EAGLE EYE TECHNICAL NOTE

Title	**Finding that Elusive Ground Fault**
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Revision History

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Introduction

Ground faults are defined as an inadvertent contact between an energized conductor and ground. They can exist on all electrical systems both AC and DC. This tech note specifically refers to ground faults and the impact they can have on battery backed standby system in which neither pole of the battery is referenced to ground.

Ungrounded DC systems are typically found in utility applications involving the generation and transmission of electricity. In these applications, a ground fault can exist at any point within the DC power system and the associated distribution. Another standby power system in which a DC ground fault can occur are Uninterruptable Power Systems (UPS's). Here, the location of a DC ground fault is restricted to the battery and the associated cabling and circuitry between the charger, battery, and inverter or within the battery itself.

Most ground faults are the result of a breakdown of the insulation between a live conductor and ground either due to physical damage to the insulation or the ingress of moisture. They can also occur when a conduction path is created due to the leakage of a conductive liquid such a battery electrolyte, often by the associated corrosion which can occur.

Identifying a Ground Fault

Why is identifying and rectifying ground faults so important? It is simple, they can cause system disruption, equipment damage and pose a safety risk to any personnel working on the system.

The electric utilities have long recognized the importance of detecting ground faults and most of their ungrounded batteries will have some form of ground fault detection associated with the DC power system. This can be as simple as two incandescent lamps with current limiting resistors, connected between each of the ungrounded battery poles to a common ground point. Under normal operating conditions, the lamps will be at the same level of brightness and if a ground fault occurs, the brilliance level of the lamps will become unbalanced and the one which has lost brilliance will be on the polarity with the inadvertent ground. This method of establishing a balanced ground reference and the detection of any subsequent imbalance, can be implement in many ways with different levels of sophistication and reporting. This is by far the most common method in service today.

For UPS installations, where the UPS has an input isolation transformer, a balanced resistor network can also be used. But for the newer generation of UPS without an isolation transformer, the challenge of identifying a ground fault condition is more difficult. This is because the operation of the semiconductors as a function of the rectifier circuit will provide a path to the system grounding of the three-phase supply. To identify a ground fault within the battery it is necessary to measure the current in both the positive and negative busses in a single Hall effect transducer, if no ground fault exists the currents will cancel each other out.

Finding the Ground Fault

Using these types of circuits and other proprietary approaches, the manufacturers of both AC and DC standby power systems will typically be able to identify any ground faults that occur within their systems. The challenge for the user is to find the actual location of these often elusive, inadvertent grounds. One of the more commonly suggested methods is to simply isolate the individual load circuits by removing or simply switching off the circuit protection devices. While this may have been an acceptable practice in bygone days, in today's 24/7 environment the loss of service that will typically result from such an approach is no longer acceptable.

Using Low Frequency AC as a Location Method

One method that does not disrupt service is to inject a low frequency AC signal between the partially grounded conductor and ground. Then using an AC current clamp with an indicator to show the presence of the AC signal, the signal can then be traced by placing the current clamp sequentially around the distribution cables from the point of injection. By identifying the distribution cables in which the signal can be detected you will eventually identify the point at which the circuit is grounded. The GFL 1000 is one such device that uses an AC signal to help in the tracing of that elusive ground.

Before starting the location process, the polarity on which the fault exists need to be determined, this can be done by measuring the voltage between each polarity and ground. The one which has the lower voltage can be assumed to be the one leaking current to ground. Now that the polarity on which the ground fault exists has been identified. If the ground fault detection circuit utilizes a balanced resistance network the next step is to disable that reference ground and the associated detection circuit.

With an ungrounded power system, the monitor ground reference is not a protective ground, so no electrical regulations are being broken by removing it. If this is not done, any attempt to follow a path to ground using a low frequency based location system will always lead to that reference ground of the ground fault monitor and not to the actual problem area.

Setting Up

To use a low frequency tone-based locator, the first step is to set up the transmitter and connect its output between the compromised polarity and a good ground point. The point at which the connection is made should be as close to the power source as possible. The battery rack is typically a convenient point at which the connection can easily be made. The actual set-up of the test equipment is specific to each instrument but will typically include ensuring that the correct level of signal is being injected into the circuit. Once the test signal is set up, the operation of the portable receiver, which will typically consist of a clamp-on current sensor and a handheld display which can be checked by measuring the level of the signal being injected into the power system. On some systems, depending on how the meter indicates the signal strength, a simple calibration may be required to set up the receiver display to show a full-scale reading at the point of insertion.

Phantom Grounds

Although these systems use a very low frequency typically between 10 and 20 Hz, any filtering capacitance in any of the load circuits may allow enough of the signal current to flow to ground and falsely indicate a possible resistive path to ground, this is what is commonly referred to as a phantom ground. As many of the previous generations of control systems did not require any reference to ground, the problems with phantom grounds were limited. Today, with the increase of computer-based controls which are powered by switched-mode power supplies, all of which require additional capacitance to ground to limit any high frequency emissions. This problem is now a lot more common than it was when control systems were all relay based. If the load is purely resistive then the AC signal voltage and current will be in phase but in a circuit with capacitance or inductance the relationship will change. On the GFL 100 that phase change in the received signal caused by the additional capacitance is shown in addition to the signal strength. This provides an indication that one could be following a phantom ground.

Finding That Ground

Once the test equipment is set up, the operator should move through the DC distribution network, following the strongest signal in the receiver. In many cases this will require the removal of covers from fuse or circuit breaker panels to allow access to the individual cables feeding the various loads. As many of these may feed further distribution panels, local knowledge or detailed distribution drawings are required, otherwise the task may take much longer and be more challenging than anticipated.

As good as the GFL 1000 is, there are often real-life operating conditions which present additional challenges to identifying that elusive ground fault,

Probably the most common problem is trying to isolate the internal ground fault monitors within the chargers themselves. When the charger uses the balanced resistor method of detection, that ground reference must be isolated, and depending on how that is implemented, it may be as simple as unplugging a separate sensor board or changing a link on the control board. On some chargers that may not be possible, and the output of the charger may have to be physically isolated. If one is lucky, that may be achieved by operating the DC output breaker, on others that may require that the charger is physically disconnected from the battery and distribution. This requires that the battery will be able to carry the load. A word of caution at one outdoor location when the charger DC output breaker was opened, the voltage at the battery dropped so rapidly it was clear that the battery would not carry the load so further investigation had to be abandoned. So, it is always a good idea to somehow test the integrity of the battery before relying on it to carry the load.

Summary

To summarize, the use of an injected low frequency based system is the best way to locate these elusive ground faults but like everything else, it takes patience and practice to get good at it, and no matter how good you are, there will still be challenges. Like the circuit you can't isolate, so you must wait for a shutdown, and of course the truly elusive one that only happens when it rains.