The Case For Hybrid Generator Grounding

By Sergio Panetta

Power continuity is essential in many industrial and commercial installations where a trip out due to a ground fault can have serious economic and/or operational consequences. An arcing phase to ground fault can pose a flash hazard to the maintenance worker close to the fault and can completely destroy the equipment. Consequential down time adds to that economic loss.

Medium Voltage Generators are not designed to withstand full fault current during a single phase to ground fault. This is the main reason that medium voltage generators are connected to a system with either low or high impedances. There are many methods to ground generators. This article will discuss the advantages and disadvantages of each method of grounding.

Low Impedance Grounded

A low impedance grounded system is comprised of a connection of the generator's neutral terminal to ground through an impedance as shown in Figure 1. The resistor typically limits ground fault currents from 200 to 800 amperes for a short duration. The fault current is selected in order to minimize damage at the point of fault as well as providing

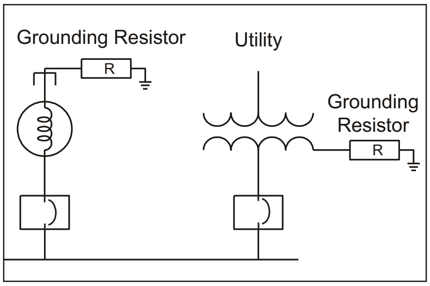

Figure 1. *Low Impedance Grounded System*

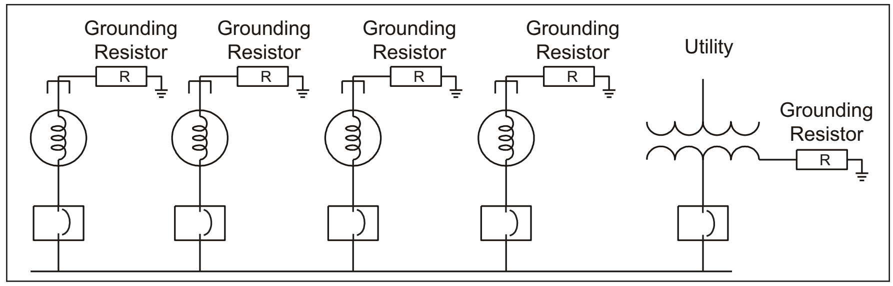

Figure 2. *Multiple Point Grounded System*

selective coordination of the protection system.

As well as minimizing the damage at the point of fault, low impedance grounded systems also minimize shock hazards caused by stray currents, minimize thermal and mechanical stresses on equipment, and control transient overvoltages. Low impedance grounded systems are used when the charging current of the facility is larger than 10 A and/or if the protection system cannot detect a ground fault of less than 5A.

As the generation capability within facility increase, as shown in Figure 2, the value of ground fault current also increases. As an example, if 4 generators are connected to a common bus, the maximum ground fault current may be anywhere from 200 A, if only 1 generator is on line, up to 3200 A if all 4 generators are online with a 800 A low resistance grounded system. As more and more generators are connected, the advantages previously listed quickly diminish.

The greatest drawback of this type of system is witnessed when a ground fault occurs within the stator winding of a generator. Experience has shown that the ground fault will not be removed from the generator even though the generator breaker has opened. The generator will continue to supply the current through the ground fault until the field excitation decays. The physical damage caused to the generator is caused by the duration of the fault and not the magnitude of the fault.

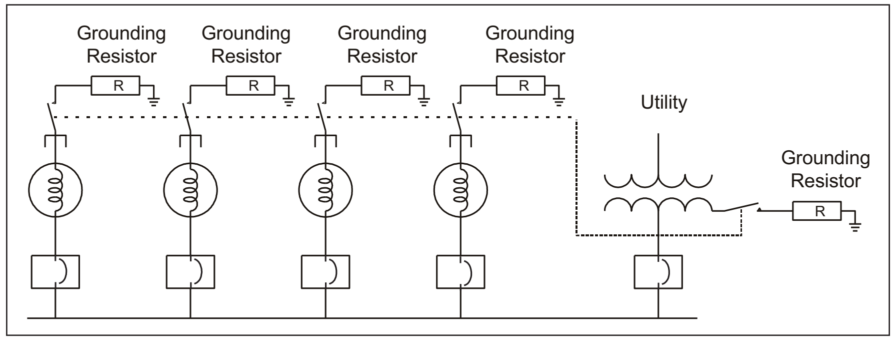

Figure 3. *Variation of Single Point Grounded System*

A different approach must be considered to maintain the advantages of the low impedance grounded system.

Single Point Grounded

Single point grounding ensures that only one source is grounded at any given time. There are three ways in which this can occur. Figure 3 shows a multiple generated connected system where neutral isolators ensure that only one resistor is connected to the electrical system at one time. This system is complex as the isolator switches are necessary. It is also necessary to implement an operation procedure for any kind of transfers. The other disadvantage of this type of system is that the system will become ungrounded should the connected grounded source become isolated. This would put the entire system at risk. As generators ramp up and placed into service they as well would be ungrounded until they are connected to the power system.

The disadvantages of the ungrounded system described in Figure 3 are addressed with the system in Figure 4. In this scenario the neutrals are all connected together and there would exist only 1 return path for any ground faults. The concern of generators going off line is also addressed. There are 2 major disadvantages of this kind of system, one being the circulating third harmonic currents through the connected neutrals, and the other being the complex serviceability of a generator. With the neutrals all connected together, a ground fault anywhere in the system will elevate the potential of the neutral whether the generator is connected to the system or not. This posses a safety hazard for any personnel working on the generators.

Figure 5 addresses the single point ground with an artificial neutral. This method is much simpler than the one in Figure 3; however the disadvantage is the ungrounded state of the generators when not connected to the electrical system.

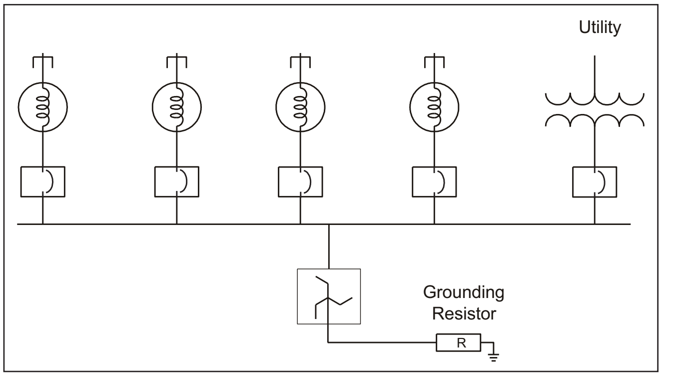

Figure 4. *Common Neutral, Single Point Grounded System*

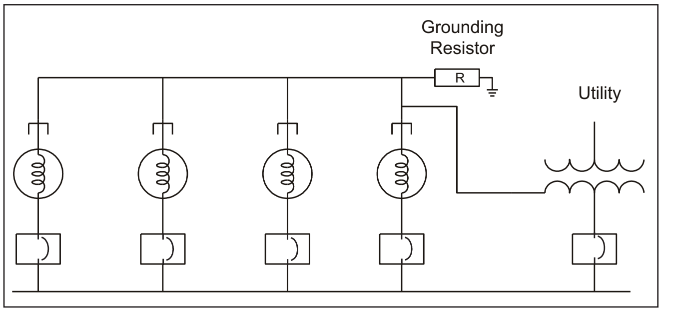

Figure 5. *ZigZag, Single Point Grounded System*

Multiple Point Grounded

The schematic shown in Figure 2 is an example of a multiple point grounded. Each generating source is grounded through its own grounding resistor. There is no risk of leaving a source generator ungrounded. There is also no safety hazard when servicing a generator.

With many generators connected, the amount of ground fault current can exceed levels that will limit the damage at the point of fault. This is extremely evident should the point of fault occur in the stator winding of the generator. With the fault in the stator winding, fault current would not be interrupted, even with the occurrence of an interruption of the circuit breaker connecting the generator to the electrical distribution system. This type of fault in a multiple point grounded system will have severe damage in the stator windings.

High Impedance Grounded

A high impedance grounded system is comprised of a connection of the generator's neutral terminal to ground through an impedance as shown in Figure 1. The resistor typically limits ground fault currents to a low value for an extended duration. The fault current is selected in order to be equal to or greater than the system capacitive charging current. The advantages of the high impedance grounded system are numerous – minimal fault current at the point of fault, continuity of operation, and a reduction of transient overvoltages as far as the ungrounded system is concerned. High resistance grounded should be the first choice when considering new installations. Other advantages include the ability to find the location of the ground fault without power interruption. This makes high resistance grounding an ideal solution for data centres, hospitals, and water treatment facilities, to mention a few.

During a ground fault, the user may detect and locate the fault. During the location process, should another fault occur on a different phase, a phase to ground to phase fault will result. Protection systems such as the i-Gard DSP OHMNI, can detect this scenario and isolate the feeder with the lowest priority using Selective Instantaneous Feeder Tripping.

As the charging current increases in large distribution networks or as more generators are placed on line, it may not be feasible to have a high impedance grounded system.

The optimal solution is a combination of the low impedance grounded system and the high impedance grounded system. The system would effectively be low resistance for all ground faults. If, however the fault is a ground fault within the generator, the system would revert to a high impedance grounded system and minimize the damage. This schematic is seen in Figure 6.

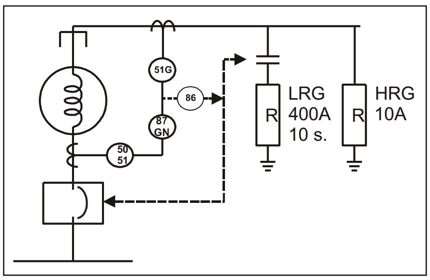

Figure 6. Hybrid Grounded System

Hybrid Grounding

The generator shown in Figure 6 is grounded through both a low impedance and a high impedance device. This scenario would allow all the benefits of the low impedance grounded systems in that all through ground faults will have the selective coordination; there is also minimal damage at the point of the fault. The ground fault current would be limited to the sum of the low impedance system and the high impedance system. In the case shown the ground fault current would be 410 A. If the ground fault was downstream then the isolating device closest to the fault will isolate the ground fault. The true benefit of this scheme is observed when a ground fault occurs in the stator winding of the generator. If the ground fault occurs within the stator winding, the ground fault current would be limited to 410 A until the differential protection isolates the generator from the supply and opens the contactor for the LRG device – thus limiting the ground fault to 10 A until the generator slows down to standstill.

This system is safer for the generator in that the generator is never left in an ungrounded state. The stator windings are protected unlike the straight low impedance grounded system.

When multiple units are placed on line and each unit is protected by the hybrid system, the tendency will be to have all hybrids identical. This would cause extremely high ground fault current when the system is in low impedance, and the benefits would be lost. To compensate for this, the schematic can be reconfigured to that of Figure 7 and all the benefits would once again be experienced.

This schematic indicates that the maximum ground fault current is in the order of magnitude of 400 A, regardless of how many sources are connected to the system,. Ground faults downstream will be isolated by the breaker closest to the fault by selective coordination and ground faults within the stator will be isolated by the differential scheme shown in Figure 6, but isolation will only occur in the supply breaker for that particular breaker. This will leave the generator in a high impedance grounded state and minimize the damage to the stator.

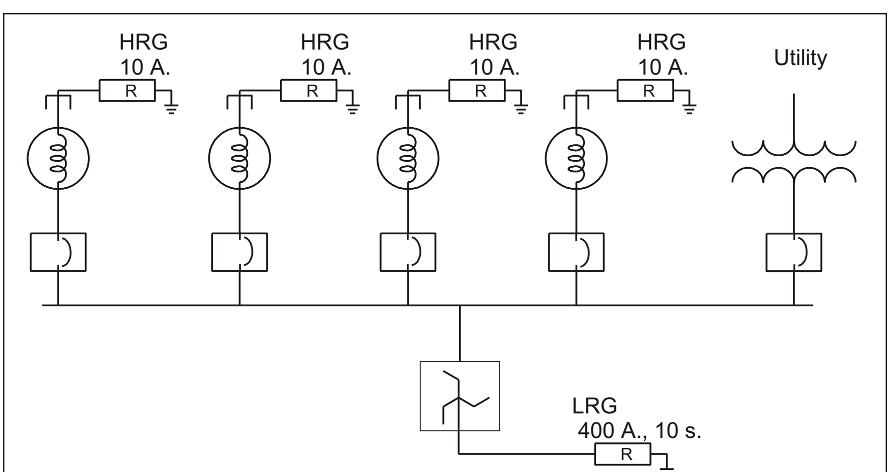

Figure 7. Variation of Hybrid Grounded System

Conclusion

In summary, low impedance grounding and high impedance grounding are both grounding options with advantages and disadvantages. Low impedance grounded systems minimize shock hazards caused by stray currents, minimizing thermal and mechanical stresses on equipment, and control transient overvoltages.

High impedance grounding comprises of a connection of the generators neutral terminal through impedance. The advantages of high impedance grounded systems are minimal fault current at the point of fault, continuity of operation, and a reduction of transient overvoltages. Today's innovations allow the user to detect and locate a fault with the ability to isolate the feeder with the lowest priority using Selective Instantaneous Feeder Tripping (SIFT).

While more and more larger distribution networks are placed online, the optimal solution is a combination of the low impedance and high impedance resulting in hybrid grounding. The system would effectively be low resistance for all downstream ground faults. If however, the fault is a ground fault within the generator, the system would revert to a high impedance grounded system to minimize internal generator damage.

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