The ART of Ground Testing

Until the most recent decade, the design and operation of ground testing instrumentation was derived from the requirements of the recognized standard, *IEEE 81, "IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System"*. This document describes the proper way to perform a resistance test of a grounding electrode (ground rod, grid, counterpoise, or any other deliberate contact with earth for the purpose of grounding an electrical system). By extension, the method dictates the requirements of instrumentation in order to meet it. The use of generic ohmmeters (for instance, multimeters) is not recommended for a variety of reasons, the most important of which is that the test result cannot be proven reliable. It simply must be accepted, much like the reading on a voltmeter.

But most electrical testing is performed on a discrete and limited object (a motor, a circuit). The parameters of both tester and test item are fairly well defined and known. If the instrument is well designed and manufactured (that is to say, the prime objective is the measurement, not the price!), then readings can be accepted at face value, with confidence. But with ground testing, all bets are off! When the electrode makes contact with the earth, it does literally that...makes the entire planet Earth part of the electrical system. This is the basis for terms such as "infinite earth" or "remote earth" that sometimes appear in the literature of ground testing. We cannot test "infinite earth", but we *can* test all but an infinitesimal part of it...that which surrounds the buried electrode in the (more or less) immediate area. It is in *defining* this area...the effective resistance field surrounding the buried electrode...that ground testing faces its challenge. When we test a motor, we (should) know exactly what we're testing. When we test a ground, the method must define the measurement.

To illustrate this concept, one can compare the long-accepted and popular method commonly called the "Dead Earth" method. This ominous sounding term actually refers to the use of a non-electrical (hence "dead") remote return in order to complete the test circuit. With a generic two-terminal multimeter, the second lead is commonly attached to the water-pipe system, although other convenient objects, such as metal fence posts, are also used. The tester will then make a loop resistance measurement of the entire circuit. It is presumed that soil resistance makes up nearly all of this value, and that lead resistance and that of the remote return are negligible. So, the test operator does in fact have a measurement, but what does it mean? (It might be pointed out that a ground tester, employing an ac signal, is superior for this test to a dc multimeter because it can eliminate noise interference and will not "load down" under the long lead length that may be required.) Among other problems and limitations, the volume of soil that is being measured between the test ground and the remote may not be representative of the actual resistance from the test ground's field or electrical "footprint". And there is no way to know. One can merely position the return connection as far away as possible, and hope. The measurement may be accurate, and it may not.

The "Dead Earth" method *is* recognized in *IEEE81*, but only with appropriate caveats. It can be used successfully as a convenient backup test at sites that have already been proofed by the comprehensive and reliable method, Fall of Potential. It is this method that is the primary focus of the standard, and hence, the basis for tester design and function. Fall of Potential, and its attendant instrumentation, gives the operator *total* control of what is being measured, and if done in a four-terminal configuration, yields a pure measurement of earth resistance *only*. The operator positions a remote return current probe in order to complete the test circuit, but the procedure doesn't stop there. A *separate* potential circuit with its own probe enables the operator to *profile* the test area in order to average out anomalies, eliminate the resistance of the return from the measurement, and determine the maximum resistance to be encountered by ground currents. This makes the procedure thorough and reliable, but it's also labor intensive and costly in terms of man-hours.

Throughout most of the last century, while instrumentation steadily improved in performance characteristics, it still adhered to the model established by Fall of Potential. Not until the 1990's was there a departure into a wholly new type of instrument, with the introduction of clamp-on testing. This technology eliminated the use of leads and probes, hence became radically less labor-intensive, by effectively addressing one of the serious limitations of the popular but risky Dead Earth method, the resistance of the remote return. The clamp-on ground tester inductively establishes the test current by clamping around the test ground. The induced current seeks its own return path, typically by utilizing the paralleled multiple returns of the utility through the grounded neutral. In one step, clamp-on instrumentation eliminates three of the major limitations of the old "Dead Earth" shortcut method: there are no leads to string, noise suppression can be accomplished through appropriate techniques, and most important, multiple parallel returns reduce extraneous resistance to a negligible factor.

But for all the advantages, there is still a serious limitation: the measurement cannot be proofed. Like a simple multimeter reading, it has to be accepted at face value. So long as the operator is *absolutely certain* of the ground path or paths, clamp-ons can be employed with confidence. But their extreme ease of operation mitigates against operator involvement. Just clamp and measure seems to be all that is necessary. But being out of the operator's control, the test current will find its own return. If one exists completely through metal, as on a multiply bonded system like a utility substation, the current will not have to enter the soil at all. It will give a reading that is merely the continuity of the grounding structure, but the unsuspecting operator will take this to be a (very good) ground measurement. If a client were paying for the service, the client would have no way of knowing that the tests were improperly done.

Fortunately, a modified technology exists which combines the traditional and clamp-on techniques in a way that compromises their limitations while taking full advantage of their strengths. This can be called the **ART** (**Attached Rod Technique**) of ground testing. Traditional (i.e., Fall of Potential and its modifications) and clamp-on techniques diverge on the testing of attached (i.e., connected to the utility) grounds. Clamp-ons very conveniently test grounds that have been connected. They *must* have this (or a similar) connection in order to complete the test circuit. But a traditional tester employs its own separate return, via a probe placed by the operator. If the test ground has been connected to the utility, the tester will measure the entire system, utility grounds included. Test current will divide according to the Law of Parallel Resistance. If this division of current could be measured, the respective contributions of the utility and test grounds could be calculated. This is theoretically possible, but just not practical under field constraints. But clamp-on technology makes it possible for the divided currents to be measured and automatically calculated into the resistance reading.

The "ART" tester will have a clamp-on ammeter built into it, along with the terminals for traditional placement of leads and probes. By clamping below the point of attachment to the test ground, the clamp measures the amount of current going to ground through the test electrode, as opposed to the total test current or the portion flowing back through the utility neutral. Only this current is used to calculate resistance through standard Fall of Potential procedure. The voltage probe is moved and resistance values graphed against distance to probe, strictly according to *IEEE81* procedure. The only difference is that the measurements are being made against the current through the local ground, with that portion diverted by the utility ground ignored. The procedure is fully in accordance with the accepted standard, and the graph it produces will prove that the measurements were taken correctly.

In summary:

▪ Clamp-on technique will separately measure attached (to utility) ground.

▪ But it cannot be proofed; must be accepted as correct.

▪ Fall of Potential (or derivative) method cannot separately measure attached rod without complicated measurement of separate currents and manual calculations.

▪ Tester with ART technique can test attached ground while affording Fall of Potential proof.

A fully equipped ART tester, therefore, can maximize both effectiveness and reliability in all (Fall of Potential, clamp-on, and attached rod) testing situations.