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Deep Grounding Lowers

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Electrical problems can be solved by reaching down into the earth.

Deep grounding is the practice of driving ground rods, often to the point of refusal, to obtain lower grounding resistance at least cost. The deep rod is assembled from shorter ground rod sections that are coupled together, end to end, as the assembly is driven into the earth. It is one of many techniques used in power and communications engineering to improve grounding systems, and in turn offer better lightning protection, better relay performance and improved safety.

Grounding practices based on NESC rules, which require ground rods at least 8 ft (2.4 m) long, have worked well. However, these rules are minimum requirements that do not guarantee satisfactory performance in every situation. On occasion, grounding must be improved because of safety or interference problems. Alternative approaches to the standard ground rod include counterpoise, buried grids and chemical grounds. One of the most popular, cost-effective solutions along power distribution lines has been to install more ground rods, either on the surface or in the form of a deep ground. Each ground rod that is added can be visualized as an added parallel resistance that connects the ground system to earth (Fig. 1).

The deep grounding method overcomes problems associated with shallow grounds such as variations of temperature and moisture at the surface of the earth. Earth resistivity is lower at deeper penetrations due to the influence of the water table. For example, resistivity drops from 20,000 ohmmeters at the earth's surface to about 850 ohmmeters at a depth of 40 ft (12 m) (Fig. 2). The drawback of the deep grounding approach is that it is not always possible to determine how far down the assembly can be driven.

Addressing an Interference Problem

An electromagnetic coupling between the Navy's extremely low frequency (ELF) radio transmitter facility and the neighboring power distribution circuits in Upper Michigan produced a signal on the distribution line neutrals that caused small currents to circulate between the neutral conductor and earth through the many pole grounds on the system. The ELF signal, nearly indistinguishable from the power signal, produces a potential difference between the

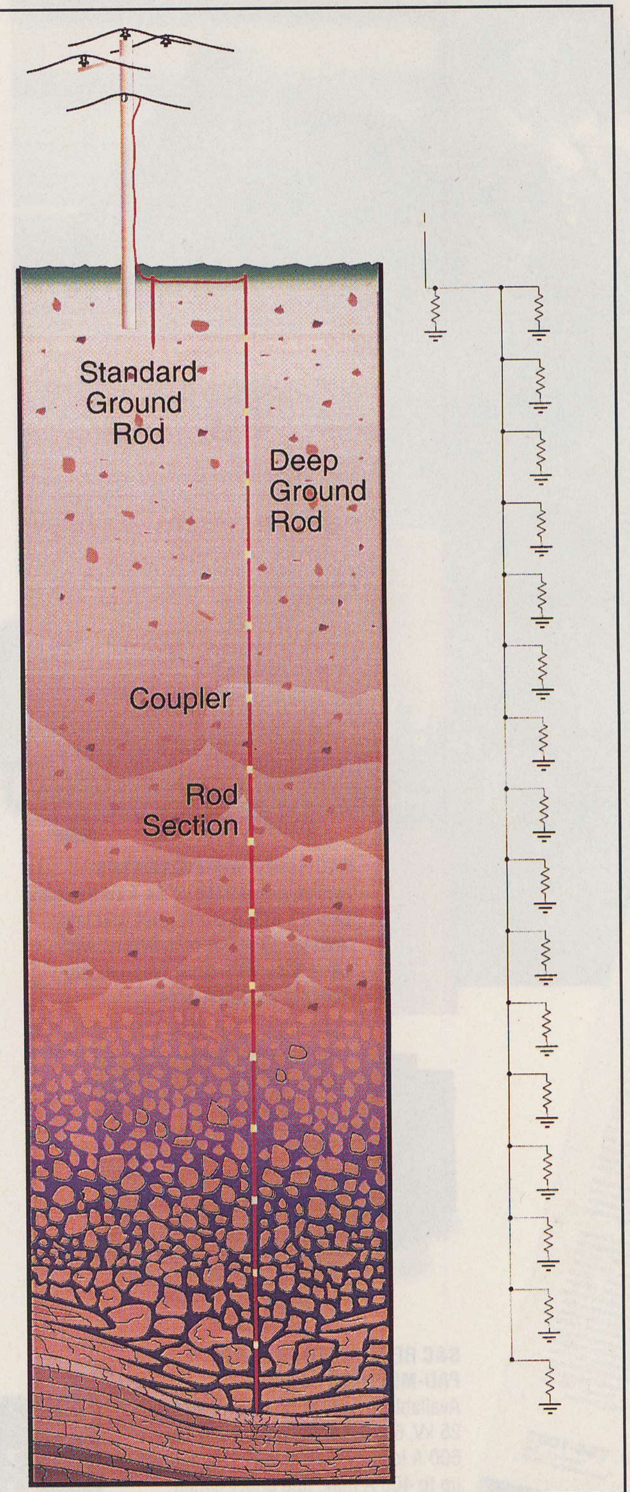

Fig. 1. Earth cutout revealing a deep ground close to a standard ground rod at the base of a pole.

Electrical Resistivity

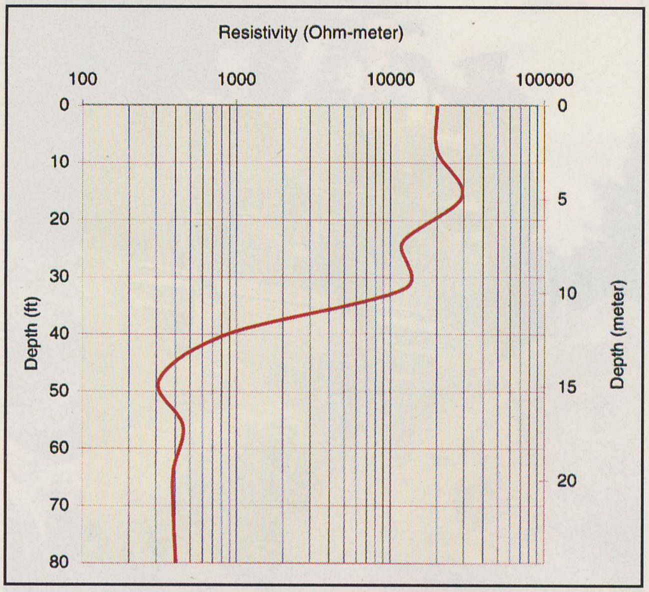

Fig. 2. Earth resistivity as a function of depth in a deep grounding case.

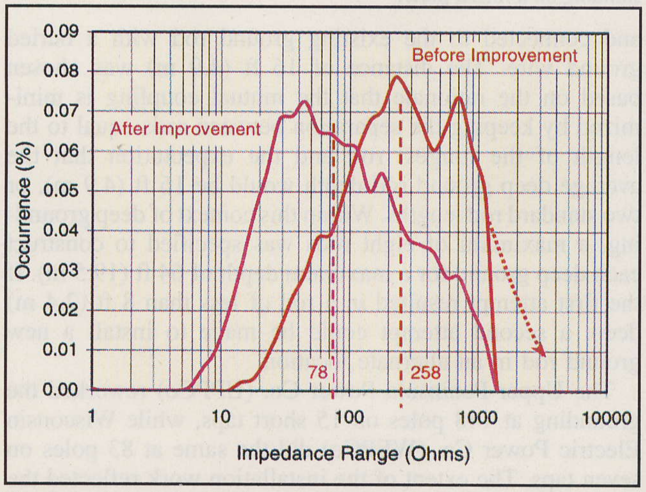

Fig. 3. Statistical distribution of pole ground resistance before and after deep grounding.

neutral wire and earth. This voltage is proportional, being high close to the transmitter and decaying rapidly as you move away from the source.

The interference in the affected area is much like the spreading ripple on a water surface where the ripple becomes ever smaller as it travels outward from the disturbance center, covering ever-increasing areas. There is a large fringe area surrounding the ELF transmitter where a number of facilities and customers are involved and where the interference is at the margin of concern. Since the grounding quality along the distribution line affects the level of induced voltage, the earth resistivity is an important parameter. In the affected areas, earth resistivity averaged 5,000 ohmmeters, indicating that there was room for grounding improvement to lower the level of the induced voltage.

A blanket measure, designed to minimize overall induction effects, had already been instituted in preparation for the initiation of operations at the ELF transmitter. This measure, which had previously been used at a similar facility in Wisconsin, consisted of ensuring that there was an 8-ft ground rod installed at every pole in the distribution circuit. About 8,000 rods were installed near the Michigan transmitter site. While reducing the interference voltage and shrinking the affected area, the installed rods were not sufficient to eliminate all induced voltage problems especially in areas close to the transmitter where other mitigation techniques were necessary.

The Deep Grounding Solution

Under pressure to reduce operating costs, the two companies with facilities in the interference area were asked to use the deep grounding protocol along a number of short taps selected by the interference mitigation engineers. The protocol devised addressed the uncertainties of deep grounding work by specifying that the deep ground could be installed at the base of the pole, using the existing rod at the pole base as the lead section, or 16 ft (4.9 m) from the pole

Fig. 4. Hammer on top of driven rod and suspended from a crane.

Fig. 5. Hammer on top of driven rod being handled by a worker standing on a raised plow.

and connected to the existing ground rod with a buried ground wire. The distance of 16 ft (4.9 m) was chosen based on the rationale that the mutual coupling is minimized by keeping the separation between rods equal to the length of the longest rod and the expectation that the average deep ground rod depth would be 16 ft (4.9 m), or two standard rod lengths. Within this context of deep grounding, a maximum of eight rods was specified to construct each deep ground for a maximum depth of 64 ft (19.5 m). If the first attempt resulted in a rod of less than 8 ft (2.4 m) deep, a second attempt could be made to install a new ground rod in an alternate location.

The Upper Peninsula Power Co. (UPPCo) reworked the grounding at 148 poles on 15 short taps, while Wisconsin Electric Power Co. (WEPCo) did the same at 83 poles on seven taps. The extent of the installation work reflected the different level of interference experienced on each company's plant next to the transmitter.

UPPCo installed most of the deep grounds at the base of the pole working with a small crew during the winter of 1996-97. Because snow and ground frost were present, the installations were made at the base of the poles. WEPCo installed all deep grounds 16 ft from the poles under the power line, working with a large crew in the summer of 1997. Although there was a difference in work methods the results were similar.

Altogether, 231 poles were treated and 791 standard 8-ft (2.4-m) rods were installed to an average depth of 30 ft (9.1 m). The deepest rod was 64 ft (19.5 m), which was the maximum allowed under the construction protocol, and occurred 10 times. There were cases where the depth was less than 3 ft (0.9 m) because of the presence of rock near the surface.

The Installation

The ground rod impedance at the pole was measured with the AMC 3730 meter before and after the grounding additions were made. In addition, the neutral voltage to earth was measured before and after to determine the effect on the neutral voltage.

The average pole grounding resistance was reduced from 258 ohms to 78 ohms, a 3.3-fold improvement in pole ground conductance, which was accompanied by an average interference voltage reduction of 24%, in line with predicted results. The before-improvement resistance distribution curve appeared to rapidly drop to zero at about 1200 ohms, because the meter used for the measurements had a maximum range of 1200 ohms, resulting in many measurements pegging at the 1200-ohm value. Therefore, there may have been resistances that were higher than 1200 ohms. After the grounding improvements (Fig. 3), few resistances were recorded at 1200 ohms.

Since material for this job was minimal and inexpensive, the principle cost was for labor. Common construction equipment was used to clear the site and to bury the connecting wire when the installation was away from the pole. The main tool was a mechanical hammer to drive the rods (Figs. 4 & 5).

Although the area was mostly rocky, the deep grounds averaged 30 ft deep (9.1 m); 10 reached the maximum allowed depth of 64 ft (19.5 m). The fact that the average was 30 ft (9.1 m) suggests that a more optimal distance for locating the deep rod away from the pole would have been about 30 ft (9.1 m) instead of the 16 ft (4.9 m) that had been specified.

The installation at each pole took about 5 manhours, with a considerable part of the time being expended by deployment, site preparation and job closing. The process of driving a rod to the point of refusal, or to the maximum allowable depth achieved by the eight-rod limit, was a fast and straightforward operation. Once set up, the depth of the ground depended more on luck than on labor expended. This fact became obvious to the installers when a rock ledge or other obstruction precluded deep grounding in the area. However, at other locations the rod penetrated easily.

In addition to encountering hard objects that brought the driving operation to an abrupt halt, the soil type could cause rod "grabbing" due to increased frictional resistance that made continued hammering ineffective. Although increasing the hammer power may have provided additional depth penetration, there was a limit on the amount of power that could be used since buckling of the rod and safety problems may develop.

Larger diameter rods and pipes, available for special efforts, were not considered for this work since the job was based on using the standard rod and installation methods to keep costs low. Any open protocol that allowed driving to refusal in all cases, without a cap such as the eight maximum rods in this job, would yield better results with an insignificant amount of additional labor.

Conclusion

Deep grounding can be an effective and inexpensive way to improve the effectiveness of a grounding system. The deeper layers of the earth are more likely to exhibit high levels of conductance due to water tables and more stable temperatures. The drawback is when the presence of surface rock makes driving ground rods a difficult task. Depending on the nature of the soil, grounds as deep as 100 ft (30.5 m) have been installed with relatively little effort in similar jobs. ■

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