UTILITY GROUNDING PRACTICES

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The basic reasons for being concerned about the resistance of grounds are presented from a practical viewpoint. It is explained how safety is affected by the resistance of the ground connection. Statements are made as to what is a "good ground".

Grounding practices are discussed as how they relate to initial ground resistance, long term stability of grounds, ease of installation, etc. Also, it is shown that several factors affecting ground electrode resistance vary from one location to the next.

It is then concluded that the only sure way of obtaining a low resistance ground is through field measurement during installation. One instrument for doing this is described.

It is also shown that this low resistance ground can lead to serious corrosion problems in other parts of the cable system. Several possible solutions to this corrosion problem are presented.

Utility grounding practices are of concern to a cable television company for several reasons. The first reason that comes to mind is that since cable TV usually rents pole space on utility poles, the cable TV company is most often permitted, or required, to bond its messenger and grounding system to the utility's existing pole grounds. It is only reasonable to assume that it would be good if the cable TV operator were aware of the utility's grounding system and how effective it is. A second reason for looking into grounding practices is that OSHA now makes the National Electrical Safety Code law and the safety code does cover grounding practices. The third and most important reason is safety to the cable TV company's linemen and installers, the general public and electronics equipment. This safety can be best assured by bonding all pole-mounted non-current carrying metal parts to a low resistance earth ground.

That brings up the immediate question: What is a low resistance ground? As I previously stated, the National Electrical Safety Code does set forth in Section 9 rules and methods of grounding power and communications lines. Paragraph 96A states that "made electrodes" shall have a ground resistance not to exceed 25 ohms. That is one definition of a low resistance ground. Quite often, power companies choose to require lower resistance grounds where certain types of equipment are located. One power company requires a maximum ground resistance of 5 ohms on any pole that supports a transformer, capacitor bank, voltage regulator ... essentially any pole on which there is equipment that is subject to high voltage surges (primarily from lightning strokes).

There is a very good reason why many power companies require such a low ground resistance. A statement is often heard that electricity takes the path of least resistance to ground. This is true enough; however, that is not the only path to ground that electricity takes. Electricity takes all paths to ground whether they are high or low resistance. Pole lines are continually subject to fault current flow to ground; the fault current is usually a result of power company equipment failure, temporary phase-to-ground faults from animals, or lightning surges. This fault current is usually in the order of magnitude of thousands of amperes. While the largest part of the fault current flows through the grounding system (path of least resistance); any other path to ground, such as strand-mounted equipment or linemen working on such equipment, will be subject to some fault current flow. This is the importance of low resistance grounds; the lower the ground resistance, the less the fault current will divide to take the other paths to ground.

Power companies have still another benefit from low resistance ground connections. Lower ground resistances result in higher fault currents which in turn enable fuses and circuit breakers to operate faster. Fast operation of protective devices greatly reduce voltage strain on equipment and exposure time to personnel.

Having discussed some reasons for needing a low resistance ground, I would like to describe the grounding practices of several utilities with which I have been associated. I would like to show how ground resistance is affected not only by the particular grounding technique but also by several variables that can be dealt with but not controlled.

Utility pole grounds are usually either driven ground rod or pole butt ground. The power company in Tampa, Florida is Tampa Electric Company. Tampa Electric's primary distribution system is a 13KV grounded wye. This distribution system uses a common neutral; one neutral for both primary and secondary circuits. The common neutral (as used by Tampa Electric) is also multi-grounded. This means that there are at least 4 ground connections per mile. At grounding points, the neutral is bonded to a #6 soft drawn copper ground wire. The copper ground wire is run vertically down the pole and connected to a driven ground rod. The ground rod that Tampa Electric uses is a slightly oversize 1/2" rod of the Copperweld type. The Copperweld ground rod is a rod with a steel core and a molten welded copper exterior. The steel core gives the ground rod good driveability. Tampa Electric went to the oversized 1/2" rod after having driving problems (bending) with the standard 1/2" rod. It was not necessary, in Tampa, to go to the stiffer and more expensive 5/8" Copperweld rod. Ground rod diameters are usually chosen in this manner; the stiffness rod needed to drive in any given area is found by trial and error in the field. Note that the safety code, paragraph 95D, sets the minimum size of Copperweld (non-ferrous) ground rods to be 1/2" in diameter while ground rods of iron or steel (only) must be at least 5/8" in diameter.

Tampa Electric's standard ground rod is 8 feet long; which is also in accordance with safety code requirements. The safety code states, in paragraph 95D, that driven ground rods" ... shall preferably be of one piece, and, except where rock bottom is encountered, shall be driven to a depth of 8 feet..." In addition to driving ground rods in this standard length of 8 feet, Tampa Electric's ground rod is threaded on both ends. Many times the 8 foot rod does not provide the specified ground resistance, such as 5 ohms at equipment installations. When this happens the groundman threads on another 8 foot section and resumes driving. (See Fig. 1) Tampa Electric, in trying to drive a low resistance ground, finds it easier (in Tampa) to drive deep grounds rather than to use multiple grounds.

This is essentially the grounding system used by Tampa Electric Company. Copper is used as the grounding electrode due to its good conductivity and superior corrosion resistance. Ground rods are also made with stainless steel replacing the copper in the Copperweld style rod and also of galvanized iron. I have no experience with either type rod and I would appreciate hearing from any of you that have.

The other common type of pole ground is the butt ground. (See Fig. 2) It can either be wire wrapped around the butt of the pole or a plate stapled to the bottom of the pole. In both cases the butt ground is installed prior to the pole being set. If the wrapped wire method is used, the safety code requires that at least 12 feet of wire be buried.

The municipal power company in San Antonio, City Public Service, use a 6" diameter copper plate as their butt ground. In contrast to the usual driven grounds of 4 per mile, CPS installs a butt ground on every distribution pole that is set. This is the only practical way of grounding in this area since almost 40% of CPS's service area is solid rock underneath the top soil.

Given these standard and fairly similar grounding techniques, I would like to briefly touch on some of the factors that can cause quite large variations in grounding resistance values just within a fairly small area.

The resistance of any ground connection is made up of 3 factors:

1. Resistance in electric connections
2. Resistance of the ground wire
3. Resistance of the surrounding earth

Careful installation of electrical connectors will insure that connection resistance is negligible. Copper ground wire and manufactured ground electrodes also do their part in not adding any appreciable resistance. That leaves the third item as the biggest culprit in ground rod resistance; resistance of the surrounding earth.

In order to be sure that a grounding system minimizes, as much as possible, the earth's resistance, it will be helpful to look at the factors that affect it. Basically, there are three:

1. Type of soil
2. Moisture content
3. Temperature

The type of soil is probably the biggest variable of the three. In general, sandy soils have a very high resistivity while soils of clay, shale and loam content have a much lower resistivity. While it is possible to lower soil resistivity by the addition of salts and other chemicals, this is not too widespread of a practice. One problem with soil treatment is that it is usually a temporary measure and its effects do not last. You essentially just have to live with the type of soil in which you are trying to ground.

For any given soil type, moisture content greatly affects earth resistivity. The reason for this is that the increased moisture better dissolves any natural salts present and makes the earth a better conductor. The temperature of the earth also affects its resistivity. Higher soil temperatures decrease earth resistivity. Knowledge of these factors affecting earth resistivity helps in designing operating procedures which will insure that each ground is low resistance and will stay that way for a reasonable period of time.

I have stated that you usually just have to live with the type of soil in which you are trying to ground. This is only partially true. (See Fig. 3) At any given location, soil type varies with depth below the surface. This explains the success of the sectional ground rod. If the first 8 feet of ground rod doesn't put you into low resistivity soil, the second or third section usually does.

Next, let us see what grounding practice will be of most help in taking advantage of the other two factors affecting earth resistivity. Moisture and temperature are primarily seasonal in nature and seasonal variations are most reduced with increased depth below the surface. (See Fig. 4) This means trying to put your grounds below the frost level and permanent moisture level, if practical in your area. Again, sectional ground rods are a convenient tool for doing this.

So far my recommendations have been to drive reasonably deep grounds in order to get stable, low resistance grounds. As you know, this is not possible in many parts of the country where there are large amounts of rock. The approach here has to be through multiple grounds at each ground location or just many more individual grounds along the pole line. If 8 foot rods can be driven (but not anything longer), then multiple rods, all tied together at this one location, are effective in lowering ground rod resistance. However, the effectiveness of multiple ground rods is diminished if the rods are driven very close to each other. (See Fig. 5) The other alternative in these rock areas, is more frequent grounding; such as the practice in San Antonio with pole butt grounds on every pole.

I have been talking about how important it is to have a low resistance ground connection and how utilities achieve low resistance grounds. What I haven't said anything about is how you can know when your ground resistance is low enough. The only way to know is to measure it.

I'm not going to go into the theory of earth resistance testing; there are several good sources for this. (See Ref. 3) I would just like to describe one instrument that is designed for this purpose. The manufacturer of this instrument calls it a Megger, Null Balance, Earth Tester. Utility people just call it a megger. In its most common use, a method called the "Fall-of-Potential" or "Three Terminal" test is used. (See Fig. 6) Two reference electrodes are driven into the ground some distance away from the electrode or ground rod under test. One reference electrode is called the "potential" electrode and is positioned just over halfway between the ground rod and the other reference electrode (called the "current" electrode). The reference electrodes are so named because the megger actually uses them as current and potential references in arriving at the ground rod resistance. After setting up the test in this manner, all that has to be done is to turn a hand driven generator within the megger and turning resistance dials on the megger in order to null a meter. The ground rod resistance is then the resistance that was dialed in to null the meter. This instrument is easy to use and lets you know exactly how good a ground you have just installed. Take note that individual grounds should be meggered before being connected to the power or telephone company's system ground. Otherwise you would be measuring the ground resistance of the entire grounding system.

Having reviewed methods and reasons for getting low resistance grounds, I would now like to point out a serious corrosion problem that is present in San Antonio.

As I have indicated a multi-grounded neutral with copper being the grounding conductor is a very common power company practice. An equally common practice is to bond down guys (for safety reasons) to the multi-grounded neutral. A classic galvanic cell is then formed. (See Fig. 7) There are two dissimilar metals (copper ground electrode and galvanized iron anchor rod) electrically connected (bonded together on the pole) and emersed in an electrolyte (soil). In some areas of the country, an extremely potent battery is created. The first metal to start corroding is the zinc galvanizing on the anchor rod. The zinc enters the soil as corrosion current flows. As the zinc is eaten up, the iron from the anchor rod then starts sacrificing itself. While you may be maintaining an excellent grounding system, the system's anchoring could be disappearing.

In San Antonio, City Public Service's policy has long been to keep their copper grounding system isolated (not bonded) from their anchoring system. However, Southwestern Bell, in this same service area, went through a period of time, when on joint use poles with power, they bonded their down guys to their messenger which in turn was bonded to power neutral. Consequently, Southwestern Bell began experiencing severe corrosion of anchor rods. During one year alone, 1968, approximately seventy-five anchor rods were replaced due to corrosion failure. Corrosion measurements were taken on over one hundred down guys thus bonded. Corrosion currents between 2 and 85 milliamperes were found; indicating extensive corrosion forces at work. Southwestern Bell reversed themselves and went to the practice of isolating their down guys from the grounding system.

There are several ways of isolating the down guy in order to break up the corrosion circuit. One way, used by both City Public Service and Southwestern Bell is to install an insulator (called johnny-ball) in the guy lead. A second way is to guy off of a separate "through bolt" from the one used for the neutral; and not install a bonding jumper. Still a third way is by using an insulated anchor rod. This is currently under trial by Southwestern Bell in San Antonio.

Now I would like to tell you about another part of the country that has successfully used the same bonding and grounding practices that failed in San Antonio. In Tampa, Fla., Tampa Electric Company, with its multi-grounded neutral, and General Telephone Company both bond all down guys to the copper grounding system.

To this date, neither company has lost any anchor rods due to corrosion. An obvious question is: why not? The same conditions for creating a galvanic corrosion cell are present in grounding practices in the Florida utilities as in the Texas utilities. The only significant difference is the type of soil. I can only conclude that the soil characteristics are such that the soil in the Tampa area is generally of pretty high resistivity and limits the corrosion currents to very small values. Conversely, San Antonio must have some pretty low resistivity soil which allows for a fine grounding system but creates potential corrosion problems.

Getting back to grounding, I would like to end with this statement: It is only through field resistance measurements that you can be absolutely sure that you are installing a low resistance ground and it is only through periodic field measurements and inspections that you can be sure that you are maintaining a good, low resistance grounding system.

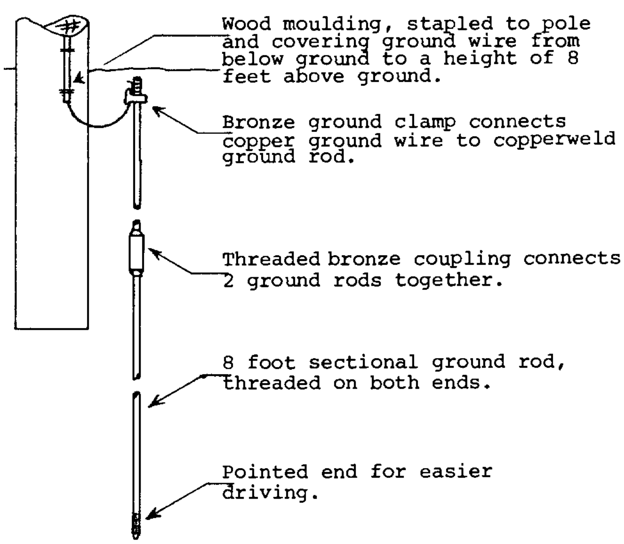

Figure 1. Typical installation of a sectional ground rod.

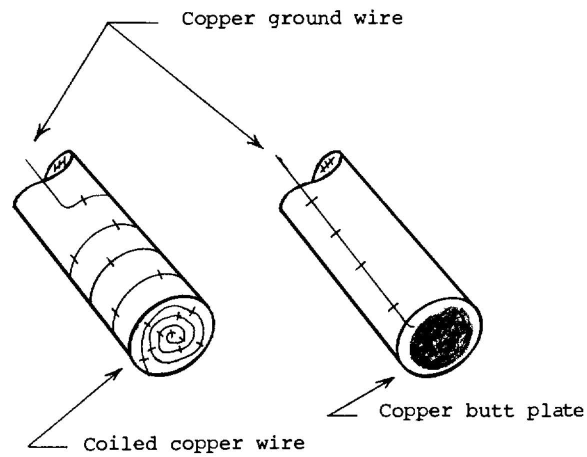

Figure 2. Pole Butt Grounds

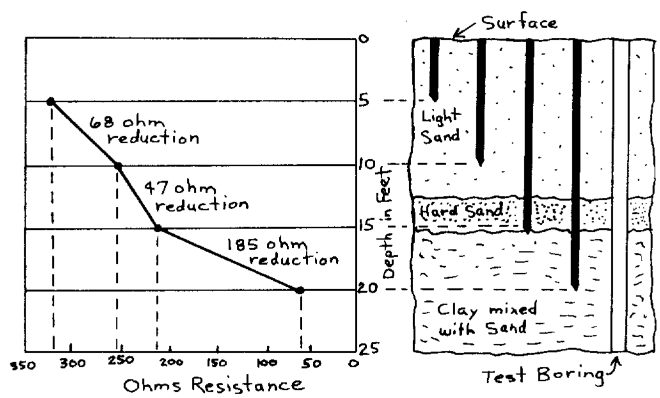

Figure 3. Relation between type of soil and resistance of driven ground rod at different depths. (Source: Ref. 4)

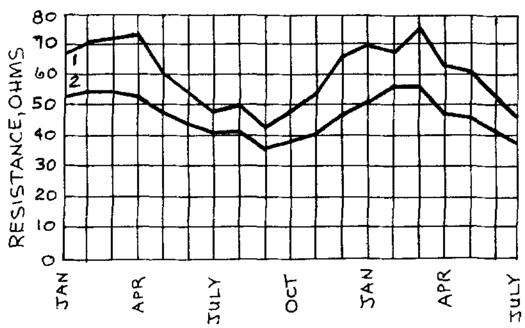

Figure 4. Seasonal variation of earth resistance. Depth of ground rod is 3 ft. for curve 1, and 10 ft. for curve 2. (Source: Ref. 3)

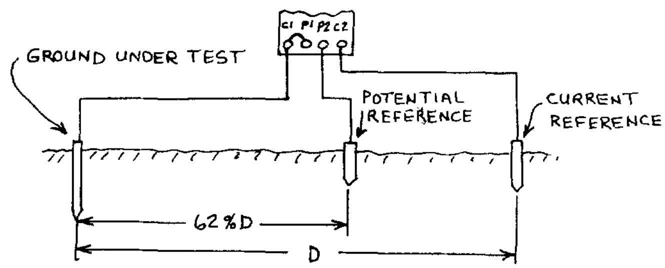

Figure 6. "Fall-of-Potential" or "Three-Terminal" earth resistance test. (Source: Ref. 3)

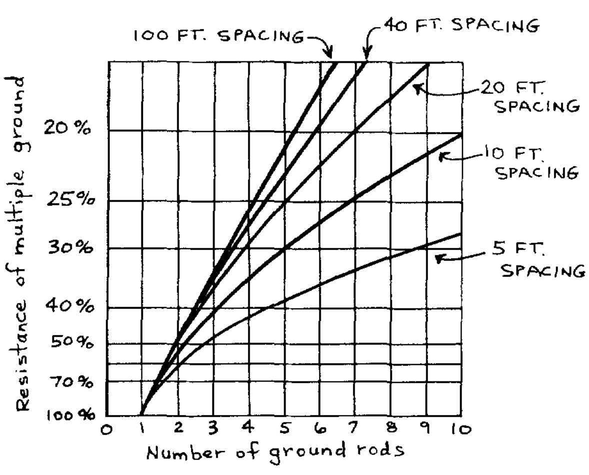

Figure 5. Effectiveness of multiple ground rod. Single rod equals 100 percent (Source: Ref. 4)

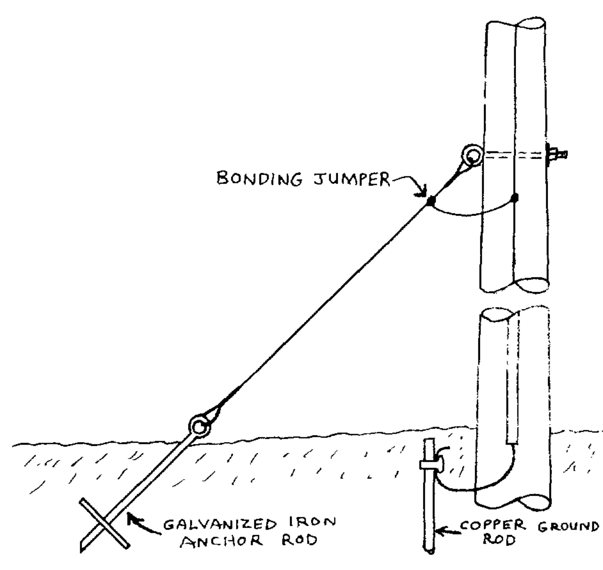

Figure 7. Grounding practice that can lead to corrosion problems.

R E F E R E N C E S

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