How Safe Are Your Ground Grids?

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The most important and critical components of an electrical utility infrastructure are the supply stations. In the early days, the supply stations contained generation and equipment to supply the power in quantity to large populated areas. In the late 1800's the first stand-alone substations were constructed to transmit and distribute the electric power to more remote areas. Many substations built in the 1920's are still in service with only upgrades to equipment. Part 1 of the National Electric Safety Code (NESC) provides guidance for the "practical safeguarding of persons during installation, operations and maintenance of supply stations and their associated equipment". This section covers everything from clearances, locations of equipment, fence requirements, lighting, etc. Section 12 specifically requires that all equipment, fences, surge arresters or other non-current carrying conductive parts are effectively grounded. In order to provide a consistent means of grounding, paragraph .096B requires "extensive grounding systems consisting of multiple buried conductors". Utilities usually take care in maintaining breakers, regulators, switches and other critical equipment, but do not have set requirements to test ground grids. Some ground grids are approaching 100 years old and have not been tested in many years if at all. Personnel within a substation during a fault are subject to step, touch, mesh and transferred potential which may result in dangerous levels if the ground grid or its connections are in poor condition.

The purpose of an effective ground is to provide a safe, low resistance alternate path to earth during normal or fault conditions and to facilitate operation of the circuit protective device. A substation ground grid system in itself may not necessarily be low resistance but should be designed to limit the potential difference, whether induced or impressed, between any grounded parts or sections of the earth (step and touch potential). So the overall ground grid system includes a low resistance grid for equipotential properties in combination with high resistance soil to limit current flow between feet to acceptable levels. The 2007 NESC provides limited information about the installation and maintenance of ground grids, but refers to IEEE std 80-2000, a much more comprehensive document.

Standard 80 was first published in 1961 and has had four revisions. This document provides excellent detailed information about how current affects the human body. Based on tolerable voltage information from these studies, an effective safety ground grid system is designed to reduce the likelihood of fatal electrical contacts when working within a substation during a fault condition. Design criteria is based on step and touch voltage limits, available fault current, and overall clearing time. When the ground grid is new and in good condition, it should provide effective protection. In order to ensure that the ground grid system will continue to function as originally designed, the grid and earth resistance should be periodically tested.

Many electricians and technicians have the misconception that grounded equipment is not energized. Often the grid is disrupted by excavation or expansion. Conductors are added, and connectors are used without regard to the type or material of connector. NESC .093A states, "If joints are unavoidable, they shall be so made and maintained as to not materially increase the resistance of the grounding conductor and shall have appropriate mechanical and corrosion-resistant characteristics", and .093B states "Connection of the grounding conductor shall be made by a means matching the characteristics of both the grounded and grounding conductors, and shall be suitable for the environmental exposure. These means include brazing, welding, mechanical and compression connections, ground clamps, and ground straps. Soldering is acceptable only in conjunction with lead sheaths. Beyond normal conductors, foliage within the substation should be removed completely. The root structure may have a serious impact on the earth resistance, thus creating a lower resistance which will result in hazardous step potentials during a fault. These practices have an impact on the integrity of the grid. Working on the ground grid should be treated like any energized conductor. Rubber gloves should be utilized, and bridging a broken grid should include the installation of a jumper using insulated sticks. Testing the soil

resistivity along with the ground grid system will identify abnormal conditions.

Testing should include a fall-of-potential test, 3 or 4 point grounding tests and stakeless earth/ground tests for testing connections to the grid. For testing tower grounding systems, special clamp-on CTs are an option that may be used with the Fluke 1625 Earth/Ground tester. Test technicians should use rubber gloves to perform all tests especially when working with ground grids of unknown integrity.

A grounding system should be installed in a manner that will limit the effect of ground potential gradients to such voltage and current levels that will not endanger the safety of people or equipment under normal and fault conditions. The system should also ensure continuity of service (Std 80 9.2). Ground grids provide a fundamental safety feature in substations and should be tested periodically just as we test rubber gloves, hot sticks or other safety protective equipment.

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