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White Paper

Ground Impedance

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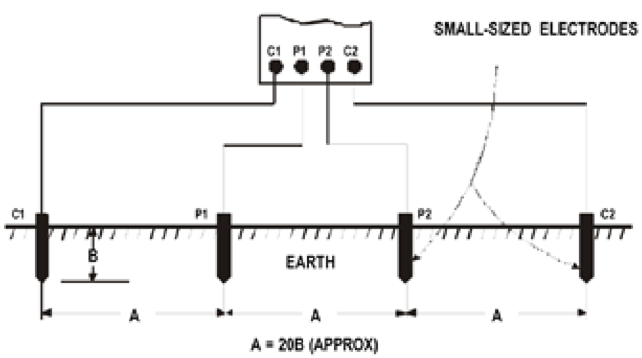
Before one can design a properly sized grounding system for the required fall of potential measurement, the resistivity of the soil must be known. The resistivity results will determine the conductor size, length, and number of radials required. The measurement will also determine how many rods are required, their length and their spacing on each radial.

Measuring Your Soil

A method for determining mean value of soil resistivity (rE) is shown. Four equally spaced electrodes are driven to a shallow depth; the penetration depth (b) is kept small in comparison to the inter-electrode spacing (a) where (a) >20(b). A known AC current is circulated between the two outer-electrodes while the potential is measured across the inner pair. The tester will provide an indicated resistance in Ohms (RE). If the electrode spacing (a) is in meters, use the formula to convert to rho (rE).

$$\rho E = 2\pi\alpha \cdot RE$$

This gives the mean value of soil resistivity (E) in Ohm-m. The electrode spacing (a) corresponds to the depth of soil seen by the test current. By varying the electrode spacing, a profile of resistivity versus depth can be obtained. The results can be in Ohm-m or Ohm-cm and are “plugged in” to other formulas determining the size and configuration of the copper electrodes in the grounding system.

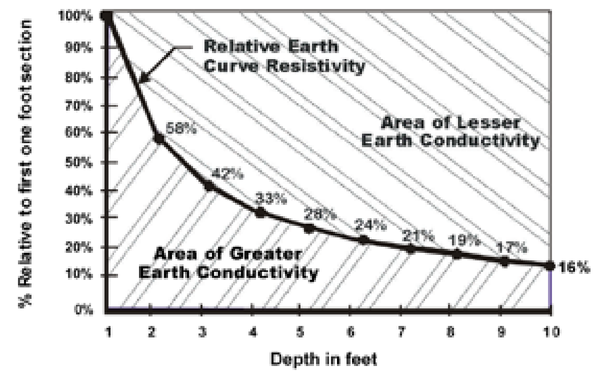


Four stake method of measuring soil resistivity.

Measuring The Ground System

There is no substitute for an actual fall of potential measurement on a ground system. Most measuring techniques and instruments are similar and have similar faults. Present techniques utilize equipment with steady state dc or (more often) low frequency AC current source waveforms. Neither comes close to simulating the dynamic surge conditions (such as lightning) where inductive voltage drops are developed. Problems would be minimized if multiple parallel inductances (radials with rods) were incorporated in the design and layout of the ground system. Multiple parallel inductances lower the overall system inductance, improve the transient response of the system, and reduce ground potential rise during a lightning “event.”

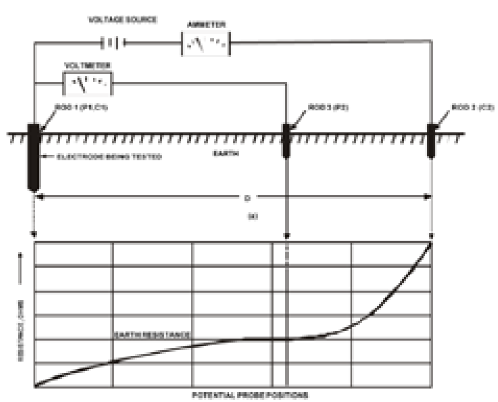
Another way to obtain a profile of the soil is to measure a ground rod as you hammer it into the soil. If no other ground conductors are present, in or along a 100-foot path, a fall of potential method (3 stake) measurement can be set up before a ground rod under test is inserted into the ground. The low frequencies used in most testers do not take into account any inductance which may exist in a ground system such as a rod penetrating a sandy layer. The best way to determine the consistency of your underground soil layers is to perform a preliminary fall of potential method measurement and log the readings for each foot that a ground rod is driven. Plotting it should approximate the Relative Earth Resistivity Curve shown below. Any large variation could mean water/clay or sand/gravel. With this knowledge, a better ground system can be designed for the RF properties of the lightning strike.



Most sites have a grounding system, but it is usually an unknown. The ground system is considered an unknown because it has never been measured or if it was measured, it has probably changed over time. The soil resistivity varies through out the year because of seasonal moisture and temperature changes. Ground system maintenance must be performed to keep it in operating condition.

Ground systems composed of copper and zinc are quickly eaten away in acidic soils; yet are stable in the presence of alkaloids like concrete. Only aluminum is unaffected by acidic soils, but it is etched by alkaloids. Soil's conductivity is determined by its water and salt content. The more salts, the less water is required to reach a specific conductivity. At least 16% water content, by weight, is required for a soil to be conductive.

Gypsum is better than bentonite and can be added to the soil. Gypsum absorbs and retains water and doesn't shrink/pull away from the conductor when drying like bentonite. Adding 5% by weight, of Epsom salts will further insure moisture retention and conductivity.



The three stake method, also known as the Fall of Potential Method, is shown and is used to measure the resistance of a single ground rod. This can be done on any four stake tester by tying P1 and C1 together. The initial spacing between electrodes P1, C1 and C2 for a simple electrode would be approximately 100 feet, while for an entire grounding system it could be 1,000 feet. The actual spacing may be increased or decreased depending upon the size of the grounding system being measured and the results of moving electrode P2.

The goal is to move electrode P2 at discrete intervals along a line between electrodes P1, C1 and C2 and record/plot the voltage measurement. It is necessary to locate the area of the curve where moving electrode P2 has little or no affect on the measured voltage, usually at 61.8% of distance between P1,C1 and C2. Most modern instruments convert voltage readings directly to (R = E/I) Ohms. (Impedance if an AC current source.)

Surge Impedance (Z)

In IEEE Transactions on Broadcasting, Volume BC- 25, No.1, March 1979, it was established that radials, together with rods, show a lower dynamic surge impedance under real lightning conditions than the resistance measured at or near dc. This results from a lightning induced ground saturation causing localized arcing and creating a momentary low impedance path between ground masses. The effective area or size of the grounding system is thereby briefly increased. The arcing occurs since any ground system, no matter how good, will momentarily elevate above the global earth potential. This temporary elevation may be due to a slow propagation of the surge through the earth and is measured as the velocity factor and time constant of the ground system. Obviously the larger the impulse, the more arcing and the lower the dynamic impedance. It has been shown, that the lower the measured impedance using the dc or steady-state low frequency ac type instruments, the smaller the difference will be between the measured and the real dynamic impedance.

Ground Propagation

As in any medium, a dynamic pulse, like RF, will take time to propagate. This propagation time will cause a differential step voltage to exist in time between any two ground rods that are of different radial distances from the strike. With a ground rod connected to the base of a tower, the lightning impulse will ideally propagate its step voltage outwardly from this rod in ever-expanding circles, like a pebble thrown into a pond. If the equipment building has a separate ground rod and the power company and/or telephone company grounds are separate still, the dynamic step voltage will cause currents to flow to equalize these separate ground voltages. If the coax cable is the only path linking the equipment chassis with the tower ground, the surge will destroy circuitry while getting through to the telephone and power grounds. (See single point ground system.)

Please contact us for questions or further information on this topic.

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