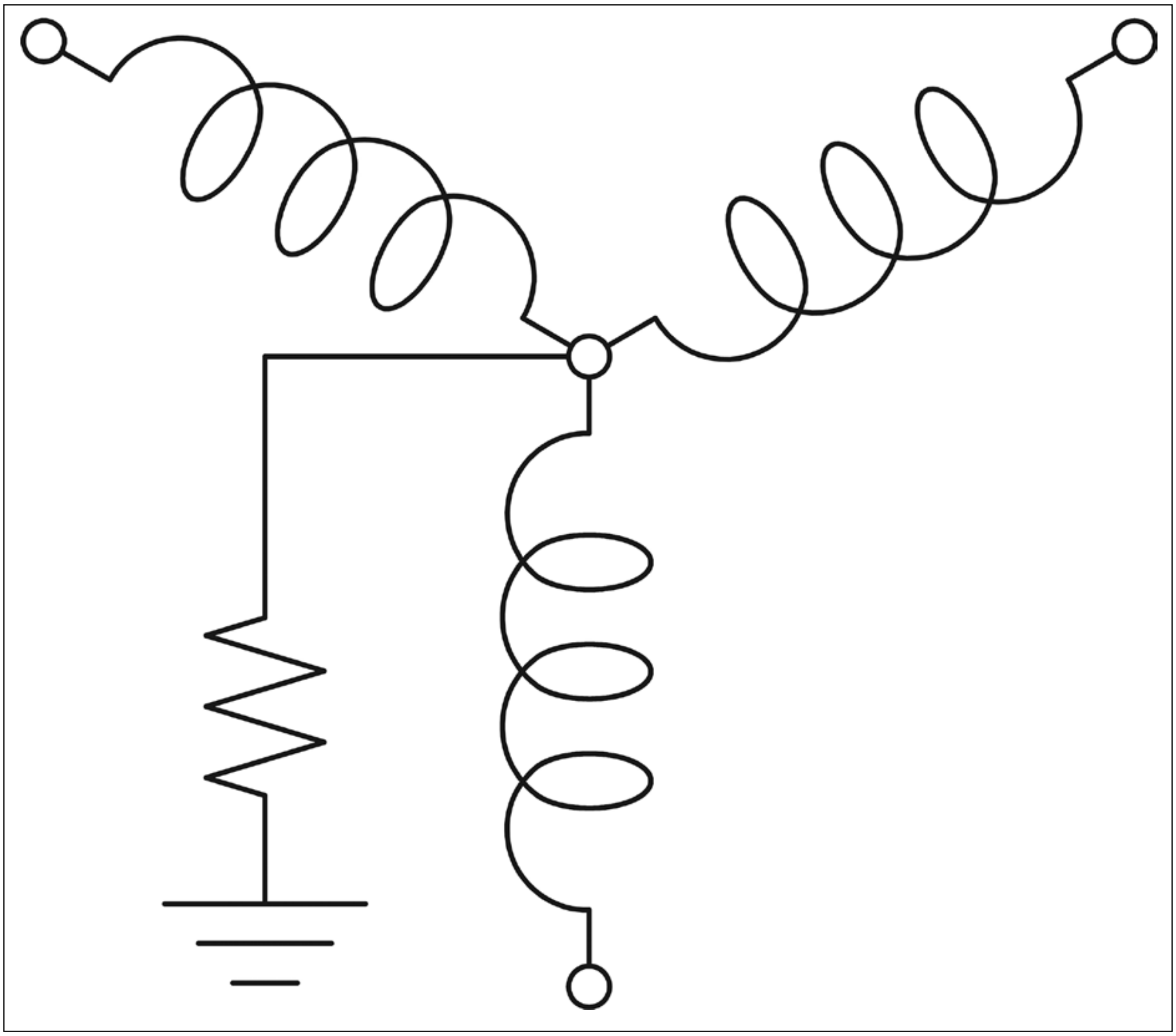

The Case for Advanced High Resistance Grounding

by Andrew Cochran

The decision on which grounding system to employ has a direct and quantifiable impact on electrical safety and reliability. As the table below indicates, high resistance grounding is the superior choice as it provides process continuity even under a single fault condition, it limits destructive transient over-voltages, it empowers the user to locate the fault, quickly and safely, and it reduces the arc flash hazard.

High resistance grounding provides all the continuity benefits of an ungrounded system without the drawbacks of transient over-voltages and inability to locate the ground fault.

IEEE 242-1986 *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*, Clause 7.2.5 compares the two technology options: "Ungrounded systems offer no advantage over high-resistance grounded systems in terms of continuity of service and have the disadvantages of transient over-voltages, locating the first fault and burn-downs from a second ground fault. For these reasons, they are being used less frequently

Productivity Impact		Ungrounded System	Solidly Grounded System	Low Resistance Grounded System	High Resistance Grounded System
		System Type			
Equipment Damage	Overvoltage's	Severe	None	Limited	Limited
	Over current – Damage at point of fault	Unknown	Severe	Minimal	None
	Maintenance Costs	High	Reasonable	Reasonable	Low
Downtime	Continuous Operation with Ground Fault	Possible; not recommended	Not Possible	Not Possible	Ideal
	Relay Coordination (Equipment Tripped, Ease of Fault Location)	Difficult	Difficult	Good	Excellent
Personnel	Safety to Personnel	Poor	Poor	Reasonable	Excellent

Diagram 1. Productivity impact

today than high-resistance grounded systems, and existing ungrounded systems are often converted to high-resistance grounded systems by resistance grounding the neutral."

High resistance grounding (HRG) like solidly grounded controls transient over-voltages but significantly reduces the likelihood of an arc flash, as fault current is limited to a low and safe level that inhibits an arc from re-striking.

In the IEEE 141-1993, *Recommended Practice for Electrical Power Distribution for Industrial Plants* section 7.2.4, it states that, "The solidly grounded system has the highest probability of escalating into a phase-to-phase or three-phase arcing fault, particularly for the 480 and 600 V systems. A safety hazard exists for solidly grounded systems from the severe flash, arc burning, and blast hazard from any phase-to-ground fault."

There is a significant difference between basic HRG technology, industry standard HRG and advanced HRG. The latter addresses many, if not all, of the concerns associated with HRG as a technology and the result is a safer and more reliable electrical distribution system.

Figure 1. Ungrounded system burn-down damage

Basic high resistance grounding is a simple resistor added to an ungrounded system that limits the fault current and controls the transient overvoltages. It is a simple and economical upgrade to any ungrounded system. However, the simplicity of the solution, limiting the fault through a basic resistor, also limits the solution — the inability to find the ground fault and to take corrective action. While this is the simplest and most economical option, it is rarely utilized.

The industry standard HRG adds pulsing capability to the basic option,

Figure 2. Arc flash on a solidly grounded system

and it is this feature that empowers the user to find the location of the ground fault and to take corrective action at a suitable time.

Despite the obvious benefits of high resistance grounding, its application has not yet become widespread due to operational concerns that can easily be addressed. Most common excuses for not choosing high resistance grounding are:

- The need to service line-to-neutral loads
- Concern over intermittent ground faults
- Loss of neutral path
- Leaving a ground fault on the system
- indefinitely
- Concern over a second ground fault before the first fault has been cleared

Line-to-Neutral Loads

It is prohibited to service line-to-neutral loads when using a high resistance grounding system; but in most industrial facilities, the line-to-neutral loads are 15% or less of the total system load. The installation of a simple isolation transformer would also enable the user to continue to service these loads, typically lighting, and yet still receive the reliability and safety benefits of an HRG system.

Given that the solidly grounded system has the highest probability of being subjected to an arc flash and given that the magnitude of the arc flash is directly proportional to the available fault current, employing a smaller transformer to supply only neutral loads reduces the arc flash potential and magnitude on the secondary side.

Intermittent Ground Faults

To find a ground fault, there must be an active ground fault present on the system. If the ground fault is intermittent or cyclical then it will be a challenge to find. This is the major drawback with visual indication products such as ground fault meters. If the found fault is active, the meter needle indicates its presence. If the maintenance personnel are not present at the time, then no one will know there is an intermittent fault on the system.

The solution is to upgrade to a relay that at a minimum has a latching indicator to advise of an intermittent fault and has some data logging function that can be analyzed to determine if the ground fault coincides with a particular piece of electrical equipment cycling in the system.

Loss of Neutral Path

Neutral grounding resistors limit the maximum fault current to a value that will not damage generating, distribution, or other associated equipment in the power system, yet will allow sufficient flow of fault current to operate protective relays to clear the fault. The neutral-to-ground path, which includes the resistor, wiring, and connections, must be in good condition for an HRG system to work properly. Good working condition is typically between 75 and 125% of desired resistance value.

When the desired resistance decreases below 75%, the system is trending toward a solidly grounded system and, as we know, a solidly grounded system has the highest incident level of arc flash issues. When the resistance surpasses 125%, the system is trending toward an ungrounded system and, as we know, ungrounded systems are susceptible to transient over-voltages and burn-downs.

The solution is to monitor the neutral-to-ground path. When there is a change in resistance for whatever reason, loose or improper connection, missing or compromised ground wire, foreign object, etc., the neutral-grounding resistor (NGR) monitor will detect the change and provide an alarm.

Although monitoring the resistor and providing an alarm for an abnormal condition is only half of the solution; it is not sufficient to have an alarm that a possibly dangerous trend is in process without the means

Figure 3.

to provide protection if the resistor fails either open or short. The full solution is a monitoring relay combined with a parallel resistor circuit that provides fail-safe protection. Should the integrity of either resistor path be compromised, the second path continues to provide ground fault protection while an alarm is raised.

Leaving a Ground Fault on the System Indefinitely

When there is a ground fault on a high resistance grounded system, the un-faulted phase is subject to full line-to-line voltage and there is a concern that this could lead to insulation degradation and a phase-to-phase fault. The first line of defence in this regard is insulation ratings and, typically, 600 V systems are protected by 1000-V rated cables and therefore there is no issue.

The second factor to consider is the time required to actually locate the ground fault. With pulsing technology, this is typically a matter of only a few hours. It is worth noting that the more advanced HRG systems available today also include phase and feeder indication. With this knowledge it not only takes significantly less time to find the fault, but given that the search starts at the feeder level, it is a safer option as the available fault current at the feeder level is much lower than at the main branch, resulting in the incident energy level to be lower and safer.

Another benefit with advanced HRG systems is feeder time-delay trip functionality. The user can select the timeframe — anywhere from 1 minute to 99 hours — that they are willing to accept the process operating with an active ground fault on the system before they want to isolate the faulted feeder. In this case, only the faulted feeder is isolated, not the entire system, and this functionality ensures that maintenance personnel must locate the fault within the timeframe mandated or the feeder will isolate.

Concern over a Second Ground Fault before the First Fault Is Cleared

With the basic or industry standard HRG technology, a second ground fault on a different phase from the first will result in a phase-to-phase fault and the overcurrent protection on the main circuit will trip; and the entire system will isolate.

With advanced HRG technology there is the option to pre-select up to 50 feeders with priority from the lowest to highest (16 different settings are available) so that in the event of a second ground fault the least important feeder will trip within 100 milliseconds (ms). This allows process continuity of the more important feeder. With this feature, the most important process in your facility will remain operational at all times.

High resistance grounding provides the highest level of reliability and safety when comparing system grounding options. Advanced HRG technology effectively addresses the concerns and excuses typically brought forth as justification for not specifying this option. With advanced HRG technology, the user receives all of the safety benefits, free from transients, reduction in arc-flash hazard, all of the reliability benefits in terms of process continuity and the added benefits of locating the fault faster and safer. The user also receives the isolation faults in a pre-determined timeframe, if they are not cleared and of continuing to operate their most important processes even under second ground-fault conditions.

This article has presented a clear comparison between ungrounded or solidly grounded and high resistance grounded and just as clear a comparison to advance high resistance grounding.

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