HIGH ON LOW Resistance

By Keith Switzer

THE goal of any grounding system is to provide a low-impedance path for fault currents until they reach the earth.

But the effectiveness of any such system depends largely on whether the soil surrounding it can absorb and dissipate large electrical currents. In other words, the soil must have low resistivity to properly support the grounding system.

The conductivity of the earth, or the ease with which it conducts electrons, varies with different soils and can be influenced by moisture content and temperature. Moisture content is important because it helps the soil around ground rods disperse the electrical current. When moisture content is below 10 percent, it can increase earth resistivity significantly. Temperatures below freezing also increase resistivity. When moisture turns to ice, resistivity increases sharply. In areas subject to freezing winters, driving the ground rod below the frost line is standard for maintaining low resistivity.

When considering the grounding conditions at any site, it is essential to test soil resistivity. Test results must be examined carefully, since resistivity levels can vary widely, even in apparently similar soils. In general, black dirt, or soils with high organic content, are usually very good conductors because they tend to retain more moisture, leading to low resistivity. Sandy soils, which drain faster, tend to be less moist and are therefore higher in resistivity. Solid rock and volcanic ash, like the soils in Hawaii, have virtually no moisture, and have such high resistivity as to be practically useless as a grounding material.

Reducing Resistivity

If soil tests show high resistivity, grounding system designers can choose from several options. Depending on the soil, increasing moisture may lower resistivity. In topsoil, resistivity may be reduced 80,000 ohms-cm by increasing moisture from 5 to 10 percent. An additional, though much smaller, reduction in resistivity can be obtained by increasing moisture from 10 to 20 percent. Then resistivity essentially stabilizes. In many places, ensuring low resistivity is as simple as driving a ground rod into a subsurface soil layer that has a relatively permanent and conductive moisture content.

In the absence of such favorable conditions, there are other options for improving conductivity. These include filling the ground rod hole with bentonite, treating the soil with a salt (copper magnesium sulfate or rock salt), or using Ground Enhancement Material (GEM™) from ERICO, Inc.

SOIL	RESISTIVITY ohm-cm Average	Min.	Max.
Fills – ashes, cinders, brine wastes	2,370	590	7,000
Clay, shale, gumbo, loam	4,060	340	16,300
Same – with varying proportions of sand and gravel	15,800	1,020	135,000
Gravel, sand, stones, with little clay or loam	94,000	59,000	458,000

Resistivities of Different Soils*

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Bentonite is a clay substance used in grounding systems in soils with high resistivity. However, conduction in bentonite only occurs when ions move. Ionic conductivity can only occur in a solution, which means that bentonite must be wet to provide low-resistivity levels. When it loses moisture, its resistivity increases and it contracts, losing contact with the surrounding soil.

Another way to lower earth resistivity is to treat the soil with a salt. Combined with moisture, salts leach into the soil and reduce resistivity. However, this same process can also cause problems. As the salts are depleted, the soil reverts to its untreated condition and the system has to be recharged periodically. Also, the leachate may contaminate groundwater; local environmental regulations, then, may rule out this alternative immediately.

Using GEM

The third alternative, GEM, is a low-resistance, noncorrosive, powdered material that offers a resistivity of 12 ohms-cm or lower when set, compared to 250 ohms-cm for bentonite. GEM improves grounding effectiveness regardless of soil conditions and is ideal for areas with high resistance, such as rocky ground, mountain tops, and sandy soil.

GEM provides excellent and permanent conductivity in even the most difficult conditions. For instance, the Oglethorpe Power Corp. had to ground a utility building at its new Rocky Mountain pumped-storage hydroelectric plant. The plant was to be built on solid rock, where conductivity needed for ground rods is virtually nonexistent. Site conditions made it imperative that the designers of the grounding system look at all options available to lower resistivity. The original specifications called for copper ground plates to be placed in holes dug out of the rock and surrounded with coke powder as the conductive material. However, because groundwater can wash coke powder away, and grounding should be permanent, it was decided to use GEM.

GEM can be installed wet or dry. It absorbs moisture from the surrounding soil and then hardens, retaining moisture in its structure. When used dry, no mixing is required and the material will reach its maximum efficiency in days. To accelerate curing time, water can be added after the material is installed, or it can be premixed with water to form a slurry.

Advantages of GEM

GEM has many advantages over bentonite and rock salt. Unlike rock salt, it does not require periodic charging treatments or replacement. And, because it is chemically stable and very low in sulfate and chloride, it protects ground conductors from corrosion instead of attacking them like salts do. The material sets up hard like cement, and fills voids between the cable and the earth. Once set, it maintains high conductivity in wet or dry conditions. GEM meets all EPA requirements for landfill.

Where ground rods can't be driven, or where limited land area makes adequate grounding difficult with conventional methods, GEM may be used. Although it costs more initially than standard fill materials such as bentonite, only a small amount is needed, so the size of the grounding array can be reduced dramatically.

At the Oglethorpe Power Rocky Mountain plant, the process began by using a trencher with bullet teeth to cut narrow slots in the rock for laying the conductor cable, and holes were drilled for 30 ground rods. All connections were made with exothermically welded connections to ensure the highest possible electrical continuity in a permanent connection.

After the cables and rods were placed, the slots and holes were filled with the material, which was worked under and around the cables. The amount used for the cables varied with their length; as an example of the amounts needed for such work, however, each rod took two 25-pound bags. Mixed with water and poured in the rod holes in a slurry, it was firm to the touch within 48 hours and completely set to a cement-like hardness in seven days.

By reducing resistivity levels at the power plant, an electrical grounding system was made possible in solid rock. However, sandy soil was the challenge for contractors who had to ground a new Toro Irrigation Control System at a 36-hole golf course. The system is like a computer-driven mini-weather station. With its central weather sensor, it daily measures temperature, wind velocity, relative humidity, and rainfall. Then, it analyzes these data and computes the evapotranspiration rate (the amount of water that has evaporated due to temperature, wind velocity, relative humidity, and rainfall) for that day and automatically adjusts the run time for each sprinkler station to give individual areas of the golf course just the moisture needed.

The main computer signals the irrigation controllers (88 in this case) that activate the course's 2,400 sprinklers. When the computer determines that the ground is too dry, it sends that information to the controllers. They, in turn, signal the sprinklers to begin their irrigation cycle. The controllers have surge arresters on each wire coming in from and going out to the sprinklers, and permanent, low-resistivity grounding for each controller is mandatory.

Given this, a low-resistance ground is necessary (designers specified resistivity of 10 ohms or less). However, the soil is highly resistant. At first, 8-foot copper-clad rods were driven at several test locations. But when these yielded a resistance of over 300 ohms, combinations of ground rods and copper plates were tried. However, the best reading obtained (85 ohms) was unacceptable. Designers then turned to GEM.

The controllers sit on cement pads throughout the golf course. For most of the controllers, one 24-by-60-inch copper sheet was installed in each pad. Then, about 3 to 5 feet away from the cement, a 10-foot-deep, 4-inch-wide hole was augered. Two 8-foot rods were exothermically welded together and driven to the bottom of the hole. The area around the rod was then filled with a GEM slurry. During post-installation tests of soil resistivity, there were no readings over 11 ohms and the average was only 6 ohms.

Ideal Conditions

Only rarely do grounding system designers and contractors get to work on a site with good grounding conditions. Even under ideal circumstances, soil structure can vary and make it difficult to achieve uniform, low levels of resistivity across a wide area. However, with GEM, the results can be a lot more predictable because it offers: a reduction in earth resistance that remains for the life of the system even during dry spells, wet or dry installation, test-proven resistivity of 12 ohms-cm or less, and maintenance-free grounding. Above all, it improves grounding system performance.

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