

LOCATING GROUNDS ON FLOATING BATTERY SYSTEMS

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ABSTRACT

Power generation and substation battery systems are floated to allow for uninterrupted power system operations when grounds occur on the control circuits. A number of indicating instruments are used to alert the operator to the existence of an abnormal resistance to ground. Fault detectors (i.e., monitors), wide range ohmmeters, and lamp indicators are used to identify the existence of ground faults. Fault detector instrument systems do not show the explicit site of the fault; the instruments only alert the system operator that a fault condition exists on the battery system. See Figure 1 for an overview of indicators. A number of test instruments have been developed for tracking faults.

The original test method was to de-energize individual circuit banks and observe the response of the fault detector when and if the alarm was cleared. This method is dangerous, as critical circuits can be de-energized, which will upset the operation of a transmission or generating station.

The field testing methods to identify the faults can be improved using commercially available test equipment. Test signals of various frequencies are connected between ground and the battery system, and then the test signal path is followed to the ground fault.

System monitors are installed on large, integrated system. These systems are not included in this equipment review.

UNWANTED GROUNDS

The situation is that all the instruments report that a ground exists. Monitor bridge circuits measure the leakage current and indicate the associated resistance to ground. The voltmeter and lamp bulb systems only indicate that a fault exists on one side of the dc bus. If a fault of equal magnitude then occurs on the other side of the dc bus, the voltmeters or lamps could show balanced voltages to ground. The fault condition has become more critical, and the operator assumes the ground has disappeared. Now, test equipment is available that permits tracking of the fault without having to de-energize any part of the operating system. The test methods to be discussed are methods for finding faults.

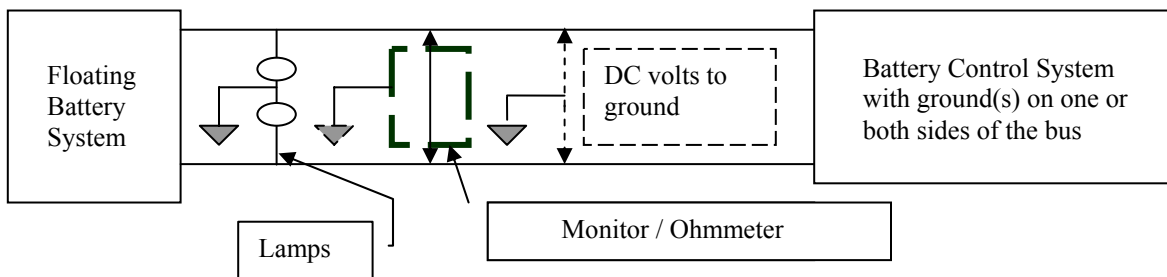


Figure 1: Floating Battery System Fault Indicators

WHAT IS BEING MEASURED WITH THE FAULT DETECTING DEVICES?

Ground monitors test the leakage resistance to ground of all the control circuits connected in parallel. This is the insulation resistance of all the parallel-connected control circuits. When excessive leakage current occurs on a circuit or group of circuits, the monitor shows this deterioration by reporting a decreasing circuit insulation resistance value. Lamps, voltmeters, and alarms are tied into the overall control system to notify the operator that problems are getting worse or when a problem has cleared. In addition to the control circuits, electrolyte leakage in the battery string can cause a ground fault indicator to alarm by shifting the balance of the voltage reference of the mid-point voltage. In most situations, we would discover water migration into remotely mounted control elements, pinched leads, or errors in rewiring circuits after an element change. Grounds can be elusive and difficult to locate.

HOW IS THE ALARM LEVEL DISPLAYED?

The system operator should be aware that an indication of $100\text{k}\Omega$ ($0.1\text{M}\Omega$) on a system that normally operates at 10^3 megohms would not be a problem. The problems become more apparent when a second circuit develops a $100\text{k}\Omega$ fault; with two parallel faults, the monitor will show $50\text{k}\Omega$. The monitor will show the progression of faults as they develop in the network. When additional $100\text{k}\Omega$ circuits develop leakage to ground, the system may report down to the $10\text{k}\Omega$ fault level. It is advisable to stay on top of the decreasing insulation resistance conditions reported by the system monitor. Some monitors show the progression of the system faults as follows.

In Figure 2, the higher insulation resistance group has white alert lamps, yellow warning lamps on the $50\text{k}\Omega$ to $30\text{k}\Omega$ middle groups, and red alarm lamps on the critical $20\text{k}\Omega$ and lower resistance levels.

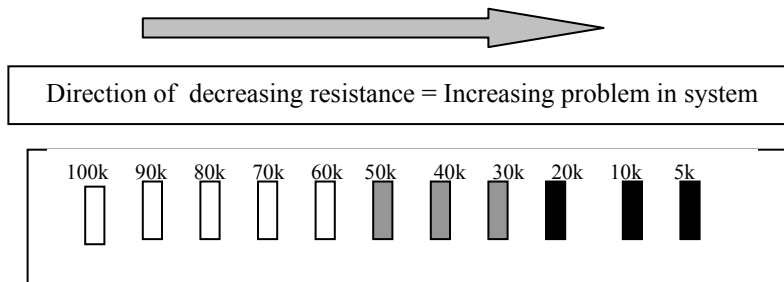


Figure 2: Ground Resistance Detector

In Figure 3, the ohmmeter, typically with a log scale, shows the progressive drop in the isolation of the floating battery system to ground, with 100k , 10k , 1k , 100Ω and 10Ω levels indicated on a log scale. The older voltmeter indicating system shows the voltage to ground from each side of the dc bus. The older systems use a set of lamps. (See Figure 4.) One lamp is connected from each bus terminal to a grounded common connection. An even glow shows balance; a change of brightness of one of the lamps indicates a fault on the system. This system does not give any objective indication of the severity of a fault on a floating battery system.

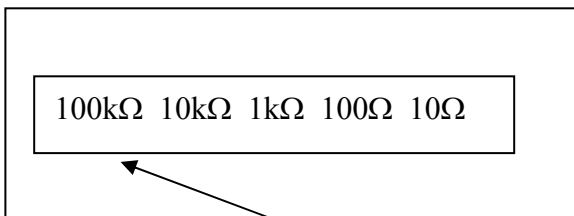


Figure 3: Ground Resistance Indicator

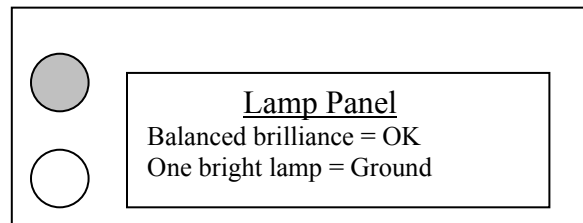


Figure 4: Ground Imbalance Indicator

Floating battery systems should have a common characteristic: the capacitance to ground from each side of the bus should be balanced, as each circuit pair contributes its own capacitance and leakage resistance values to ground. (See Figure 5.) With identical lead pairs having the same (pfd/foot) capacitance, we should have balanced capacitance readings to ground. If the capacitance values from each side of the bus are not equal, then a voltage divider is created, which can cause unbalanced voltage reference to ground.

GOOD DC CIRCUIT PAIRS CREATE A BALANCED VOLTAGE TO GROUND

The detector circuits react to an unbalanced voltage alarm when the balanced leakage paths are upset. The indication of unbalance is not limited to the insulation resistances. The unbalanced ground reference can be created by locating different noise filters from each side of the battery bus to ground. The capacitance values must be equal, otherwise a voltage division is created. This ground reference will be evident in all the circuits, and the level of the signal will be inversely proportional to the impedance of capacitor to ground. Some test methods identify the circuit and the magnitude of the capacitance to ground.

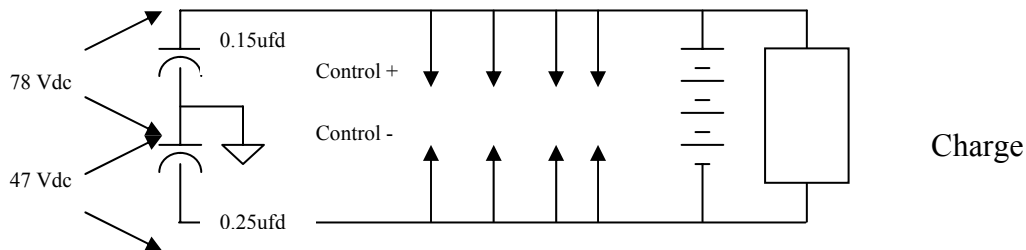


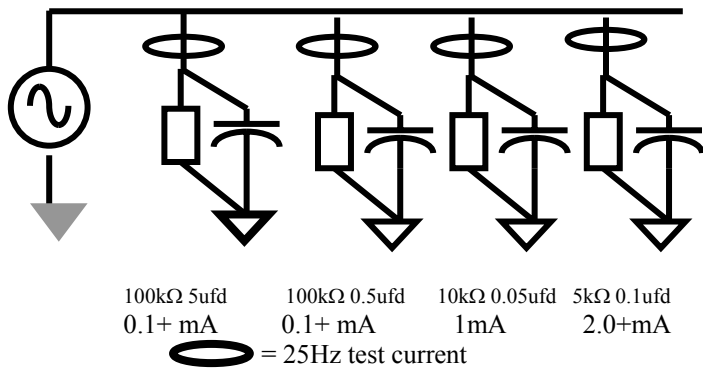
Figure 5: Ground Reference Upset by Filter Capacitors

To review, the methods of identifying the location of the fault are as follows:

1. The most dangerous method is to randomly open circuit breakers and observe what occurs on the fault indicator. The danger is that the operator may not realize how all the safety circuits are interconnected.
2. High frequency test currents are injected between the bus and ground. The signal will be present on all the control circuits. The high frequency will flow to all the control circuits, which have capacitance to ground. The signal will identify phantom faults, and longer control circuits will be falsely identified. These phantom faults cause the trace current to get weaker as the operator gets further away from the source of the test current. The operator will be wasting time tracing the phantom circuits.
3. Low frequency – pulsed dc current, using the battery system as a current source, can cause problems. The operator can induce a dc current level that may cause a relay to drop out. If the fault is on the negative side of the bus, the test current is derived from the positive side of the bus and is passed through a pulsing circuit on which the level of the pulse is manually adjustable. A pickup clamp-on meter is used to identify the circuit path with the pulsing current. The incorrect setting of the test current and the type or location of the fault may cause a control circuit to be activated.
4. Low frequency – low level signal level current (low frequency sinusoidal or pulsed dc signals at a low current level) with a tracer circuit established to identify the tracer signal can identify both phantom and hard faults.

LOW FREQUENCY AC SIGNAL (CURRENT) TEST METHOD

This method has been used extensively in the field with great success. The transmitter uses a soft start procedure that electrifies a coupling capacitor connected to the side of the bus with the lowest dc voltage to ground. The initial soft start step minimizes the creation of any transient signal that could upset noise sensitive relays in the control circuit. Then, after a short time delay, the transmitter introduces a weak, low 10Hz to 25Hz signal across the faulted side of the battery system to ground. The typical low frequency signal is distributed across all the circuit nodes. All the paths of the circuit will use some of the weak test signal; the bulk of the signal current will be distributed to ground by the capacitance of the circuit leads. The ground fault or faults will show the balance of the connected signal current. This minimizes the amount of current that passes through the control elements that are not part of the ground fault.



All circuit pair of leads will have some measurable signal current reading. The magnitude of the leakage current to ground will be inversely proportional to the resistance to ground. Those circuits with high capacitance to ground will show high signal currents that will be a function of the circuit length and may be labeled as phantom faults.

Figure 6: Typical Ground Fault Elements

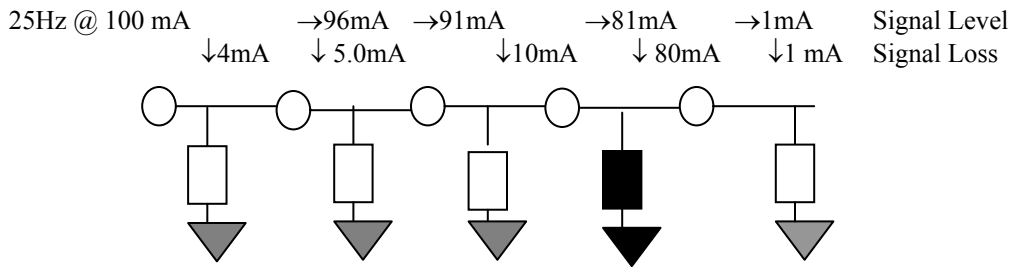


Figure 7: Ground Fault Tracing

An operator then moves from distribution panel to junction box to follow the current to ground. When the test signal is lost, the operator has located or has passed the point of the fault. When a number of circuits show high levels of signal flow, a feedback circuit coupled with a capacitance and resistance bridge, or a resistance/capacitance identification display, are used to determine the nature of the fault to ground. This identifies phantom faults, which are the longer control circuits. The elimination of tracking a phantom fault improves the speed of locating the actual fault. The presence of multiple faults can be established at the offset of the testing, as more than one fault may exist on the dc control system.

The signal used to stimulate the test method is normally performed at 10 to 15Vrms, with a typical 100mA of test current. This signal is introduced across the battery system via soft start circuit. The typical signal imposed on a 5kΩ fault would be 2 to 3 ac milliamperes. The balance of the test current will be distributed through the leakage resistance and capacitive reactance of all the parallel circuits. When operating in a battery system with noisy inverters, the test current can be increased to override the noise in the system. The test current may not have to be raised if the operator connects the tracer detector around the circuit pair of leads. The noise signal on the positive line will then be 180 degrees from the noise on the negative line. This cancels the noise, and the search for the faults is conducted at the nominal signal level. With hard shorts to ground, the test voltage may be less than 5Vac to generate a suitable tracking signal.

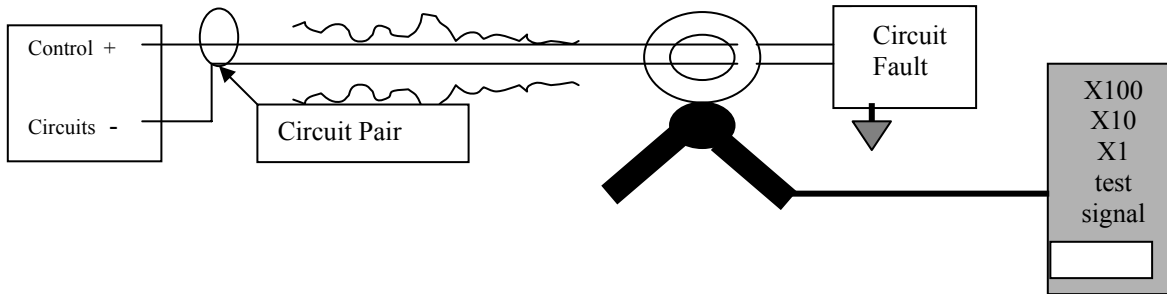


Figure 8: Noise Reduction

The operational steps should include the following:

1. Isolate the fault monitor from the battery system.
2. With a voltmeter, measure the Vdc from each side of the bus to ground. This will identify the side of the system with the fault to ground.
3. Measure the Vac to ground from each side of the bus. If ac voltage exists, determine the cause and correct the situation. This voltage source may be the cause of the ground fault.
4. Have the line diagrams for the system available for guidance when tracking faults. The circuit start and end locations, from the distribution panel to the next junction box, are valuable information. This will reduce the time needed for tracking fault signals through the system.
5. Alert the system operator of steps being taken; notify the operator when entering junction boxes and performing tests.
6. When clearing faults, retest the Vdc from the bus to ground to determine if additional faults remain on the system.
7. Do not forget to check the battery string; you may find an electrolyte path to ground.
8. Reconnect the fault monitor to the battery system.
9. Has the system returned to balance? If not, start over again.

FIELD OBSERVATIONS

The information in this paper is from field testing.

- The sites varied, from old, stoker-fired plants with wiring 40+ years old to newer, gas-fired plants, and many nuclear plants. In addition to power plants, distribution and substation ground faults were identified and cleared.
- Due to the nature of the testing which, in general, is non-invasive, the system operators should, at all times, be consulted prior to conducting any tests.
- When the location of the fault has been determined, the final clearing of the fault may be performed during less critical load generation periods.
- When systems have parallel-connected chargers, it is advisable to isolate one of the chargers for the duration of the test. These units can be a source of excessive noise that may mask the test signal.
- Observe the dc load on the system, and verify that one of the chargers has the capacity to carry the present load.
- Do not trust the fault indicator panels. Always make an independent voltage test to verify the side of the bus with the ground fault. Some indicators may be wired for reverse indication.

CONCLUSION

DC control systems are floating, so that the power generation and/or distribution system can continue to operate with one hard ground on one side of the bus. The system engineers should be in a position to take corrective action when the ground fault detector indicates resistance to ground. The resistance level at which this corrective action becomes critical should be established. Maintenance teams should be schooled in the test procedures on a regular basis. Because ground faults can occur at any time, electricians should be given periodic training so that corrective actions can be performed efficiently. The testing to determine the fault location is performed on-line; therefore, the electricians who perform the operation should always be aware that 125Vdc or 250Vdc may be present on a control circuit element. When conditions occur that the operators may not understand, do not hesitate to contact the instrument manufacturer to clear up any misunderstanding on the operation of the instrument.