Ground System Testing - Fall-of-Potential & Alternative Testing Methods

Most installations of grounding systems follow the very minimum requirement of the National Electrical Code. These installations will consist of one or two rods driven to a depth of 10 or less feet. Why? This is all the contractor must do to meet the code or minimum electrical system requirements. Without further instructions he will only complete the scope of work as outlined.

Once a grounding system is installed, in 99+% of the time it is not properly tested for resistance (performance). In .5% of the cases it is tested improperly, if tested at all. Less than 1% of grounding installations are tested properly by a qualified and experienced technician with the proper equipment.

Why do you need to test grounding systems?

Good (low resistance) grounding systems enhances life safety.
Reduces standalone and networked systems noise.
Protects from lightning and unwanted voltages.
So power surges and impulses can be shunted by surge protection devices.
So circuit breakers can function properly.
So lightning protection systems can operate properly.
(For other reasons – See Grounding & Bonding – The Basics)

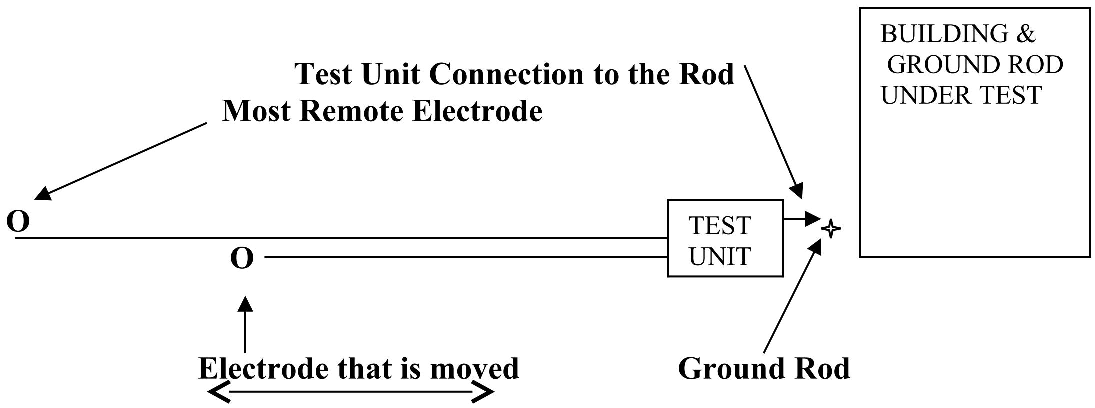
Proper installation procedures call for grounding to be tested during system installation. This allows for equal potential grounding installation and eliminates any potential hot spots (high resistance components) in the system.

A driven rod installation should have individual rods tested during and after installation and overall system testing upon completion. Once the completed system has been tested, it can be certified to the owner and a base point can be established for the recommended annual testing. In lightning prone areas, it is recommended the grounding of a sensitive facility be tested annually.

Testing is recommended to be by the fall-of-potential method. It should be completed by a trained, experienced technician using test equipment in current calibration and following the equipment manufacture operator's manual. The fall-of-potential method is often referred to as the "three point method". Utilizing a ground resistance meter (digital is preferred), two auxiliary electrodes are driven into the soil at predetermined distances, per the testing specifications, in a straight line from the ground being tested. Grounding mats and grounding systems, other than rods, often require a modified test method. If you have questions for these test procedures please contact PSI directly. During a normal test of ground rod(s) the meter supplies a constant current between the ground rod(s) under test and the most remote auxiliary electrode. A series of measurements of the voltage drops between the ground rod(s) under test and the remote electrode are made by moving the intermediate electrode in steps away from the ground rod under test. The goal

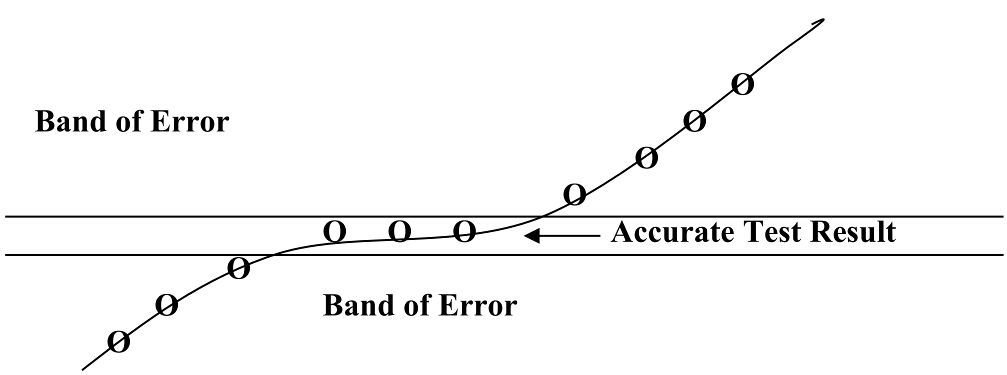
is to reach the actual rod's resistance and this is most often reached at the 62% distance point.

Accurate testing is confirmed by testing a second time in an opposite direction. See the diagram below for a very basic outline of the test equipment placement and testing procedures.



The most remote electrode must be placed a minimum of 5 times the distance of the length of the ground rod being tested. It is preferable the most remote electrode be placed a distance equal to 10 times the length of the rod under test. During the test the neutral must not be connected to the ground rod. The neutral / ground bond must be disconnected as the current flow on the neutral will invalidate the test results and not all the test instrument to provide an accurate reading.

When graphed, the series of measurements of the voltage drops between the ground rod under test and the remote electrode when graphed will provide a chart that will look like the one below. The band of error will be those areas outside the flat part of the graph.



A highly trained, experienced technician will be able to determine the resistance of the ground rod after a number of readings are taken by moving the intermediate electrode away from and then closer to the rod under test. The most remote electrode must remain in the same position for the results to be accurate.

If the test results are "too good to be true", in most cases they are just that not accurate. There are a number of reasons the test results are not accurate. (In no special order)

- Neutral is connected to the ground during the test.
- The distance of the conductor is too short for the length of the rod installed.
- The instrument being used for the test is not accurate.
- The technician does not know how to use the instrument properly.
- The leads are not extended away from any possible source of interference. (Run parallel to the building foundation that is bonded to the ground rod)
- Pipes (metal) that are bonded to the ground rod are run under the area where the test electrodes are placed. (A good reason to test in more than one direction.)
- The utility phase and neutral conductors are run in the ground in the area of the test electrodes.
- Metal conduit, bonded to the ground is in the area of the electrodes.
- Weak battery installed in the test equipment.
- Test is completed during or after a hard rain and soil conditions are wet.
- The ground rod or area has been "salted" with something to improve the test.
- The test was a one shot test and the intermediate electrode was not moved to determine the band of error.
- Rod(s) under test are bonded to another structure on the site that is in the area of the auxiliary and remote electrode.

The above list does not comprise the only "errors" that can be made.   Rods driven to depth require the test instrument be equipped with very long wires running between the test instrument and the remote and auxiliary electrodes. If the test instrument will not automatically adjust for the wire length involved, the readings will not be accurate. In this case, the technician will have to refer to the test instrument manual and also complete a resistance test of the test leads. After a calculation (to include the resistance of the wires), accurate testing can be completed and graphed.

If readings are not taken in the area of 62% of the remote electrodes wire length by placing the auxiliary electrode either side of the 62% point, the test results are not accurate.

There are test situations where fall-of-potential will be difficult at best. Hilly terrain and deep driven rods are but one case where fall-of-potential may prove to not be the best method. There are times when 5 or 10 times the rod length may be difficult. How do you measure a ground rod in New York City on 5^{th} Avenue? What if you cannot disconnect the neutral / ground bond?

AEMC has an answer for these situations. While not as accurate, but very close to the accuracy of the fall-of-potential method, the AEMC instruments are the best substitute for a fall-of-potential test.   LEM NORMA GmbH also has instruments

that perform very accurate testing without using the three point, fall-of-potential method.

These instruments take advantage of the connection between the ground and the utility neutral. The fall-of-potential method requires this bond not be in place. The AEMC jaws contain two current transformers (CTs) and the LEM instruments are provided with clamp on CTs. One CT induces a high frequency, fixed voltage into the conductor. If a continuous circuit exists, a resulting current flows. The second CT then senses and measures the flowing current. The instrument already knows the amount of voltage induced, and it can calculate the resistance in Ohms and display the results. AEMC also has an answer for those installations where it is dangerous to use the AEMC clamp on models. The AEMC 3780 has sensing units that can be separated from the reading unit.

The goal of this article is to stress the importance of proper grounding design and testing. If you have any comments or questions, please contact PSI.