Functional Overview of the Underground AutoRANGER® Fault Indicator

Jag Bakthavatchalam

Background

Traditional underground faulted circuit indicators (FCIs) require users to specify single, fixed, factory-calibrated nominal trip ratings. On a long circuit, traditional FCIs installed near the substation require higher trip ratings than those applied farther out on the circuit. Misapplying an FCI to a conductor size it is not calibrated for can result in a failure to trip on a fault or a false trip in response to load current. Properly applying multiple types of FCIs with different trip ratings in different locations takes time, effort, and training.

The SEL Underground AutoRANGER Fault Indicator (AR-URD) is an underground FCI that helps alleviate the challenges of applying FCIs with fixed trip ratings. The AR-URD uses SEL AutoRANGER technology to automatically configure a trip threshold based on the magnitude of the load current flowing in the conductor. Hence, the AR-URD is able to adjust automatically for load fluctuations caused by load growth or circuit reconfiguration, reducing the need for field service.

This document explains the functionality of the AR-URD. It defines the AR-URD AutoRANGER trip logic, principles of operation, fault indication options, inrush restraint, and testing and reset functions.

Operation Overview

To detect faults or loss-of-current events, the AR-URD must be in the armed state. In the armed state, the AR-URD detects faults using autoranging technology whereby the trip threshold is selected automatically based on the load current (I_{LOAD}), which is sensed every 30 seconds. The trip threshold is adjusted according to the graph in Figure 1.

The AR-URD has eight distinct trip current thresholds (I_{TH}): 50, 100, 200, 300, 450, 600, 900, and 1,200 A. Based on the measured load current, the AR-URD will either remain at its existing threshold or autorange to a different threshold. This feature helps the AR-URD handle variable loads caused by seasonal and time-of-day fluctuations. The load current ranges overlap, as shown in Table 1, to prevent the AR-URD from oscillating between thresholds when the load current falls on the edge of two thresholds. Once the AR-URD sets a trip threshold based on the load current, any current above that trip threshold is identified as fault current.

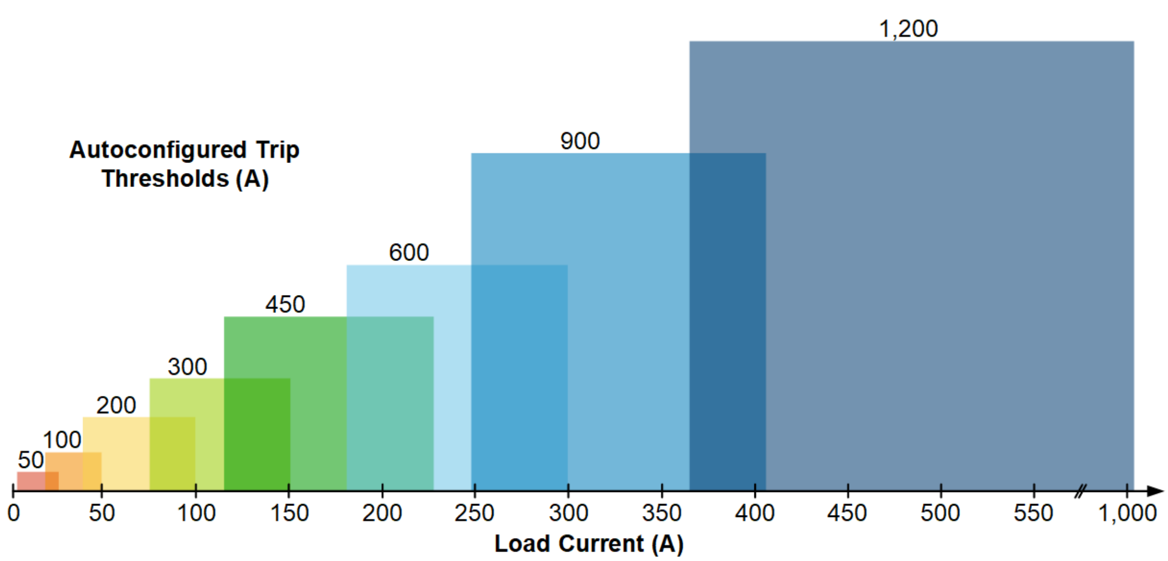

Figure 1 Autoranging Graph Used by AR-URD to Configure Trip Threshold

Table 1 Eight Trip Thresholds and Associated Load Current Ranges

n	I_{TH} (A)	Minimum I_{LOAD} (A)	Maximum I_{LOAD} (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	1,200	386.7	600

Principles of Operation

Trip Response Time

Fault current must exceed the trip threshold for a certain period of time called the trip response time to qualify as a fault. The AR-URD has a factory-set dynamic trip response time for each trip threshold. The response time is reduced for increasing levels of fault current. The AR-URD must detect sustained fault current for the number of half cycles shown in Table 2 to indicate a fault.

For example, an AR-URD that has autoconfigured a 300 A trip threshold will trip and indicate a fault if it detects 3 half cycles of current exceeding 300 A or 1 half cycle exceeding 450 A, but not any currents below 300 A.

Table 2 Trip Response Times Based on Trip Thresholds (60 Hz System)

I_{TH} (A)	Dynamic Trip Time (ms)	Minimum Half Cycles	Maximum Half Cycles
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
1,200	1	1	4

Backfeed Restraint

Backfeed current can emanate from many sources on a distribution circuit, such as a stored energy device, residual current flowing during single phasing, and inductive coupling to adjacent circuits. Without backfeed restraint, a backfeed current of sufficient magnitude and duration could cause the AR-URD to falsely reset without actual load current being restored after a fault is cleared.

The AR-URD uses normalization current (I_{NORM}) to prevent false resets caused by backfeed current. I_{NORM} is defined as 0.05 • I_{TH}. The AR-URD will not start its reset timer until the current exceeds I_{NORM} for 3 minutes. As such, the I_{NORM} threshold moves in tandem with the self-configured trip threshold and represents a dynamic reset current threshold, as shown in Table 3. Backfeed currents are typically below I_{NORM} for a given load current range and are therefore ignored by the reset timer.

Table 3 I_{NORM} for Each Trip Threshold

I_{TH} (A)	I_{NORM} (A)
50	2.5
100	5
200	10
300	15
450	22.5
600	30
900	45
1,200	55*

*The normalization current for the 1,200 A trip level is slightly lower than the normal 5 percent level and is nominally at 55 A.

Inrush Restraint

When applied on circuits that use reclosing schemes, AR-URDs on unfaulted phases can detect inrush currents caused by the energization of the conductors upon reclosing. These inrush currents can exceed the self-configured trip thresholds of the AR-URDs. However, the inrush restraint feature disarms the AR-URDs on circuits deploying reclosing schemes, making them immune to inrush currents.

The AR-URD considers current below I_{NORM} for 5 cycles to be a loss-of-current event. When three-phase protection upstream from the AR-URDs operates for a single-phase-to-ground fault, there is a loss of current on all three phases. Once the AR-URDs on the unfaulted phases detect a loss of current (i.e., current below I_{NORM} for 5 cycles), they enter the inrush restraint lockout mode, thus becoming unarmed and unable to detect faults. When the upstream three-phase protection recloses after timing on the open interval, the AR-URDs on the unfaulted phases will not trip to indicate a fault even if the inrush current is higher than the self-configured trip threshold.

The AR-URDs exit the inrush restraint lockout mode and become armed again once they sense load current greater than or equal to I_{NORM} for 3 minutes continuously. In the example shown in Figure 2, an AR-URD on an unfaulted phase sees inrush current above its trip threshold during the reclosing attempts between T3 and T4 but does not falsely indicate a fault because it is in inrush restraint lockout mode. After sensing a load current greater than or equal to I_{NORM} for 3 minutes continuously, the AR-URD exits the inrush restraint lockout mode and becomes armed and ready to respond to faults.

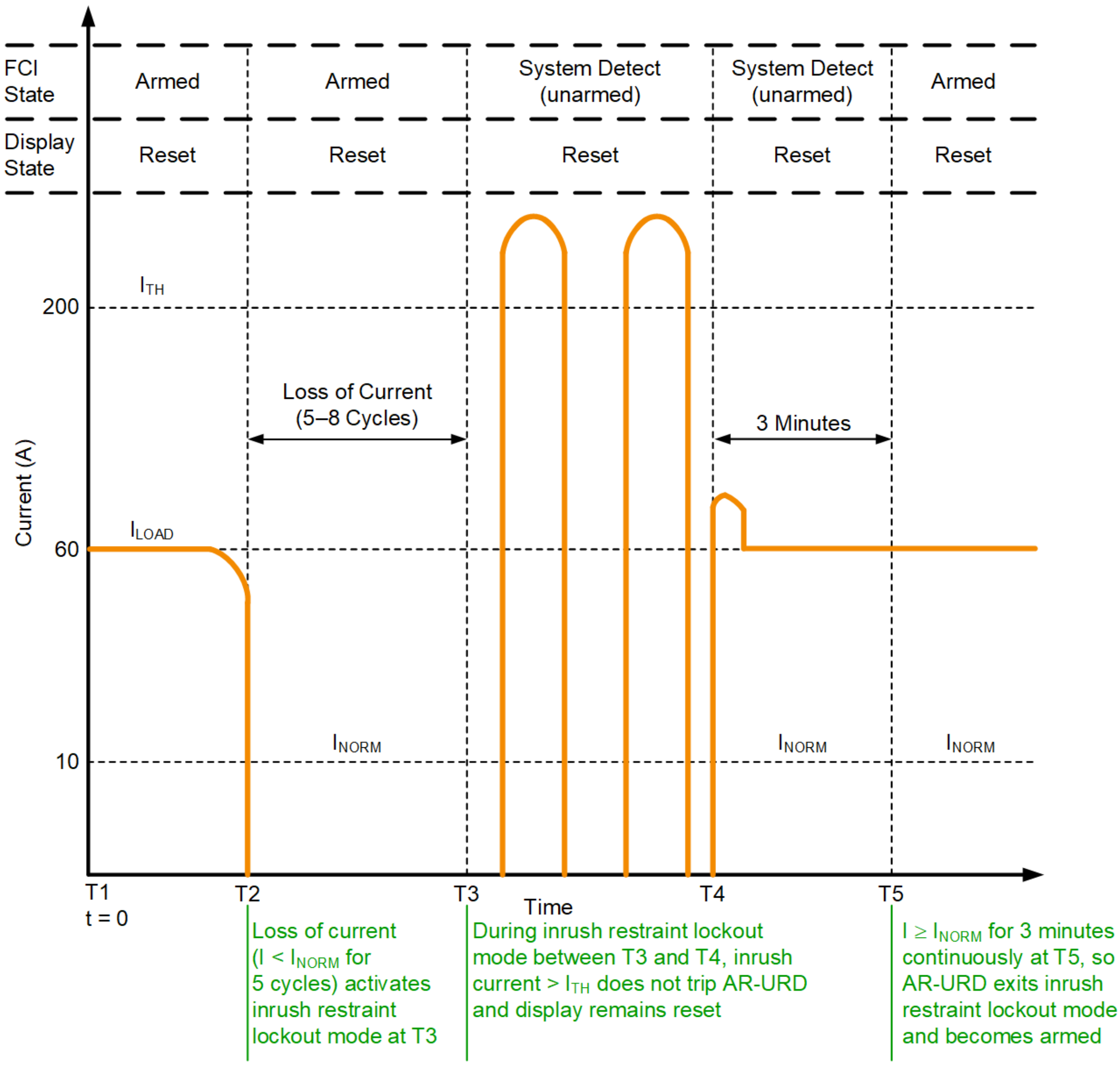

Figure 2 Response of AR-URD to Inrush Currents Falsely Appearing as Fault Currents

Display Options for Fault Indication

Target Display

The AR-URD uses a red target for fault indication. The standard "V" display has one red target for indication. The large "L" display has two red targets for indication. The V display can be integral to the AR-URD or located remotely, but the L display can only be located remotely. The standard lead length of the cable for a remote display is 6 feet. The target display options are shown in Figure 3.

Figure 3 Standard V Target Display (left) and Large L Target Display (right)

BEACON® LED Display

The V and L target displays can also be combined with a BEACON LED display.

Bolt Display

The AR-URD can be applied with a tamper-proof BEACON Bolt® display (Figure 4) that flashes for a fault. This display is particularly useful in areas prone to vandalism.

Figure 4 BEACON Bolt Display

Radio Communication Via RadioRANGER® Wireless Fault Indication System

The AR-URD can be combined with the RadioRANGER Wireless Fault Indication System, as shown in Figure 5. The AR-URD sends fault status information to the SEL-8300 Wireless Interface of the RadioRANGER system through a magnetic interface probe. The SEL-8300 communicates the fault status to a handheld SEL-8310 Remote Fault Reader via a radio. The RadioRANGER solution eliminates the need to access subsurface vaults to retrieve the AR-URD status and allows utility personnel to safely and quickly retrieve that information at street level.

Figure 5 Wireless Fault Indication System Option

Reset and Test

The AR-URD is a current-activated timed reset (CATR) device that uses a combination of current and time to reset. The time-out period for the CATR timer (0, 2, 4, 8, or 16 hours) is chosen by the user when the product is specified and is then permanently set.

Once the AR-URD activates its display for a fault, it waits for a load current greater than I_{NORM}. After sensing load current greater than I_{NORM} for 3 minutes continuously, it starts the CATR timer. At the end of the CATR time-out period, the AR-URD resets the display. Because the display stays tripped for the outage duration plus the CATR time, the CATR feature provides sufficient time for line personnel to identify the fault location. When the CATR time-out period is 0 hours, the AR-URD behaves as a current reset device and resets immediately after sensing load current greater than I_{NORM} for 3 minutes.

A magnetic current reset and secondary reset test tool (CRSRTT) can be used to test the operational functionality of the AR-URD (see Figure 6). This tool can either trip or reset the AR-URD. The AR-URD needs to be on the line and sensing at least 3 A of current to be tested.

Figure 6 CRSRTT Tool

The CRSRTT can also be used to manually reset the AR-URD display without waiting for the CATR timer to expire. When using the CRSRTT, ensure that the conductor is energized and that minimum load current (3 A) has been present for at least 3 minutes. Hold the CRSRTT against the bottom of the housing as shown in Figure 7 for at least 15 seconds. Then, remove the tool to complete the trip or reset process.

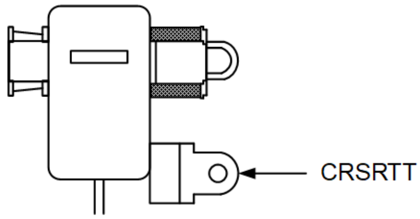

Figure 7 Field Testing Using the CRSRTT Tool

Conclusion

The AR-URD leads the way in underground fault indication. With the ability to configure trip thresholds automatically based on load current, the AR-URD can be applied on a wide range of circuits. The backfeed restraint feature provides security against false resets caused by backfeed currents. The CATR feature provides sufficient time for a crew to identify the fault location after post-fault automatic circuit reconfiguration from advanced distribution automation schemes. Together, these features—combined with a 10-year warranty—provide a versatile fault indicating solution that adapts to a growing distribution system.

Biography

Jag Bakthavatchalam received his B.Tech degree in electrical and electronics engineering from the National Institute of Technology in Tiruchirappalli, India in 2013 and his M.S. in electrical engineering – power systems from Missouri University of Science and Technology in Rolla, Missouri in 2015. He is currently an application engineer for Schweitzer Engineering Laboratories, Inc. in Lake Zurich, Illinois.

Making Electric Power Safer,
More Reliable, and More Economical

Schweitzer Engineering Laboratories, Inc.
Tel: +1.509.332.1890 | Email: info@selinc.com | Web: www.selinc.com

LWP0028-01