Addressing Ground Faults on MV Generators

A hybrid grounding system design allows flexibility

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Medium-voltage (MV) generators are not designed to withstand full fault current during a single phase-to-ground fault, which is why they are connected to a system with either low- or high-impedance devices.

There are many methods to ground these generators. Let's discuss the advantages and disadvantages of each (relative to performance) under ground fault conditions.

Low-impedance grounded. A low-impedance grounded system consists of a connection of the generator's neutral terminal to ground through an impedance, as shown in **Fig. 1**. The resistor typically limits ground fault current magnitudes from 100A to 800A for a short duration. The selection of the magnitude of fault current is made to minimize damage at the point of fault and provide selective coordination of the protection system.

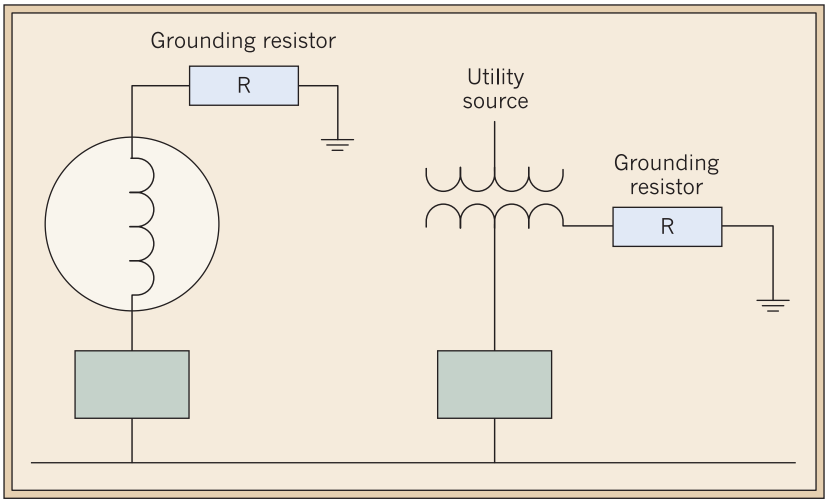

Fig. 1. Schematic of the low-impedance grounded system.

In addition to minimizing the damage at the point of fault, low-impedance grounded systems minimize shock hazards caused by stray currents, minimize thermal and mechanical stresses on equipment, and control transient overvoltages.

As the generation capacity increases within a facility, as shown in **Fig. 2**, the value of ground fault current also

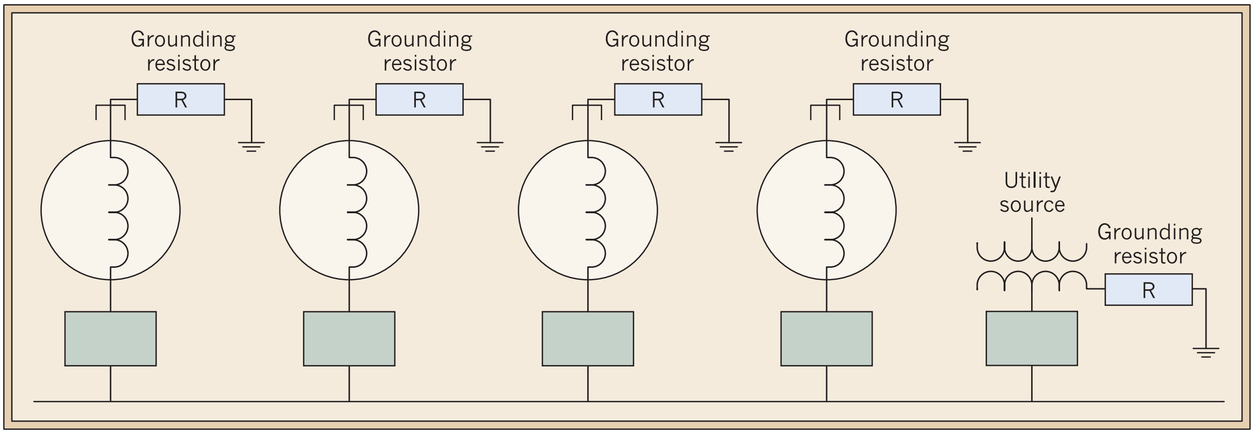

Fig. 2. Schematic of the multiple-point grounded system.

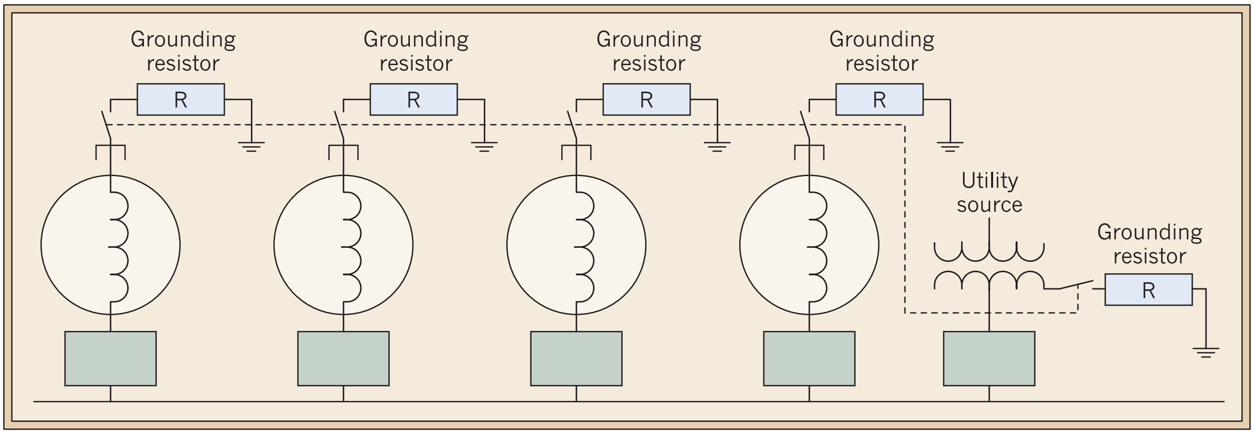

Fig. 3. Schematic of a variation of the single-point grounded system.

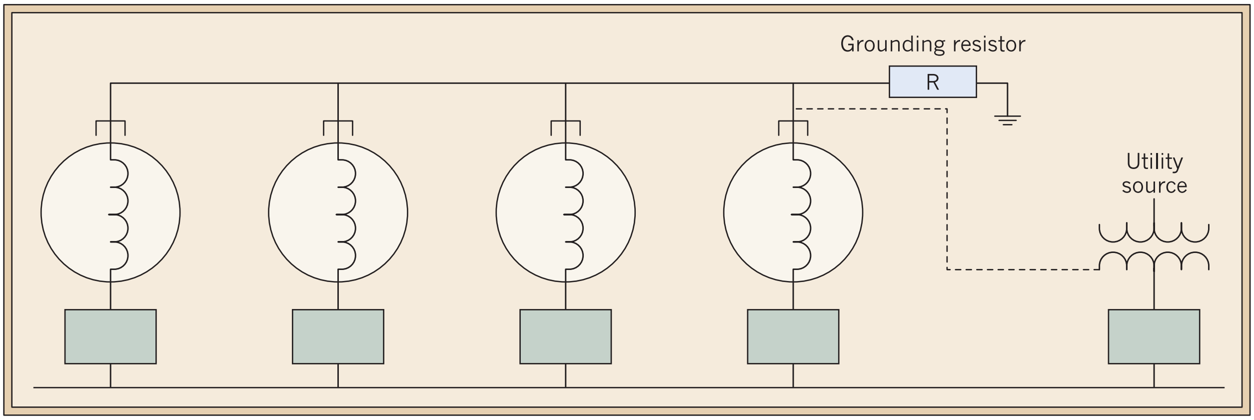

Fig. 4. Schematic of the common neutral, single-point grounded system.

increases. For example, if four generators are connected to a common bus, the maximum ground fault current with an 800A low-resistance grounded system may be between 800A (if only one generator is online) to 3,200A (if all four generators are online). As more generators are connected, the advantages previously listed quickly diminish.

The greatest drawback of this type of system is when a ground fault occurs within the stator winding of a generator. Experience shows that the ground fault will not be removed from the generator when the generator breaker has opened. In fact, the generator will continue to supply the current through the ground fault until the generator's field excitation decays. The resulting physical damage to the generator is a function of the duration of the fault, not its magnitude. Thus, consider a different approach to maintain the advantages of the low-impedance grounded system.

Single-point grounded system. Single-point grounding ensures only one source is grounded at any given time. There are three ways this can occur. **Fig. 3** shows a multiple generator-connected system in which neutral isolators ensure that only one resistor is connected to the electrical system at one time.

A disadvantage to this arrangement is complexity because of the necessity of the isolator switches. The system also requires an operation procedure for any kind of transfer.

Another disadvantage is that the system will become ungrounded if the connected grounded power source become isolated. This would put the entire system at risk because, as generators are ramped up and placed into service, they will also be ungrounded until connected to the power system.

The system shown in **Fig. 4** addresses these disadvantages. In this scenario, the neutrals are connected together, and there is only one return path for any ground fault. This scenario also addresses the concern of generators going off-line.

Two major disadvantages are inherent in this kind of system: circulating third harmonic currents through the connected neutrals and the complex serviceability of a generator. With the neutrals 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 results in a safety hazard for any personnel working on the generators.

The arrangement in **Fig. 5** on page 24 addresses the single-point ground by way of an artificial neutral. This method is much simpler than that shown in Fig. 3. However, the disadvantage is the ungrounded state of the generators when not connected to the electrical system.

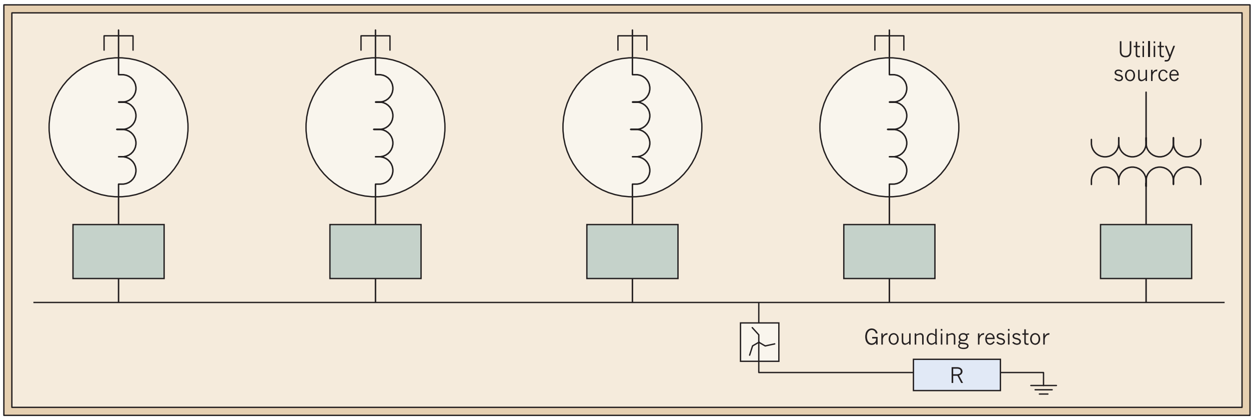

Fig. 5. Schematic of the zig-zag, single-point grounded system.

Multiple-point grounded system. Figure 2 is an example of a multiple point grounded system. Each generating source is grounded through its own grounding resistor. There is no risk of leaving a source generator ungrounded, and there is 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 if the point of fault occurs in the stator winding of the generator. Here, fault current would not be interrupted, even with the opening of the circuit breaker connecting the generator to the electrical distribution system. The result will be severe damage in the stator windings.

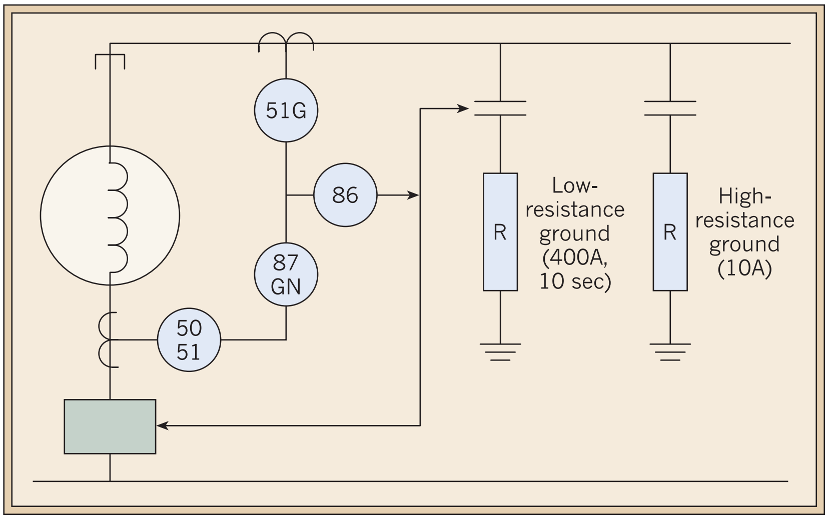

Fig. 6. Schematic of the hybrid grounded system.

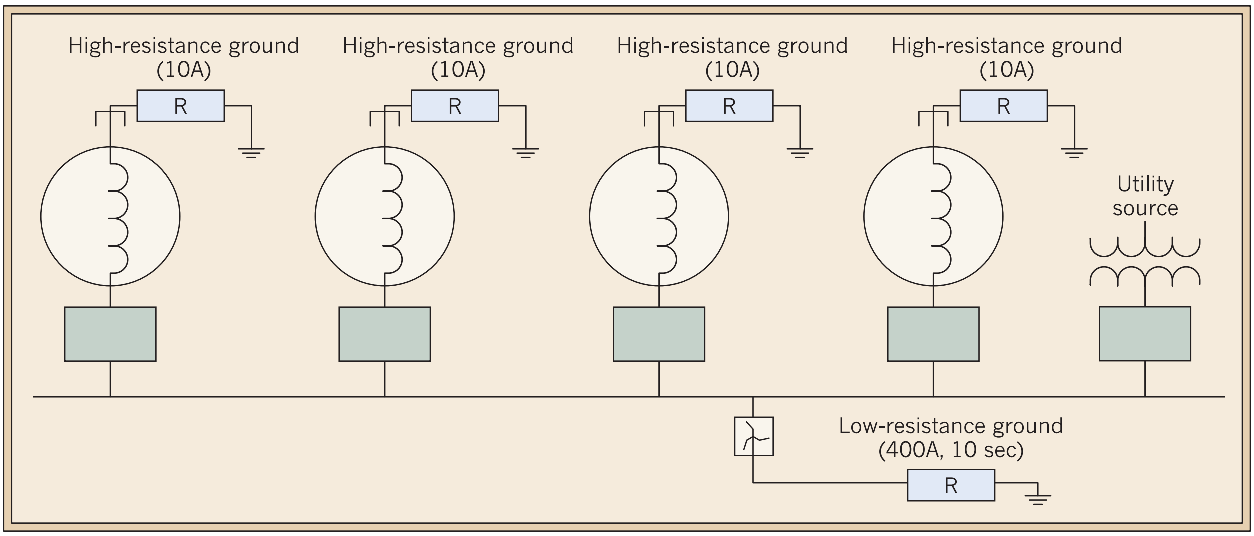

Fig. 7. Schematic of a variation of the hybrid grounded system.

High-impedance grounded system. A high-impedance grounded system consists of a connection of the generator's neutral terminal to ground through an impedance, as shown in Fig. 1. In this system, the impedance is high, with the resistor typically limiting ground fault currents to a low value for an extended duration (see **Fig. 6** on page 24). The magnitude of fault current is selected so that it is equal to or greater than the system capacitive charging current.

The advantages of the high-impedance grounded system are:

- Minimal fault current at the point of fault,
- Continuity of operation, and
- Reduction of transient overvoltages as far as the ungrounded system is concerned.

One disadvantage of this system is the sensitivity required for the detection of a ground fault. With the ground fault current in the order of magnitude of 10A, more sensitive ground fault protection is necessary. Another disadvantage is that as the charging current increases in large distribution networks — or as more generators are placed online — it may not be feasible to have a high-impedance grounded system.

Hybrid grounding. The optimal solution is a combination of the low- and high-impedance grounded systems. This hybrid system would effectively be low resistance for all external 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 scenario allows all the benefits of the low-impedance grounded systems, in that all through ground faults will have selective coordination — and there is 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 schematic shown in Fig. 5, the ground fault current would be 410A. If the ground fault was downstream, then the isolating device closest to the fault would isolate the ground fault.

The true benefit of this scheme is seen when a ground fault occurs in the stator winding of the generator, because the ground fault current would be limited to 410A until the differential protection isolates the generator from the supply and opens the contactor for the LRG device, thus limiting the ground fault to 10A until the generator slows to a standstill.

This system is safer for the generator because it is never left in an ungrounded state. Also, the stator windings are protected, unlike the results with a straight low-impedance grounded system.

When multiple units are placed online — and each unit is protected by the hybrid system — the tendency is to have all hybrids identical. However, this would cause extremely high ground fault current within the system, as with the low-impedance system. Thus, the benefits of the hybrid system would be lost. To compensate for this, you can reconfigure the hybrid grounded system to that shown in **Fig. 7** on page 24.

This schematic would result in a maximum ground fault current in the order of 400A, regardless of how many sources are connected to the system. Ground faults downstream will be isolated by the breaker closest to the fault, through selective coordination, and ground faults within the stator will be isolated by the differential scheme shown in Fig. 6, occurring only in the supply breaker for that particular generator. This will leave the generator in a high-impedance grounded state, thus minimizing the damage to the stator.

If the existing grounding system does not lend itself to the zig-zag bus grounding source (no spare breaker, no room to expand, economics, etc.) — or it is designed to operate with any generator being the sole source — you can still use the hybrid system. Here, you would operate some of the hybrid ground sources in high-resistance grounding mode only and allow only a limited number of the sources to operate in the low-resistance grounding mode. Use control logic to accommodate this flexibility. **EC&M**

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