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Measuring Ground Resistance – The Fall of Potential Method

The basic procedure for testing ground electrodes is described by The Institute of Electrical and Electronics Engineers in IEEE Standard #81, *IEEE Recommended Guide for Measuring Ground Resistance and Potential Gradients in the Earth*. A grounding electrode is defined as “a conductor embedded in the earth, used for maintaining ground potential on conductors connected to it, and for dissipating into the earth current conducted to it.” It should be obvious that the efficiency of the electrode is inversely proportional to the resistivity of the surrounding earth. Ideally, it would be nice to have a resistance of “zero,” but that is not practically realizable. Values of a fraction of an ohm can be achieved, however, with appropriate diligence applied to the design. A reliable means must, therefore, be available to test the efficiency of such an installation. Note that while grounding electrodes can vary from a single rod to a grid or array that is several

hundred feet across, the fundamentals of testing are the same. There are some comparatively minor considerations in technique and procedure

that apply to specific types of electrodes, but the similarities far outweigh the differences in testing across the spectrum of electrode designs.

The most fundamental and general of procedures is called “fall of potential.” There are others, generally devised with an eye toward simplification, but they suffer from notable limitations that are included in their IEEE 81 descriptions. The most thorough and reliable method is fall of potential. Its shortcomings are largely psychological, so it is worthwhile for the operator to understand what the test is doing and why.



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Lab technicians generally work in a controlled environment in which the technician is master of the situation. Circuitry and components are laid out according to a schematic which rigorously guides the investigation. Measurements tend to be predictable or, if not, point the way toward their correction. A ground test, on the other hand, is being performed on planet earth. Any alteration of results is likely to involve some form of excavation. This can be intimidating to someone trained on a bench. Field workers are used to "thinking on their feet" in atypical situations. But the rigors of a fall of potential test tend to seem impractical, and they would like to have something more cost-effective.

Remember, a ground test is not being performed on a circuit in the conventional sense, where current is being neatly directed from point to point by human design. Rather, it is governed by nature, in the form of local soil and geological conditions, and it is the human who must adapt. That does not sit well with many operatives. But it is precisely what the fall of potential test was designed to address. Current going to ground via a buried electrode is not constrained to follow a straight-line path in the way we commonly think of electrical current. This is a critical difference in the nature of a ground test. Fault current radiates in all directions from the electrode. It is the ability of the surrounding soil to accommodate this pattern of dispersal that determines how good or poor the ground connection is and to which the test procedure and instrumentation must be adapted.

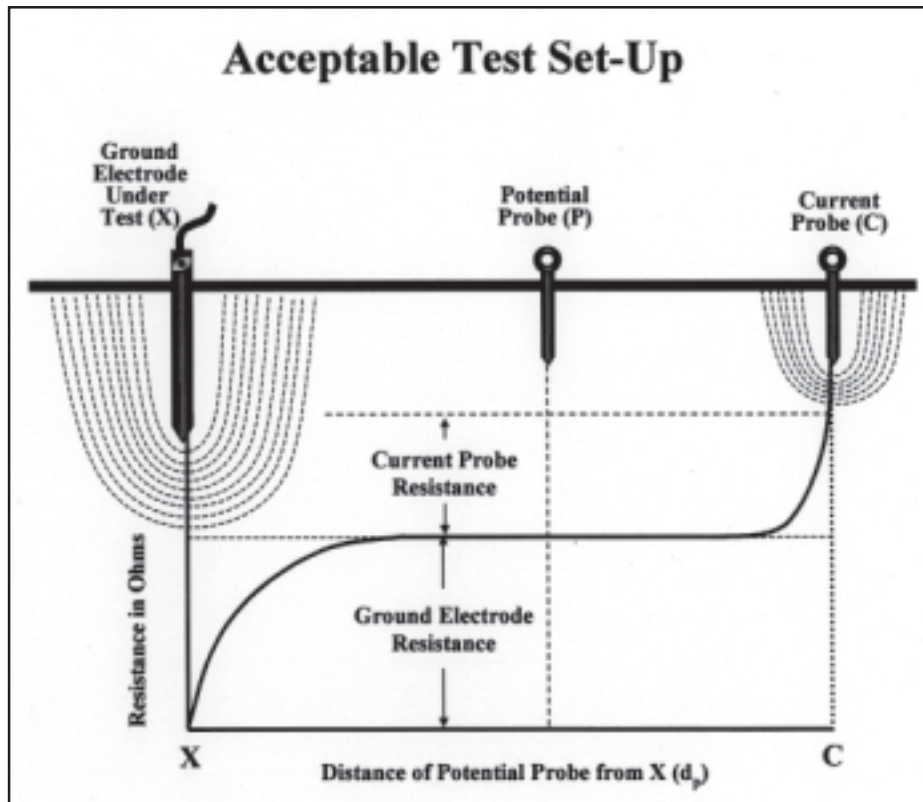


Figure 1

When an electrode is buried and the electrical system tied to it, an electrical connection has been made with the entire Planet Earth. This sounds like a tall order! But, in fact, one need only be concerned with the immediate environment. It is like a Physics 101 question: if you fire a gun, does the Earth recoil? Yes, it does, but to such an infinitesimal degree that it is of no consequence, except possibly to musings on the theoretical level. Grounding acts much the same way. Fault current going to ground encounters resistance from the immediate environment, but because it is free to spread out in all directions, attenuation is rapid. If this were not so, the whole concept of grounding would be ineffective! In a conventional circuit, the gauge of the wire holds this parameter constant. But in a ground circuit, the current path is rapidly expanding with distance from the electrode. The net effect is that any significant resistance is concentrated in the area immediately around the buried electrode. Beyond a critical distance, the rest of the planet offers so little additional resistance as to be, like the recoil from a rifle, of no practical consequence.

This phenomenon can be thought of like the dirt around the roots of a balled tree. A certain critical volume is required to maintain the tree. Similarly, a critical volume of soil surrounding the electrode determines its capabilities. In fairly standard environments, with moist, water-retentive soil, this volume is small, perhaps on the order of twenty feet or so. But in difficult areas, with dry, sandy, or rocky soil, it can extend hundreds of feet. Further, a temporal effect superimposes upon the basic relationship of electrode design to surrounding soil. Rainfall contracts the field of influence and lowers resistance. Dry conditions and freezing expand and increase it. A test method, therefore, must be flexible, adaptable, and understood.

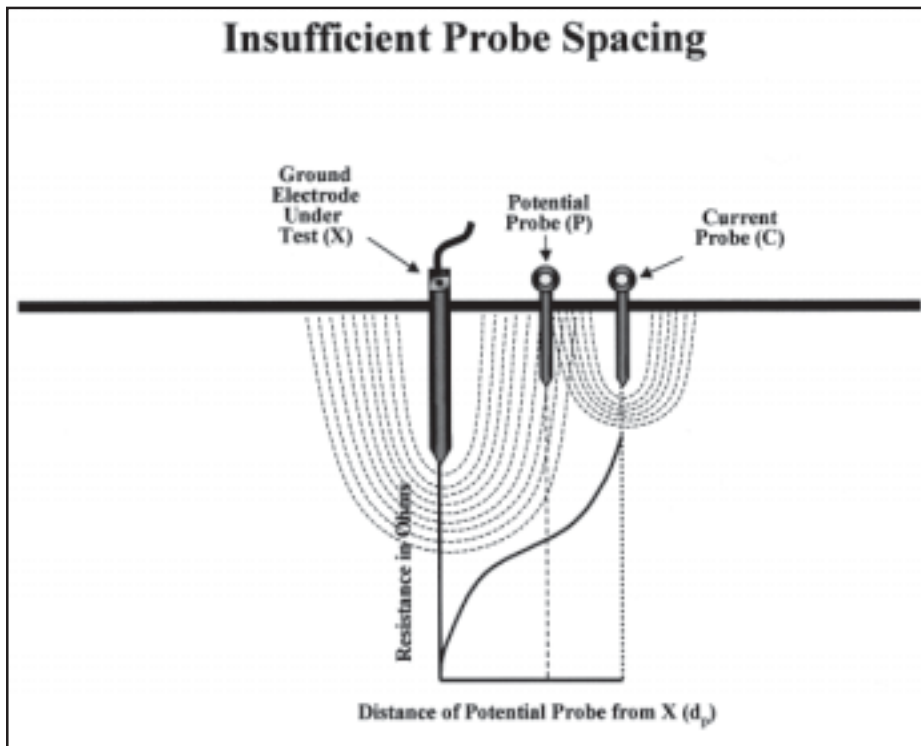


Figure 2

A fall of potential test is the most general of methods for meeting the above criteria. It may also be referred to colloquially as a “three-point” test, although this term is also applied to a separate test that is likewise defined in IEEE 81. With reference to fall of potential, three points of contact are made with the soil. One is the connection to the electrode under test. The other two are probes that the operator places in the soil, one for current and the other for potential. The test set acts as a current source, and the current probe establishes a circuit through the soil via the electrode under test. The potential probe then senses the voltage gradient established by the test current against the local soil resistance. With current and voltage drop accurately measured, the test set simply uses Ohm’s law to calculate and display the resistance.

Simple, right? Yes, from the standpoint of theory of operation, it is. To avoid polarization effects, the test sets commonly employ an alternating square wave current. IEEE suggests this be at or near power frequency. A slight offset from multiples of the utility frequency enables the test set to base its reading on its own signal without interference from utility harmonics. Lightning strikes occur at high frequencies, and both those and ground faults can involve enormous currents. Some test sets do operate with high frequencies and currents, but these are dedicated toward specialized investigations. For everyday practical use, microprocessor sensitivity permits test sets to be portable and simple to operate while affording a reasonable approximation of the test ground’s capabilities when called on-line.

The complication that many find frustrating is the procedure. Technicians are used to hooking up and taking a reading. With ground testing, it is not that simple because one is not working on an isolated circuit. A common error is to simply run the leads provided by the manufacturer out to their full length and read accordingly. If this results in an accurate test, it is purely by luck because the infinite variability of earth defies the establishment of set routines. To be reliable, the potential probe is “walked” at regular intervals and a series of readings taken. When graphed, the result should be a rising curve where the probe is within the influence of the test electrode and then a leveling off. See Figure 1. Within the influence of the current probe, an additional resistance is superimposed, so the curve will rise again. It is the value recorded at the level point that is the measurement of the test item’s resistance. Readings taken within the test ground’s sphere of influence (on the rising curve) only reflect the resistance to that point, not the resistance that will be felt by a fault current. If there is insufficient spacing between the electrode under test and the current probe, there is no location where the potential probe is outside the influence of the other two probes and the graph does not become horizontal. See Figure 2. Test results can be readily manipulated by moving the potential probe close to the test ground, but that would not be the true resistance of the electrode.

Installation and service contracts are often written with a clause requiring that a full fall of potential graph be constructed and submitted as the test result. If the current probe was not located sufficiently distant, the two spheres of influence would coincide. Resistance would continue to rise with each probe placement, and there would be no way to tell from the graph how much resistance was associated with the test ground. The “proof” of the result, therefore, is included in the procedure. If it does not graph out with the characteristic shape, the current probe must be moved farther out and the procedure repeated. Tables appear in the literature relating current probe spacing to electrode dimensions. These are intended only as a help, not as a rule. They provide a fairly good chance of having an acceptable test on the first try. But, if for reasons of practicality, a shorter distance is used, and it yields a coherent graph, the result is good.

Numerous other methods exist. Some are independent, but many are based on simplifications or special adaptations of fall of potential. Understanding how and why this test method was devised provides a foundation for the whole field of ground testing.

In the next issue, we look at the slope method. 

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