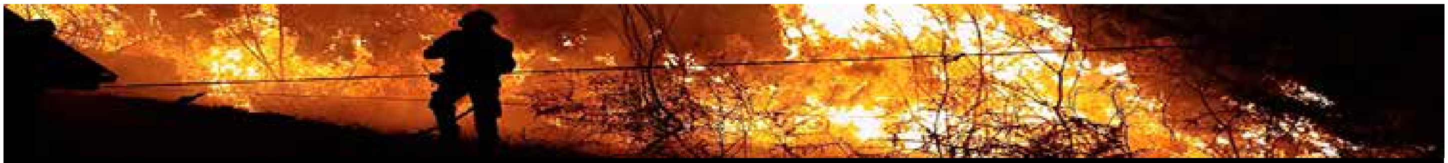
ELECTRIC POWER RESEARCH INSTITUTE

DISTRIBUTION PROTECTION OPTIONS TO REDUCE DAMAGE AND IMPROVE PUBLIC SAFETY

May 2020



Executive Summary

EPRI has been exploring protective device configuration approaches targeted at minimizing the chances of adverse interactions with the power system and the environment. More specifically, electrical faults caused by vegetation, animals, conductor slap, lightning and equipment failures can each create an unintended fault current pathway and that fault current can cause arcing until the circuit protection detects and opens the circuit. The longer the fault current is present the more arc energy and the higher the likelihood of experiencing enough arc energy to either damage system hardware, or to create other hazards such as creating a shock hazard from a downed live power line or creating ignition risk for nearby vegetation on a high-fire-threat day.

Most prominently this document describes the implementation of approaches and technologies that reduce the arc energy associated with certain fault types. While not all approaches are applicable to every power system configuration, or to every fault type, this document provides a starting point for understanding which approaches can be considered and for understanding where additional demonstration and research may still be needed.

In all ten approaches were considered and summarized. The primary categories included:

- *Curve Shaping*
- *Reduced Coordination Margin*
- *Modified Fusing Philosophy*
- *Pilot Wire Relaying*
- *Ground Relaying*
- *Negative Sequence Relaying*
- *Modified Recloser Schemes*
- *Adaptive Protection Schemes*
- *Advanced Reclosers*
- *Communications Enabled Protection Settings*

While there is no single solution here that works in every scenario, the good news is the diversity of options and approaches provides flexibility as demonstrations and testing move forward. For consistency each protection category is described along with the remaining research needs and estimates of the potential impacts.

Figure 1 – Some modern protection devices have advanced features to reduce damage to distribution assets, minimize energy into a fault during reclose attempts, and save fuses to reduce the work of field crews.

Introduction

Several protection options could reduce damage by reducing the duration of arcing events, particularly during extreme weather. Faster protection can affect scenarios such as:

- *Arcing that burns down a conductor:* Conductor damage is a function of wire size, level of fault current, duration of the fault current, and whether the conductor is covered or bare. Burndowns can lead to downed, energized conductors, which is a safety hazard for the public.
- *Arcing in the air:* Sparks generated from the arc can trigger ground fires.
- *Arcing inside equipment that causes a violent failure:* This is a function of fault current, fault duration, and arc length.
- *Failure of a connector that causes a downed wire:* This is a function of fault current, fault duration, and connector condition.
- *Arc-initiated ignition of flammable materials:* Arcs can ignite some materials like animal guards. This can damage additional equipment and trigger wildfires.

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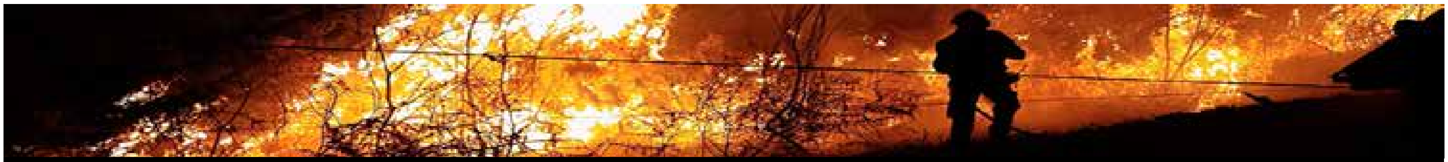


The arc energy can be reduced in two ways: reducing the arc time and reducing the magnitude of the short-circuit current. The arc time can be reduced by accelerating fault detection and isolation, while the magnitude of the short-circuit current can be reduced by increasing the impedance in the circuit. For single- and two-phase faults, the current magnitude can be reduced by introducing an impedance into the system grounding on either a transient or permanent basis.

The following sections outline specific approaches to reducing impacts by improving distribution system protection.

Traditional Approaches

Curve Shaping

Normally, when utilities add reclosers, they slow down curves on upstream reclosers to ensure that all devices in the circuit's fault path are coordinated. This ultimately leads to slower clearance times for faults near the head of the feeder, which in turn leads to greater arc energy for those faults closest to the substation. It is common that overcurrent curves are coordinated across most (if not all) of their current range. It is possible to shape curves more effectively to avoid this problem and clear most faults faster instead of generically slowing down a curve to coordinate with the downstream protective devices [1]. This is achieved by only slowing down the parts of the curve where there is coordination overlap. For those areas of the curve where no coordination is necessary, the trip time should actually be accelerated.

The effectiveness of such a solution will depend on the curves used and the available short-circuit current. For fastest clearing and maximum arc-energy reduction (for wildfires, for example), it may be impossible to retain coordination.

Potential impact. The main impact of this approach is faster clearing times.

Research questions. This approach is well understood, and protection engineers can design systems using existing technologies. The main questions on the use of this approach are:

- What is the right balance between coordination and speed?
- How much improvement in clearing speed is realistic?
- How much does coordination overlap affect customer reliability?
- How should coordination range allow for variation in fault level due to, for instance, inverter-interfaced energy sources displacing conventional synchronous generators?

Research needs. The main needs for research and development on this strategy include:

- *Case studies:* Examples of coordination applied to real circuits could help quantify impacts on fault durations, miscoordinations, and impacts on reliability.
- *Pilots:* Utility implementations may help identify best practices under real-world conditions.

Reduced Coordination Margin

Protection devices use a coordination margin to allow the device closest to the fault to trip first. Coordination thus ensures selectivity between devices. The coordination margins used by utilities tend to be established based on years of experience, but is primarily dictated by protection operation time, recloser operating time, and arc extinguishing time [2].

The coordination margin differs between different utilities and the selected protection technology (for example, electromechanical versus microprocessor relays, fuses, and vacuum circuit breakers versus solid-state circuit breakers), but a typical example would be 18 cycles. On feeders with multiple reclosers, these coordination times can accumulate, resulting in fastest fault clearance times for faults beyond the last recloser and slowest fault clearance times for faults near the head of the feeder, where the fault current level is greatest and contains the greatest arc energy.

Where fast-acting protection devices are used, a tighter coordination margin could be used. A 10- to 12-cycle coordination margin could be achieved with modern protective equipment. Multiple reclosers in series could significantly reduce fault clearance times. The greatest acceleration in fault clearance time is for faults near the feeder head.

Potential reduction in fault clearance time. Fault clearance time can be reduced up to 6 to 14 cycles per pair of reclosers, depending on the existing coordination time margin and the protection technologies.

Research questions. The main questions on the use of this approach are:

- What is the tightest margin that can still coordinate?
- What methodology could utilities use to determine an appropriate coordination margin for their protection devices?
- Does the tightest margin depend on the devices? Is it practical to account for devices separately?

Research needs. The main needs for research and development on this strategy include:

- *Review of data:* A review of event records from protection relays or digital fault recorders can provide sufficient information to determine typical and maximum operating times for different classes of protection devices on a grid and hence to what degree the coordination time can be reduced.
- *Pilots:* Utility implementations may help identify best practices under real-world conditions.
- *Hardware:* Along with the standard device testing, a portable fault generator could be constructed that enables sectional fault application, in order to test the coordination approach and calibration.

Fusing Philosophy

An evaluation of fusing philosophy and load characteristics could be performed to identify whether existing fuse sizes and types could be changed to reduce fault clearance times. If smaller fuses or ones with shorter operating characteristics were acceptable, then they would not only reduce fault duration and energy for faults on laterals but also allow faster tripping of upstream reclosers [3].

Current-limiting fuses are those that open and clear fault current in less than half a cycle. A common application of such fuses is for limiting the fault current to industrial control panels. Applying such fuses to the distribution grid could, potentially, limit fault energy and duration and reduce the risk of burndowns, equipment failures, and fire ignition.

Negative-Sequence Relaying

Feeder protection of solidly grounded distribution systems commonly consists of phase overcurrent and ground overcurrent relaying. The minimum pickup of phase overcurrent protection must exceed the maximum feeder loading and must coordinate with the feeder's cold-load pickup and transformer inrush characteristics. Under normal load conditions there is minimal current unbalance across the three phase conductors, and hence negative-sequence current should be limited. As such, negative-sequence overcurrent elements can be adopted to provide increased sensitivity and reduced fault clearance time for phase-to-phase faults much in the same way as ground overcurrent elements do for ground faults [4].

Ground Relaying

The sensitivity of ground relays to ground faults is limited by the load imbalance. With better feeder-level and device-level data, it may be possible to better tune ground relays to clear ground relays faster. This could also be accompanied by phase balancing and control of loading on single-phase taps. This could be enhanced with AMI data assuming that AMI information is readily accessible.

Communication-Enhanced Options

More Devices with SCADA Communications

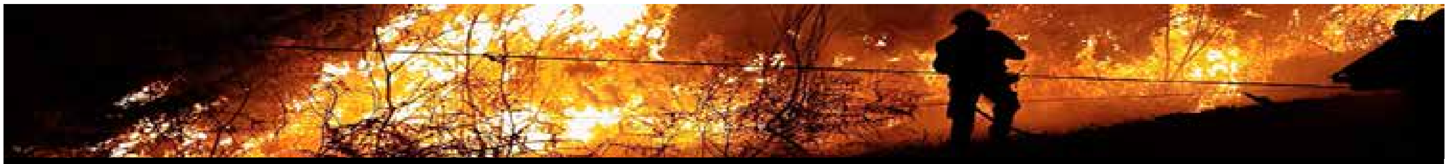
The use of more reclosers with communications (including tap devices like the TripSaver®) can reduce total fault durations. These devices may improve performance by:

- Enabling mode and settings changes (such as block or unblock reclosing).
- Acting as a fault indicator.

Communication-Assisted Blocking Schemes: Pilot-Wire Relaying

In pilot-wire relaying, the circuit breaker and reclosers are configured to trip with a fast-tripping curve, a definite-time curve, or an instantaneous curve [5]. If a device detects fault current, it will send a blocking command to the next upstream device. In this way, only the device closest to the fault location will trip. The fault-detection criteria need to be more sensitive and faster than the criteria for the tripping curve, for example, an un-delayed overcurrent element.

If sources for fault current could exist downstream of the recloser, then a directional fault-detection element may be required to prevent incorrect blocking commands from being issued. This situation would arise if closing a downstream, normally open switch could supply the feeder load from another source. However, this situation could also exist in some cases where distributed energy resources (DERs) exist downstream of the recloser. With downstream DERs, a directional fault-detection element is needed only if the magnitude of the fault current cannot be used alone to determine whether the fault is downstream or upstream of the recloser. Rotating DER such as hydro, diesel, or gas turbine generators could meet this requirement due to their large contribution of fault current, but in some cases, with low fault levels and high penetrations of inverter-interfaced DER, the need may also exist. Short-circuit analysis of the feeder can be used to determine this.



These schemes do not have a high bandwidth requirement, but latency is the key parameter. The fault clearance time will depend on how long the relay should wait for a blocking command before tripping. This wait time is determined by the slowest fault-detection time for the downstream device plus the overall latency of communication links from the downstream device through to the upstream device.

If the communications fail to operate, then the fault clearance time will not be affected, but a larger number of customers will be experienced a power outage during the reclose dead-time. As such, the latency and reliability of the communication system are key design parameters, which will, in general, result in this being a higher-cost option. Further research could examine options for lowering the cost of such schemes.

Potential improvement in fault clearance time. The fault clearance time is primarily determined by the latency of a communication link. With fiberoptic communications, fault clearance times of a few cycles could be achieved. Other communication media such as microwave or cellular networks could be considered, but they may not provide the reliability or latency requirements necessary to make a pilot-wire system an effective solution.

Research questions. Pilot-wire systems have a long history on transmission circuits, but their use on distribution systems is new. Some unknowns on the use of this approach are:

- What is the real-world latency for different communication technologies?
- What is the real-world reliability for different communication technologies?
- Are wireless technologies affected by environmental conditions like heavy rain or icing?
- How is the communication infrastructure impacted during an extreme weather event?
- How will this system work with advanced FLISR schemes?
- How long of a delay is needed for different technologies? Can this be adaptable?
- How does fast tripping coordinate with tap fuses?
- What is the most economic technology combination?
- How complex is the relay/recloser-control programming?
- How should protection functions change in the event of a loss of a communication channel?

Research needs. The main needs for research and development on this strategy include:

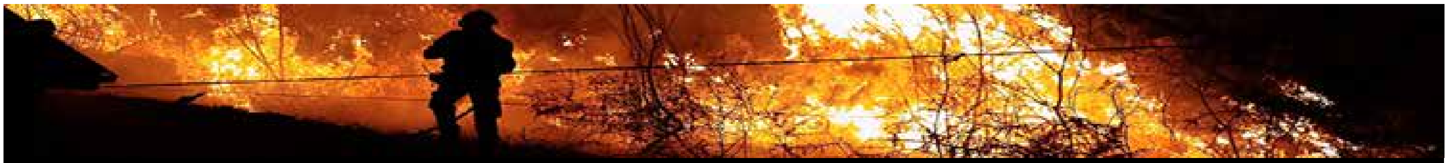
- *Case studies:* Examples of coordination applied to real circuits could help quantify impacts on fault durations, miscoordinations, and reliability.
- *Pilots:* Utility implementations may help identify best practices under real-world conditions.
- *Laboratory tests:* Particular communications technologies can be tested in a lab.

Communication-Assisted Permissive-Reclose Schemes

Where communications to reclosers are available but are not fast enough to provide a real-time, pilot-wire type of protection, then reclosers may still be leveraged for "permissive reclose" schemes [6]. With this approach, the circuit breaker relay and all reclosers on a circuit will trip on a definite time (instantaneous) curve or fast-tripping curve. When a fault occurs, one or more devices upstream of the fault will quickly trip and isolate the fault. Communications between the relays are then used to automatically determine fault location and therefore which devices should reclose. If a device trips, it sends a "permit reclose" command to upstream devices, which can then reclose after an appropriate time delay. Reclosers downstream of the fault location will not send this "permit reclose" command; therefore, the first device upstream of the fault will not reclose, as shown in Figure 2 (next page).

As reclose-times of several seconds of a permissive-reclose scheme are typical, and a command is a simple binary permit-reclose command, the bandwidth and latency requirements are not challenging. Centralized or point-to-point communications can be used. Furthermore, failure of the permissive-reclose scheme would not impact arc energy and risk of equipment damage, albeit at the expense of an increased customer outage duration.

Although such a scheme would significantly reduce fault clearance time on circuits with multiple reclosers in series, it does so at the cost of increased system complexity and design time. Where reclosers are already equipped with SCADA remote control and slow recloser times, the hardware costs may be relatively low.



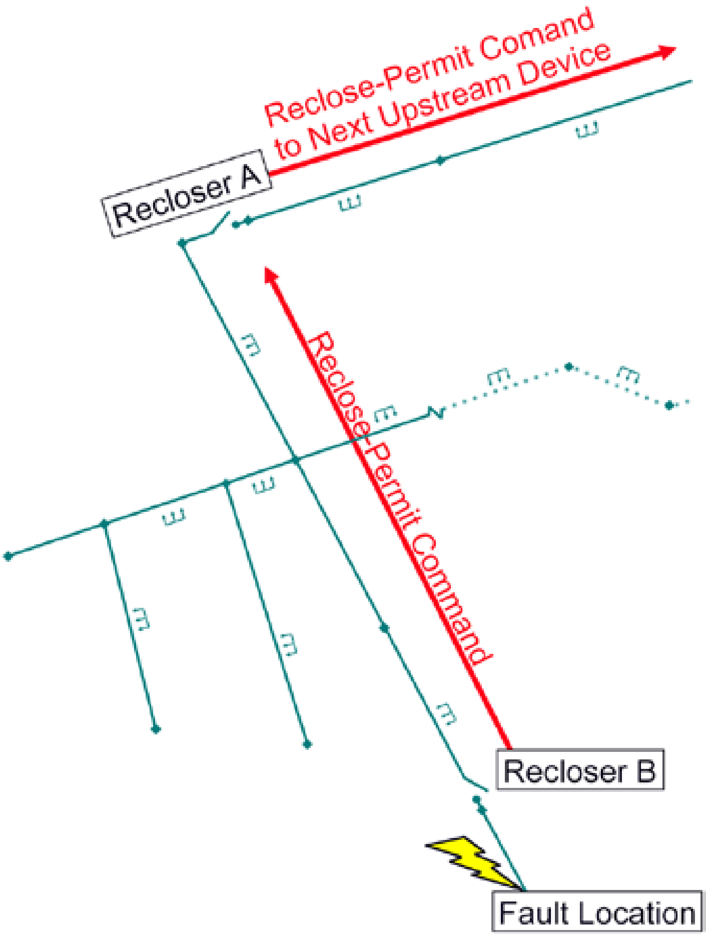


Figure 2 – A recloser-permit scheme coordinates downstream and upstream devices when a recloser trips.

Research questions. These systems can fit in well with the automated distribution systems that many utilities already have. Some unknowns on the use of this approach are:

- What is the reliability of communications?
- How difficult are designs?
- What is the real-world benefit of faster upstream tripping?

Research needs. The main needs for research and development on this strategy include:

- *Case studies:* For utilities that have used many permissive-recloser schemes, data on live, downed conductors may provide insight on application criteria.
- *Pilots:* More field implementations will provide lessons learned on reliability, complexity, and best practices for designs.

Equipment Options

Use of Advanced Reclosers

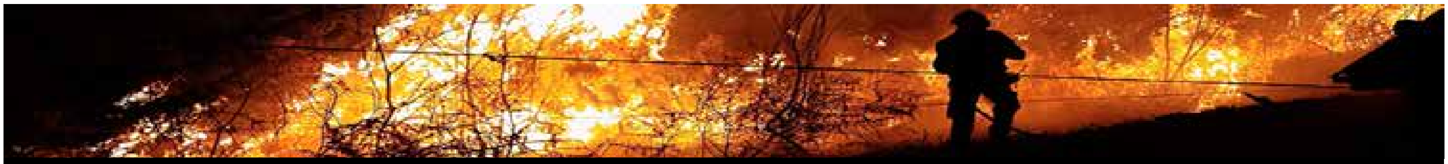
In recent years, vendors have brought advanced protective devices to the market that could be applied to the grid. An example is the S&C IntelliRupter recloser [7], which has a feature called PulseClosing, which minimizes energy into a fault during reclose attempts by using a short-duration pulse to test the system. This approach is beneficial because reclosing can be enabled without appreciably increasing fault-arc energy and risk of equipment damage.

Fast Trip after a First "Fuse-Save" Shot

Some of the benefits of PulseClosing can be achieved by using a fast shot after the first normal trip curve and treating the subsequent fast shots like the IntelliRupter pulse. In terms of fault duration (and energy) to the fault location, this will be greater than the IntelliRupter, but in at least some cases, it will still have a significant reduction in fault duration. Consider an example where the first fuse-blowing shot is 30 cycles. With a traditional scheme with two reclose attempts, the total fault duration is 90 cycles. With the IntelliRupter, the total event is 30 cycles because the two reclose attempts are replaced with pulses. With this fast tripping scheme, the total fault duration could be 36 to 40 cycles, depending on the device speed (one 30-cycle fault followed by two events lasting 3 to 5 cycles).

Replacing Fuses with Reclosers

In addition to conventional reclosers, some vendors have begun offering products that are direct slot-in replacements for fuses. Such devices could offer increased sensitivity. Examples include the "TripSaver" by S&C [8] and "FuseSaver" by Siemens [9]. In some cases, these devices have limited current-breaking capability, so for very high-current faults, they can be configured to not operate. Typical short-circuit current ratings are 6.3 kA. Because these devices are programmable, they provide flexibility in operation. For example, on laterals passing through sensitive areas, reclosing can be blocked, or the device could be configured with a fast tripping curve, which would limit the energy of a fault arc. In addition to decreasing the fault clearance time, their performance may also justify the use of smaller time coordination margins with upstream reclosers and thus allow faster tripping of upstream devices for faults on the feeder. Using reclosers as a replacement for expulsion fuses also removes a source of possible wildfire ignitions.



Some utilities have had more instances of live, downed conductors after replacing fuses with reclosers. Smaller conductors found on taps are more susceptible to mechanical breakage and damage from fault arcs. More live, downed conductors can result from:

- *Reclosing:* A fuse cannot reclose. If a fault results in a conductor breaking and landing on the ground, the fuse operation has left the conductor deenergized. A recloser can reclose and hold in this scenario, leaving a high-impedance fault.
- *Slower tripping:* For some fault currents, a recloser is slower than a fuse. This can increase the probability of arcing damage and burndowns.

To minimize burndowns, reclosers should only be applied where the conductor is large enough to withstand arcing for the given fault current and duration, accounting for the number of reclose attempts.

Potential impact. This approach has several benefits, including increased fault sensitivity, faster fault clearance, and adaptable protection configuration.

Research questions. Pilot-wire systems have a long history on transmission circuits, but their use on distribution systems is new. Some unknowns on the use of this approach are:

- How can the devices be applied to make sure that live, downed conductors do not increase?
- What are the best application criteria based on load, location, fault current, and conductor sizes?
- How flexible and adaptable are these devices, and how can utilities maximize benefits from them?

Research needs. The main needs for research and development on this strategy include:

- *Case studies and field pilots:* For utilities that have used these devices, document performance of the devices.
- *Laboratory tests:* Tests of coordination with burndowns could be performed to identify application criteria to minimize burndowns.

Proprietary Solutions

While most protection relays on the market provide similar fundamental protection algorithms, such as phase and ground overcurrent, some vendors also offer their own proprietary solutions. These include solutions such as traveling wave, arc-sense, delta-quantities, high-impedance fault detection, waveform recognition, and others.

Reclose Options

Blocking Reclose

Blocking reclosing during extreme-weather periods is another approach to reduce the number of times that the fault is energized and hence reduce total arcing time and energy. This has been recently done by utilities during periods of extreme fire risk. The impact of blocking reclosing can be reduced by:

- Using fault indicators.
- Using SCADA reclosers as sectionalizers.

SCADA reclosers used as sectionalizers could be coordinated with upstream reclosing devices to quickly restore service to customers upstream of the faulted circuit section.

Other Reclose and Reset Options

The PulseCloser approach (or the fast trip after a fuse-save shot) is not perfect. In some events, the fault arc will clear, so the reclose does not immediately trigger a fault. This happens on some tree-branch faults (verified during EPRI testing on tree branches). The fault can trigger after a delay of several seconds as the branch reignites. This could be avoided by blocking reclosing completely. One option is to review the reset and tripping options to make sure the recloser or circuit breaker trips on a fast curve if another fault is detected within a prescribed interval. Another option is to use adaptive technology to decide whether to reclose based on the fault type. Hydro Quebec has demonstrated that it is possible to use the arc voltage in a fault to detect the type of fault. A tree fault has a reasonably high arc voltage [15]. If the arc voltage in the first fault is appreciable, do not reclose.

Adaptive Protection Schemes

With the approaches discussed above, there may not be one set of configuration options that are optimal for all scenarios. Adaptive protection schemes could be employed using multiple setting groups or the blocking/release of individual protection functions within a recloser [10]. These could be altered remotely if communications are available or else based on date, time, weather conditions, power flow, or other available data point or measurement. Several such schemes have been successfully deployed across North America

and Worldwide. Examples include an adaptive protection scheme deployed by New Jersey Power & Light [16], which de-activates fuse-saving mode on substation circuit breakers when lightning or high wind speed is detected by a weather station located at the substation.

Grounding Approaches

Reactance-Grounded Systems

Table 1 compares the different kinds of reactance-grounded systems. By introducing an impedance into the grounding circuit, the short-circuit current magnitude for ground faults can be reduced. In industrial systems and some distribution grids, grounding resistors are connected between the supply transformer neutral and ground. In industrial site installations, high-resistance grounding is frequently used to protect against the impact of low voltage and limit fault current.

Resonant grounding is used interchangeably with terms such as arc suppression coil (ASC), Petersen coil, or compensated grounding. The approach was originally applied in Sweden but has become widely used on distribution grids around the world. It became particularly popular in Europe due to its continuity-of-supply and power quality benefits as well as in parts of Australia, where it has been widely deployed to reduce the risk of wildfire ignition.

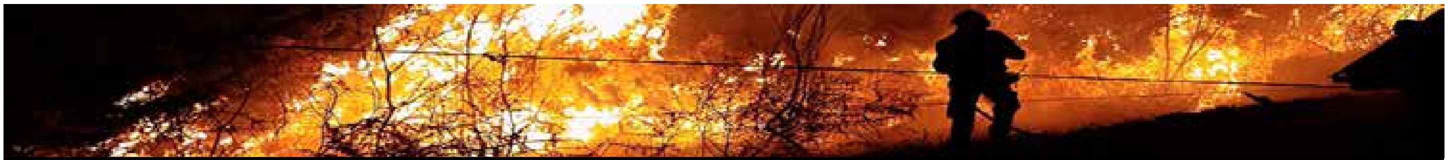
Resonant grounding is implemented on radial systems by inserting a high-impedance reactor between the supply transformer neutral and ground [11]. The neutrals of all other transformer and capacitor banks on the feeders are isolated from ground. The reactor is sized (tuned) to resonate with the zero-sequence capacitance of the local system. This tuning significantly impacts the system impedance during ground faults such that fault current is commonly of the order of a few amps. The consequence is that the ground fault current is not large enough to sustain an arc or even to cause any significant voltage dip on the faulted phase. The net result is that for most transient single-line-to-ground faults on the distribution grid, the arc self-extinguishes without needing protection tripping or fuses opening. Customers are usually not aware that a fault has occurred in the vast majority of cases because their power supply is not interrupted, and they do not experience any voltage dip.

Transitioning a grid over to resonant grounding can be challenging, but it has been shown to provide significant benefits. Between 2001 and 2002, ENEL , the distribution grid operator in Italy, migrated their networks from isolated neutral to resonant grounded 17]. This resulted in an 87% reduction in the number of single-phase transient faults experienced by customers. The transition resulted in transient faults reducing from 2380 in 2001 to just 301 in 2002.

Prior to commissioning, the reactor is tuned to compensate for the total shunt capacitance of the downstream feeders. If the downstream shunt capacitance changes over time due to additional feeders or laterals, the reactor may need to be re-tuned. Modern coils have adjustable taps, making the change process easier. Some include controllers and can auto-tune, but the tuning may still be imperfect. In such cases, there may still be several amps to, in worst case, tens of amps of ground fault current. Equipment for resonant grounding will generally be more expensive than for the other methods of grounding systems. The lack of fault current can also mean it is more difficult to find an exact fault location compared to other neutral grounding methods, but new technologies have been developed to improve fault location.

Table 1 – Characteristics of Different Reactance-Grounded Systems

<table>
<tr><th>Grounding System</th><th>Ground Fault Current Range as a Percentage of Three-phase Fault</th><th>Transient Over-voltage Risk</th><th>Insulation Requirements</th></tr>
<tr><td>Solidly Grounded</td><td>~100%</td><td rowspan="5">Unlikely</td><td>Full insulation at windings and lower insulation at neutral.</td></tr>
<tr><td>Low Reactance</td><td>25-100%</td><td rowspan="4">Partially graded (insulation level can reduce from full insulation at windings to reduced insulation level at neutral).</td></tr>
<tr><td>High Reactance</td><td>5-25%</td></tr>
<tr><td>Low Resistance</td><td><20%</td></tr>
<tr><td>High Resistance</td><td><1% but not less than charging current</td></tr>
<tr><td>Resonant Grounded</td><td>Almost 0%</td><td>Very likely</td><td>Full insulation throughout the system.</td></tr>
</table>



Rapid Earth Fault Current Limiter Technology®

As new feeders are added to distribution grids or taken out of service, the arc-suppression coil may no longer be tuned to match the zero-sequence capacitance of the downstream grid. In such cases, the level of ground fault current would increase.

Specifically for delta distribution systems without grounded neutrals and line-to-ground fault scenarios, Rapid Earth Fault Current Limiter Technology (REFCL) has been applied to provide a dynamically variable neutral impedance, which will respond to single-line-to-ground faults to choke off any remaining ground fault current. With this technology, a power electronic switch is connected across a neutral grounding reactor on the supply transformer. When a downstream ground fault occurs, the system detects the ground fault current and injects a current of equal magnitude but opposite polarity. Field deployments have shown that this impedance tuning effect completes within approximately 5 cycles of fault initiation and can reduce ground fault current from the order of amps to tens of amps at the time of fault initiation to below 0.5 A once tuning completes.

Because the fault current is very low, fault location can be difficult to calculate, but the fault arc should self-extinguish. Therefore, in the majority of cases, circuit breakers are not required to trip unless the fault persists for an extended period (such as more than 30 seconds).

REFCL technologies have been trialed and rolled out by AusNet [12] and Powercor's [13] 22-kV grids since 2017. They have estimated that the technology has reduced fires due to powerline faults by 50%.

While the distribution grid code in Australia requires insulation design of 1.8 pu for 10 seconds, the introduction of the REFCL could result in the phase-to-ground voltage on unfaulted phases rising to 1.9 pu for greater than 10 seconds. To mitigate these impacts, two approaches were taken: 1) hardening customer equipment against higher voltage or 2) installing isolating transformers between the grid and customer transformer. Utilities in Victoria, Australia replaced 40 to 50% of surge arrestors and a small selection of cables on those feeders equipped with REFCL [14]. Coordination with industrial customers was also necessary to ensure that systems and assets were protected .

Experience from Australia illustrates that when multiple REFCL are used in an area, they can render protection from overcurrents during ground faults difficult to coordinate, potentially resulting in misoperation. Therefore, the technology may require fine tuning over a period of time. According the vendor, the technology continues to improve with more and more field experience.

Potential impact: This approach can dramatically reduce arc currents from a phase contact to ground.

Research questions. Some unknowns on the use of this approach are:

- What effort would it take to convert a three-wire system to be compatible with this design?
- What effort would it take to convert a four-wire system to be compatible with this design?
- What are the best application criteria?
- How common is the 1.9 pu overvoltage? What factors does this depend on?
- What are the operational and maintenance issues with this approach?

Research needs. The main needs for research and development on this strategy include:

- Field pilots: Real installations will provide lessons on many issues.
- Laboratory tests: Tests could help gain confidence prior to field installations.

Industry Needs

All of the options outlined here are options for implementation, exploration, and research. Most are based on existing technologies, but many of the approaches have not been used widely on distribution systems. Additional pilots, field tests, and laboratory tests would allow utilities to more optimally apply the approaches and gain more confidence in achieving reliability and benefits of damage reduction. EPRI intends to work with member utilities interested in piloting some of the presented approaches as part of the Improving Grid Resilience and Safety project 3002014953 where the objective is to document the performance results over time. Most of the technologies and approaches described will require a dedicated pilot at either a substation or on one or more feeders to truly understand how physical distance, available communications and system configuration impact the desired reduction in arc energy.

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Program 180, Distribution Systems

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