GROUNDING AND THE WEATHER

Certainly, ground resistance testing is affected by the weather as much as any common electrical test, and more so than many. Both the instrument and the test item are affected. In this instance, the test item is not so readily managed as a motor or electrical circuit, which can be dried, cleaned, placed in a controlled environment or some other adaptation to accommodate easy or standardized testing. Here, the test item is actually a complex interplay between the grounding electrode and its soil environment. Both of these elements will be examined in turn.

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The soil component can be a relatively tight hemisphere around a ground rod, or a rather vast expanse surrounding a large grid. The composition of the soil itself constitutes a baseline for its resistance with types such as loam and clay exhibiting relatively low resistivity (good grounding) while others like sand and rock are typically quite high. Superimposed on basic soil structure are the effects of weather, in the form of moisture and temperature. These factors too have a broad range of influence on electrical measurement.

It should come as no surprise that a paramount consideration is moisture. A good ground is a low resistance ground, and the reciprocal of low resistance is high conductivity. Whether or not soil is a good conductor is a point that must be considered from perspective. Compared to copper, certainly not. Soil would hardly function in any effective manner if constricted into a long strand, as copper is in a wire. But the advantage of the Earth (that is, the planet itself, or the immediate portion of it) is simply that there is so much of it. Fault current from a grounded electrical system can be dissipated effectively once it has cleared the immediate hurdle of transferring from the electrode into the surrounding soil and to infinite earth. This current flow is promoted by moisture and dissolved ions, not unlike the function of a battery. As moisture content increases, soil resistivity decreases. The degree of reduction is initially dramatic, but reaches the "law of diminishing returns" and becomes progressively less so. An illustrative example is a study of top soil where resistivity dropped from 165,000 Ω-cm to 53,000 Ω-cm as moisture content increased from 5 to 10 percent. But the same study showed only a decrease from 21,000 to 12,000 Ω-cm as moisture went from 15 to 20 percent, with decidedly smaller decrements thereafter (Table 1). As a general rule of thumb, 18 percent moisture can be considered about a saturation level, beyond which the change becomes more academic than functional. However, soil types do vary enormously and the effects of moisture may vary accordingly. So it is wise to perform an actual study and rely on tables only as a guideline.

Table I: Effect of Moisture Content on Earth Resistivity*

Moisture Content, Percent by Weight	Resistivity (Ohm-cm)	
	Top Soil	Sandy Loam
0.0	1,000 x 10^6	1,000 x 10^6
2.5	250,000	150,000
5.0	165,000	43,000
10.0	53,000	22,000
15.0	21,000	13,000
20.0	12,000	10,000
30.0	10,000	8,000

**From "An Investigation of Earthing Resistance" by P.J. Higgs, I.E.E. Journal, vol. 68, p. 736, February 1930*

It is obvious, then, that weather, especially in the form of rainfall, has a dramatic effect on ground resistance and the performance of a grounding system. Rainfall is not the only variable, but certainly a major one in explaining the sometimes confusing effectiveness of grounding systems at different times and in different locations. The same design, protecting the same equipment, will perform well in one location but poorly in another, or seem to be reliable through numerous known faults only to unexpectedly fail at another time. Equipment is lost during a fault clearance on a system that had tested well for ground resistance and was thought to be fully protected.

In keeping with the battery analogy, ions are the other critical element in soil conductivity. De-ionized water is, in fact, an effective insulator, but salts in the soil provide the necessary ions to promote current flow. The concentration of salts follows the same pattern as that of moisture percentage. In a typical study done on sandy loam, an increase in percentage of salt by weight of moisture from 0.1 to 1 percent decreased resistivity from 1800 Ω-cm to 460 Ω-cm, while a further increase from 5 to 10 percent decreased it only from 190 Ω-cm to 130 Ω-cm (Table 2). Ion concentration is much more a function of fundamental soil composition than of weather, but weather is not entirely without its effect. Furthermore, that effect might seem counterintuitive. Certain granular types of soil, sand being an example, do not hold ions well, and a concentration of rainfall can actually wash ions away and decrease conductivity. It might be reasonably expected that after a heavy rain, the soil would be saturated with water and a ground test would be expected to read comparatively low. In most instances, this would be true but a surprise may occur, and if it does, make a closer examination of the soil type. Loss of ions is the likely culprit.

The other major weather component, of course, is temperature. This does not have as profound an effect as does moisture, but still must be taken into account. Temperature effects can vary in opposite directions on different types of material, so it is wise not to generalize. In soil, decreasing temperature slows the movement of ions and decreases conductivity. Again, the battery analogy holds. The truly critical change occurs over a single degree when going from liquid to ice. If the ground becomes frozen, ice immobilizes the ion flow and resistivity takes a quantum leap. A typical study is once again illustrative. On sandy loam, a drop from 50° to 32° F was found to increase resistivity from 9900 to 13,800 Ω-cm, but in going from liquid to freezing, the same sample increased resistivity to 30,000 Ω-cm! For ground electrode installation, this means that the working structure must be below the frost line, whether that be permafrost or the anticipated worst winter case. Deep-driven rods can ultimately achieve the necessary contact with unfrozen soil, but in areas of shallow bedrock, frost can present a double whammy to the use of multiple shallow rods.

Table II: Effects of Salt Content on Earth Resistivity*

Added Salt Percent by Weight of Moisture	Resistivity, (Ohm-cm)
0.0	10,700
0.1	1,800
1.0	460
5.0	190
10.0	130
20.0	100

*For sandy loam; moisture content, 15% by weight; temperature 63° F (17° C)

Freezing presents another potential problem, and one that is insidious because it is completely unseen. That is, freezing and thawing can exert a mechanical strain on the grounding electrode apart from the electrical stress applied by fault clearance. Grids can separate and sections become lost from connection to the electrical system. The most extreme of weather conditions, lightning, can have a similar effect. Of course, lightning does not have the long-term effect of moisture or temperature, but for the milliseconds that it lasts, it can disintegrate a grounding electrode below grade. The overall effectiveness of what remains can be readily determined by a routine ground test, but high-current grid testers are also available that can indicate damage to the point-to-point structure of the grid itself. This information can be valuable in repairing the grid in order to head off further disintegration.

TECH TIPS

Weather averaged out over representative periods produces climate. The one effect to be aware of here is the impact on the water table. This is more likely to be man-mad, by activities like well drilling, but whether man-made or climatic, a change in water table will affect ground resistance. If the water table drops, as by lesser rainfall of the siphoning off from wells, a grounding electrode that was installed in good conductive soil may later be sitting in a much drier environment.

What is the effect of all this on ground testing? More than anything, it is important to be aware of the possibilities and not treat ground testing as a once-and-done. The results of a ground resistance test---an installation test, for instance---will be heavily influenced by recent weather conditions. At the time of installation, a once-and-done test could leave the electrical system and associated equipment protected for part of the year only. Around the calendar, the resistance on any given day can vary mightily, and a fault clearance event occurring on the high end of this cycle could result in loss of equipment. Put fundamentally, a ground electrode is only as good as its worst day. In general, grounding conditions are optimal in spring and autumn when weather conditions tend to be moist and reasonably warm. In summer, drought can put the electrical system at risk, and in winter, freezing can present a similar danger. If an installation test is made at an optimal time and just meets spec, there is a high risk of it being considerably out of spec at another time of year. Specialized grounding equipment is available to mitigate this sawtooth effect by artificially creating a more stable environment around the electrode. This can be accomplished by appropriate backfills, chemical rods, and similar treatments (Fig. 1). But don't overlook the effects these treatments may have on concrete foundations, water table, environmental regulations and even the electrode itself. The additional maintenance that may possibly be required must also be taken into account.

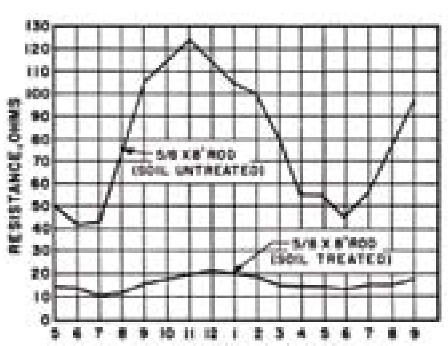


FIGURE 1: *Chemical treatment of soil lessens seasonal variation of electrodes' earth resistance*

Knowledge is the most effective tool for field work, and it becomes that much more valuable in applications where variables are as large and uncontrollable as they are in ground testing. Assess the site and recent conditions in order to make an educated decision as to where test results may fall on the min/max cycle, then proceed accordingly. At the least, arrangements should be made to retest at a suspected worst time. If a maintenance schedule is to be established, be judicious about the interval. For most electrical maintenance, a regular schedule, for instance annually or semiannually, is the order of the day, but be careful not to apply this practice to ground maintenance. Testing at regular intervals will result in readings being taken under the same general weather conditions year in and year out. If these are optimal times of year, a false sense of security can develop. Instead, test at irregular intervals such as 5, 7, or 11 months, so that all times of year and all weather conditions will be evaluated. A worst case will be recognized, and, if necessary, the grid can be expanded or improved so that there will be no unpleasant surprises.

Testing around the calendar may result in the disagreeable necessity of working in snow. "When you have to put food on the table in the wintertime, you have to think of these things," says Burt Brooks of Power Quality & Ground Testing LLC. It may seem counterintuitive, but in frigid climes, snow can provide an advantage. First, the test rods must be driven through the frost layer. The ground tester must establish a minimum amount of current through the soil in order to meet its measurement parameters and to sense the voltage drop across the measured resistance. Modern testers include indicators that will warn the operator if these parameters are not being met. Additional measures must then be taken, such as driving deeper rods, to bring the test setup within specifications. Pouring hot water provides only a marginal temporary advantage and can backfire by freezing solid around the probe and making it near impossible to remove. Once an adequate setup is accomplished, Brooks advises, testing under snow is just as reliable as at any other time. Where snow actually can afford an advantage is when it falls early in the season before the first major frost. Snow may then insulate the ground and limit frost penetration to more workable depths, say six to eight inches. If snow has been plowed or drifted away, frost penetrates deeper and test results may be rendered less consistent. Testing under snow can actually be more reliable. Just shovel away an area large enough to drive the test rods.

The final consideration is that of the test instrumentation itself. No one is likely to want to perform a ground test in a driving rain, and lightning conditions, even if miles away, are to be avoided because of the risk to the operator. Dangerous voltages developing on the power lines can be transmitted through the grounding system and will appear at the terminals of a tester if a test is in progress. But aside from these extreme circumstances, ground testing can be performed on moist or rainy days, and the sudden appearance of a shower need not send the operator scurrying. The determining factor here is the IP rating of the instrument. This rating should be available in the instrument's specifications and is commonly referred to as ingress protection. It was established by the International Electrotechnical Commission (IEC) in Standard #529, and provides a means of evaluating the effectiveness of an instrument's casework in keeping out dirt and moisture. The IP rating consists of two numbers, the higher, the better. The first number indicates how well the instrument is sealed against particle invasion, with "6" being dust tight. Quarries and mines are particularly bad environments in this regard, while a steady wind in a dusty environment can also pose a hazard to the instrument. The second number refers to moisture ingress, with "8" the highest rating representing continuous immersion. Since ground tests are not performed under water, this would be overkill, but note the IP rating and obtain an instrument that is adequate to the rigors of the field.

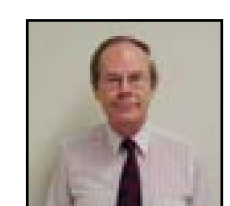
Armed with knowledge and a good instrument, the skilled technician will be a match for anything the weather can deal.

SOURCES OF INFORMATION:

MEGGER®, A Simple Guide to Earth Testing

MEGGER, Getting Down to Earth

Power Quality & Ground Testing LLC, Newton, MA



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