Substations - Volume X: Grounding

An Online Continuing Education Course for Engineers

Course Number: E-4042

Credit: 4 Hours / 4 PDH / 4 CPD

Substations - Volume X: Grounding

Lee Layton, P.E.

Preface

This course is one of a series of thirteen courses on the design of electrical substations. The courses do not necessarily have to be taken in order and, for the most part, are stand-alone courses. The following is a brief description of each course.

Volume I, Design Parameters. Covers the general design considerations, documents and drawings related to designing a substation.

Volume II, Physical Layout. Covers the layout considerations, bus configurations, and electrical clearances.

Volume III, Conductors and Bus Design. Covers bare conductors, rigid and strain bus design.

Volume IV, Power Transformers. Covers the application and relevant specifications related to power transformers and mobile transformers.

Volume V, Circuit Interrupting Devices. Covers the specifications and application of power circuit breakers, metal-clad switchgear and electronic reclosers.

Volume VI, Voltage Regulators and Capacitors. Covers the general operation and specification of voltage regulators and capacitors.

Volume VII, Other Major Equipment. Covers switch, arrestor, and instrument transformer specification and application.

Volume VIII, Site and Foundation Design. Covers general issues related to site design, foundation design and control house design.

Volume IX, Substation Structures. Covers the design of bus support structures and connectors.

Volume X, Grounding. Covers the design of the ground grid for safety and proper operation.

Volume XI, Protective Relaying. Covers relay types, schemes, and instrumentation.

Volume XII, Auxiliary Systems. Covers AC & DC systems, automation, and communications.

Volume XIII, Insulated Cable and Raceways. Covers the specifications and application of electrical cable.

Chapter 1: Issues Affecting Substation Grounding

This chapter is concerned with safe grounding practices and design for outdoor 60 Hz AC substations. DC substations and the effect of lightning surges are not covered.

An effective substation grounding system typically consists of driven ground rods, buried interconnecting grounding cables or grid, equipment ground mats, connecting cables from the buried grounding grid to metallic parts of structures and equipment, connections to grounded system neutrals, and the ground surface insulating covering material. Currents flowing into the grounding grid from lightning arrester operations, impulse or switching surge flashover of insulators, and line-to-ground fault currents from the bus or connected transmission lines all cause potential differences between grounded points in the substation and remote earth. Without a properly designed grounding system, large potential differences can exist between different points within the substation itself. Under normal circumstances, it is the current flow through the grounding grid from line-to-ground faults that constitutes the main threat to personnel.

An effective grounding system has the following objectives:

1. Ensure such a degree of human safety that a person working or walking in the vicinity of grounded facilities is not exposed to the danger of a critical electric shock. The touch and step voltages produced in a fault condition have to be at safe values. A safe value is one that will not produce enough current within a body to cause ventricular fibrillation.

2. Provide means to carry and dissipate electric currents into earth under normal and fault conditions without exceeding any operating and equipment limits or adversely affecting continuity of service.

3. Provide grounding for lightning impulses and the surges occurring from the switching of substation equipment, which reduces damage to equipment and cable.

4. Provide a low resistance for the protective relays to see and clear ground faults, which improves protective equipment performance, particularly at minimum fault.

While line-to-ground faults may result in currents of tens of thousands of amperes lasting several seconds, modern relay systems generally reduce the fault duration to a few cycles. During fault current flow, a low ground grid resistance to remote earth, although desirable, will not, in itself, necessarily provide safety to personnel. It is necessary that the entire grounding system be designed and installed so that, under reasonably conceivable circumstances, personnel are not exposed to hazardous potential differences across the body.

Designing a proper substation grounding system is complicated. Numerous parameters affect its design, and it is often difficult to obtain accurate values for some of these parameters. Furthermore, temperature and moisture conditions can cause extreme variations in the actual resistivity of the ground in which the system is installed. Methods of dealing with the design problem are necessarily based to some extent on approximations and the exercise of engineering judgment. The design approach has to be conservative because of the aforementioned uncertainties.

A good grounding system provides a low resistance to remote earth in order to minimize the ground potential rise. For most transmission and other large substations, the ground resistance is usually about 1 ohm or less. In smaller distribution substations the usually acceptable range is from 1 to 5 ohm, depending on local conditions.

For reference material, IEEE Std. 80, "Guide for Safety in Substation Grounding," is generally recognized as one of the most authoritative guides available. It is recommended for any person concerned with the design of substation grounding systems.

This course describes some of the different modes in which ground fault current may flow with respect to substation grounding systems. Included is discussion of safety considerations in and near substations when all or a portion of this fault current flows through the substation grounding system. Specific recommendations for the design, installation, and testing of safe and effective grounding systems for substations are included.

Definitions

Listed below are a few definitions related to substation grounding.

DC Offset is the difference between the symmetrical current wave and the actual current wave during a power system transient condition. Mathematically, the actual fault current can be broken into two parts: a symmetrical alternating component and a unidirectional (DC) component. The unidirectional component can be of either polarity, but will not change polarity and will decrease at some predetermined rate.

Earth Current is the current that circulates between the grounding system and the ground fault current source that uses the earth as the return path.

Ground Fault Current is a current flowing into or out of the earth or an equivalent conductive path during a fault condition involving ground.

Ground Potential Rise (GPR) is the maximum voltage that a ground grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. The GPR is equal to the product of the earth current and the equivalent impedance of the grounding system.

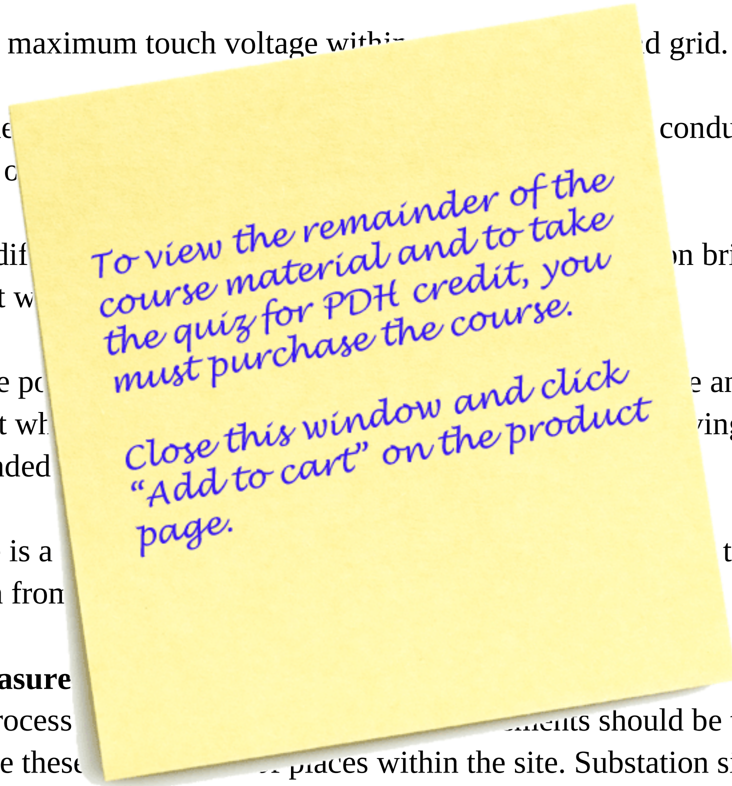
Mesh Voltage is the maximum touch voltage withi... d grid.

Soil Resistivity is the ... conductivity. The value is typically given in c...

Step Voltage is the dif... n bridging a distance of 1 meter with his feet w...

Touch Voltage is the po... e and the surface potential at the point wh... ving his hands in contact with a grounded ...

Transferred Voltage is a ... transferred into or out of the substation from...



Soil Resistivity Measure...

Before the design process ... ments should be taken at the substation site. Make these ... places within the site. Substation sites where the soil may possess uniform resistivity throughout the entire area and to a considerable depth are seldom found. Typically, there are several layers, each having a different resistivity. Often, lateral changes also occur, but, in comparison to the vertical ones, these changes usually are more gradual. Make soil resistivity tests to determine if there are any important variations of resistivity with depth. The number of such readings taken should be greater where the variations are large, especially if some readings are so high as to suggest a possible safety problem.

The Wenner four-pin method as shown in Figure 1 is the most commonly used technique for taking soil resistivity measurements.