High Resistance Grounding vs. Ungrounded Systems

1. Introduction

Ungrounded systems (IT) are defined by the IEC 60364, either as systems without connection between live parts and ground or with one single connection through a high impedance. In both cases, the main advantage achieved by IT systems is to reduce the first ground fault currents down to a non dangerous level, so that the system does not require immediate disconnection, giving a clear advantage in the power availability and process functions continuity.

Beside the above mentioned advantage, traditional IT systems might lead to troubles, when a ground fault must be located on big systems, with complex topology and many feeders. This is now solved with the automatic fault location systems for IT systems.
For our convenience we will refer hereinafter to IT systems, only for totally Ungrounded systems, i.e. with live parts galvanically insulated from ground. We will refer to HRG systems, when a system has one high resistance grounding.

The way on which insulation of IT and HRG systems can be monitored and their fault can be located automatically, are totally different. For IT systems, a permanent insulation monitor according IEC 61557-8 must be used, and a fault location system according IEC 61557-9 can be added as well. For HRG systems, the above two standards cannot be used, and actually there is no IEC standards which says how to monitor and locate faults on HRG systems. In fact, HRG control method are described only in North America local codes (NEC or CAN/CSA), but there is not an international standard for this.

Please consider that any active Insulation Monitoring Device (IMD) for ungrounded IT systems, according the IEC 61557-8, cannot work on HRG systems as well, because it's DC, VLF or ULF measuring signal should not find any additional resistive path to ground, in addition to the insulation resistance of the system. Indeed, when a transient overvoltages' dumper is required on an ungrounded IT system, it must have a non linear impedance, i.e. a very high DC resistance (> 1 MΩ), and a much lower value at the system main frequency of 50-60 Hz (e.g. 2 kΩ).

Correspondingly, the measure of the differential currents on which is based the fault location of a HRG system, cannot work on a fully ungrounded IT system, because the first fault condition's leakage currents (only capacitive), can be very low and quite unpredictable on a complex system.

First conclusion we can arrive to, is we need a clear choice between ungrounded IT systems OR HRG IT systems. The ground fault monitoring and automatic ground fault location is possible in both cases, but it will follow two very different strategies, and will make use of different devices, which are incompatible with each other.

In the next part of this document, we are pointing out the main advantages and disadvantages of the two systems. It is our opinion that a fully ungrounded IT system with a permanent insulation monitor and an automatic fault location system is the very best solution for a wide and complex power distribution system.

1.1 Main advantages of ungrounded systems (IT systems)

1) System can still work after first ground fault, and high current protections does not trip.
2) Only (low) capacitive currents can flow through the ground after first ground fault.
3) A well-timed alarm is issued by the permanent Insulation Monitor Device (IMD) in case of first fault
4) The IMD measures the resistive part only of the line to ground impedance, which is directly connected to the insulation materials' physical characteristics.
5) An IMD with active measuring principle can easily detect any kind of ground fault, including symmetrical fault (e.g. all the live wires of a cable with the same low resistance to ground, due to mechanic or thermal damage), like required by the IEC 61557-8. This is of vital importance to avoid hot points, especially in fire risk environments.
6) Information on the insulation level and decay can be obtained in a true advance, thanks to the high sensitivity of the IMD (up to the MΩ range).
7) IMD with adaptive control works fine, even on very large systems with leakage capacitance up to 500 µF. The ground resistance measure is absolutely not affected by potential unbalances of the line to ground capacitances.
8) On systems with static power converter, using the adaptive control, the fault can always be detected across all stages of conversion and over the full range of the controlled variable regardless of the controller topology.
9) An automatic fault location system can be added, according IEC 61557-9. The fault location system works on either AC or DC side ground faults.
10) Thanks to high sensitivity fault evaluators, ground faults can be located even at an early stage (in the range 10-100 kΩ @ 3AC 480 V). A second faults on a different feeder can also be located if the first fault resistance is not too low ($R1 \neq 0$) and the two of them are not too much different ($R2 < 10 \times R1$).
11) Using a bus connection for synchronization of the IMD and the fault evaluators of the fault location system, the risk of false alarms due to transient disturbs on feeders is eliminated. Possible false alarms due to interference with very low frequencies generated by variable speed drives, can be eliminated as well by using specially a crafted test signal and specific digital filters.
12) This system is exclusively based on internationally recognized IEC standards.

1.2 Main disadvantages of ungrounded systems (IT systems)

1) Multiple power sources' systems, may require additional control logic.
2) Automatic fault location system is available only for Low Voltage systems (up to 790 V AC).
3) Increase on voltage stress under line to ground fault conditions (line to line voltage).
4) Immunity to transient overvoltages may require an additional dumping impedance.
5) Protection against a MV-LV arc fault, may require an additional overvoltage discharger.
6) Differential current devices (RCD or RCM) may not work properly.
7) Relay co-ordination not possible.

1.3 Advantages of HRG systems

1) System can still work after first ground fault, because fault currents which flow through the ground are limited by the resistance and protections does not trip.
2) Available for both Low Voltage and Medium Voltage systems (up to 5 kV max).
3) System can still work after second ground fault under certain conditions.
4) Ground fault protection can easily be implemented by a monitoring device (CT) on the HRG connection.

5) An alarm is issued by the permanent HRG's Current Monitoring Device when the ground current is too high (usually 1-10 A).
6) High immunity to transient overvoltages.
7) Equipment protected against arc fault damage.
8) Easy of locating first ground fault, through differential current monitoring systems (although it may require Type B RCD for feeder with converters).
9) Easy implementation of loads management in case of second fault, by setting different residual current limits and different time delay for each of them (relay co-ordination).

1.4 Disadvantages of HRG systems

1) Leakage currents values depend on the system voltage. The lower is the system voltage, the lower are the leakage currents. This measuring method can not be practically used below a nominal voltage of 480 V.
2) Sensitivity to the insulation faults is quite low (usually in the 2-3 kΩ range). Above this fault resistance value, the fault is neither located nor detected.
3) Symmetrical ground insulation fault cannot be detected (i.e. one of the main characteristics required by the IEC 61557-8, is not fulfilled).
4) The current which is measured through the CT on the HRG has both the resistive and the capacitive components, and it is not easy to distinguish one to the other, especially on large system with high leakage capacitance.
5) Possible unbalance of the lines to ground capacitances can lead to a permanent current in the HRG connection. Moreover connection and disconnection of feeders can change the capacitances significantly (especially where EMC filters are used), and lead to a change of the measured currents which has nothing to do with an insulation decay.
6) DC components of the ground fault current cannot be measured (except using special Type B measuring devices). On the contrary, DC components can lead to saturation of Type A measuring device, with the consequence to significantly increase their measuring error.
7) To correctly detect faults on a feeder with converters, it is often required a differential current monitor of Type B (IEC 60755).
8) Ability to detect faults on the load side of controllers utilizing complex power conversion electronics and over the full range of the controlled variable is questionable.
9) It is in conformity to the NEC or CAN/CSA national code only.

Comparison table between HRG and IT-System

CHARACTERISTIC	HRG SYSTEM	IT SYSTEM
Early fault detection capability	Poor at the 2000 Ω – 3000 Ω level	Several orders of magnitude better than a HRG; at the MΩ Level
Fault detection dependence on harmonic content of ground fault signal	Very dependent; performance questionable in today's high-tech systems	Independent of signal content
Ability to detect faults on the load side of controllers utilizing complex power conversion electronics and over the full range of the controlled variable	This ability is questionable	Can detect faults across all stages of conversion and over the full range of the controlled variable regardless of the controller topology.
Overvoltage hazard	None	None when sized within kVA limit guidelines. Not influenced by changes in the system line-to-ground capacitances.
Symmetrical faults across multiple phases	Cannot detect	Not a problem
Voltage-to-ground of ungrounded phases when there is a solid ground fault	Line-to-line voltage	Line-to-line voltage
Identification of faulty feeder	Poor sensitivity	Excellent
Dependence on magnitude and symmetry of line-to-ground Capacitances	Affects the level at which a fault can be detected. Loads being switched ON and OFF will affect the early fault detection capability. Equipment based phase-to-ground noise suppression filters could create overvoltage problems if done or introduced without the knowledge of the plant engineer.	Adaptive control maintains same level of performance for line-to-ground capacitances up to 500 µF. Performance not affected by loads being switched ON and OFF.

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