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Application Note

Battery Ground Fault Detection in Transformer-less UPS installations

Scope

There are important considerations regarding the detection of battery ground leakage current, particularly in UPS systems utilizing rack-mounted, flooded electrolyte batteries. Some older specifications require that the DC circuit be "floated" or galvanically isolated to ostensibly provide a "safer" battery for maintenance activities. The multitude of transformer-less UPSs, that are commonly in use today, do not float or isolate their DC circuits. How then is personnel safety ensured? Eaton's position is that battery isolation in the UPS can provide a false sense of security, and *should not be depended on* as a safety feature. This paper will describe recommended practices for ensuring battery safety, which do not require, or depend on, transformer isolation of the DC/battery circuit.

Rack-mounted battery safety

A battery system with exposed battery terminals, such as a rack-mounted system should be protected for shock hazard. The concern is that, if a grounded user touches a battery terminal, there is a direct path back to through the rectifier/charger semiconductors to the UPS ac input voltage, (or through the inverter to the UPS ac output voltage).

Some UPS designs "float" the battery system, using transformers on both the UPS input and the UPS output. No terminal of the battery is intentionally connected to ground. This would "allow" the exposed battery terminal to be inadvertently touched, without danger of electrocution, since, in this arrangement, there exists no continuous loop for fault current to flow. In Eaton's estimation, this conveys a false sense of security, because, **if there is an undetected battery ground fault**, the danger of shock is the same as if the battery were grounded. *For this reason, Eaton recommends NEVER TOUCHING A BATTERY TERMINAL, whether the battery system is "floating" or not!!!* Battery terminals should be treated with the same caution and respect given to any AC terminal in the system.

The incorrect perception that "battery terminals are safe to touch" can be a dangerous misconception, and should be, but is not always, explicitly stated in the cautionary sections contained in guidelines, procedures, and documentation associated with the battery. This is true for both rack-mounted and cabinet-mounted batteries.

Some UPS vendors will state that, since they have an input transformer, the rack-mounted battery is therefore "safer". Some purchase specifications will require that the battery be "isolated" or "floated" for safety. It is important to communicate to the purchaser, user, and the installer, that in order to "float" the battery system, an input isolation transformer, AND an output transformer, BOTH are required inside the UPS. If a UPS has only an input transformer, for example, then the battery is NOT floating. Remember, even a "floating" or "isolated" battery is unsafe to touch, due to the possibility of an undetected ground fault mentioned above.

It is Eaton's position that a transformer-based UPS provides negligible additional battery safety compared with a transformerless design. Eaton recommends that plastic or rubber battery terminal covers (much less expensive than transformers) be installed on battery systems with exposed terminals. Also, maintenance on rack mounted batteries should be performed with the battery breaker open. This eliminates the possibility of contact with AC voltages associated with the UPS. If the battery system is comprised of multiple strings, then there will typically be a breaker for each string, allowing the remaining string(s) to support the UPS if a power outage occurs while one string breaker is opened for maintenance.

Battery Ground Fault Detection

The requirement for battery ground fault, or DC ground fault detection, continues to appear in some UPS specifications. The (faulty) line of reasoning is, apparently: "I need a battery ground fault alarm to warn me when it's **unsafe** to touch the battery terminals." Refer to the paragraph above for compelling reasons why it is **never safe** to touch the battery terminals!

However, from the above discussion, we can see that timely and reliable detection of a battery ground fault may be useful. A battery ground fault occurs when an undesired conductive path develops from any point on the DC circuit to ground. (see figure below) This happens most often with rack-mounted wet cell batteries, where leaked or spilled electrolyte forms a conductive path from a battery terminal to the grounded rack. This can be a shock or fire hazard. The best preventative for this problem is to make sure the battery system is kept clean and inspected frequently, and all spills or leaks eliminated.

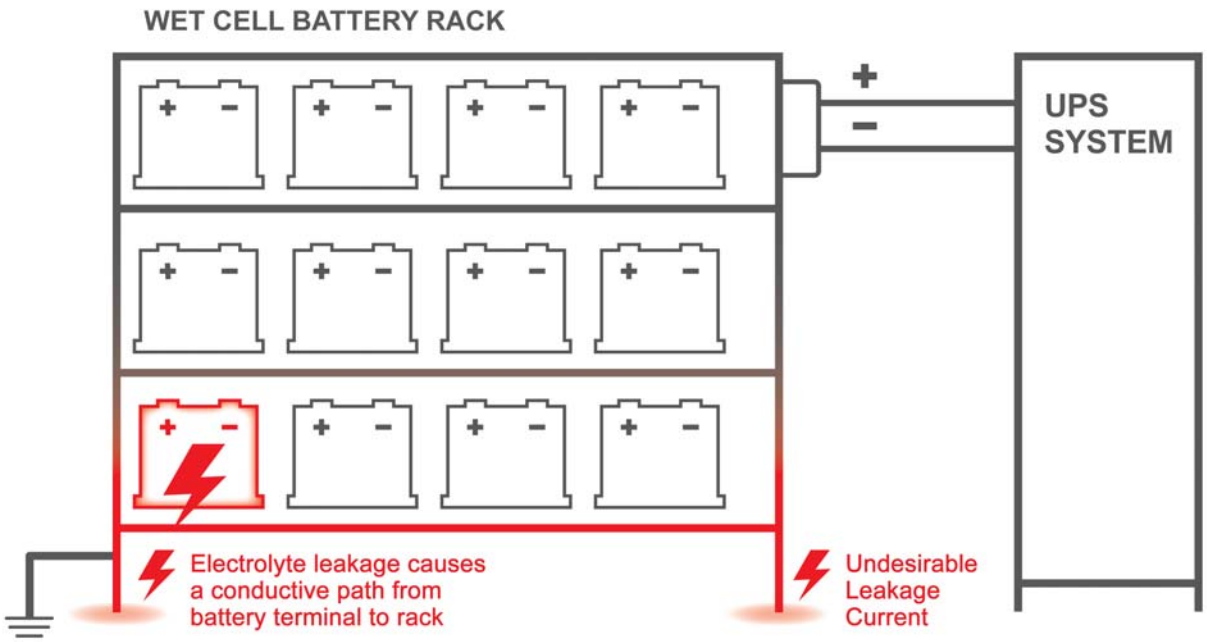

Figure 1: Example of Battery Ground Fault

Older UPS systems contained input and output isolation transformers, which allowed the battery system to be completely isolated from ground. This was called a “floating” battery. A single ground fault on a floating battery would provide a ground reference for the UPS system. The ground fault would not conduct much current but would cause the battery voltage to be unbalanced between battery plus (+) to ground and battery minus (-) to ground. A simple high impedance resistor divider network and a voltage monitor in the UPS was used to detect this imbalance and alarm the condition. Modern transformer-less UPS systems do not float their batteries, and most do not offer internal DC ground fault alarm capability. When a ground leakage fault occurs a small amount of current will conduct along the leakage path to the grounded battery rack. If a specification or RFQ requires DC ground fault detection, there are 3rd party ground current sensing and alarming devices which perform this function. The 3rd party device should be capable of measuring AC and DC currents down to 10mA to properly detect and alarm the condition.

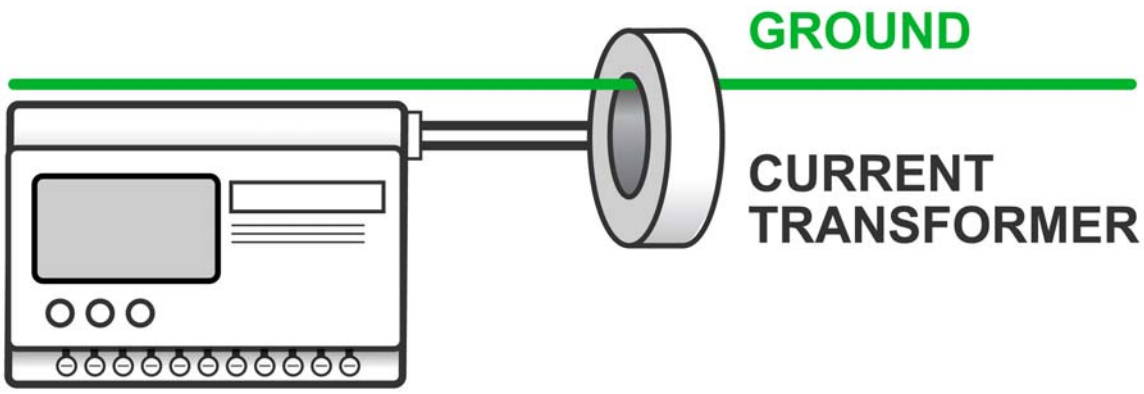

Figure 2: Example of an external ground leakage current detector

These compact devices can be mounted on the battery rack or on the wall in the battery room. This product provides a safety benefit, because ground faults are annunciated locally, inside the battery room, visually and audibly. Comparably, a conventional UPS ‘DC Ground’ alarm is annunciated on the UPS, which is usually located in a different room from the battery. If the intent is to warn the battery maintenance technician of a fault, why place the alarm in a different room? (Eaton can recommend detectors of this type, and they are far smaller and less expensive than the alternative, which is a pair of input and output transformers and a resistor divider network!).

When installing and configuring the ground leakage detector it is important to properly set the alarm limits to match your installation. Additionally choose a detector that has the ability to latch the alarm condition until manually reset by an operator, by nature the battery leakage may evaporate which would cause the alarm to be intermittent and clear itself before being noticed. An Eaton trained service engineer can help configure and setup your monitoring and detection for your system.

It should be noted that cabinetized, VRLA batteries are much less likely to develop ground faults, because their cases are "sealed". They are less able to leak, and this is the main reason that smaller UPS systems which use VRLA batteries seldom offer battery ground fault alarm capability. However, the 3rd party ground detectors described above can be used with VRLA batteries also, and provide the same benefits.

High Resistance Ground (HRG) input systems

Another possible option to facilitate isolation of the battery circuit is to operate the UPS from a "high resistance ground" source. Most often used in an industrial environment, this type of system minimizes the risk of service interruptions due to ground faults. The ground fault can occur anywhere in the system, including the line and load side AC wiring and battery room faults. A high resistance ground system enables the site electrical system to continue to operate with a single line-to-ground fault. The resulting current in the neutral-to-ground resistor will signal a "ground fault" alarm. The same condition will exist in a UPS system with a (single) battery ground fault. The unit will continue to run, but a battery ground leakage detection monitor will sense the ground current, and then can trigger an alarm on the monitor, and/or through a "building alarm" in the UPS. Note that not all Eaton UPS systems are intended to run from an HRG source. The 9390, for example, will require the Neutral Reference Kit for proper UPS operation.

Summary of Eaton Recommendations

For any stationary battery system, regardless of the topology of the UPS, Eaton recommends the following:

1) Use terminal covers on all exposed battery terminals and inter-battery links. These protect both from terminal-to-ground faults as well as from positive-to-negative faults.
2) Use a 3rd party DC ground fault detector, if a battery ground alarm is desired. Mount the detector and alarm indicator in the battery room, not in the UPS room.
3) Use insulated tools for all battery installation and maintenance to eliminate faults due to dropped tools. Use heavy duty rubber gloves during maintenance activities.
4) Open the battery string circuit breaker or disconnect switch before beginning any maintenance. This isolates the maintenance technician from the UPS and from any parallel strings. If there is only one battery string, we recommend operating the UPS on a backup generator, so that the battery can be isolated without putting the critical load at risk of a power outage.
5) Clean up any spilled electrolyte immediately. Remove corrosion, dust and debris from all surfaces of the battery. Inspect the battery system frequently for cleanliness.