Technical Bits … *of knowledge*

Ground Impedance – TB008

A substation ground grid is a system of ground electrodes that are interconnected and buried in the earth, providing a common ground for electrical equipment and metallic structures. The ground grid is a part of the grounding system which provides a path for power system currents during fault conditions. An adequate grounding system is required so that ground faults can be quickly detected and cleared by the protective devices. During ground fault conditions, significant voltages can be created which can result in hazards to personnel and damage to equipment. The level of the ground voltage rise is directly influenced by the grounding system impedance. An effective ground grid is designed to minimize the ground voltage rise which can reduce touch and step voltages. The design and installation of a ground grid can be verified by measuring the ground impedance. Assuming that the ground grid was properly designed and installed, the ground impedance can become elevated over time if the ground grid has been compromised. The grounding system can be compromised in a number of ways, including:

- Severed ground conductors
- Deteriorated ground electrodes
- Loose ground connections

Testing and measuring of the ground system on a routine basis ensures that the grounding system integrity has not been compromised. The ground impedance can be measured in a number of ways including:

- Two-point method
- Three-point method
- Fall-of-potential method
- Current injection
    - Power-frequency
    - Off-frequency

It should be noted that when measuring the ground impedance, the result is an ohmic value typically referred to as ground *resistance*. However, for large systems (when the ohmic value is less than 0.5 Ω), the reactive component should be taken into account.

Two-point method. This method does not apply for substation grids.

Three-point method. This method requires large spacing between the test rods, and typically does not provide highly accurate results.

Fall-of-potential method. This method (or a variation of this method) is typically preferred because this method provides highly accurate results. This method, however, requires that the current electrode be effectively outside the influence of the ground to be tested. "This influence is sometimes called *extent* of station ground and may be considered as the distance beyond which there is a negligible effect on the measured rise of ground voltage caused by ground current." A rule of thumb is to place the current electrode 6.5 times the diagonal distance (or 10 times the maximum length) of the ground grid under test. This typically poses problems. The slope method is a variation of the fall-of-potential test which requires a distance of only 2-3 times the maximum length of the ground grid. A detail description of this procedure can be found in MEGGER's publication "Getting Down to Earth".

Power-frequency current injection. This method requires the current to be high enough to swamp any noise on the grounding system. Although this method has the advantage of using traditional RMS wide band multimeters, the disadvantage is the size of the required power source.

Off-frequency current injection. Several manufacturers offer specialized test equipment for this test method. The advantage is the easily identifiable measurement signal (same as the injection signal), hence there is no need to worry about interference from noise on the grounding system allowing for a significantly lower power source requirement than power-frequency current injection. However, the disadvantage is similar to the fall-of-potential method which requires a test lead which is at least 6 times the diagonal length of ground grid under test. Another disadvantage is that the multimeters must be frequency specific.

Regardless of measurement method, periodic validation of the grounding system is an important maintenance test for facilities with high-voltage substations. For more detail on the test procedures referenced above, see IEEE Std. 81, IEEE Std. 81.2, and MEGGER publication "Getting Down to Earth".