

To accomplish the trip threshold rampdown, the SEL-ARU waits for the expiration of the T_{RDR}. After the time-out period, it lowers its trip threshold to the next lowest fault threshold level. The SEL-ARU will continue to lower its trip threshold every hour until the conductor current satisfies the required I_{NORM}. Once this happens, the SEL-ARU will begin operating normally.

Fault Detection

The SEL-ARU monitors instantaneous cable current. When the current magnitude of the cable exceeds the SEL-ARU fault indicator’s fault threshold, the SEL-ARU starts an internal timer that measures the length of time the cable’s current magnitude exceeds the fault indicator's fault threshold current.

NOTE: SEL-ARU fault thresholds are calibrated for a cable diameter of 1.4″. Fault threshold currents and autorange current levels will increase with larger cable diameters and decrease with smaller cable diameters.

There are two requirements for the SEL-ARU to indicate a fault condition. First, instantaneous current magnitude must exceed the trip threshold for more than 1 ms during consecutive half-cycles of the power system frequency. Second, the current must exceed the trip threshold for a factory-set number of consecutive half cycles (see *Table 4*).

In *Figure 14*, the duration of instantaneous current exceeding the SEL-ARU fault indicator’s fault threshold is defined as t_{FP}. The waveform illustrated in *Figure 14* is intended to show only the nature of the instantaneous current detection. The figure shows how the SEL-ARU detects the instantaneous current exceeding the fault threshold in pulses separated by half-cycle periods of time. The time during which the instantaneous fault exceeds the fault threshold current must be greater than 1 ms (as measured by internal software), or the SEL-ARU ignores it, neither tripping nor autoranging.

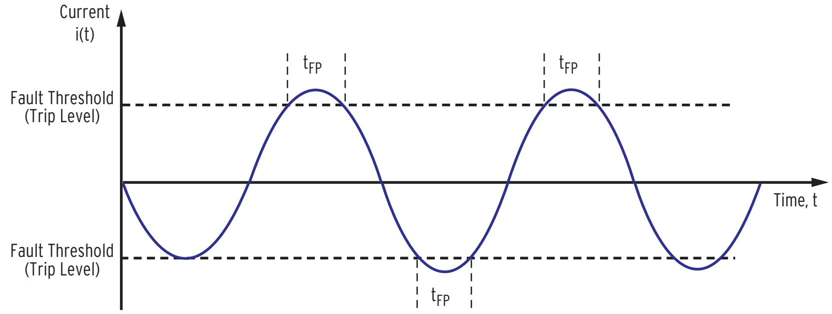


Figure 14 Example of a Current Waveform With Periods of Instantaneous Overcurrent

Dynamic Trip Response Time

The SEL-ARU configures a Dynamic Trip (DT) response time for each individual fault threshold. The response time for increasing levels of fault current is reduced. The SEL-ARU will indicate a fault for any of the time-current combinations at or above the automatically configured fault threshold. Through a feature referred to as Dynamic Trip, the SEL-ARU scans the fault current waveform with all of its fault threshold levels and will indicate a fault for any valid combination of current and time. This behavior is analogous to a fuse operation where the energy through the fuse is a function of the current magnitude and its duration.

The SEL-ARU has factory-set DT response times. These times correspond to integer multiples of the 60 Hz distribution system frequency. Thus, the SEL-ARU needs to detect sustained fault current for a number of half cycles of the 60 Hz power system frequency. Each fault threshold has a factory-set DT duration. *Table 4* shows the SEL-ARU fault indicator's factory-set DT settings. *Figure 15* shows a graphical representation of the DT response.

Table 4 Dynamic Trip Time vs. Fault Threshold

I_{TH}(A)	Dynamic Trip Time (ms, 60 Hz)	Minimum Half Cycles (60 Hz)	Maximum Half Cycles (60 Hz)
50	200	24	30
100	100	12	18
200	50	6	12
300	16	3	8
450	1	1	4
600	1	1	4
900	1	1	4
1200	1	1	4

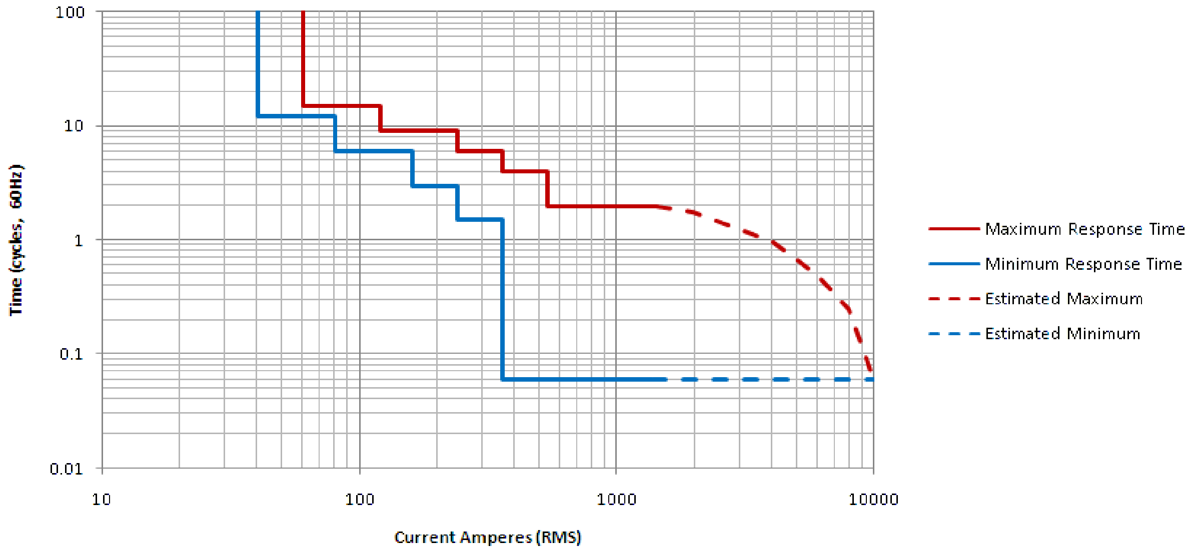


Figure 15 SEL-ARU Trip Response Curve

To illustrate DT behavior, we use the following example. An SEL-ARU that has automatically configured a 300 A fault threshold will trip and indicate a fault if it detects three half cycles of current exceeding 300 A, or one half cycle exceeding 450 A or more, but not any currents below 300 A. In general, the SEL-ARU will decide whether to indicate a fault based on both the magnitude of the fault current and its associated duration.

In *Figure 16*, we see the fault current exceed 300 A for the required three power system half-cycles, and the SEL-ARU indicates the detected fault.

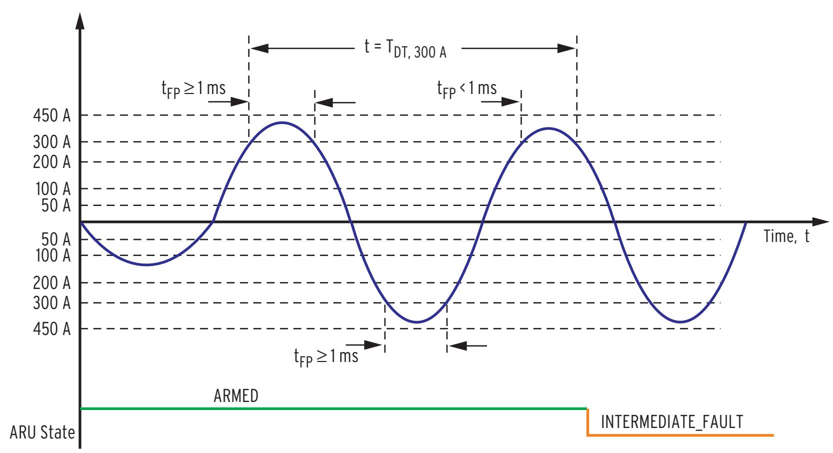


Figure 16 300 A Dynamic Trip Response

In *Figure 17*, we see that the same automatically configured 300 A fault threshold will respond in half of a power system cycle if the detected current magnitude is larger (i.e., greater than 450 A).

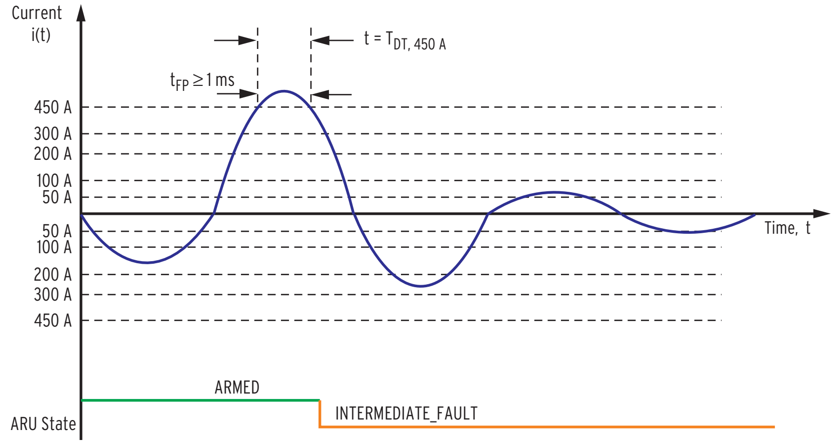


Figure 17 450 A Dynamic Trip Response

Figure 18 shows how the SEL-ARU will ignore transients that do not meet the time-current criteria for DT.

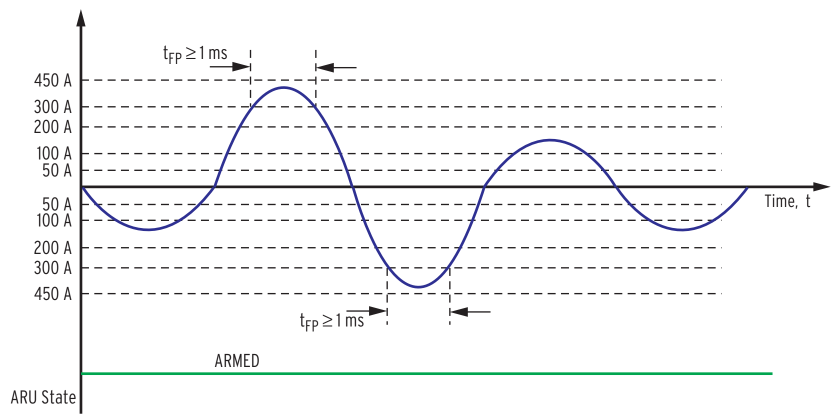


Figure 18 300 A Configured Fault Threshold With Transient Current Waveform

The SEL-ARU trips and indicates a fault if it detects fault current pulses that last 1 ms or longer, exceed the SEL-ARU fault indicator's fault threshold, and occur at least every half cycle during a previously defined DT time. *Table 4* lists the minimum and maximum number of consecutive half cycles for which fault current must be present before the SEL-ARU detects a fault. There can be a period as long as 17 ms between fault pulses before the algorithm considers pulses to be nonconsecutive. The SEL-ARU ignores any event for which detected fault current pulses are not sustained consecutively for a time greater than or equal to DT time.

Fault Indication

To indicate faults, the SEL-ARU fault indicator performs the following:

- Displays targets or LEDs
- Connects to an SEL RadioRANGER® Wireless Fault Indication System
- Closes auxiliary contact relays
- Combines more than one of these methods

The display targets may be integral to the body of the fault indicator or mounted externally. Mechanical target displays are powered by the same line energy stored within the SEL-ARU. Other fault indication means such as LEDs and radios typically derive their operating energy from a combination of batteries and system line current.

Current-Activated Timed Reset (CATR)

For timed-reset functionality, the SEL-ARU has Current-Activated Timed Reset (CATR). The factory configures the duration of CATR (T_{CATR} = 0, 2, 4, or 8 hours) according to customer specifications. The SEL-ARU fault indicator's CATR feature uses a combination of current and time to determine when to reset the fault display. The SEL-ARU begins a timed-reset period after normal system current returns to the monitored power line. CATR timed reset begins when the SEL-ARU returns to the Armed state after a fault event.

The fault indicator considers current less than I_{NORM} to be backfeed current; this current is insufficient to return the device to the Armed state and activate the timed-reset function of CATR. By remaining in the System Detect state, the SEL-ARU prevents backfeed current that might be present because of single-phase sectionalizing a three-phase system from causing an unwanted reset (see *Backfeed Restraint on page 12*). Once current greater than or equal to I_{NORM} is present following a fault, the SEL-ARU will begin its CATR mode. *Figure 19* illustrates how I_{NORM} prevents the FCI from resetting and rearming after a fault is detected. If the current is below I_{NORM}, T_{DET} does not begin until the current returns above I_{NORM}. After T_{CATR}, the SEL-ARU resets, returning its means of fault indication back to the normal state (LED off, white target, open auxiliary contact, etc.).

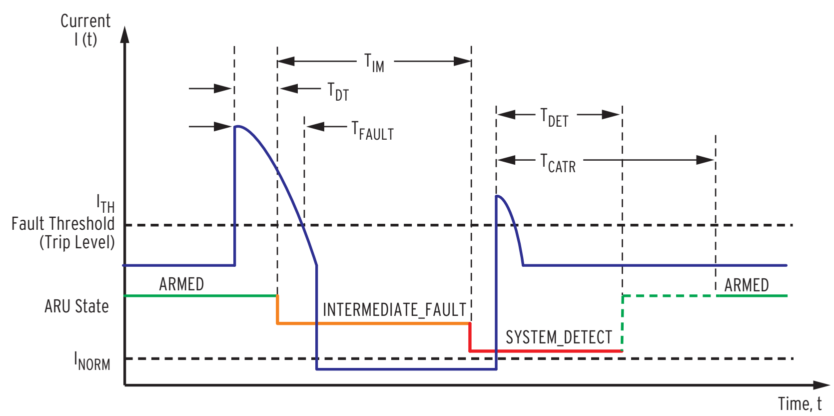


Figure 19 Fault Detection With System Restoration and CATR Timing

The SEL-ARU records the amount of CATR time that it has detected I_{NORM} in its Flash memory. To record CATR time in Flash memory, the SEL-ARU divides the selected CATR time-out into four equal sub-time-out periods, T_{CATR_0}, T_{CATR_1}, T_{CATR_2}, and T_{CATR_3}, each one fourth of the factory-configured CATR period. The SEL-ARU records the expiration of each sub-time-out in Flash memory. When the SEL-ARU turns on upon restoration of current, the CATR period begins from the last sub-time-out period prior to loss of power. If load current drops below the minimum operating current and the SEL-ARU loses power, it "remembers" how much time remains to satisfy T_{CATR}.

IR events detected by the SEL-ARU during CATR only extend the CATR period by the time necessary to re-enter the Armed state.

Installation

Always install fault indicators in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements.

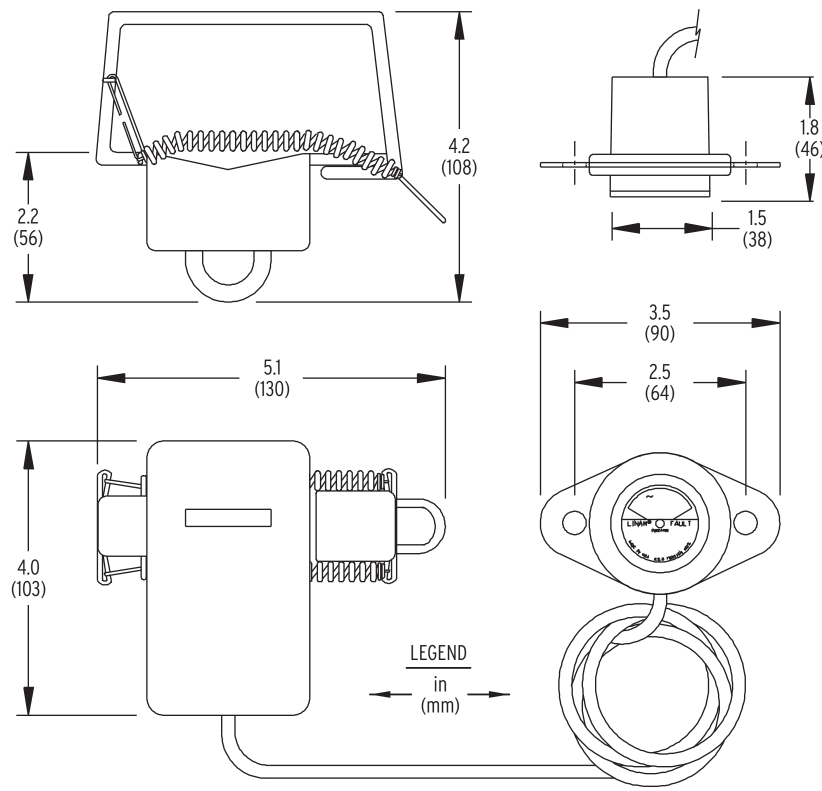


Figure 20 SEL-ARU Reference Dimensions for Standard Core

Proper Concentric Neutral Training

Proper concentric neutral training is essential for proper functioning of the SEL-ARU. *Figure 21* and *Figure 22* show five methods of neutral training. Double-back training (*Figure 21*) is the recommended method. *Figure 22* shows acceptable alternatives. *Figure 23* shows incorrect neutral training.

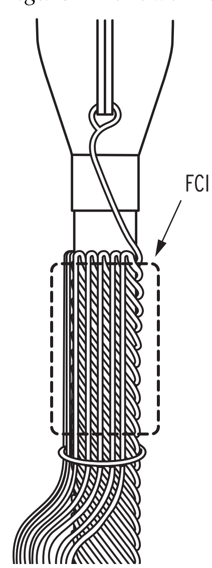


Figure 21 Double-Back Neutral Training (Recommended)

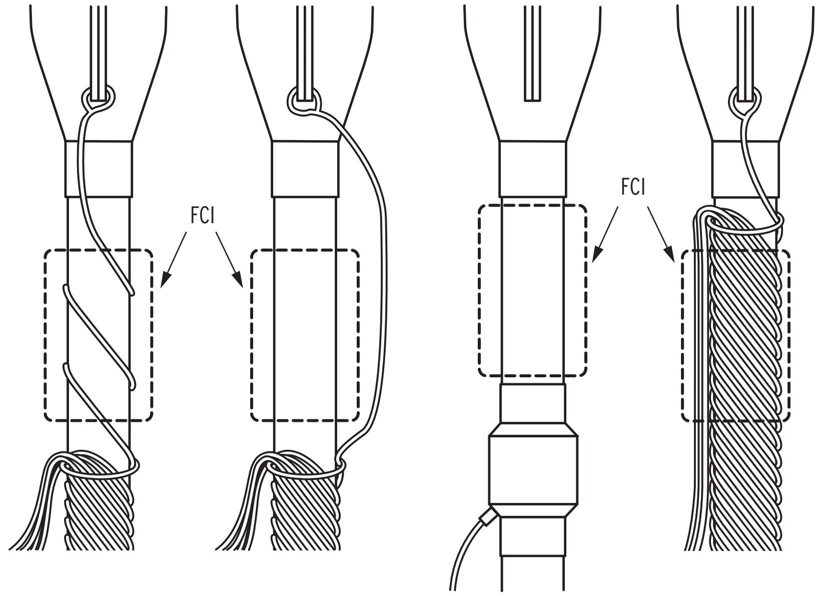


Figure 22 Acceptable Alternate Neutral Training Methods

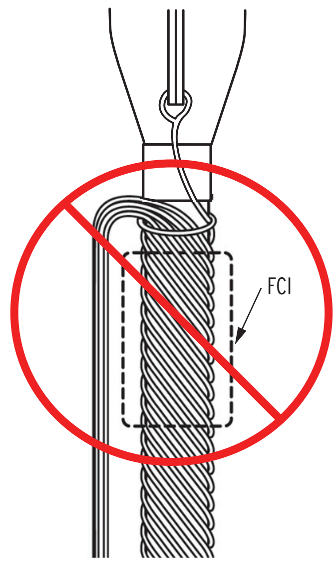


Figure 23 Incorrect Neutral Training

Install the Remote Display (If Applicable)

Step 1. Punch or drill two 10.5 mm (25/64") and one 27 mm (1 1/16") holes as shown in *Figure 24*, or use the template to align the holes. Consult the enclosure manufacturer for recommended corrosion treatment of the holes.

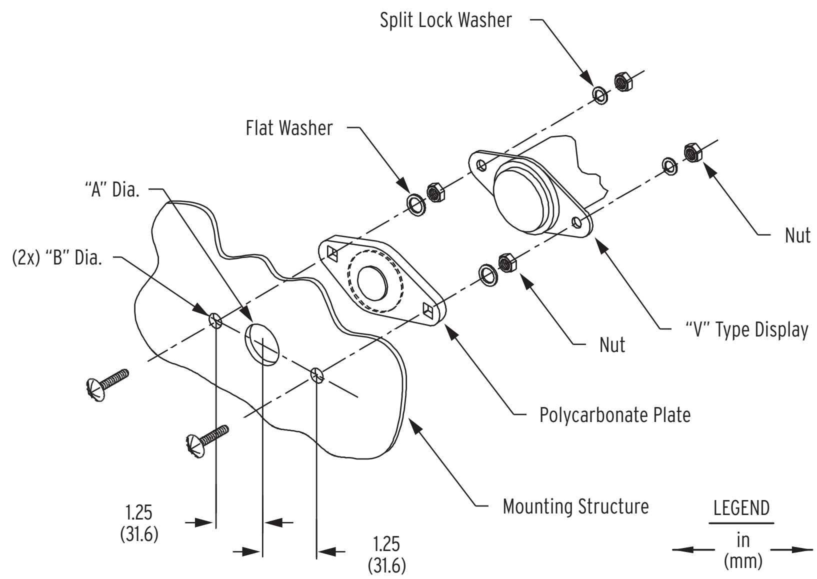


Figure 24 Remote Display Installation

Step 2. Remove the polycarbonate plate from the assembly kit bag and secure it to the mounting structure with carriage bolts, flat washers, and nuts as shown in *Figure 24*.

Step 3. Slide the stainless steel mounting plate onto the carriage bolts.

Step 4. Position the target area of the display against the polycarbonate plate.

Step 5. Secure with the lockwashers and nuts.

Install the "AA" 3.6 V Lithium Battery (1BARUV Model)

Step 1. Unscrew the battery cap located on the end of the remote display housing.

Step 2. Insert the battery into the cap with the negative (–) terminal inside the cap (see "NEG" on cap).

Step 3. Insert the battery and cap the positive (+) terminal leading into the battery holder compartment.

Step 4. Hand tighten the cap until it is snug against the gasket. Do not over tighten.

Upon installation of the battery, the LED might begin to flash. To manually clear (reset) the flashing mode, follow the directions in *Test Activation and Manual Reset on page 22*.

Connect the Auxiliary Contacts (1ARUV_A and 3ARU3_A Models)

Terminate the auxiliary contacts following your company's normal procedure. Use sealing appropriate for the installation location.

Install the Magnet-Backed Junction Box (3ARU3_A Model)

Step 1. Position the magnet-backed junction box on a flat surface within the enclosure. If the junction box cannot be held magnetically, it can be mounted using screws. These screws are not provided.

Step 2. Allow sufficient cable lead length from the junction box to the installation point on the cable for safe installation of the phase sensor. (Magnetic Cable guides Cat. No. MCG are available to assist with cable lead training.)

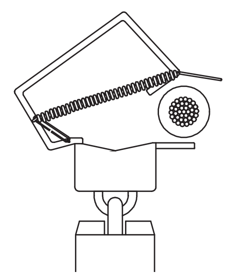
Magnetic cable guides hold cables and leads neatly within the enclosure.

Figure 25 Magnetic Cable Guide

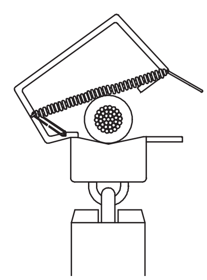
Install the Phase Sensor

Step 1. Using the hotstick, grasp the molded hookeye on the face of the phase sensor.

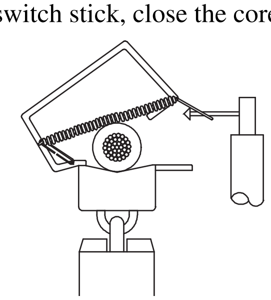
Step 2. Open the core and push onto the cable.



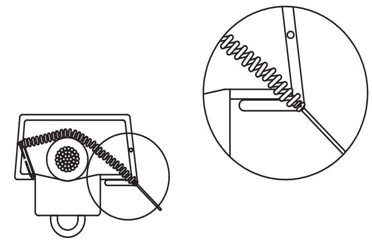
Step 3. Position the cable to rest in the molded "V" of the phase sensor housing.



Step 4. Using the switch stick, close the core around the cable.



Step 5. Be sure the core is closed and mated properly.



Test Activation and Manual Reset

NOTE: Before using the CRSRTT tool, remove the silver shorting bar. Replace the shorting bar after use.

To verify the operational functionality of the SEL-ARU, the fault indicator has test activation capability. Hold a CRSRTT tool (sold separately) against the SEL-ARU, activating a reed switch and the test activate signal. Activating the test activate signal can cause the SEL-ARU to activate or reset the display depending upon its state when the magnetic tool is applied. See *Figure 26*. For test activation, the magnet tool must be held to the SEL-ARU housing continuously for 15 seconds. The test activate signal is accepted when the tool is removed after being held to the housing for at least 15 seconds.

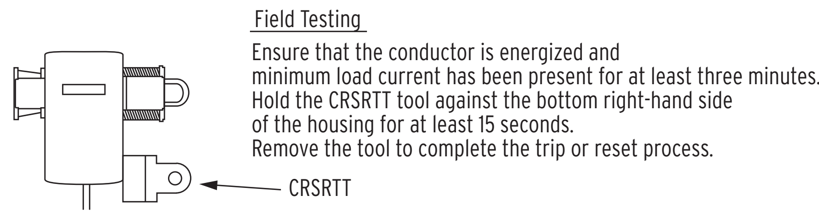


Figure 26 SEL-ARU Test Activation/Reset Tool Placement

If the fault display is in the reset state, test activation causes the red target to display or the LED to blink. A test activation that causes the fault display to trip (or blink the LED) will set the fault threshold to 50 A. Test activation sets the fault threshold to the minimum to satisfy all possible normalization current requirements and return the SEL-ARU to Armed. SEL-ARU ignores CATR time-outs for fault displays caused by test activation, and the display resets immediately upon entering the Armed state, regardless of the configured CATR reset option.

If the fault display is in the tripped state, the test activation causes the display to reset or the LED to stop blinking. To perform a test activation, the SEL-ARU must be in the Armed state. Current equaling at least 3 A must be present in the monitored power line for the SEL-ARU to have enough energy to trip or reset the fault display. Test activate operations to reset the fault display on an SEL-ARU with a zero CATR configuration are not possible because the fault display resets immediately upon entering the ARMED state. Additionally, a test activation that results in a tripped target will change the state of the SEL-ARU to System Detect. Thus, there is a limit as to how quickly successive test activate events can occur and be accepted by the SEL-ARU. One must provide at least T_{DET} time between test activate signals or the SEL-ARU ignores these signals. Refer to *Figure 8* for details on how the test activate signal affects the operation of the SEL-ARU.

SEL-ARU Models and Configurations

Three-Phase SEL-ARU

SEL-3ARU3

The SEL-3ARU3 provides for a three-phase configuration in which each phase controls a corresponding target. The fault indicator's three-phase display integrates three individual targets for this purpose. In this configuration, each SEL-ARU device acts independently of the others and controls a dedicated mechanical target in the three-phase display. See *Figure 27* for an illustration of the three individual target display.

SEL-3ARU

The SEL-3ARU can be applied in a three-phase configuration that uses a single indicator target. See *Figure 28* for an illustration of the three-phase/single-display option. In a three-phase/single-target configuration, the units will not be electrically isolated from each other.

Three-Phase SEL-ARU Configuration

The phase connected to the indicator target is referred to as the main phase. For proper operation, all phases need sufficient load current to power the circuitry and provide reset or fault signals to the main phase and/or the target display. Provided that the main phase has sufficient energy, any phase can detect a fault and send control signals to the main phase for target activation. The output from the minor phase sensors (SEL-ARU devices not connected to the display) will be connected to dedicated input circuitry on the main phase. When the device operates as a three-phase unit, any individual phase that detects a fault will cause the display to indicate the fault. All three phases must indicate a reset condition before the device resets the display target.

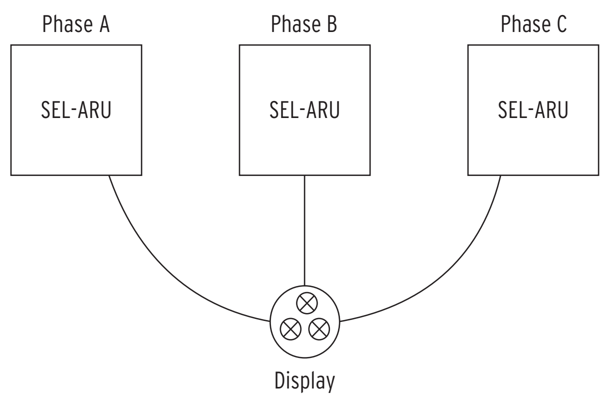


Figure 27 Three-Phase SEL-3ARU3 Configuration With a Three-Phase Remote Target Display

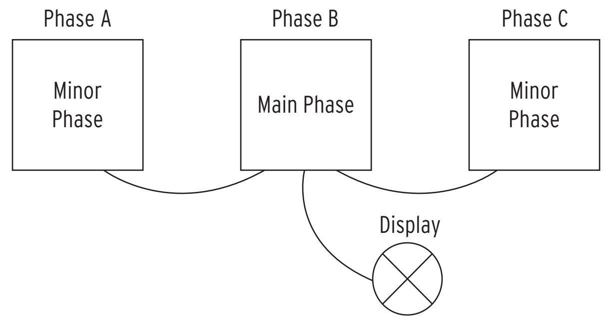


Figure 28 Three-Phase SEL-3ARU Configuration With a Single Remote Target Display

LED and Fiber-Optic Displays

Some applications benefit from fault indication in the form of LEDs or fiber-optic displays. As with remote target displays, these lighted displays are visible from the exterior of pad-mounted transformers or switchgear on which the SEL-ARU fault indicators are installed. The difference is increased visibility. During fault conditions, the SEL-ARU activates the red LED with a single blink every two seconds to indicate the presence of a fault. Both single- and three-phase SEL-ARU fault indicators are available with LED displays.

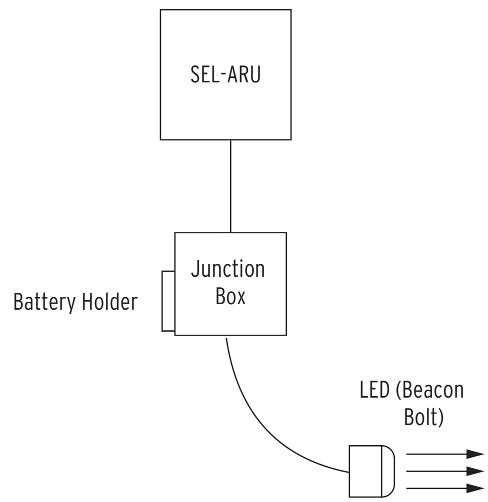


Figure 29 SEL-ARU With an LED Display

While the SEL-ARU stores sufficient energy from the distribution system to operate a mechanical target display, it does not store enough energy for LED and fiber-optic displays. As a result, SEL-ARU fault indicators with lighted displays are equipped with replaceable batteries in an external junction box. The external battery provides power only to supply current to the LED or display; the fault indicator does not use the battery for power, but derives its operating power from the cable on which it is installed. Mechanical target displays operate from capacitive stored energy, regardless of battery condition.

To maximize battery life, SEL-ARU fault indicators with LED displays are available with a Timed Reset (TR) feature. SEL-ARU fault indicators with TR automatically shut off the LED display after a set time after a fault causes the SEL-ARU to trip. The CATR time-out overrides the timed reset for the LED, so the LED stops blinking after the mechanical target is reset.

To save additional battery power, SEL-ARU fault indicators with LED displays reduce the rate at which the LED operates to one blink every five seconds after it has been blinking for longer than eight hours.

Auxiliary Contact for Communication Via SCADA

SEL-ARU fault indicators are available with auxiliary contact relays. Each normally open auxiliary contact relay connects to the SCADA system. The auxiliary contact is housed in a remote junction box along with a replaceable battery that operates the relay. *Figure 30* illustrates an SEL-ARU with an auxiliary contact.

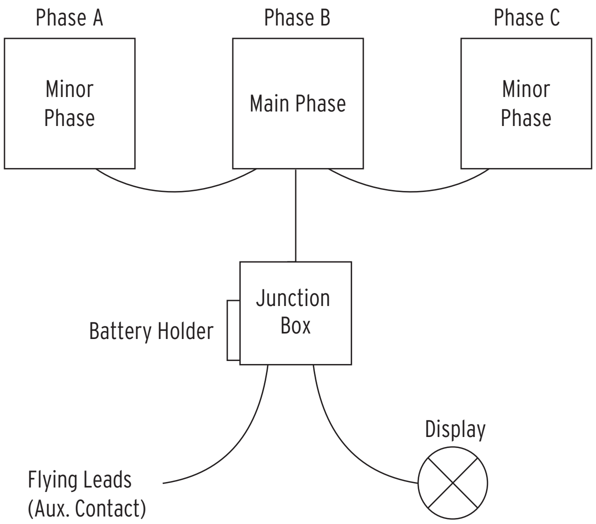


Figure 30 Three-Phase SEL-ARU Configuration With a Remote Target Display and Auxiliary Contact

Radio Communication Via RadioRANGER Wireless Fault Indication System

The SEL-ARU is available as part of the SEL RadioRANGER Wireless Fault Indication System. The RadioRANGER system sends the status of the SEL-ARU—tripped or reset—to a handheld Remote Fault Reader via a radio signal, keeping line crews safe and shortening fault location time. SEL does not offer the SEL-ARU with both RadioRANGER and LED/target options.

Please visit selinc.com/FCI for more information about these models and configurations.

Battery Safety

⚠CAUTION
This product is shipped with or contains a lithium metal cell. Lithium metal cells and batteries may present a risk of fire or explosion. Do not short circuit, recharge, puncture, incinerate, crush, drop, disassemble, immerse, or incorrectly install lithium metal cells or batteries. Do not expose lithium metal cells or batteries to temperatures that are above the declared operating temperature range of this product. This product must be disposed of in accordance with all applicable rules, laws, and regulations, such as EPA's Universal Waste Rule, the EU Batteries Directive and other local rules.

This product is shipped with or contains a lithium metal cell. Lithium metal cells are often classified as dangerous goods by dangerous goods shipment regulations. These regulations along with your package carrier specify the packaging and labeling to be used, along with the information to be provided when shipping dangerous goods. This product must be transported in accordance with all applicable rules, laws, and regulations, such as the rules published by the Pipeline and Hazardous Materials Safety Administration; the International Civil Aviation Organization; the International Air Transport Association; the Maritime Dangerous Goods Code; the UN Model Regulations on the Transport of Dangerous Goods and rules for inland, waterways, road and rail transportation, and others. Please consult any applicable regulations and your package carrier for proper handling of this product.

Specifications

ARU

Trip Thresholds:	50 to 1200 A
Voltage Range:	Equal to voltage class of shielded underground cable.
Maximum Fault Current:	25 kA for 10 cycles
Minimum Operating Current:	3 A
Current-Activated Timed Reset:	0, 2, 4, 8, or 12 hours
Battery (for BEACON LED display only):	3.6 V high-capacity lithium battery with a 20-year shelf life
Trip Response Time:	Function of trip threshold
Inrush Restraint Response Time:	5 cycles
Approximate Weight	560 g (1.25 lbs)
Temperature Range:	–40° to +85°C (–40° to +185°F)

Canada ICES-001 (A) / NMB-001 (A)

ARU With Fiber-Optic Display

Trip Thresholds:	50 to 1200 A
Voltage Range:	Equal to voltage class of shielded underground cable.
Maximum Fault Current:	25 kA for 10 cycles
Minimum Operating Current:	3 A
Time Reset With Current Reset Override:	0, 2, 4, or 8 hours
Battery (for BEACON LED display only):	3.6 V high-capacity lithium battery with a 20-year shelf life
Trip Response Time:	Function of trip threshold
Inrush Restraint Response Time:	5 cycles
Approximate Weight:	840 g (1.85 lbs)
Temperature Range:	–40° to +85°C (–40° to +185°F)

Canada ICES-001 (A) / NMB-001 (A)

Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

Notes

⚠WARNING
Operator safety may be impaired if the device is used in a manner not specified by SEL.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

⚠AVERTISSEMENT
La sécurité de l'opérateur peut être compromise si l'appareil est utilisé d'une façon non indiquée par SEL.

⚠ATTENTION
Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

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