IntelliRupter® PulseCloser® Fault Interrupter Ground Fault Response Applications

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GROUND FAULTS ON THREE-WIRE, THREE-PHASE NETWORKS OVERVIEW

With three-wire, three-phase distribution systems not having a neutral connection, they don't have a route for zero-sequence ground current to flow. Resistive grounding, suppression coils, and a substation Rapid Earth Fault Current Limiter (REFCL) with suppression coils are three common connections made within the substation transformer windings to help with this. These designs are used to limit the current that flows when a ground fault occurs on a feeder.

Utility system designs that apply the variety of impedances in the ground connection are typically trying to keep the ground fault current at single-digit ampere levels, or even to create a circuit condition that eliminates the ground fault current entirely. This creates a situation with minimal zero-sequence overcurrent with the intent of improving safety and/or minimizing the risk of fault arcs creating sparks.

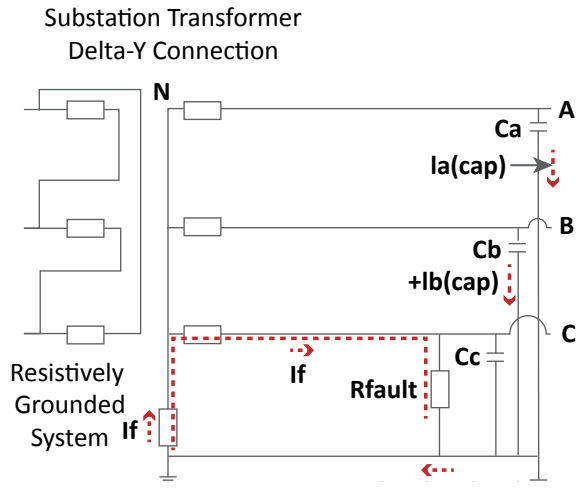
Limiting the ground fault on the feeder makes it more difficult for protection devices to react properly. In analyzing the potential total fault current in a three-wire, three-phase system, line capacitance should also be considered when looking at ground-current protection. While current from unfaulted phase

capacitance is usually neglected in solidly grounded systems, it must be considered in systems that limit ground current substantially.

Typically, there are three ground-fault current suppression systems used worldwide, and they are briefly summarized here:

- **Resistive Grounding:** Resistive grounding uses a resistor connected in the substation transformer wye winding ground connection to limit the ground fault current at any point on the system served by the transformer winding. A low resistively grounded system (LRG) might be designed to limit the current to several hundred amperes in a typical industrial power system, or a high resistively grounded system (HRG) limits the current to typically 10 amperes or less. See Figure 1.

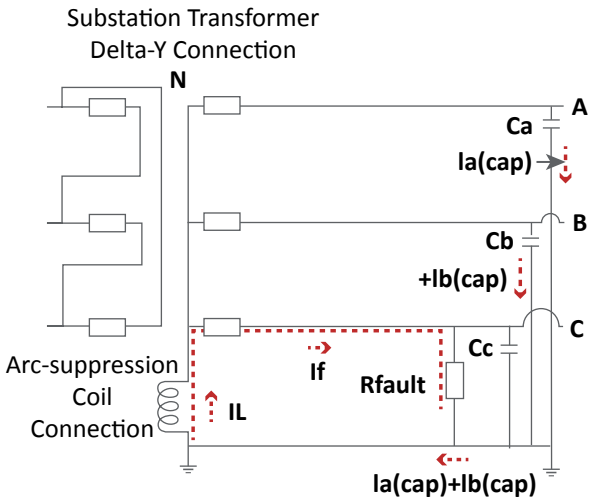
FIGURE 1. An LRG is connected to the substation transformer to limit ground-fault current on a feeder. The red dashed lines detail the fault-current flow, showing several hundred amperes flowing from the substation grounding and typically less than 10 amperes flowing from line capacitance in phases A and B into phase C.



- **Suppression Coil:** An arc-suppression coil (Peterson coil) is installed in the substation transformer wye winding ground connection to compensate for fault current on the network that results from the capacitance distributed along the distribution system served by that transformer. The arc-suppression systems are typically designed to limit the ground fault current to approximately 35 amperes or less. If the reactance of the coil exactly matches the total capacitance of the system, then the component of the ground-fault current that flows because of the arc-suppression coil will be equal and opposite to the current flowing through the system capacitance, therefore resulting in suppression of the ground fault current. See Figure 2.

FIGURE 2. An arc-suppression coil is connected to the substation transformer and tuned to match the capacitance of the circuit, thus limiting current flowing from ground. The red dashed lines detail the fault-current flow, showing less than 35 amperes flowing from the substation grounding and typically less than 10 amperes flowing from line capacitance in phases A and B into phase C.

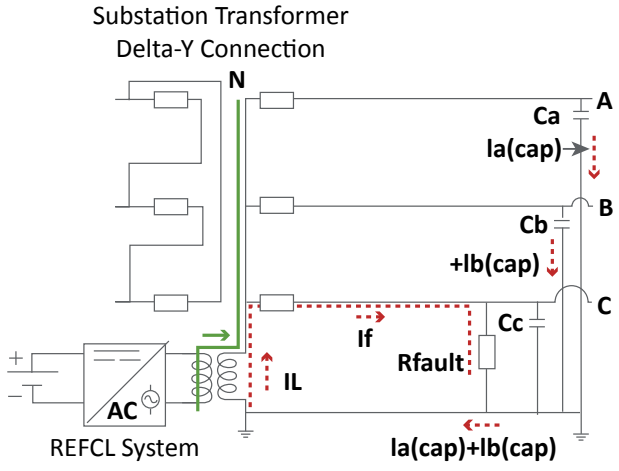
For balanced conditions: Ia(cap) + Ib(cap) = IL.



- **Substation REFCL:** In addition to an arc-suppression coil, an REFCL system can be added to the substation wye winding ground connection. REFCL systems use a power electronics package coupled with an arc-suppression coil. The sensors and controls detect a shift in the neutral point when a ground fault is present on the system served by the transformer. The controls use the inverter system to create a zero-sequence voltage injection through the Peterson Coil, which reduces the faulted phase voltage at the substation to 250 V or less. The intent is to reduce the fault voltage to a point an arc is difficult to sustain at the fault point. See Figure 3.

FIGURE 3. An REFCL system and arc-suppression coil is connected to the substation transformer so the REFCL system can automatically limit ground current to only several amperes. The red dashed line slows the fault current flowing from the substation grounding, and typically less than 1 ampere is flowing from line capacitance in phases A and B into phase C. The green line shows the current being injected through the Peterson Coil into the neutral.

For balanced conditions: Ia(cap) + Ib(cap) = IL. REFCL system injects current (IREFCL) into neutral.



IntelliRupter® Fault Interrupter and Ground Faults on Three-Wire, Three-Phase Networks

The IntelliRupter fault interrupter has protective device elements electric utility distribution engineering personnel can set to detect different fault events. The IntelliRupter fault interrupter's use of PulseClosing® Technology is designed with high-accuracy voltage and current sensors in each phase to increase the security and selectivity of the protection elements. Specifically for ground faults, the IntelliRupter fault interrupter has a Sensitive Earth Fault (SEF) function, a Voltage-Supervised Sensitive Earth Fault (VS-SEF) function, a Watt-Metric function, and zero-sequence transient power detection for systems using a REFCL device.

IntelliRupter fault interrupter ground-fault application:

The IntelliRupter fault interrupter can be applied along the feeder or in the substation to sense and clear ground faults on three-wire systems using resistance ground connections in the substation. The IntelliRupter fault interrupter offers the following characteristics that provide superior performance in these applications:

1. High-accuracy voltage and current sensors in each of the phase units calibrated in the factory
2. Directional zero-sequence elements that can be applied to properly sense faulted feeder conditions in medium-voltage distribution systems that use resistance-grounded substation designs (Sensitive Earth Fault (SEF) elements can be used in these applications. A voltage-supervised sensitive earth fault (VS-SEF) protection element is also available with higher

sensitivity. In resistively grounded systems, the fault resistance impacts the voltage shift as well as the magnitude of the fault current that flows at the point of fault. The resistance in the substation will result in a real power flow toward the substation on the faulted feeder, which also makes the watt-metric element an alternative sensing technique on these systems.)

3. Fast Watt-Metric directional zero sequence elements that can be applied to properly sense faulted feeder conditions in medium-voltage distribution systems that use arc-suppression coils
4. A direction transient active power element used to detect ground faults on medium-voltage distribution systems used with an REFCL system

IntelliRupter Fault Interrupter Application for Ground Fault Detection

When setting ground-fault protection elements in series distribution line devices, S&C recommends coordinating feeder devices for the selective device response. However, using the PulseFinding™ Fault Location Technique with time-current characteristic (TCC) shifting is also an option available when using PulseClosing Technology with IntelliRupter fault interrupters. See Table 1.

Applications of devices in ***resistive grounded networks***, directional SEF, VS-SEF, or Watt-Metric elements can be used in the IntelliRupter fault interrupter. The selection of the protection element for ground-fault detection depends on feeder conditions, local regulations in some areas, and the protection philosophy used by the protection engineers.

Application of protection devices in systems using ***arc-suppression coils and arc-suppression coils with REFCL*** can, respectively, use the Watt-Metric and the Directional Transient Active Power elements in the IntelliRupter fault interrupter. The protection element in the IntelliRupter fault interrupter offers the protection engineer a device that can provide sectionalizing capability in these types of systems.

See S&C Instruction Sheet 766-530 for more details on how to configure the applicable elements.

TABLE 1. IntelliRupter Fault Interrupter Applications Guide Chart For Grounding Connections

IntelliRupter Fault Interrupter Application	*Resistive Grounding*	*Arc-suppression coil*	*Arc-suppression coil with REFCL*
SEF	Capable	Not Applicable	Not Applicable
VS-SEF	Recommended	Not Applicable	Not Applicable
Watt-Metric	Not Applicable	Capable	Not Applicable
Directional Transient Active Power	Not Applicable	Not Applicable	Capable

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