

An Introduction to Ground Testing by Megger®

Before performing a ground test, it is advisable to develop a working familiarity with two important concepts: how the tester accomplishes the measurement and what the operator must do to assure a proper test.

Choose the Proper Instruments

The first consideration is helpful in the selection of an instrument and the fundamental application of the test. Ground tests are frequently attempted with a variety of ohmmeters that happen to be conveniently at hand. This practice is doubly damaging because it may result in an incorrect measurement that is accepted by the operator.

Two-point measurement with a multimeter will give a loop resistance of the circuit that is defined by the arbitrary points of connection, and this will include in its path the soil between those points. But, so what? This is not necessarily an indication of the electrical condition that the ground electrode has established with the surrounding soil. Furthermore, the measurement itself can be made inaccurate by the influence of transient currents that travel in the soil from a variety of sources.

Understand the Test

To perform a ground test, a dedicated ground tester, not a generalized ohmmeter or multimeter, is requisite. The manner in which the ground tester uniquely accomplishes its purpose is diagrammed in the accompanying simplified schematic. Its operation is similar to, but in a sense opposite, that of the familiar Megger[®] Insulation Tester.

The instrument uses two precise measuring circuits (voltage and current), and combines the values through Ohm's Law to give the desired measurement (resistance).

The two test circuits are established through the soil by strategic placement of probes, attached via leads to their respective terminals. The current terminal, lead, and probe set up a test current of a unique, square wave frequency, apart from the harmonics

of utility power, through the soil to the ground under test. It is only this current that contributes to the measurement, leaving interfering transients out. Likewise, the voltage probe enables measurement of the drop over the soil to its critical point of placement.

Both circuits are completed by connection of a second pair of terminals (or a common in the case of three-terminal testers) to the ground under test. (See Figure 1.)

Understand the Test Environment

Providing the most applicable and highest quality tester, however, is only the first part of the operator's responsibility. No ground tester can perform a successful test all by itself since a ground test is never routine. The operator's knowledge and skill must always be an essential element of a proper test.

The proper placement of the probes is critical and defies standardization of procedure. A degree of trial and error cannot be avoided, because the earth is not a defined circuit, like a piece of equipment. The experience and ability of the operator are valuable in reducing this process to an efficient level, and no instrument can substitute for this factor.

The resistance environment with which the ground electrode is surrounded, whether it be a single rod or complex grid, is determined by a critical volume of soil. This volume may be thought of as an area of electrical field influence around the electrode. It has at the same time both a fixed nature, determined by soil type, structure of the electrode, electrical demands upon it and other factors, and a variable component, determined by transient factors like moisture and temperature.

Put simply, this entire critical volume must be measured, for it is what influences the flow of fault current from the ground electrode into the earth. For the proper volume to be measured, probes must be sufficiently spaced. Only the operator's knowledge can accomplish this placement properly and efficiently. Because soil conditions are never precisely the same, there is no set method to predict spacing in advance, and no instrument design can eliminate the operator.

Space the Probes Properly

If the potential probe is too close, measurements are taken within the electrode's sphere of influence, and different readings would be obtained with other placements. Indeed, a quality tester will give an accurate measurement to that point, but it is not taking into account all the resistance that a fault current will meet.



Figure 1: Simplified schematic of four-terminal instruments

Ground Test Equipment



This is what happens when shortcut two-point tests are made. (See Figure 2.) If the current probe is too close, its electrical field will overlap that of the ground electrode, and the potential probe will find itself making measurements in an electrical environment of conflicting influences. (See Figure 3.)

With adequate spacing, however, the potential probe will make its measurement beyond the boundary of maximum resistance exerted by the field influence of the ground electrode, in an area where additional distance does not contribute significantly to the tested electrode's resistance, and measurements will be reasonably stable. This uniformity of measurement will persist with increasing distance until the sphere of influence of the current probe is entered. This is the method that is referred to as Fall of Potential (also called the "three-point method," in reference to the three points of soil contact established by the electrode under test and the two probes). It is the method described by IEEE Standard #81 as the recognized basis for earth testing in the U.S. (See Figure 4.)

Conclusion

Simplified methods have been developed from the full Fall of Potential concept, and their descriptions are readily available in the literature. These various methods take advantage of simplifications of the calculus associated with a typical Fall of Potential graph to provide quick and easy mathematical tests that will throw out the results of tests made with inadequate setups, and accept only those results that are accurate and reliable measurements.

Familiarization is necessary for the proper conduct of earth tests, and with this familiarization, the knowledgeable operator can reduce trial and error, and indeed the work itself, to minimal levels.



Figure 2: Insufficient spacing of potential probe



Figure 3: Insufficient spacing of current probe



Figure 4: Correct probe spacing



TESTING LARGE SYSTEMS

Large ground systems are an important part of the protection of the electricity supply network. They ensure that fault current will enable protective devices to operate correctly. A substation must have a low ground resistance to reduce excessive voltages developing during a fault which could endanger safety of nearby people or animals.

In order to obtain a low enough value of ground resistance, ground systems may consist of an earth mat covering a large area or many interconnected rods. Suitable test techniques must be used for large systems to ensure that valid readings are obtained. This is unlike a small single electrode (i.e., a lightning conductor or domestic ground) which can be simple to test.

Fall of Potential Testing

For single electrode grounds, such as tradesticon Tuble and the grounds and the ground the analytic support of the ground the surrounding soil is limited and current test spikes can be quite close (typically 30 to 60 ft.) to the electrode under test. It is usually quite easy to find a flat portion of the ground resistance curve which should be close to the resistance of the electrode. Testing several points or drawing up a curve will help the understanding of

curve will help the understanding of the area around the electrode. It is always best to check results by using a different direction or a longer distance to the test spikes. This will help to eliminate errors caused by nearby b b b wvAco(trode.)Tj0 -1imite errors caused b2 TI is ITightnit is

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The Megger[®] DET2/2 uses a sophisticated filtering system that can reject more noise than any other earth tester available. Test frequency adjustment and selectable levels of noise filtering also help to remove stray noise that could affect the reading. A high current range increases the test signal strength in comparison with the noise.

In extreme cases it may still be necessary to carry out the test when the noise has decreased. However, the DET2/2 can keep going at higher resolutions long after other earth testers have given up.

Conclusion

The latest generation of digital ground testers greatly simplify the testing of electrical ground systems. However, care is still needed interpreting the results. Error indicators can alert the user to misconnected leads or conditions that may lead to an invalid reading but simply taking one reading is not sufficient to measure the resistance of any ground electrode.

It is always best to repeat a ground test using a different direction or distance to verify the results. This may remove any errors from hidden differences in the soil and increase confidence in the results.

When selecting a ground tester, ensure that the resolution and accuracy are suitable for the application. Instrument errors can lead to unnecessary expense in the design or maintenance of ground systems or, worse still, unsafe installations.

Use a Megger[®] DET2/2 if testing low values (<1 Ω), or in the presence of induced noise. A high level of noise filtering is required for accurate results in real life situations.

LAZY SPIKE METHOD

Certain field conditions such as asphalt preclude the use of driven ground rods when attempting to test a ground system. In the past, the operator would have been unable to make the required test. New technology has led to the development of the "lazy spike" method of ground testing, an approach that allows for effective testing even under these types of adverse conditions.

Lazy spike takes advantage of the exceptional resistance tolerances built into the Megger[®] Ground Testers' current and voltage circuits in order to provide the operator with a means of dealing with the oft-encountered problem of no available soil to make contact. The "spike" (contact probe) doesn't have to break the surface in order to take a valid measurement. Suppose the test is being performed in a congested urban area, a sprawling parking lot, or an airport. Older-technology testers used to require fairly high voltages and currents in order to operate. Contact resistance with the surrounding soil posed a problem, and mandated a solidly driven probe. With recent technology, however, sensitivities have improved so that mere surface contact is frequently sufficient. And as could be expected, Megger models offer the best capabilities on the market.

When making a measurement using the lazy spike method, simply lay the probes



SOIL RESISTIVITY TESTING (4 point method)

The most common method utilized for measuring soil resistivity is the Four Point Method using the equally spaced Wenner Arrangement. This method is commonly referred to as the Four Pin Method. This method is the most accurate method in practice for measuring the average soil resistivity of large volumes of earth. This method utilizes a specialized ground test instrument that has a four-terminal arrangement. Small electrodes are driven into the earth, all at depth B and spaced (in a straight line) at equal distance intervals A. The test current (I) is passed between the two outer electrodes (C1 and C2) and the voltage (V) is measured between the two inner electrodes (P1 and P2). The instrument knowing the voltage and current calculates the resistance from Ohms law (V/I) and gives the resistance (R) in ohms.

Four Point Method using Equally Spaced Pin Arrangement