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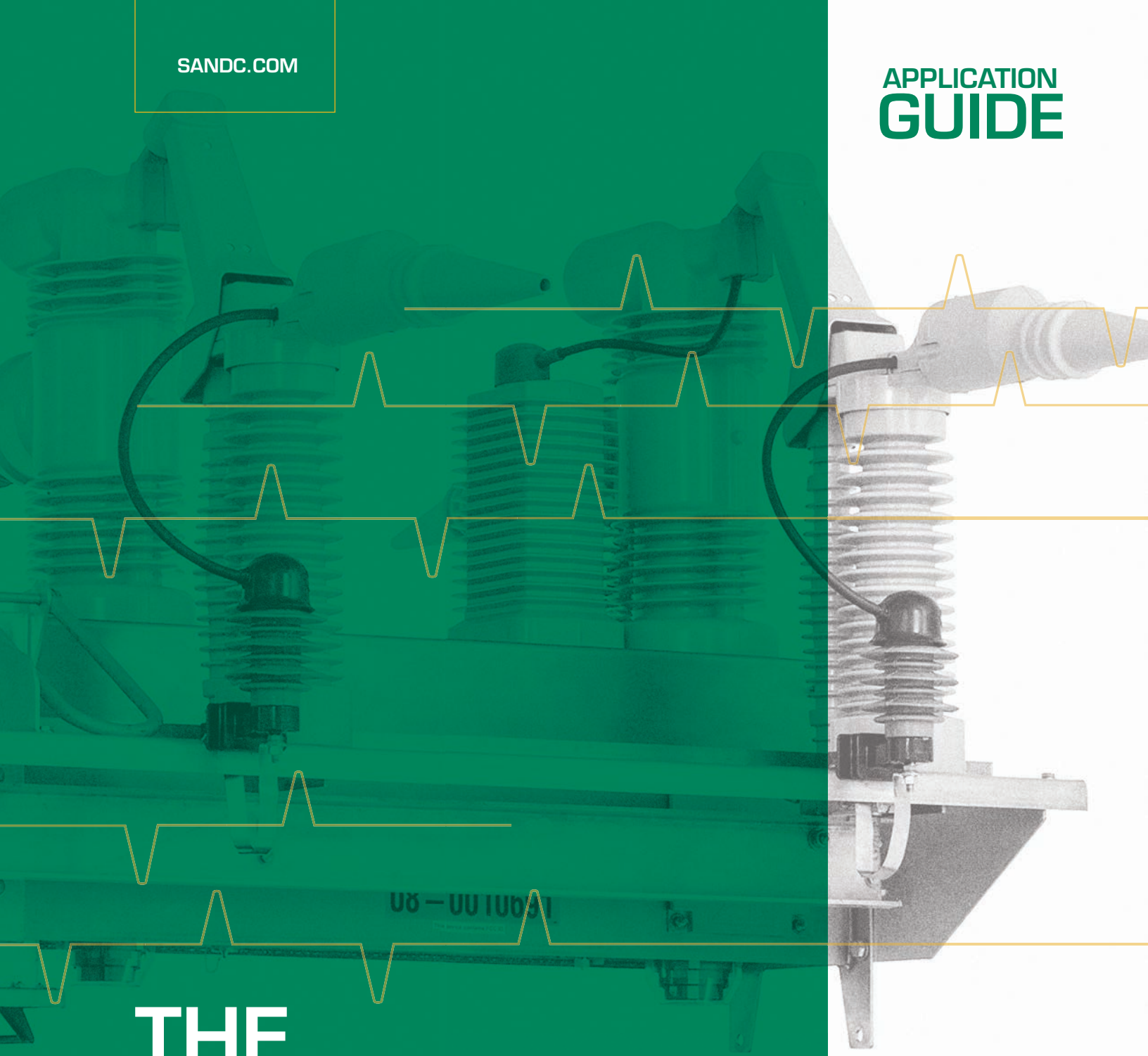
APPLICATION GUIDE



THE PULSEFINDING™ FAULT LOCATION TECHNIQUE:

INTELLIRUPTER® PULSECLOSER® FAULT INTERRUPTER

⚠ WARNING

This guidebook is not a replacement for requisite training and safety procedures for this product. Read S&C Instruction Sheet 766-530 thoroughly and carefully before using this guidebook and installing and operating your IntelliRupter® fault interrupter. Failure to have adequate training and understanding of these instructions may lead to serious injury or death.

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CUSTOMER CHALLENGES

Increased dependence on electricity to power everyday life means utilities are facing pressure to achieve high levels of reliability for their customers. To begin advancing their systems, many utilities start with the approach of increasing segmentation to obtain immediate reliability improvements.

By installing more protective devices, utilities can divide their feeders into a greater number of segments. This enhances reliability by reducing the number of customers powered by each feeder segment, therefore minimizing the number of customers who will experience an outage in most fault scenarios. See Figure 1.

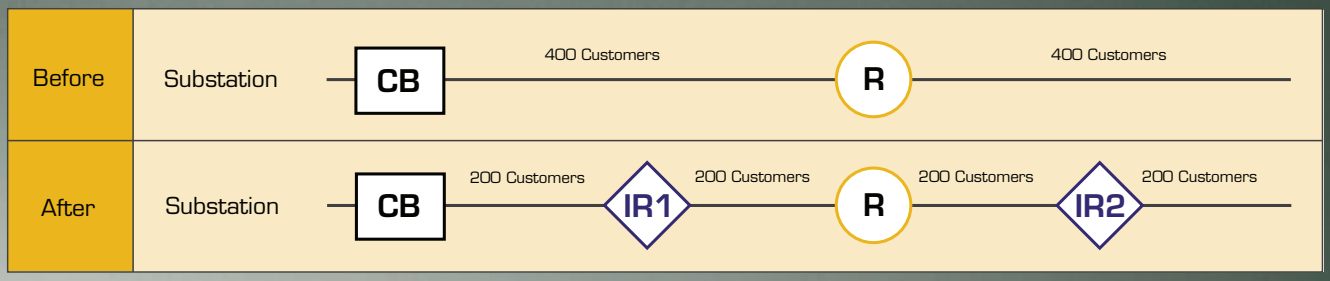


Figure 1. Diagram showing how the addition of two IntelliRupter fault interrupters to this feeder reduces the customers per segment from 400 to 200.

THE LIMITATIONS OF CONVENTIONAL RECLOSERS

Though many utilities turn first to increasing segmentation to improve reliability, this seemingly simple solution is often complicated by the limitations of conventional reclosers.

SEGMENTATION

Greater segmentation, while maintaining coordination, is often not possible with conventional reclosers because the coordination space available between the substation circuit breaker and grid-edge devices is finite. Additional protective devices usually cannot be added without their TCC curves overlapping, which risks miscoordination — a step backward for reliability. See Figure 2.

TIME AND RESOURCES

On feeders where time-current characteristic (TCC) coordination is not yet "full," increasing segmentation using conventional reclosers can still prove challenging. Individual protection settings are needed for each new device, and often existing assets such as substation circuit breakers and reclosers require updated settings to allow for installation of additional reclosers. Even when this method is possible, using conventional reclosers to increase segmentation puts a significant burden on utility time and resources.

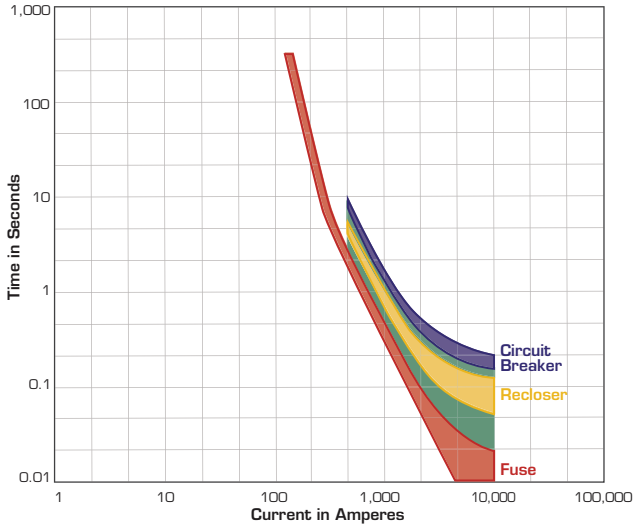


Figure 2. TCC chart showing the limitations of coordination with conventional reclosers. The green spaces on the chart highlight the finite coordination space between devices and demonstrate that additional devices cannot be added without their coordination characteristics overlapping those of the existing devices.

MISCOORDINATION

Even on a meticulously coordinated system, miscoordination events can occur because of changes in load levels, tight or miscoordinated TCC curves, and high-current faults. In these situations, conventional reclosers cannot adequately respond or recover, meaning continued use of these devices subjects your customers to avoidable outages. Figure 3 shows an example of the negative reliability impact conventional reclosers can have because they lack the ability to recover from miscoordination events.

Step #1	Fault detected	
Step #2	Because of miscoordination, both reclosers open	
Step #3	Recloser 1 begins reclosing	
Step #4	Recloser 1 fully closes and Recloser 2 begins reclosing	
Step #5	Recloser 1 and Recloser 2 lock out because of miscoordination from the fault downstream	
RESULT	Customers powered by the feeder segment between Recloser 1 and Recloser 2 experience an avoidable permanent outage.	

Figure 3. An example showing the negative reliability impact conventional reclosers can have because they lack the ability to recover from miscoordination events.

INTRODUCTION TO THE PULSEFINDING FAULT LOCATION TECHNIQUE

WHAT IS IT?

The PulseFinding Fault Location Technique is a feature of S&C's IntelliRupter fault interrupter, a three-phase smart grid device that uses PulseClosing® Technology to test for faults using 95% less energy than conventional reclosers.

The PulseFinding technique is an easy way to locate and isolate faulted line segments without the added burden of TCC coordination. This simplified feeder-coordination method results in increased segmentation to improve reliability for your customers.

HOW DOES IT WORK?

The PulseFinding technique is enabled by PulseClosing Technology. This low-energy fault testing avoids the negative consequences of conventional reclosing—namely voltage sags upstream and on adjacent feeders—and ensures upstream devices will not sense fault current and re-trip during the test sequence of downstream devices.

The PulseFinding technique works by coordinating multiple IntelliRupter fault interrupters—exclusively or in combination with existing assets—on identical or intentionally overlapping TCC curves. This coordination method is a trip operation used to ensure all devices necessary for fault isolation open nearly simultaneously. The most upstream open device will then begin testing to detect whether a fault is present. If this test doesn't identify a fault, the device will close in and the next device in series will take over, beginning its own test for the fault. The devices continue one by one downstream in this fashion, working together to hunt down and isolate faults within seconds.

WHAT CONDITIONS ARE REQUIRED TO TRIGGER THE PULSEFINDING TECHNIQUE?

For an IntelliRupter fault interrupter to trip using the PulseFinding technique, each of the following conditions must be satisfied:

- The PulseFinding technique has been turned on.
- At least one test after the initial trip has been configured to use PulseClosing technology.
- The user-configurable percent of overcurrent trip timing has been reached or exceeded AND the device's source voltage is below the user-configurable open-source voltage threshold.

WHAT KIND OF CIRCUITS CAN IT BE USED ON?

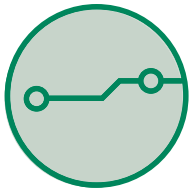
Feeders with existing assets:
Even on complex circuits, The PulseFinding technique enhances reliability by circumventing the limited segmentation capabilities of conventional reclosers and mitigating miscoordination events.

Feeders with only IntelliRupter devices:
Typically using a single TCC curve for all IntelliRupter fault interrupters using the PulseFinding technique, this feature allows for nearly unlimited segmentation without complicating coordination.

WHERE ON YOUR SYSTEM SHOULD IT GO?

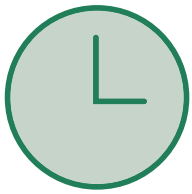
The PulseFinding technique should be used in areas where coordinating multiple devices in series would require significant engineering effort or when it isn't possible to fully coordinate all devices. Common locations for maximizing reliability improvements include worst-preforming feeders, areas with frequent customer complaints, and circuits where there is need for greater segmentation but the limits of coordination have been reached.

BENEFITS OF THE PULSEFINDING FAULT LOCATION TECHNIQUE



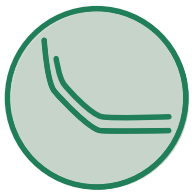
INCREASE SEGMENTATION

By overcoming the coordination limitations of conventional reclosers, the PulseFinding technique makes greater segmentation possible on *any* circuit.



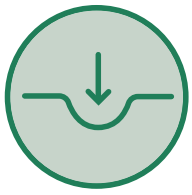
SAVE TIME AND RESOURCES

Increasing feeder segmentation with conventional reclosers requires a significant investment of your utility's time and resources. Requiring significantly less engineering effort to implement, the PulseFinding technique helps your utility increase segmentation without putting a strain on your business.



MITIGATE MISCOORDINATION

Allowing the IntelliRupter fault interrupter to automatically recover from miscoordination events that conventional reclosers cannot, the PulseFinding technique can be applied to any circuit, fully coordinated or otherwise, as a catch-all recovery from miscoordination events.

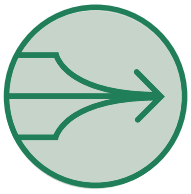


MINIMIZE SYSTEM STRESS AND VOLTAGE SAGS

During all PulseFinding technique operations, IntelliRupter fault interrupters use PulseClosing Technology to test for faults using 95% less energy than conventional reclosers. This avoids subjecting your system to the stress of the full fault current and increases reliability by mitigating voltage sags upstream and on adjacent feeders during fault testing.

ISOLATE FAULTS FAST

The PulseFinding technique is completed within seconds, even on complicated or loop circuits.



SIMPLIFY COORDINATION

The PulseFinding technique is specifically designed to recover from overtripping events—providing utilities a valuable tool to reduce the engineering effort and simplify the process of coordinating feeder assets.

OPTIMIZE GRID-EDGE PROTECTION

The time-current characteristic coordination space made available by the shared TCCs of series devices when using the PulseFinding technique enables faster coordination curves for main feeder protective devices. This leaves more room to coordinate downstream devices while maintaining efficient protection at the grid edge.

AUTOMATE WITHOUT COMMUNICATIONS

The PulseFinding technique is included with all IntelliRupter fault interrupters and works on any system with no communications required.

BACK-UP YOUR COMMUNICATION-BASED PROTECTION

Though communication-based protection offers many reliability benefits, there's always a chance your communication system could go down. The PulseFinding technique can be enabled as a back-up for systems using communication-based features to ensure your system is always able to isolate faults to the smallest segment.

USING THE PULSEFINDING TECHNIQUE WITH ONLY INTELLIRUPTER FAULT INTERRUPTERS

When implementing the PulseFinding Fault Location Technique on a feeder with exclusively IntelliRupter fault interrupters, the IntelliRupter devices will be coordinated on one or multiple shared TCC curves. See Figures 4 and 5.

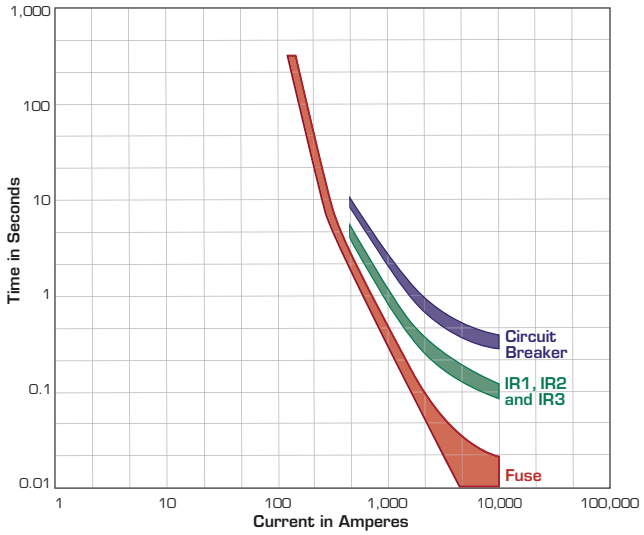


Figure 4. TCC chart showing a single shared TCC curve for three IntelliRupter fault interrupters using the PulseFinding technique.

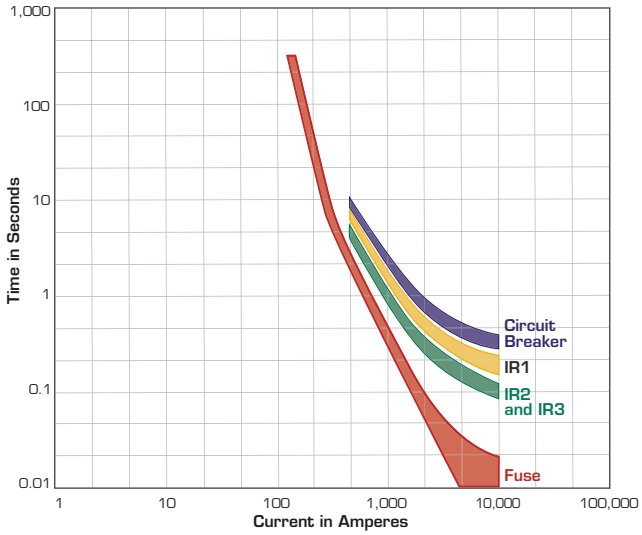


Figure 5. TCC chart showing multiple shared TCC curves for several IntelliRupter fault interrupters using the PulseFinding technique.

When a fault occurs on a feeder with exclusively IntelliRupter fault interrupters using the PulseFinding technique, all devices on the shared TCC curve(s) will open.

The IntelliRupter fault interrupters will then recover from this intentional overtripping, starting with the most upstream device. The first device in the series will complete a low-energy PulseClosing Technology sequence.

If no fault is identified, the IntelliRupter fault interrupter will close, energizing the next device in series and allowing it to begin its own PulseClosing Technology sequence.

The devices will continue one by one downstream in this fashion until the fault is identified and the device closest to the fault locks out or the fault is determined to be temporary and all devices return to their pre-fault closed state. See Figure 6.

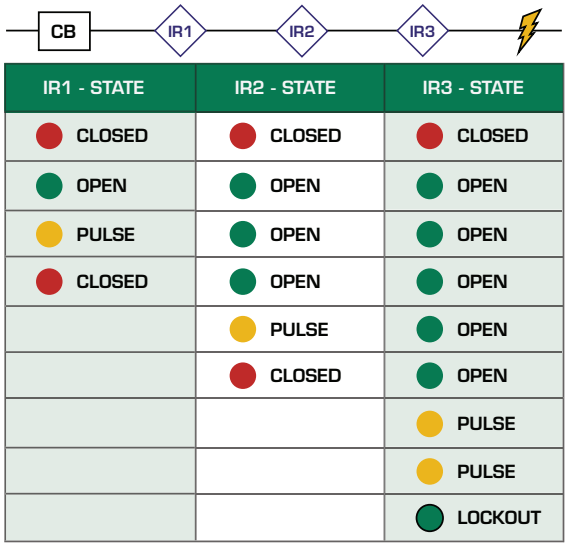


Figure 6. Line diagram and table showing how a series of IntelliRupter fault interrupters using the PulseFinding technique would react to a permanent fault occurring downstream of the last IntelliRupter fault interrupter on this feeder.

USING THE PULSEFINDING FAULT LOCATION TECHNIQUE WITH EXISTING ASSETS

When implementing the PulseFinding Fault Location Technique on a feeder with a mix of IntelliRupter fault interrupters and conventional protective devices, one or more IntelliRupter devices are coordinated on a TCC curve that overlaps that of the nearest upstream conventional device. See Figure 7.

When a fault occurs on a feeder with a mix of existing assets and IntelliRupter fault interrupters with the PulseFinding technique enabled, both the nearest upstream conventional device and downstream IntelliRupter device(s) with overlapping TCC curves may open.

If a fault occurs between an upstream conventional device and a downstream IntelliRupter fault interrupter, the conventional asset will complete its fault-testing sequence as normal—locking out if the fault is permanent and closing back in if it is temporary.

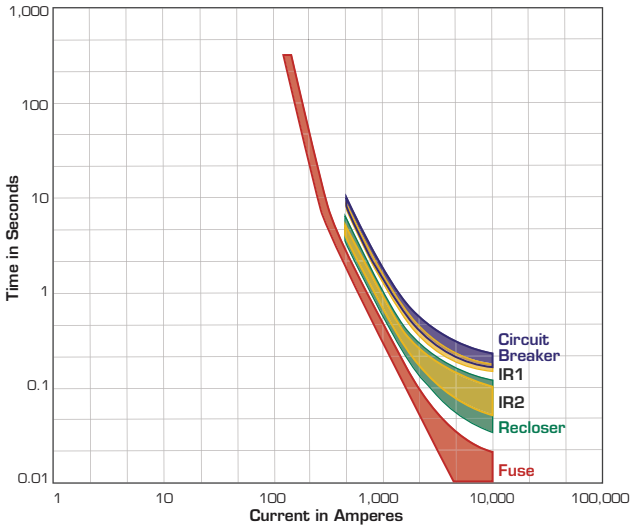


Figure 7. TCC chart showing how, when using the PulseFinding technique, an IntelliRupter fault interrupter's coordination is programmed to either overlap or match that of an existing asset – in this case overlapping the substation circuit breaker and exactly matching the midline recloser.

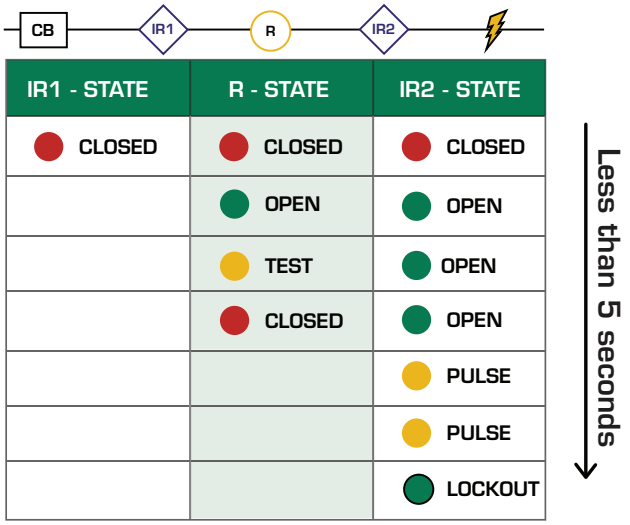


Figure 8. Line diagram and table showing how conventional assets, here a substation circuit breaker and midline recloser, coordinated with IntelliRupter fault interrupters using the PulseFinding technique, would react to a permanent fault occurring downstream of the last fault-testing device on this feeder.

If a fault occurs downstream of an IntelliRupter fault interrupter and an upstream conventional device, both the IntelliRupter device and the conventional device may open if their TCC curves sufficiently overlap. When the conventional device recloses to test for fault presence, no fault is detected because any downstream IntelliRupter fault interrupters are already open. This successful reclosing reenergizes the IntelliRupter fault interrupter next in series, allowing it to complete a low-energy PulseClosing Technology sequence. See Figure 8.

Any remaining downstream IntelliRupter fault interrupters that have opened in response to the fault will perform their typical PulseClosing Technology sequence one by one until the fault location is identified and the nearest upstream IntelliRupter fault interrupter locks out or the fault is determined to be temporary, and all devices return to their pre-fault closed state.

IMPORTANT CONSIDERATIONS

Certain feeder characteristics can impact functionality of the PulseFinding technique. Before implementing this application, utilities should carefully consider whether one or more of the following circumstances may apply to their system.

DISTRIBUTED ENERGY RESOURCES

If distributed energy resources (DERs) are slow to disconnect after a fault, IntelliRupter fault interrupters may not see the level of voltage loss required to trigger the PulseFinding technique. To ensure proper functioning of this application, feeders with 50% or more load carried by DERs should take extra consideration.

Solution: Adjust loss-of-voltage settings to account for a possible slow disconnect of DERs.

HEAVY VEGETATION

Heavy vegetation can cause reinitiating phase-to-phase or phase-to-ground faults that may occur after an IntelliRupter fault interrupter has completed a PulseFinding technique sequence and closed. Each time the fault is reinitiated, all devices in the fault path and using the PulseFinding technique will re-trip and continue their programmed test sequences—causing a lockout miscoordination.

Solution: Use the PulseFinding technique in conjunction with S&C's patented TCC Shifting feature. TCC shifting allows an IntelliRupter fault interrupter to temporarily transfer to a faster TCC curve on the close if a PulseClosing Technology test does not detect a fault. This allows downstream devices to react faster than upstream devices in the event a fault reinitiates, avoiding lockout miscoordination.

UNEQUAL LOAD DISTRIBUTION

Feeder load contributes to the fault-current level a device will sense, therefore impacting how quickly a device will trip based on its TCC curve coordination. If an upstream device has a significantly higher load, it will react to a fault faster than downstream devices—potentially beginning its testing sequence before downstream devices have opened. In this case, the upstream device would detect the fault and lock out before the fault has been isolated to the smallest segment.

Solution: For feeders where upstream devices have significantly higher load, a utility should plot device response times to determine tripping responses. When necessary, the percent phase overcurrent setting can be lowered on downstream devices to enable tripping responses at nearly the same rate as devices upstream.

THREE-WIRE SYSTEM WITH LOW FAULT CURRENT

For three-wire systems, or systems without a neutral line, low fault-current levels can lead upstream IntelliRupter fault interrupters to lock out before the entire PulseFinding technique sequence can be completed.

Solution: Use the PulseFinding technique in conjunction with the TCC shifting feature. The user-configurable hold time of the TCC shifting feature can transfer upstream devices to a slower response, allowing the downstream device closest to the fault to react faster following a close caused by low fault-current levels.

KEY SETTINGS: INITIAL TRIP RESPONSE

REMEMBER:

Overcurrent protection settings must be programmed on all IntelliRupter fault interrupters before turning the PulseFinding technique on or adjusting PulseFinding technique settings.

TO TURN ON THE PULSEFINDING TECHNIQUE IN THE INTELLILINK® SETUP SOFTWARE:

Setup > Protection > General Profile > Direction Current > Initial Trip – Additional Features, Direction 1 Current, and Direction 2 Current can be set based on directional requirements.

If an upstream device trips before a series IntelliRupter fault interrupter reaches its full trip state, the IntelliRupter device will rely on its PulseFinding technique settings to trip. For this technique to be successful, the PulseFinding technique must be turned on and the loss of voltage and percent overcurrent settings must be properly configured, as explained below. This ensures the desired initial overtripping required for the PulseFinding Fault Location Technique.

LOSS-OF-VOLTAGE SETTINGS

For an IntelliRupter fault interrupter to operate using the PulseFinding technique, it must detect overcurrent followed by loss of upstream voltage. Adjustments to the loss-of-voltage settings enable quicker device reaction times, which is critical for proper tripping responses and optimal restoration using the PulseFinding technique.

OPTIONS: Default setting is 20% of positive sequence voltage, but it can be adjusted within a range of 5%-100%.

LOCATION: *Setup > Protection > General Profile > Voltage, Frequency, and Sectionalizing > Open-Source Sectionalizing (Positive Sequence)*

PERCENT OVERCURRENT SETTINGS

Adjusting this value allows a downstream IntelliRupter fault interrupter to operate faster by tripping when its current measurement reaches the set percentage of the overcurrent value. See Figure 9. This setting ensures downstream devices trip nearly as fast as upstream devices, maintaining the proper sequencing required for the PulseFinding technique.

OPTIONS: Percent of phase, ground, and negative sequence overcurrent can be adjusted to 20%, 50%, or 80% based on feeder conditions. The lower the percentage, the greater the probability an IntelliRupter fault interrupter will trip upon sensing an overcurrent event.

LOCATION: *Setup > Protection > Advanced Setup > Advanced PulseFinding*

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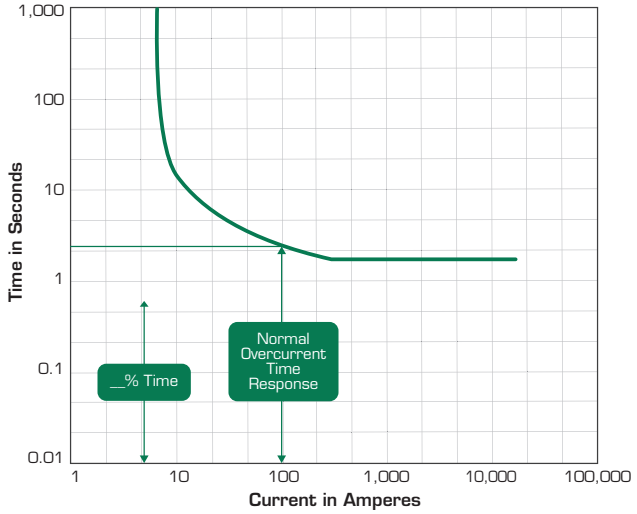

Figure 9. TCC curve representation of adjustment to the percent overcurrent setting.

KEY SETTINGS: ADDITIONAL CONSIDERATIONS

LOSS OF SOURCE TIMEOUT

This setting determines how long an IntelliRupter fault interrupter will remain in its test sequence while it has also lost source voltage. When this timer expires, the loss of source is considered to be permanent, the PulseFinding technique or test sequence operation is canceled, and the IntelliRupter fault interrupter will go to lockout.

OPTIONS:

Based on the sustained outage standard in the United States, the default setting is five minutes and the max is 10 minutes. To ensure an IntelliRupter fault interrupter does not attempt to close back in while crews are working, this setting cannot be turned off or set to zero.

LOCATION:

Setup > Protection > Advanced Setup > Global Timers > Test Seq. or PulseFinding Loss-of Source Timeout

TCC SHIFTING

TCC shifting is a feature used in conjunction with the PulseFinding technique when there is opportunity for faults to reinitiate after PulseClosing Technology events have been completed. This feature can also be applied to three-wire systems to ensure correct tripping responses with the PulseFinding technique.

OPTIONS:

This feature should be applied to systems that may experience reinitiating faults – most commonly, feeders with dense vegetation or frequent conductor slaps. The TCC Shifting feature is also recommended for three-wire systems with low fault current.

LOCATION:

Setup > Protection > General Profile > Direction Current > Initial Trip – Additional Features

NOTE:

Check the PulseFinding technique and TCC Shifting check boxes for all series devices configured with the same Initial Trip TCC settings, including the IntelliRupter fault interrupter closest to the source.

DON'T OVERCOMPLICATE IT!

The PulseFinding technique is a straightforward way to simplify the tasks of increasing segmentation and improving reliability. It comes preprogrammed with default settings S&C has identified as applicable for most utilities.

While these settings are applicable for most utility systems, S&C recommends every utility carefully review them before applying the PulseFinding technique.

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CONCLUSION

The simple reality is conventional reclosers cannot keep up with rising customer expectations for electric reliability. Conventional reclosers are unable to increase segmentation without complex, time-consuming, and expensive investments, and they are entirely incapable of mitigating miscoordination events.

Innovative technology will improve both your user reliability metrics and the customer experience. Rely on the many applications of the IntelliRupter PulseCloser Fault Interrupter and customizable, hands-on support from the S&C team to achieve the reliability your system and your customers require.

To learn more about the PulseFinding Fault Location Technique and discover other unique applications of the IntelliRupter fault interrupter, visit sandc.com/intellirupter.

NEED HELP?

RESOURCE	DESCRIPTION	HOW TO ACCESS	RECOMMENDED FOR
General Training	Led by our application engineering team, S&C's *Distribution Automation Workshop:* IntelliRupter® Fault Interrupter covers a multitude of IntelliRupter fault interrupter applications, including a live demo of the PulseFinding technique, and places emphasis on hands-on learning exercises.	Visit sandc.com/workshops	Engineers
Customized Training	For utilities interested in educational resources catered specifically to their system and needs, customized training is available by request.	Contact your sales representative	Operations, line crews, and engineers
Protection & Coordination Study	For assistance determining parameters and optimal device locations, S&C's Consulting and Analytical Services team is available to conduct personalized protection and coordination studies.	Contact your sales representative	Engineers
Configuration Assistance & Hands-On Support	S&C's application engineering and field services teams are available to provide assistance with device settings and operation of IntelliLink software.	Submit a request at sandc.com/tech-support or call 1-888-762-1100 and an S&C representative will be in touch.	Engineers

For additional resources on S&C's IntelliRupter fault interrupter, such as installation and operation videos, product specifications, technical literature, utility case studies, and more, visit sandc.com/intellirupter.