5 Steps to Modernize Your Feeders

with IntelliRupter® PulseCloser® Fault Interrupters

Introduction

You know the grid has changed drastically in recent years.
The challenge is what to do about it.

Feeders often are the starting point for reliability improvement on the distribution system because one issue on these lines impacts many customers.

However, feeder improvements are becoming ever more important—even in comparison to transmission improvements—because the distribution system is where the biggest changes to the grid have occurred and where future changes, such as distributed generation, will happen.

This guidebook walks you through five simple steps to modernize your feeders, and one device is the cornerstone for these improvements: the IntelliRupter PulseCloser Fault Interrupter.

Contents

Problem 4

STEP 1: Leverage the Innovations of IntelliRupter® Fault Interrupters 6

STEP 2: Segment Radial Feeders 8

STEP 3: Loop Your Circuits 10

STEP 4: Implement Advanced Restoration Schemes 12

STEP 5: Think Holistically to Realize the Ideal System 14

Working with Legacy Devices 17

Where Are You in the Process 18

Conclusion 19

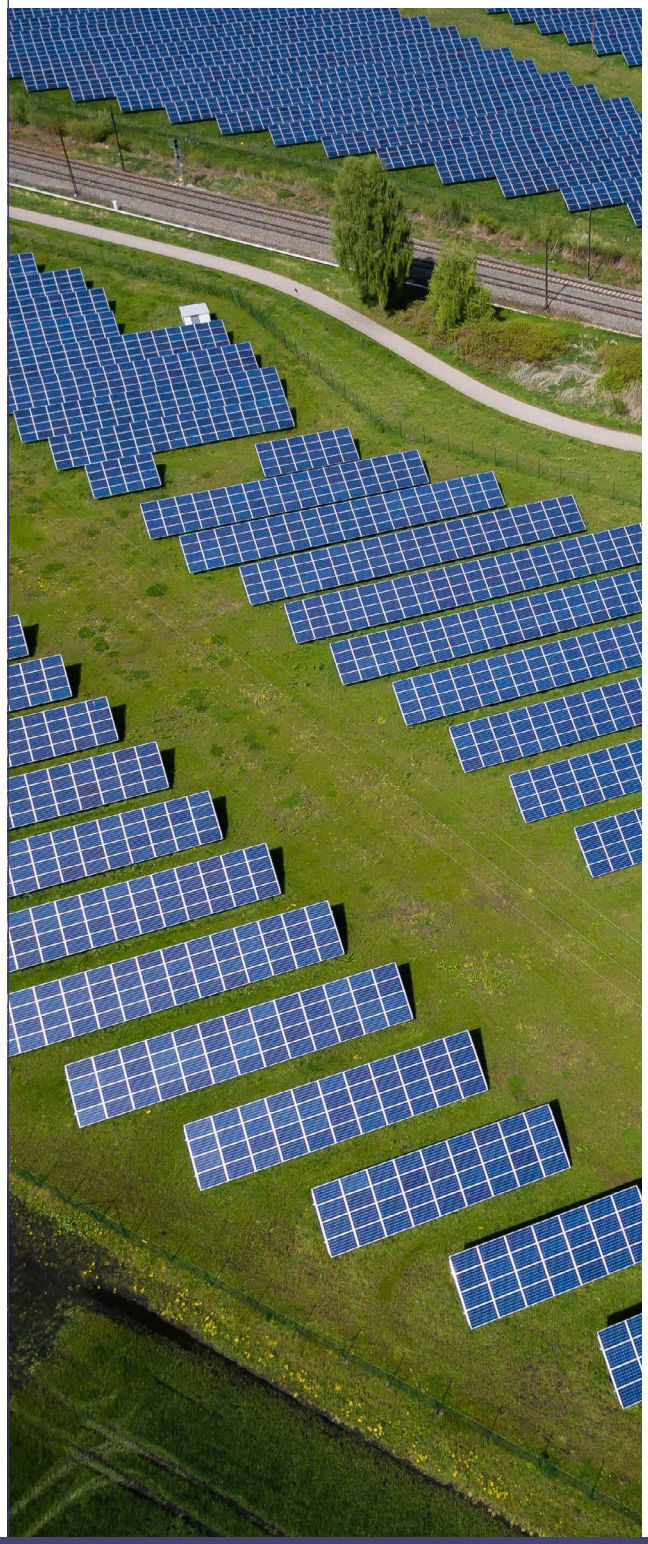
Problem

BI-DIRECTIONAL POWER FLOW

Distributed energy resources (DERs), such as solar and wind, have been one of the historically biggest disrupters to the industry. These DERs have forced a system built for one-way power flow to transform into a two-way system, which obsoletes many protection strategies and the devices that were once tried-and-true solutions.

MOMENTARY OUTAGES

While utilities have typically strived to reduce their System Average Interruption Duration Index (SAIDI), momentary outages are now becoming a more critical issue. A mere blink in power will kick inverter-based DERs offline, causing a long reconnection process and limiting the potential from these investments.

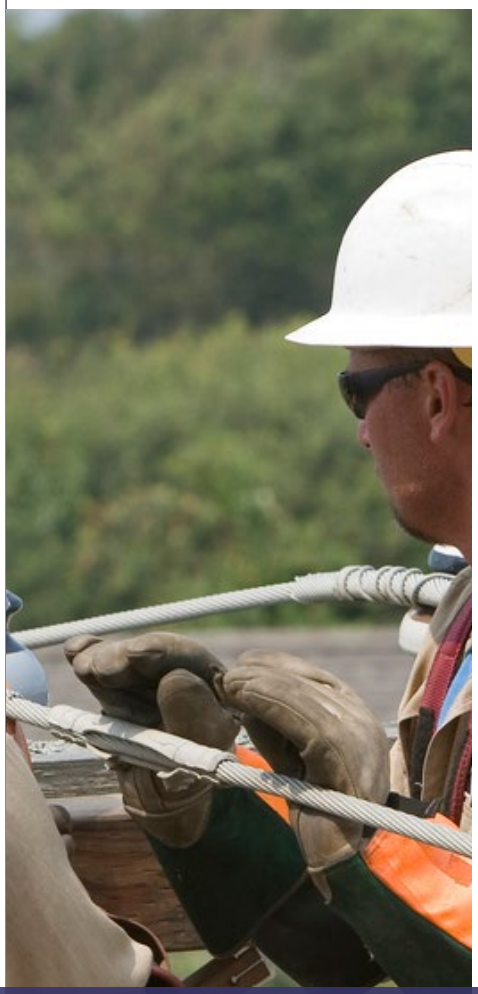


CUSTOMER EXPECTATIONS

In the digital era, customers are significantly more disrupted from outages long and short. Automation systems with programmable logic controllers, robotics, and data processing for running industrial facilities and businesses cannot withstand even a quick interruption. If an interruption occurs, it severely affects production and productivity, costing thousands of dollars in lost time and work. Even everyday consumers have come to expect uninterrupted power—and are publicly vocal when they don't get it. Social media is a highly visible public record—and a potential public relations nightmare.

O&M EXPENSES

Utilities are feeling increasing pressure to minimize operation and maintenance expenses to protect their bottom line. They're looking for ways to automatically and quickly restore power to reduce how often they need to send crews to the field.



EVOLVING WORKFORCES

Utilities are bracing for a wave of retiring employees with fewer newcomers to fill the oncoming void. They're relying on their equipment to do more because they may not have the people to do it. Additionally, as new technologies pave the way for more data and improved safety procedures, workers are searching for ways to collect information and operate devices with minimal proximity to equipment and exposure to risk—remotely whenever possible.

Fortunately, the IntelliRupter fault interrupter solves all of these challenges. Let's get started.

STEP 1
to modernize your feeders

Leverage the Innovations of **IntelliRupter® Fault Interrupters**

IntelliRupter fault interrupters represent the first breakthrough in reclosing technology in 70 years. While there are many benefits to using IntelliRupter fault interrupters, there are two baseline differentiators that result in immediate benefits:

Accurate Sensing

IntelliRupter fault interrupters have incredibly precise sensors, which enable the devices to close in on the same sine wave point every time. Their controls protect simultaneously both upstream and downstream, looking for faults in both directions.

WHY IT HELPS

- Voltage sensors on each side of the device enable advanced automation functions for restoration, and high-accuracy current sensors manage the bi-directional flow of power especially important with the influx of DERs onto the grid.

PulseClosing® Technology

IntelliRupter fault interrupters use PulseClosing Technology, which reduces the let-through energy during fault-testing by **95%**. This is achieved through the devices' ability to close in on the same sine wave point every time.

WHY IT HELPS

- Millions of dollars are spent each year replacing substation transformers, splices, connectors, and conductors damaged from the immense stress of conventional reclosing. By reducing the energy during fault-testing, your system experiences less mechanical and electrical stress, which extends assets' life cycles and saves you money.
- Lower let-through energy also results in fewer arcs and sparks, making IntelliRupter fault interrupters a safer option. See Figures 1 and 2.

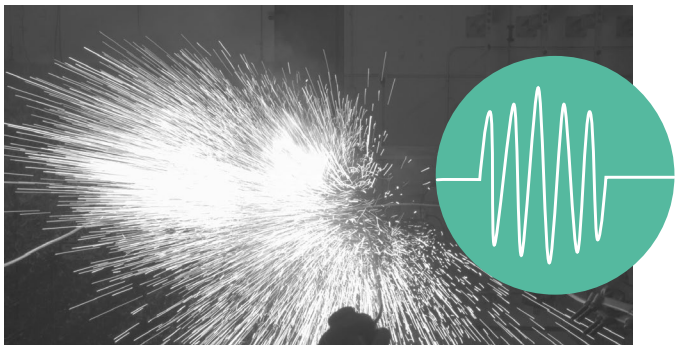


Figure 1. Severe impact from conventional recloser during fault testing.

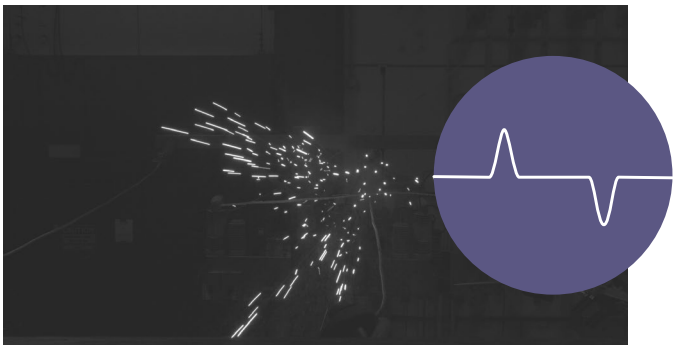
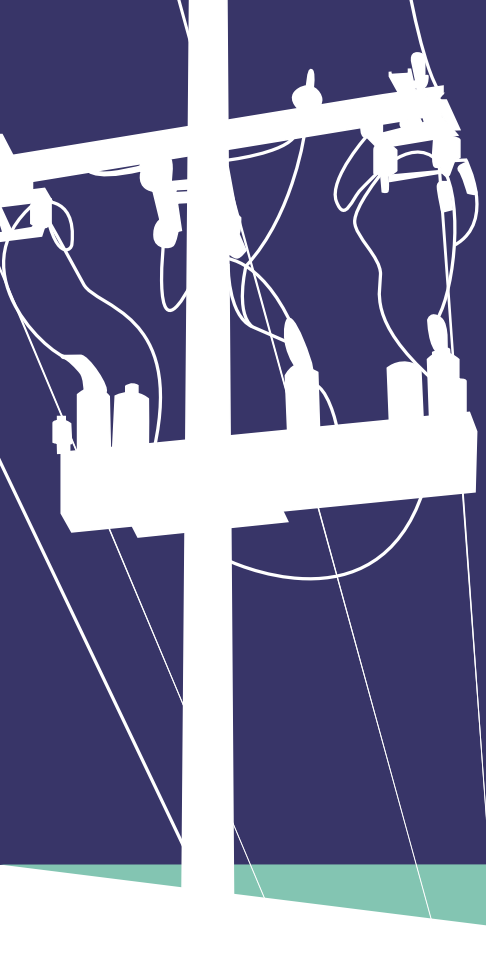


Figure 2. Significantly minimized impact from PulseClosing Technology.

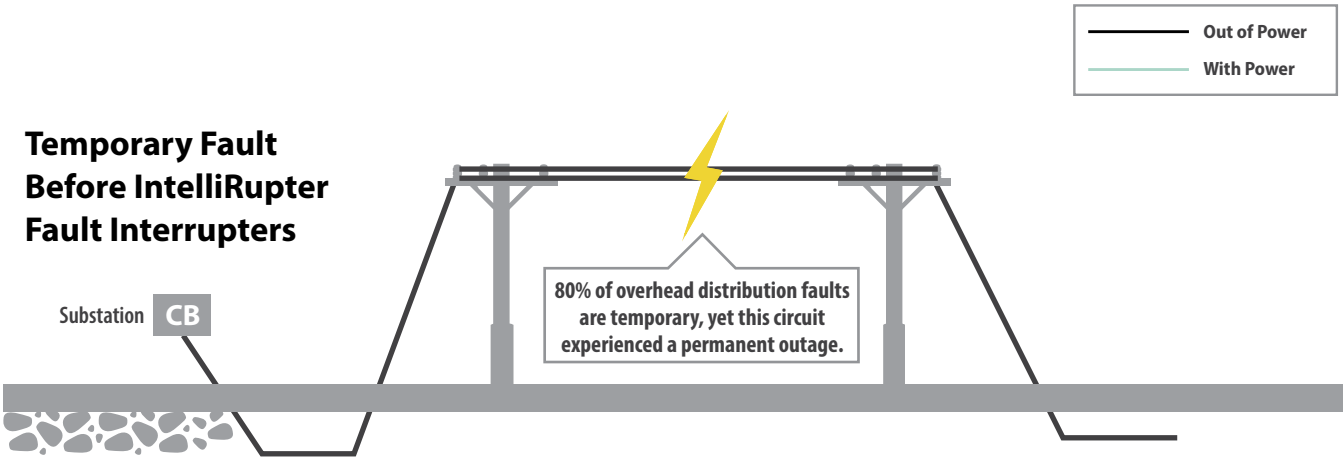


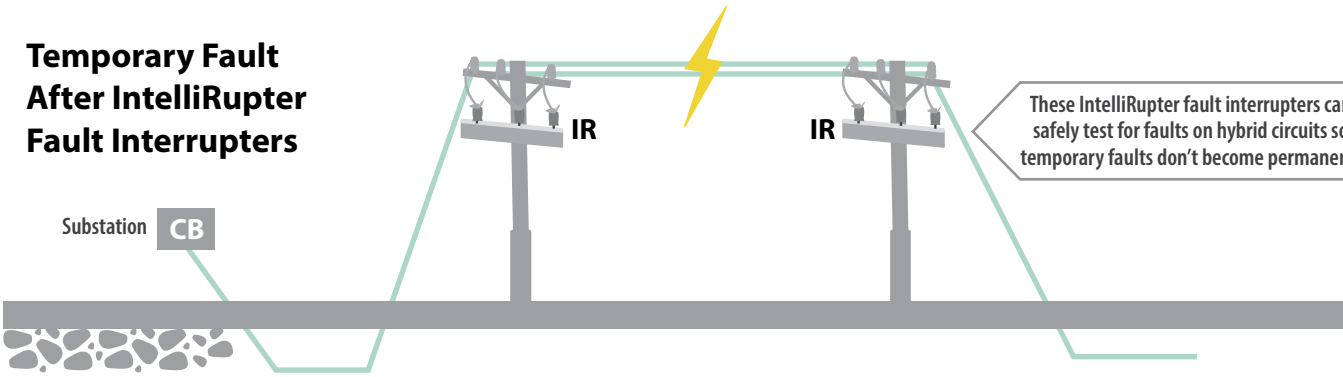
STEP 1 System Spotlight

While every system can benefit from the basic features of IntelliRupter fault interrupters, PulseClosing Technology is a game-changer for **underground lines and hybrid circuits**.

Utilities with underground lines and hybrid circuits (a combination of both overhead and underground lines) are shortchanging their reliability because of the risk of using conventional reclosers on underground lines. Because the impact of fault-testing is so grave with conventional reclosers, utilities with these systems avoid pounding on underground lines with every reclose out of fear of damaging underground cables and splices, and the subsequent difficulty of finding and fixing a fault on an underground line.

Instead, PulseClosing Technology makes it possible to test for faults in these circumstances.





STEP 2
to modernize your feeders

Segment Radial Feeders

The more segments on your feeder, the fewer the customers that will be out of power when a fault occurs. Having more segments also makes it faster to locate faults, ultimately reducing maintenance costs. IntelliRupter fault interrupters' accurate sensing and precision measurement lead to better protection and coordination on radial circuits, ultimately improving reliability.

Coordinated Segmentation

Precise sensing results in time-current characteristic (TCC) curves with an accuracy of **+/- 2%**, compared to roughly **+/- 10%** in conventional reclosers.

WHY IT HELPS

- Conventional reclosers are plagued with coordination challenges, but the IntelliRupter fault interrupter's "skinny" TCC curves and fast operation mean more devices can be placed in series on a feeder without risk of miscoordination. More coordinated devices on a feeder allows you to further segment lines. See Figures 3 and 4.

PulseFinding™ Fault Location Technique

This technique uses a pulse of current to hunt down the location of a fault. For ultimate simplicity, all the devices using this technology can even be placed on the same TCC curve, so you do not need to coordinate them with each other.

WHY IT HELPS

- There may be situations where you can coordinate multiple devices in a series—but only up to a point. For the rest of the circuit, you can use the PulseFinding technique to continue segmenting feeders without worry of miscoordination.
- If you want to drastically simplify coordination, you could only use PulseFinding technique on a circuit. Theoretically, you could have an infinite number of IntelliRupter fault interrupters on a feeder.
- The PulseFinding technique provides similar benefits to communication-based coordination solutions without the cost and maintenance of a communication system.

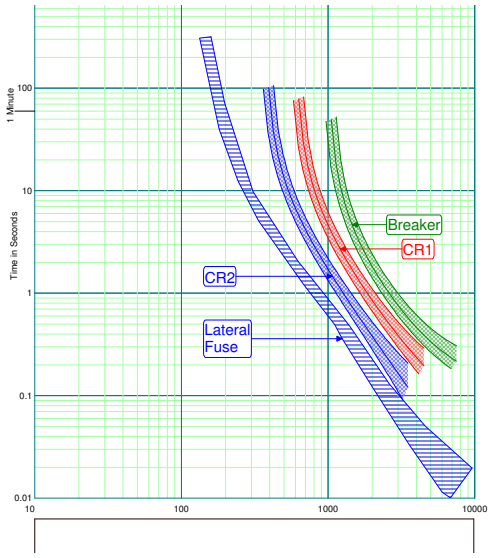


Figure 3. Conventional recloser TCC curves.

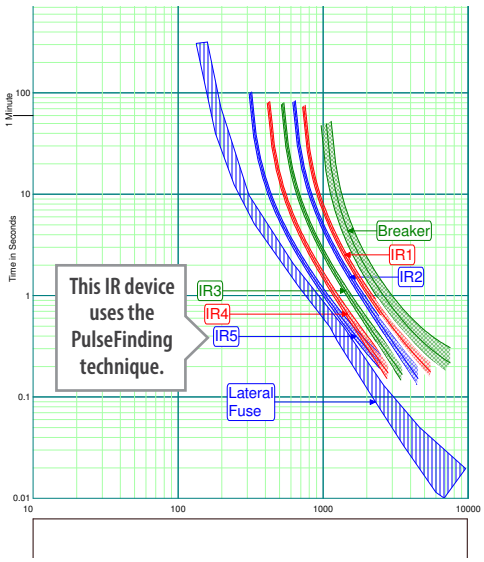
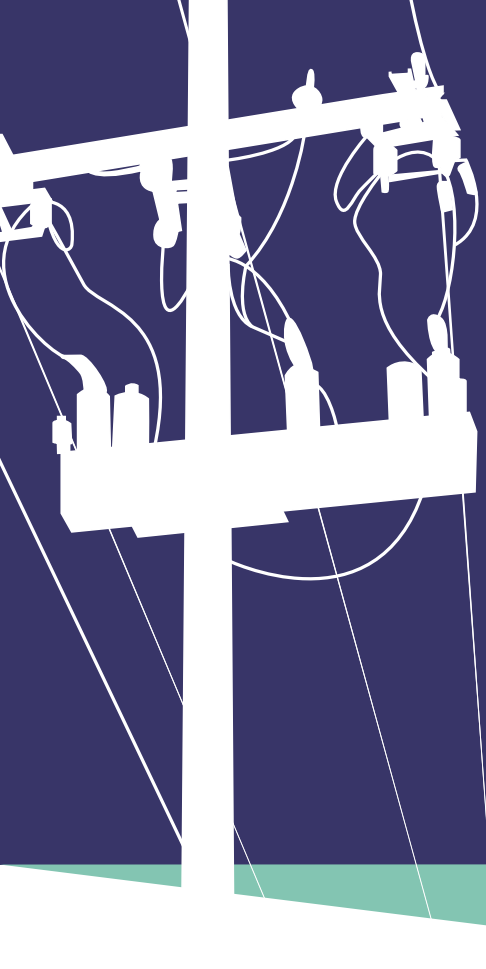


Figure 4. IntelliRupter fault interrupter "skinny" TCC curves.



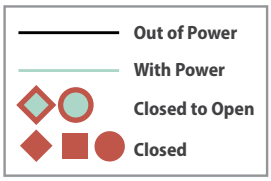
STEP 2 System Spotlight

While every system can benefit from increased segmentation and the PulseFinding Fault Location Technique, they advance reliability for areas with **dense populations** and **long feeders**.

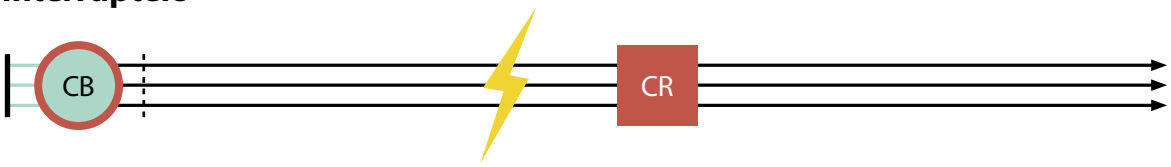
In areas with dense populations, one segment can serve thousands of customers. Saving simply one more segment from losing power can mitigate the impact for a significant number of people—and improve your reliability scores.

When power goes out on long feeders, it results in long drives for your repair crews. Saving more customers from initially losing power is ever more critical when they may have to wait a while for crews to arrive and restore power.

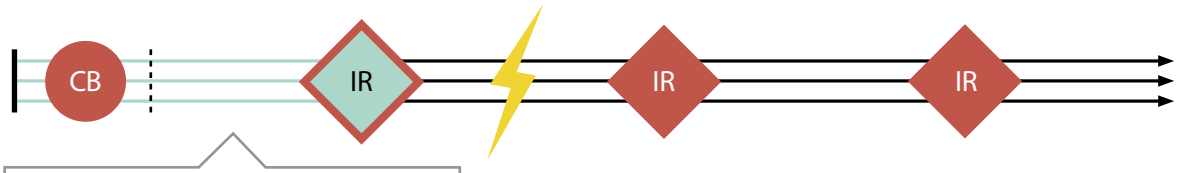
Instead, IntelliRupter fault interrupters increase feeder segmentation to resolve these issues.



Before IntelliRupter Fault Interrupters



After IntelliRupter Fault Interrupters



Power stayed on for customers in this segment, resulting in 25% improved reliability for the same fault.

STEP 3
to modernize your feeders

Loop Your Circuits

Radial circuits reach a limit to their reliability, and customers at the far end get little or no relief from outages. To move the needle on reliability improvements, turn your radial circuits into loops, connecting two together with a normally open tie point. IntelliRupter fault interrupters are critical to achieving this advancement because their sensors and controls detect bi-directional power flow, they enable more devices to be coordinated in series, and their use of PulseClosing Technology decreases the impact from fault-testing.

Automatic Fault Isolation and Restoration

Sensing overcurrent on a faulted segment, the upstream device closest to the fault opens, the downstream device opens to isolate the segment, and the normally open tie point closes. Power is rerouted from an alternative source, keeping the lights on for all customers except those in the faulted segment—all without needing communications.

WHY IT HELPS

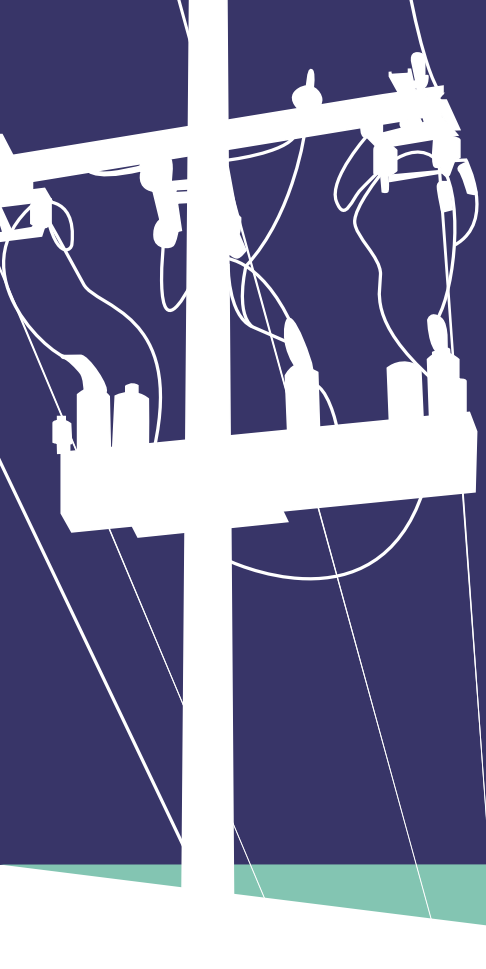
- Isolating only a small segment around a fault results in a massive reliability improvement. Unlike radial feeders, where the faulted segment and all customers downstream lose power, on looped circuits only the faulted segment loses power.

Voltage Sag Elimination

If you use a conventional recloser for loop restoration, the recloser is testing for faults by producing overcurrent conditions that cause voltage sags on the adjacent circuit. However, because IntelliRupter fault interrupters use PulseClosing Technology to gently test for faults with very little impact on the system, these devices can reroute power without causing voltage sags on the adjacent feeder.

WHY IT HELPS

- Voltage sags translate into power-quality issues, which can cause major complications for customers, especially those in the commercial and industrial sector. Using IntelliRupter fault interrupters keeps power quality high and the power on for more people.

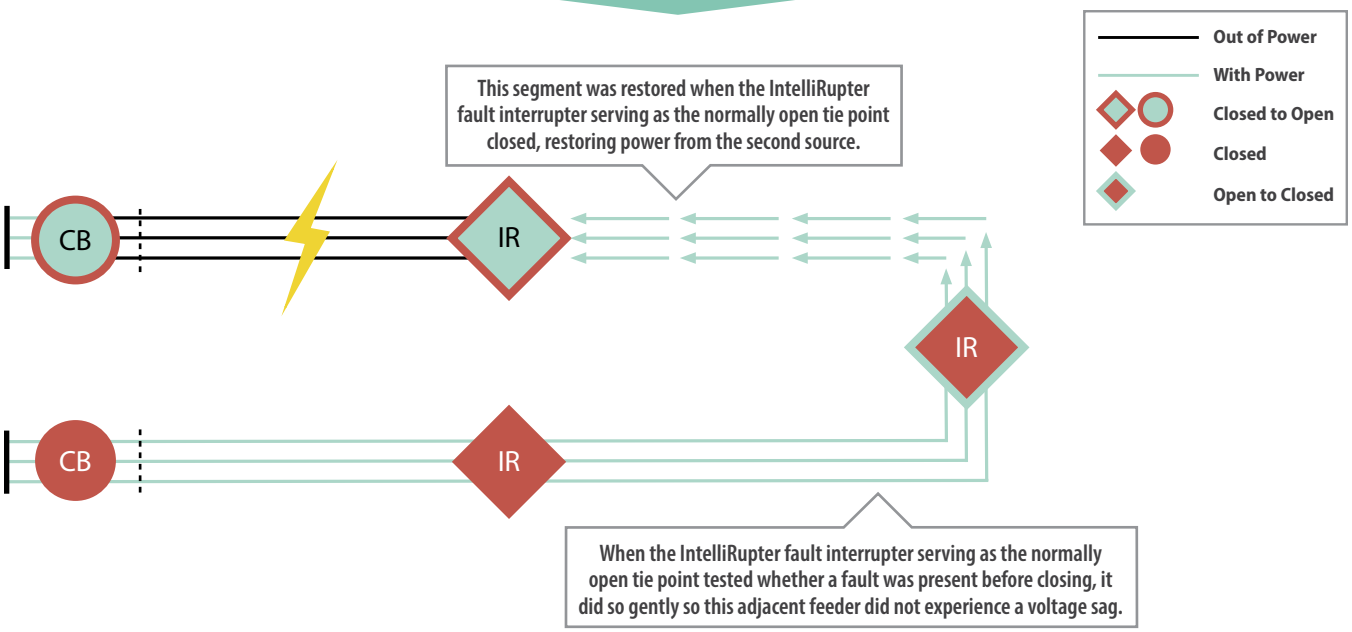


STEP 3 System Spotlight

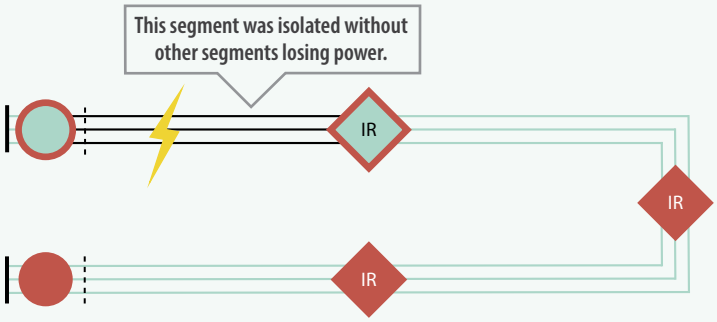
While every system can benefit from looped circuits, they radically reform power restoration for **dense populations** and locations with **commercial and industrial customers**.

The crux of these locations is quantity and risk. Losing power impacts many people, and voltage sags can cause significant damage for industrial and mission-critical facilities, such as manufacturing plants and hospitals, that require a high degree of power quality and reliability.

Instead, IntelliRupter fault interrupters provide a communication-free solution that restores power quickly without affecting the rest of the system.



Alternatively, you could also loop your circuits and place all the IntelliRupter fault interrupters in a normally closed state. This is particularly beneficial if the loop is fed by the same substation because the voltage is the same throughout and won't result in losses or inefficiencies. When all the IntelliRupter fault interrupters are closed, their sensors will automatically detect and isolate a fault—and only the faulted segment will ever experience power loss.



STEP 4 ⟩
to modernize your feeders

Implement Advanced **Restoration Schemes**

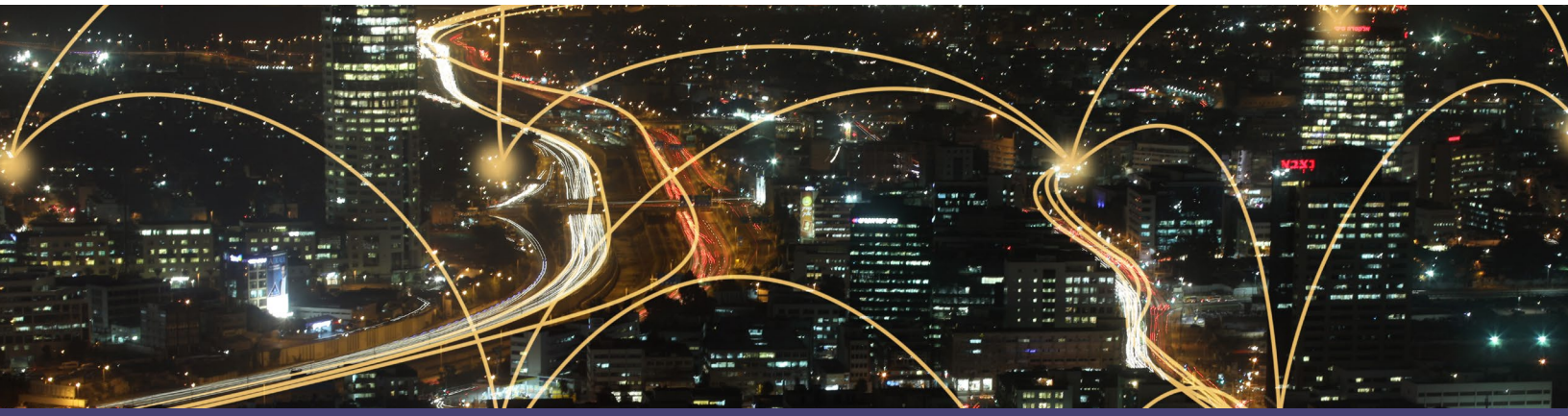
Some situations require more intricate configurations than automatic loop restoration. For example, you may have troublesome areas or complex circuits on your system that need real-time analysis of an issue to evaluate restoration options and determine the best course of action—and do so quickly. In these circumstances, adding communications can provide a more surgical fix and quicken restoration.

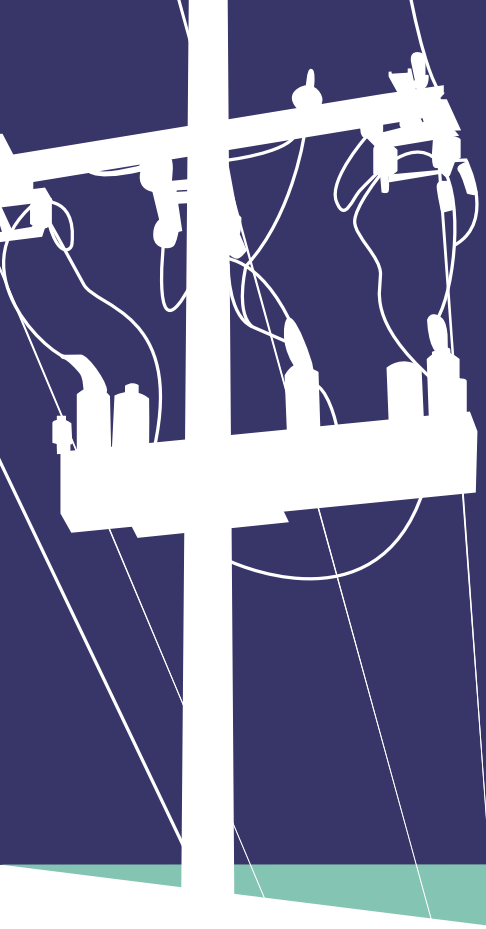
IntelliTeam® SG Automatic Restoration System

IntelliTeam SG system software bundles IntelliRupter fault interrupters into "teams," which assess the situation around them and make decisions at the team level while using system-level knowledge.

WHY IT HELPS

- For advanced restoration approaches, many utilities tend to turn immediately to Distribution Management Systems (DMS) as a solution that models their entire system and provides recommendations for resolving faults. However, these systems cost millions of dollars, take years to implement, still require manual oversight of the system's decision-making, are often limited to single contingency events, and take minutes to restore power. Instead, the IntelliTeam SG system can be installed in months to spot-fix the trickier or more critical parts of your grid without needing a full-scale system model. Its localized decision-making means it can analyze various restoration possibilities—taking loading data and multiple contingencies into account to draw conclusions with certainty—and automatically reroute power within seconds.
- The influx of DERs on the grid adds an additional layer of complexity a DMS typically can't handle. However, the IntelliTeam SG system and IntelliRupter fault interrupters together address DERs' two-way power flow and their variable, quick-changing nature.





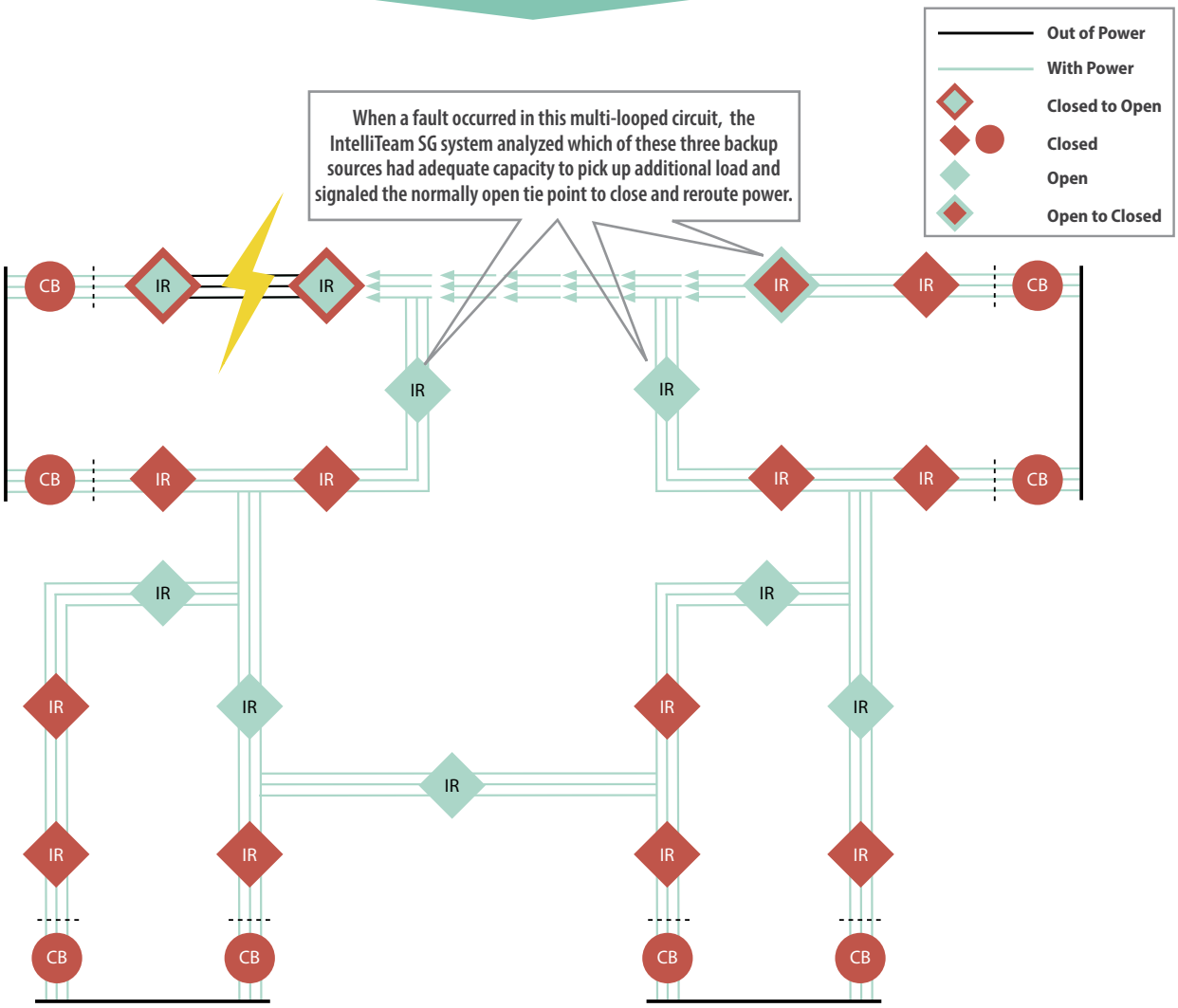
STEP 4 System Spotlight

While every system can benefit from advanced restoration schemes, they bring an enhanced solution to **commercial and industrial customers** and **multi-looped circuits**.

Commercial and industrial customers require a high degree of power reliability, so even brief outages can wreak havoc on production or cause severe safety concerns—even from the moments of delay involved in manually reviewing and approving DMS restoration recommendations.

To build reliability and resiliency into their systems, utilities are beginning to connect looped circuits together to provide redundancy and multiple backup sources on the grid. However, accounting for several system contingencies severely complicates fault-restoration logic and confuses more basic restoration approaches.

Instead, pairing the IntelliTeam SG system with IntelliRupter fault interrupters brings an advanced layer of intelligence that locally investigates issues on the grid, rapidly assesses numerous restoration options, and quickly chooses the best solution—all within seconds.



STEP 5 ⟩
to modernize your feeders

Think Holistically to **Realize the Ideal System**

Many utilities make decisions at the substation level that restrict—or even jeopardize—reliability throughout the distribution system:

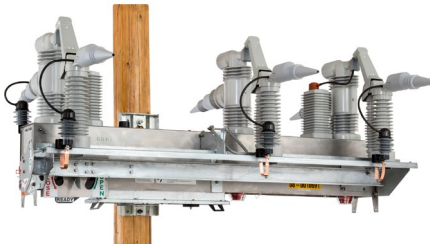
- **Coordination limitations –** Protecting substation transformers by placing circuit breakers on instantaneous trip interferes with your ability to implement any effective coordination to protect your distribution system from outages.
- **Momentary outages throughout feeders –** Lateral fuse-saving strategies require upstream breakers and reclosers to trip before the lateral fuse can operate. However, this practice produces questionable results because many fuses aren't saved. Furthermore, this strategy blinks the entire feeder for any fault—permanent or temporary—causing many customers on the feeder to suffer unnecessary outages.
- **Accepted permanent outages –** Historically, many utilities with hybrid circuits have not only avoided fault-testing on feeders because of the impact of reclosing on buried cables, but they have also shied away from fuse-saving strategies for the same reason. They set substation breakers to one shot to lockout to avoid stressing underground lines—accepting all outages as permanent on feeders and laterals.

To reach a quintessential system, it requires thinking beyond the feeder and taking a holistic approach—from substation to grid edge. Whether it's a mindset change or simply making sure your transmission and distribution teams don't operate in silos, reconsidering substation protection in relation to a suite of advanced solutions—from the head of the feeder down to the end of your lateral—together solves multiple reliability shortcomings and epitomizes the ideal system.

STEP 5 continued

IntelliRupter Fault Interrupters Outside the Substation

Start by removing the instantaneous trip on your substation circuit breaker and then placing an IntelliRupter fault interrupter outside the substation.



WHY IT HELPS

- Not only do you still adequately protect your substation transformer with the IntelliRupter fault interrupter, but you reclaim more of the feeder versus leaving the initial segment to be protected by the substation breaker—bringing the benefits of the devices to 100% of these lines.
- You unbridle coordination for all your distribution devices and execute the tight, precise protection you've always wanted throughout your system.

TripSaver® II Cutout-Mounted Reclosers

These single-phase reclosers combine the best of both fuse-saving and fuse-blowing strategies by testing for faults on laterals and restoring power if a fault is temporary. They work independently of substation breakers and can be coordinated with the nearest IntelliRupter fault interrupter.

WHY IT HELPS

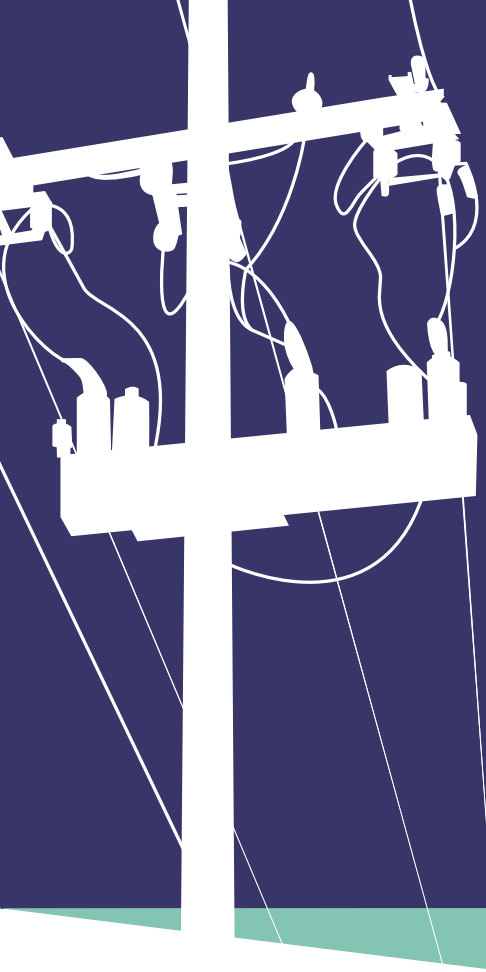
- TripSaver II reclosers isolate issues on a lateral only to that particular lateral. If a fault is temporary, only the lateral with the fault sees a blink, and then power is restored. If a fault is permanent, only that lateral will lose power until a crew can restore it. This means customers on the feeder and other lateral circuits are never affected by these issues, which significantly improves reliability scores and reduces truck rolls.

VacuFuse® II Self-Resetting Interrupters

These single-phase devices replace fuses intended to protect overhead distribution transformers and act as a self-resetting fuse. They automatically reset if a fault is temporary and will lock out after one test if a fault is permanent.

WHY IT HELPS

- Up to 70% of faults that occur at these areas of the grid are nuisance outages, which typically mean the reason for the fault is temporary and the resulting sustained outage caused by a blown fuse could have been avoided. That 70% equates to 70% of wasted maintenance expenses for these issues, which can be saved with VacuFuse II interrupters.
- Every utility has pockets of its system that are troublesome or serve critical (or vocal) customers. Some utilities even track how many times specific customers experience multiple interruptions. VacuFuse II interrupters can address these pinpointed customer satisfaction opportunities.

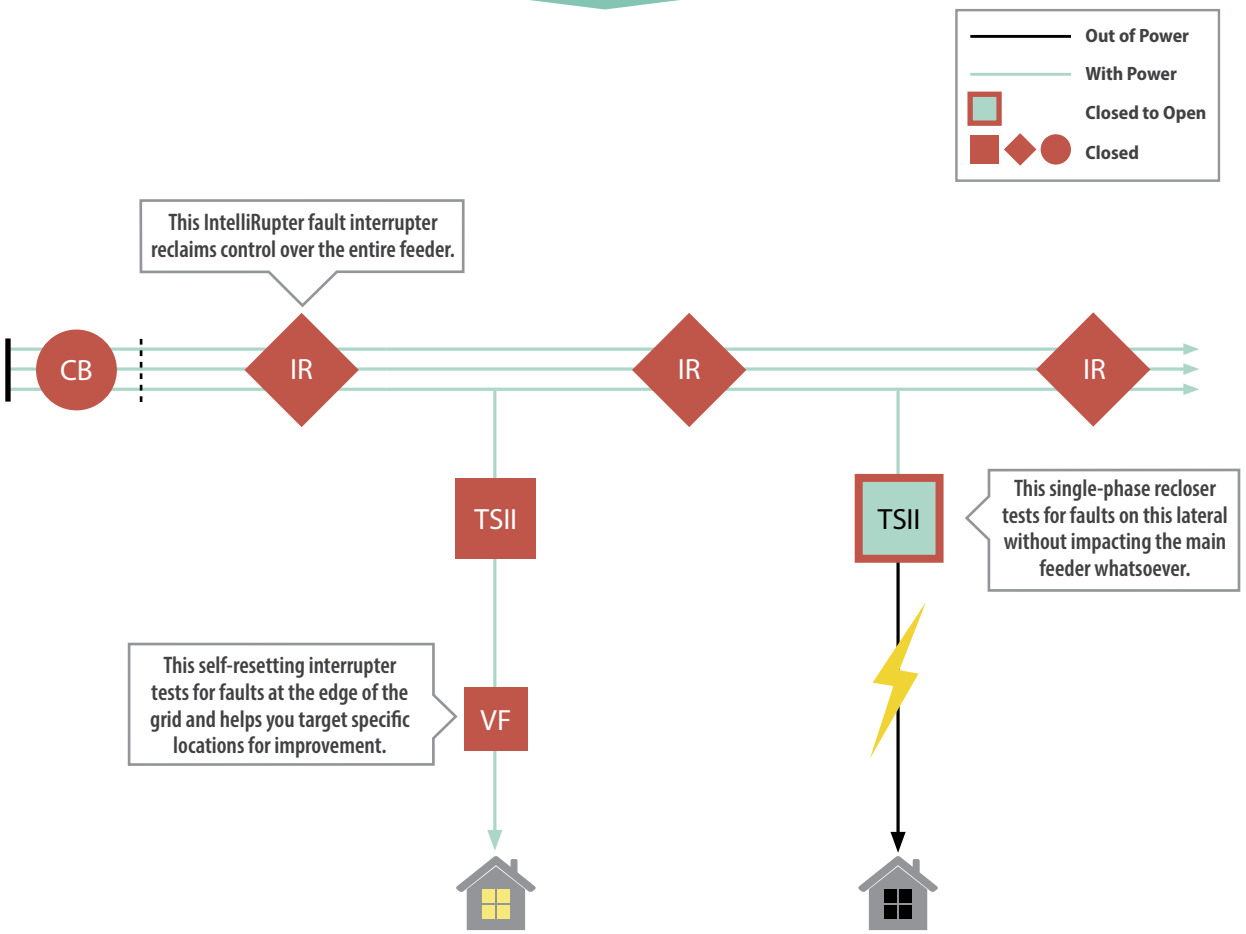


STEP 5 System Spotlight

If you're a utility that **seriously prioritizes reliability improvements**, this holistic distribution protection is the last step to achieving an optimal system.

Additionally, if you have **hybrid or complex circuits**, these solutions together mean you can implement modern technology everywhere on your system versus presuming use of underground lines forces you to forgo additional protection strategies.

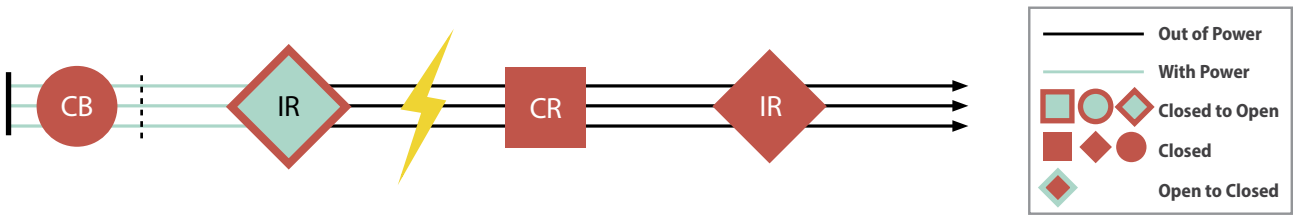
The greatest reliability improvements come from thinking systemwide, reviewing how your devices work together, and coordinating your system's protection settings—from substation to grid edge.



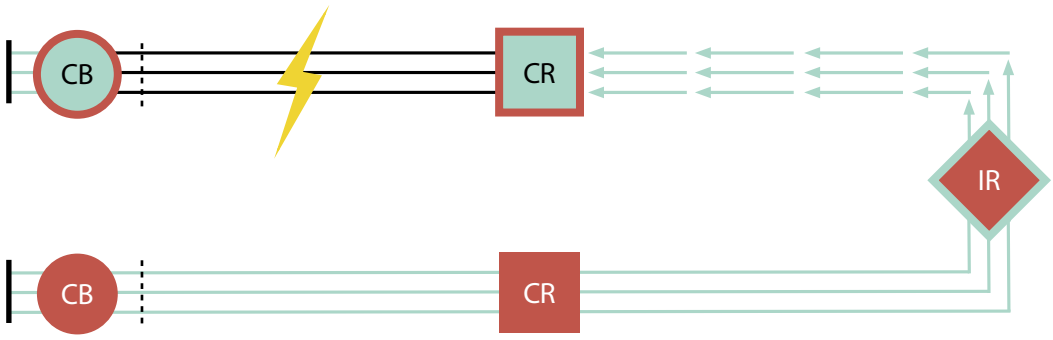
Working with **Legacy Devices**

It's likely you're somewhere along this journey and that some of these steps look familiar to you. The biggest question you may be asking is whether you can use IntelliRupter fault interrupters along with the legacy equipment on your system. While you won't reap all the benefits from IntelliRupter fault interrupters unless you use them exclusively, it is still possible to execute most of these grid modernization steps by combining them with other devices. Here are the two most common examples:

- **Example 1: Segmentation –** Many utilities understand the benefits of feeder segmentation and have placed a conventional recloser at the mid-line. If you only use conventional reclosers, it will limit the number of additional devices you can place on the line, but you can place IntelliRupter fault interrupters on either side of the mid-line recloser. The IntelliRupter fault interrupters' accuracy and "skinny" TCC curves typically can still coordinate with the conventional recloser, and additional segmentation beyond that point could be achieved through the PulseFinding Fault Location Technique.



- **Example 2: Looped Circuits** – Many utilities are looking into fault-restoration strategies and want to tie together two radial circuits that have previously been segmented with conventional reclosers. It is possible to work with these segmented circuits, but it is absolutely critical to use an IntelliRupter fault interrupter as the tie point. With its simultaneous bi-directional protection and low-impact fault-testing, it can detect faults in either direction and won't cause voltage sags on adjacent feeders when testing for faults prior to closing.



Where Are You in the Process?

As tempting as it can be to skip steps or jump directly to the ideal system, system improvements tend to need a step-by-step approach to build a solid base, move steadily forward, and reach holistic system modernization. To get started, think about the challenges you are or will soon encounter and the state of your present system:

Modernization Questionnaire	
Reliability Goals	
What are your present reliability indices?	SAIDI:
	SAIFI:
	MAIFI*:
	CEMI:
What are your reliability improvement targets?	SAIDI:
	SAIFI:
	MAIFI*:
	CEMI:
	Other:
Which problems are you presently dealing with or see near on the horizon? *Circle all that apply.*	DERs customer satisfaction voltage sags reliability momentary outages evolving workforce other:
System Assessment	
Which step best represents your overall system? *Circle the best answer.*	Step 1 Step 2 Step 3 Step 4
Which step best represents your 10 worst-performing feeders? *Circle the best answer.*	Step 1 Step 2 Step 3 Step 4
Existing Assets	
How much capital do you spend on replacing connectors, splices, and conductors annually?	
How much O&M do you spend to install new connectors, splices, and conductors annually?	
How frequent is the maintenance cycle for legacy reclosers?**	
How much O&M do you spend maintaining legacy reclosers every maintenance cycle?**	

** Not tracking MAIFI? Especially as DERs proliferate the grid, momentary outages will become a bigger and bigger problem. Are there industrial loads in the circuit served by your utility company?*

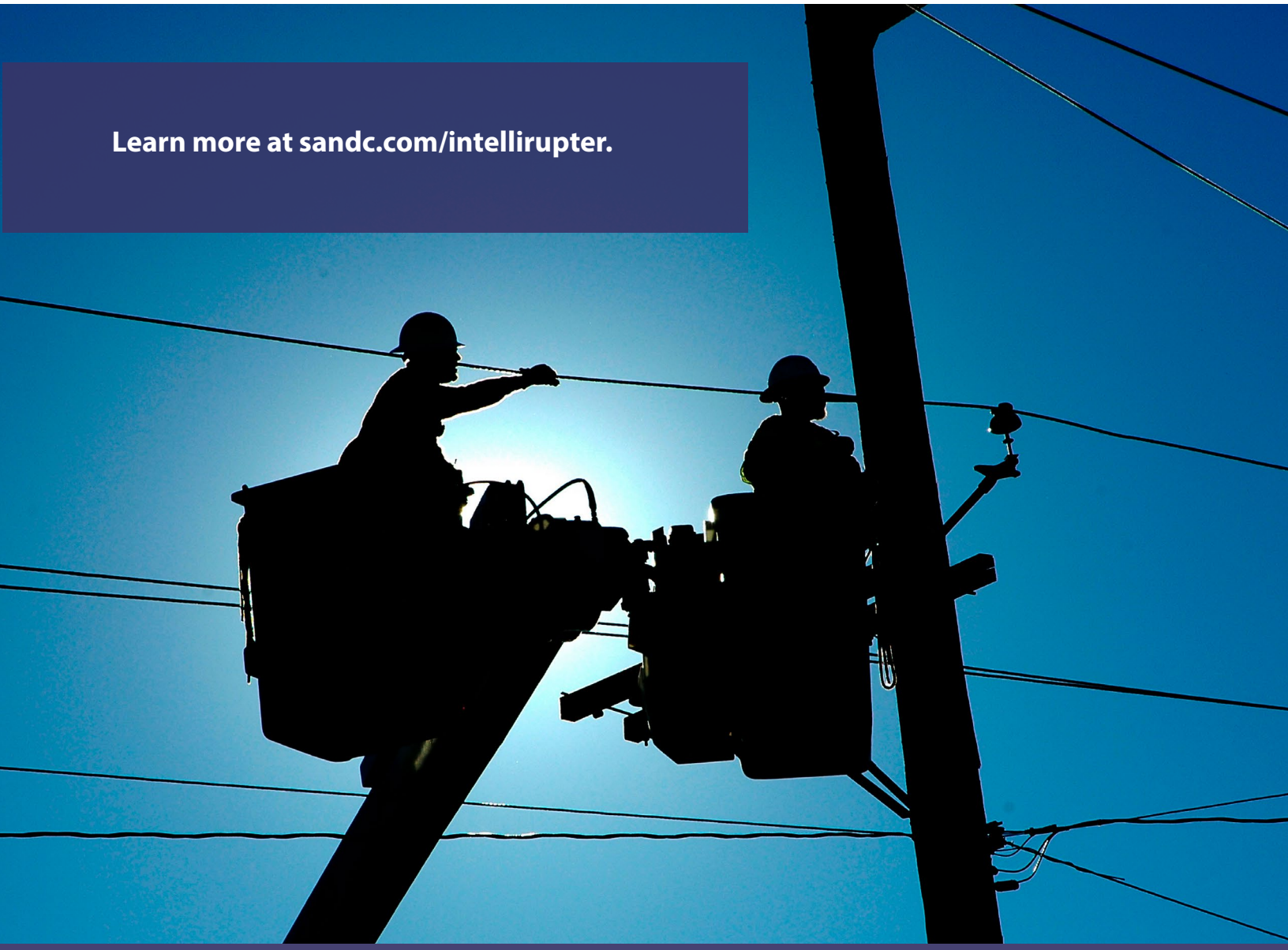
*** You may have equipment that requires routine maintenance. Although these products have already been purchased and are up on your lines, they likely have a high total cost of ownership from reoccurring O&M expenses. It may be more economical to buy new, low-hassle products and use your existing assets' maintenance schedules as a trigger to install replacements.*

Conclusion

With so many changes to the grid in recent years, it's easy to feel caught between two ends of the spectrum—as if you're falling behind quickly and need to do something soon yet are hesitant to do anything out of fear that what you do may be unable to handle more changes to come.

The good news is that IntelliRupter fault interrupters can do both: They can catch you up in solving today's challenges, and they have the flexibility and functionality to still be relevant tomorrow. IntelliRupter fault interrupters serve as a foundation to grid modernization and create a roadmap to tackle system updates in manageable steps. Modernizing your system can seem far less intimidating when you break it down into smaller chunks.

Simply start. Start by analyzing where you are and taking one, incremental step forward. **And you can always start with us.** We're here to help you bring this step-by-step plan to life.



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