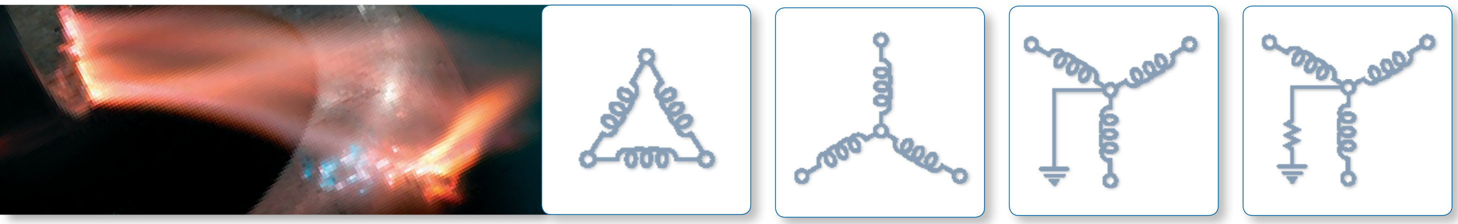
Unparalleled Protection

SYSTEM GROUNDING
DEFINITION & DIFFERENT TYPES

HRG

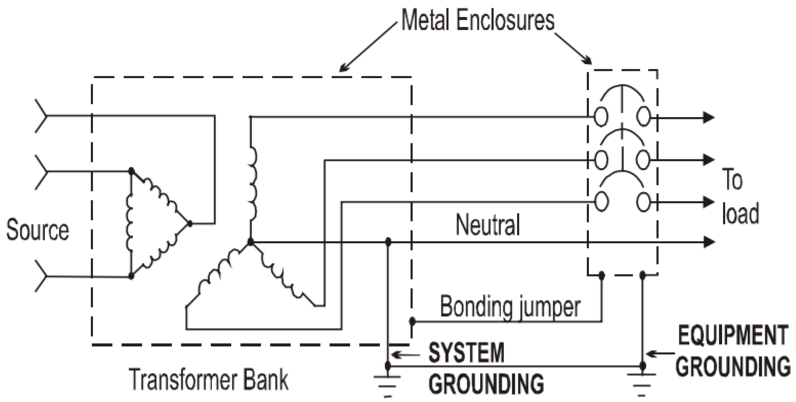


ASK THE EXPERTS, October 2018

WHAT IS GROUNDING?

The term grounding is commonly used in the electrical industry to mean both “equipment grounding” and “system grounding”. “Equipment grounding” means the connection of earth ground to noncurrent carrying conductive materials such as conduit, cable trays, junction boxes, enclosures and motor frames. “System grounding” means the connection of earth ground to the neutral points of current carrying conductors such as the neutral point of a circuit, a transformer, rotating machinery, or a system, either solidly or with a current limiting device.

Figure 1 illustrates the two types of grounding



WHY SYSTEM GROUNDING?

System grounding, or the intentional connection of a phase or neutral conductor to earth, is for the purpose of controlling the voltage to earth, or ground, within predictable limits. It also provides for a flow of current that will allow detection of an unwanted connection between system conductors and ground [a ground fault].

WHAT IS A GROUNDED SYSTEM?

A system in which at least one conductor or point (usually the middle wire or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through impedance. (IEEE Standard 142-1991 1.2) The types of system grounding normally used in industrial and commercial power systems are, solid grounding, low-resistance grounding, high-resistance grounding and ungrounded.

WHAT IS A GROUND FAULT?

System grounding, or the intentional connection of a phase or neutral conductor to earth, is for the purpose of controlling the voltage to earth, or ground, within predictable limits. It also provides for a flow of current that will allow detection of an unwanted connection between system conductors and ground [a ground fault].

OVER-CURRENT PROTECTION

Q. I have over-current protection, do I need additional ground fault protection?

A. The over-current protection will act to interrupt a circuit for currents for which it was designed and set to operate. However, some ground faults, particularly low level arcing faults, will produce significant damage and create a fire-ignition source without ever reaching the level necessary to activate the overcurrent protective device.

UNGROUNDED SYSTEM

Q. Is there any danger in running a 480 volt ungrounded system in an old manufacturing plant? Should we ground the system?

A. The main danger in running a 480V ungrounded system is that when a ground fault occurs the only indication you will have is the 3 lights. The voltage on the ungrounded phases will increase to 480V with respect to ground; the voltage on the grounded conductor will be 0V with respect to ground. With this system the only way to indicate the presence of a ground fault will be when 2 lights are of greater brilliance than the faulted phase light. In order to locate the ground fault you must cycle every feeder breaker until all three lights appear at equal brilliance again. Once this is done you continue down that feeder until you find the fault. This sounds very easy to do, but proves to be very difficult in the real world.

The plant is normally ungrounded because it is a continuous operational plant and isolation due to a ground fault should be avoided. This unfortunately translates to location of a ground fault. The only way to locate the ground fault is through cycling of the feeder breakers. This is also what you are trying to avoid. So at the end of the day, the ground fault remains on the system, because there is no easy way to locate it. This is dangerous because any maintenance being performed on the system in a grounded state is subject to full line to line potential with respect to ground. The good news is that there is a solution. Ungrounded facilities can be easily converted to high resistance grounded facilities and the detection and location of a ground fault can accomplished without power interruption.

In addition, several generator manufacturers require resistance grounding as the generators are not rated for ground faults as they are often times higher than three-phase faults. IEEE Std 142-1991 (Recommended Practice for Grounding of Industrial and Commercial Power Systems) states in section 1.8.1 'Discussion of Generator Characteristics' that "Unlike a transformer ... a generator will usually have higher initial ground-fault current than three-phase fault current if the generator has a solidly grounded neutral. According to NEMA, the generator is required to withstand only the three-phase current level unless it is otherwise specified ..." This is due to very low zero-sequence impedance within the generator causing very high earth fault currents. For generators 600V or below, this may not be an issue. However, it is usually always an issue as the voltage class increases.

UNGROUNDED SYSTEM

Q. How can we measure earth fault and unbalance current in ungrounded systems? How does open delta PT and core balance CT function against faults? What effect does it have on open delta PT?

A. In ungrounded systems the phase to ground voltages of the three phases change when there is an earth fault. Under normal conditions Phase to ground voltage= phase to phase voltage/ 1.73 and it is the same for the three phases. On the occurrence of an earth fault, the phase to ground voltage on the faulted phase is zero and for the other two phases it becomes equal to phase-to-phase voltage. The unbalance in phase to ground voltages is measured by YY connected PTs and is used to indicate earth fault. Open delta connected PTs are connected line-to-line and do not see this change and are unaffected hence cannot be used for earth fault detection.

Any energized conductor will have capacitance to ground, so in three phase system there are three balanced distributed capacitances to ground due to natural conductor insulation. In ungrounded systems these three capacitive charging currents, I_{C0}, are normally balanced and there is no net ground current flow. In an earth fault as the voltage to ground on the faulted phase goes to 0 the charging current in that phase also goes to 0, where as the charging current increases in the other two phases which are driven at line to line voltage magnitude. They add up to become 3 I_{C0}. This charging current can be detected by a zero sequence sensor (also called CB-CT) to indicate earth fault. These currents are normally 0.1A to 2A in LV systems and up to 20A in MV systems.

FLOATING GROUND

Q. What is the impact, if any, on moving equipment designed for a plant with a floating ground or ungrounded secondary to a plant that has a true grounded system? My thoughts are, it shouldn't really matter, but I could be mistaken.

A. In your case (from an ungrounded system to a solidly grounded system) NO, it does not matter. However, if you were going the other way (from SG to a UNG system), then Yes it would matter. During normal operation, it more than likely will not matter, however, during a ground fault it will. In an ungrounded system, the faulted phase voltage collapses to ground potential (or ~0V) and the unfaulted phases rise to phase-to-phase voltage with respect to ground. For example, a 480V system will have ~277V phase-to-ground voltage during normal operation, so it should work OK. However, a ground fault on A-phase makes its voltage go to 0V and the other two phases will rise from 277V to 480V phase-to-ground.

Since this doesn't happen on a solidly grounded system, anything rated only 300V phase-to-ground will explode, such as TVSSs, VFDs, meters, and more.

EARTH FAULT

Q. How can we detect earth fault on floating earthing system through core balance CT?

A. Any energized conductor will have capacitance to ground so in a three phase system there are three balanced and distributed capacitances to ground due to natural conductor insulation. In ungrounded systems, three capacitive charging currents, I_{C0}, are normally balanced and there is no net ground current flow. In an earth fault, as the voltage-to-ground on the faulted phase goes to 0 the charging current in that phase also goes to 0, where as the charging current increases in the other two phases which are driven at line to line voltage magnitude. And they add up to become 3 I_{C0}. This charging current can be detected by a zero sequence sensor (also called core balance CT) to indicate earth fault. These currents are normally 0.1A to 2A in LV systems and up to 20A in MV systems.

SENTRI

Sentri

Arc Flash Mitigation

ZSIP Selective Instantaneous Protection

40 trip levels from 100 mA up to 1200A

HRG DC POWER

Q. Are there disadvantages to utilizing a high resistance grounding scheme on 4000 A 1000V DC switchgear? Does this class of DC gear have arc-flash hazards the same as AC switchgear?

A. No, I do not see any disadvantages in high resistance grounding 1000Vdc switchgear. Where would you apply the high resistance grounding? Is center tap available to allow +/- 500V? This would be the most convenient place to apply HRG and you can monitor the system for ground faults. Yes, Arc Flash Hazard exists in the 1000V DC systems as well and can be quite severe because of low source impedance.

Q. I would say that use of HRG will greatly reduce the risk of arcing faults on a 480V system, since the large majority of faults begin life as a line-to-ground fault. But what the others are saying is that it does NOT reduce the hazard that can exist for a three-phase arcing fault, so the required PPE is still based on the worst-case three phase fault. This is pretty clearly addressed in IEEE 1584. There is still an arc-flash hazard since the HRG has no effect on phase-phase or three-phase faults.

A. You are correct. Arc flash calculations are based on the arc flash current, time, distance and bolted fault data. There is no way that the grounding system can reduce the arc flash hazard analysis. The only thing a high-resistance grounding system can do is limit the fault current of a single phase to ground fault. Now that the fault current is limited to 5 A., the probability of that fault escalating to a phase to phase fault or a three phase fault is greatly reduced. In contrast a single phase to ground fault in a solidly grounded system has the highest probability of escalating to a three phase fault. The Red Book is stating that most faults in the electrical industry start of as ground faults. The probability of that fault escalating into a three-phase fault in a solidly grounded system is high, whereas the probability of that fault escalating into a three-phase fault in a high-resistance grounded system is low. If the Statement 7.2.2 is interpreted this way, then the statement remains true.

ARC FLASH AND HRG

Q. What about existing installations? Would just installing HRG alone solve possible risks? What else should we consider in an industrial installation? Please advise.

A. HRG will limit ground fault currents to a low value. You should have an arc flash hazard assessment performed so you know what the hazards are. You should acquire the appropriate PPE and insure you have good training programs and safety policies. This is just a start.

Q. Are you kidding? How can you ensure your electrician ONLY drops his screwdriver between one phase and ground? The other 2 phases are only inches away! This is why IEEE 1584 and NFPA70E base everything on 3-phase bolted faults! Am I wrong?

A. Correct the other two phases are inches away. I go to many conferences and I hear stories of people who are racking in breakers with a misaligned stub and it caused a ground fault and an arc flash. Another case had someone testing voltage with a meter and the probe slipped and caused a ground fault and an arc flash. These arc flash incidents could have been avoided with a HRG system. The operator, wearing the appropriate PPE, would have been alarmed that a ground fault occurred, rectified the situation and most importantly hugged his wife and kids when he went home instead of the grim reality that did occur.

Now I cannot guarantee that electrical accidents will only affect a single phase and ground. There will be incidents that will involve other phases and ground or all three phases, but you should be wearing the appropriate PPE for that. We are not stating that you need to wear less PPE, just because you have a high resistance grounded system. I can guarantee that if you are working on an electrical system with no faults on it and accidentally contact a single phase to ground, you will walk away and the equipment can be put back into service. No one cannot guarantee the same thing with a solidly grounded system.

If I had the choice, I would prefer the added insurance with a high resistance grounded system. But the choice in the end is yours and you are gambling with a lot more than just an opinion.

Falcon

Optical Arc Detection

Photoelectric Technology

Trips in less than 1ms

Q. I have a transfer switch with two breakers, as my main service disconnect. Power is through a 480V transformer/generator. Can I use one HRG for both?

A. There are two methods of inserting a single HRG System with 2 sources. You can create another neutral on the common bus that is fed both sources and ground that new neutral with a resistor to limit the fault current. This way it doesn't matter which source is on, the system will be protected.

You can tie both neutrals together and ground it through a resistor. This method is problematic as the voltage of one neutral may elevate to 277V with respect to ground even though it is not connected directly to the system. For example, if the transfer switch is on transformer and you are servicing the generator and a ground fault occurs, then the votage on the generator will rise to 277V, unless more costly switches are placed to isolate the neutrals under certain system conditions.

Q. I don't understand the quote, "There is no arc flash hazard, as there is with solidly grounded systems, since the fault current is limited to approximately 5 A." There is still phase-to-phase arcs that have just as high arc flash hazard. Can you please explain?

A. According to IEEE 1584, using high resistance grounding system increases the incident energy by approximately 30%. This is the only mathematical proof we have that high resistance grounding works. Now according to the Red Book 7.2.2 and the Green Book we can reduce the number of incidences that an arc flash may occur. The purpose of IEEE 1584 is to calculate the incident energy in an arc flash. We can use the information form the Red, Green, Buff Books to reducce the number of incidences.

An arc flash can occur on a high resistance grounded system. When it does, we can calculate the incident energy that we need to protect ourselves from, and wear the appropriate PPE. High resistance grounding reduces the probability of a single phase fault escalating to a three phase fault.

Q. Acknowledged that phase to ground faults have much lower fault current with HRG. However, with no reduction in severity of phase-phase faults, does the Arc Flash PPE category decrease?

A. The equation for calculating Incident Energy from IEEE 1584 is as follows:

$$lgEn= K1 + K2 + 1.0811glа + 0.0011G$$

Where,

En is the incident energy (J/cm) normalized for time and distance
K1 is -0.792 for open configuration (no enclosure) and;
is -0.555 for box configuration (enclosed equipment)
K2 is 0 for ungrounded and high-resistance grounded systems and;
is -0.113 for grounded systems
G is the gap between conductors (mm)

As you can see the only term that differentiates the grounding is K2.

K2 can be either 0, for ungrounded and high-reistance grounded systems, or -0.113 for solidly grounded systems. If everything else is identical then the term lg En for high-resistance grounded system is 0.113 more than a solidly grounded system. And since En=10lgEn then the incident energy for a high-resitance grounded system or an ungrounded system is 29.7% greater than for a solidly grounded system. According to IEEE 1584, you need to wear PPE with a higher degree of protection due to the high-resistance or ungrounded system.

Q. Since HRG does not reduce L-L fault current, does it meet the legal and safe intent of all arc flash reduction requirements?

A. Making a statement that HRG will eliminate arc flash would be criminal. No one at this stage can state that they can eliminate arc flash hazards. But HRG can be used with other protection systems to reduce the probability of an arc flash.

Q. If a solidly grounded system is coordinated based on safety and arc flash currents in mind and not the continuous operation of equipment isn't the solidly grounded system a better method because the fault is isolated immediately? In this case, it does not matter if whether the fault is a ground fault or a phase-to-phase fault.

A. The fault can only be isolated immediately if it is detected. In a properly coordinated electrical system intentional time delays are placed where the fault current is the greatest. In order for the protective relays to detect an arcing fault, there must be a current greater than the set point of the protective and it must persist for a time greater than the time delay of the protective relay. Arcing currents are lower than bolted fault currents. It is possible for a low level arcing ground fault to be present on the system and go undetected. This arcing current can propagate into a phase-to-phase or a three-phase fault quickly. In a high resistance grounding, the arcing ground fault will not propagate into a phase-to-phase or three-phase fault.

Q. On its most basic level, is this the same principle as a GFCI outlet in a residential application?

A. No, I would equate a GFCI with a fuse. If the leakage current is greater than 5 mA then the fuse, GFCI would open clearing the fault from the system. High resistance grounding actually limits the fault current to a desired value. The GFCI does not limit, it only detects and isolates.

Q. For HRG installations, is it essential to run equipment grounding conductors inside the conduit (versus using the conduit for just a ground conductor)?

A. The installation does not have to be different than any other installation. If the code allows you to use the conduit as a bonding conductor then it would be allowed in a HRG installation.

Q. Why does the NEC not require detection on ungrounded systems?

A. NEC 250.21(B) ground detectors. Ungrounded alternating current systems as permitted in 250.21(A)(1) through (A)(4) operating at not less than 120V and not exceeding 1000V shall have ground detectors installed on the system. So, ground detectors are required on ungrounded systems. The problem is that there are no efficient ways to find the ground fault when it occurs. Ground defects are voltage based. You measure the voltage with respect to ground. The voltage on the faulted phase will decrease to 0V. The voltage on the un-faulted phases will increase to near the full line-to-line potential. So you now know that you have a fault on "C" phase. You have no way of finding and importantly clearing that fault other than cycling every breaker or switch in the plant until it is found. Normally, facilities choose the ungrounded system to avoid outages. The only way to find the fault is with an outage, temporary as it might be., maintenance personnel are the only ones that lose in the situation. You can't find the fault unless you cycle the breakers and you can cycle the circuit breakers because you need continuity of power. I have stated that most ungrounded facilities I have visited have a ground fault. The maintenance electricians always have more important issues to work on, so they wait for the second fault to clear the system. This is unacceptable but allowed.

Q. HRG- isn't second fault at 480V not 277V and greater energy than at 277V?

A. The second ground fault, if it is on a different phase will be a phase-to-ground-to-phase fault. I would not say that there is more energy in the second fault as far as the IEEE 1584 is concerned as it uses a voltage of 0.48kV to calculate the fault energy. The attractive part of your question is the second fault. You will know when you are at risk of the second fault, because you would have had a first fault and you are looking for it. I have had systems that are very complex and I can find the fault within an hour. In solidly grounded systems there is no warning. You do not know when you are at risk. We also have products that isolate the second fault should it occur. This is done on a priority level. The two faulted feeders communicate with each other and determine which one should trip based on the priority that the user programs into them.

Q. What about healthcare applications? Recommended?

A. We have installed many HRG systems in hospitals. In fact, hospitals were the preferred customer base for our DSP product. This particular product afforded the user the luxury of tripping on the second fault should one occur.

Q. What should be considered when retrofitting 5kV systems from LRG to HRG systems?

A. When converting any system from LRG (low-resistance grounded) to HRG the main thing to consider is the sensitivity of the protection system. If your protection is set up to detect a 200A, 400A ground fault, it may not have the sensitivity to pick up a 5A, or 10A ground fault. This can be easily overcome. Similarly, for converting an ungrounded system to a HRG system you must ensure that you can detect a fault when one occurs.

Q. What about existing installations? Is just installing HRG that we solve possible risks? What else should we consider in an industrial installation?

A. HRG will limit ground fault currents to a low value. You should have an arc flash hazard assessment performed so you know what the hazards are. You should acquire the appropriate PPE and insure you have good training programs and safety policies. This is just a start.

Gemini

- Dual path current limiting resistor
- Redundant fail-safe resistor circuit
- Integral ground fault relay
- Integral ground monitoring relay
- Fault location through pulsing
- Harmonic filter and time / current adjustments to reduce false trips

STANDARD

DSP-OHMNi

- Monitors and protects up to 50 feeders on one relay
- 1st Fault Alarm, 1st Fault Trip or 1st Fault Time Delay Trip
- Resistor Monitoring Module
- Selective Instantaneous Feeder Trip on 2nd ground fault

STANDARD

Sentinel

- Current limiting resistor
- Voltage and current sensing
- Integral ground fault relay
- Integral ground monitoring relay
- Fault location through pulsing
- Harmonic filter and time / current adjustments to reduce false trips
- Inrush detection restraint
- Multi-feeder protection
- Second fault protection
- MODBUS for remote monitoring

PREMIUM

Gardian

HRG reduces the frequency of arc flash incidents and optical detection reducing impact, all in one.

ULTRA PREMIUM

GARD

Unparalleled Protection

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