

**ERCIYES UNIVERSITY FACULTY OF ENGINEERING
DEPARTMENT OF ENERGY SYSTEMS ENGINEERING**



EXPERIMENT SHEET

EXPERIMENT TITLE

GROUNDING EXPERIMENT

COURSE INSTRUCTOR

INSTRUCTOR CONDUCTING THE EXPERIMENT

Name

Surname:

Student ID:

Group:

Experiment

Date:

Submission

Date:

EXPERIMENT - 5

GROUNDING EXPERIMENT

OBJECTIVE OF THE EXPERIMENT:

THEORY OF THE EXPERIMENT:

Grounding is the process of connecting a specific point of an electrical system, equipment, or conductive component directly to the earth through a conductive path. In engineering applications, grounding serves various purposes, including system safety, protection of human life, proper operation of equipment, and electromagnetic compatibility. One of the fundamental functions of grounding is to safely conduct hazardous voltages or leakage currents resulting from electrical faults to the earth. **Figure 1 presents photographs of grounding applications.**



Figure 1: Photographs of grounding applications

Grounding systems are based on establishing physical contact with the soil by means of a conductor connected to metallic parts that are not energized during normal operation. This contact provides a low-resistance path for electrical current to flow into the earth. However, for this process to be safe and effective, factors such as grounding electrode construction, placement, and soil resistivity must be appropriately considered in the design. Otherwise, the intended flow of fault current into the earth may be impeded, posing risks to life and property.

1. Types of Grounding

Grounding has three fundamental purposes. According to these purposes, grounding is classified into **protective grounding, operational (system) grounding, and functional grounding.**

1.1. Protective Grounding: Protective grounding is the grounding of a conductive part that is not

part of the operating current circuit in order to reduce the risk to people from potentially dangerous voltages that may occur on the external surfaces of electrical equipment.

1.2. Operational (System) Grounding: Grounding a point in the operating current circuit in order to regulate the operating conditions of devices and installations and maintain voltage balance.

1.3. Functional Grounding: Grounding performed to enable a communications installation or an operating component to fulfill its intended function. This grounding also carries the operating currents of communications equipment that uses the earth as a return conductor.

1.4. Building Grounding: Grounding that prevents a building from being affected by static electricity. **The types of grounding are illustrated in Figure 2**

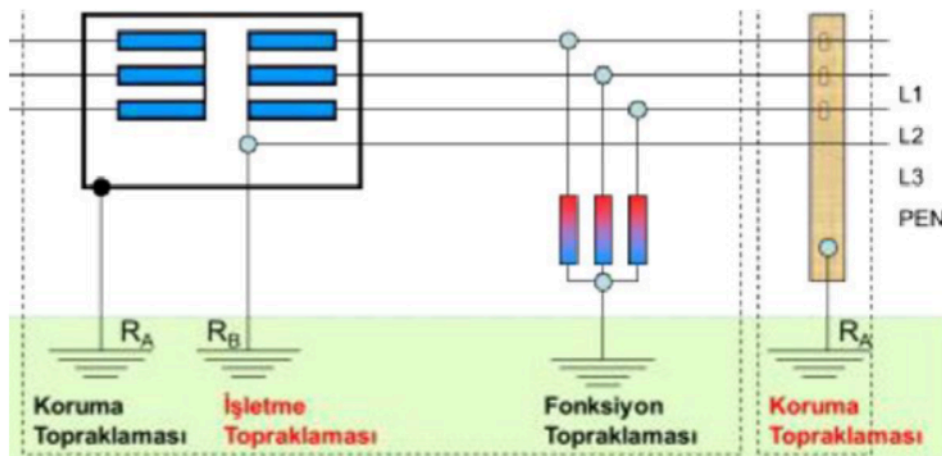


Figure 2: Types of grounding (protective, operational, functional, and protective grounding, from left to right)

In modern energy systems, particularly in low- and medium-voltage installations, grounding is an indispensable component of electrical protection. Protective devices such as residual current devices (RCDs), fuses, and automatic disconnection systems require effective grounding to operate properly. Grounding also plays an important role in ensuring electromagnetic compatibility in energy systems and preventing interference in communication lines.

2. Importance of Grounding and Applications

Grounding is extremely important both for protecting human life and for ensuring the safe and efficient operation of electrical systems. Insulation deterioration, short circuits, or lightning strikes may produce hazardous voltages on conductive surfaces. Such voltages can cause electrical current to flow through the human body upon touch or contact. Grounding reduces these risks by providing a low-resistance route for fault or leakage current to flow into the earth, helping prevent hazards such as electric shock.

Grounding systems are necessary not only for safety but also to maintain system stability, protect equipment against overvoltages, and support the correct operation of automatic protective systems. For example, effective operation of protective devices such as residual current devices or circuit breakers in an electrical panel depends on a properly functioning grounding system. An electrical installation without grounding therefore poses serious risks to both users and equipment.

The Fundamental situations in which grounding is required include:

- Preventing hazardous voltages on the metallic enclosures of equipment **in electrical installations** from harming people.
- Maintaining system balance and reducing the effects of overvoltages by connecting the neutral point to earth **in electrical generation, transmission, and distribution systems.**
- Safely transferring high-energy lightning currents to the earth **in lightning protection systems.**
- Reducing electromagnetic interference and improving system stability **in industrial plants and environments containing sensitive devices.**
- Eliminating differences in earth potential and improving signal quality **in communications and signaling systems.**
- Ensuring user safety by using portable grounding systems **in temporary installations such as construction sites and mobile generators.**

Grounding can be performed in various configurations as well as for different purposes. If an

operating component is connected only to its own grounding electrode, this is called individual grounding. In star grounding, the grounding conductors associated with multiple operating components converge at one point in a star arrangement and are connected to earth. Multiple grounding refers to an operating component or device connected to several grounded conductors, such as an equipotential bonding conductor, protective conductor (PE), or functional earthing conductor (FE). These grounding conductors may be connected to the same earthing bonding conductor or to different grounding electrodes. Surface grounding is a configuration in which the non-current-carrying conductive parts of operating components and communications installations are interconnected in a network and connected to protective grounding, or to combined functional and protective grounding.

3. Grounding Terminology

Protective Conductor (PE): A conductor that connects the exposed conductive parts of equipment to the equipotential bonding bar, grounding electrodes, or grounded point of the electrical power source as a safety measure against hazardous fault currents through exposed conductive parts.

Combined Protective and Neutral Conductor (PEN): A grounded conductor that combines the functions of the protective conductor and neutral conductor in a single conductor.

Foundation Grounding Electrode: A conductor embedded in concrete and having a large contact area with the earth through the concrete.

Grounding Electrode: These are conductive components buried in the ground with a conductive connection to the soil, or embedded in concrete with a large-surface-area connection. They can take the form of strips, tubular profiles, braided conductors, or plates. Surface grounding electrodes are generally installed at a depth of 0.5 to 1 m. They can be made of galvanized strip, round or braided conductor, and may be star-shaped, ring-shaped, loop-shaped, or a combination of these. Deep grounding electrodes, on the other hand, are typically installed vertically to a depth of more than 1 m. They can be made of galvanized pipe, round rod, or similar profile materials.

Earth electrode spreading resistance (RE): This is the resistance of the soil between an earth electrode or grounding system and the reference ground. The spreading resistance can be approximated as ohmic resistance.

Soil Resistivity: The electrical resistivity of the soil. Its unit is $\Omega \cdot \text{m}^2/\text{m}$ or $\Omega \cdot \text{m}$. This resistivity is the resistance between two opposite faces of a soil cube with an edge length of 1 m.

Soil type	Soil resistivity ρ_e ($\Omega \cdot m$)
Swamp	5-40
Mud, clay, humus	20-200
Sand	200-2500
Gravel	2000-5000
Weathered rock	Generally <1000
Sandstone	2000-3000
Granite	>50000
Moraine (glacial deposit)	>30000

Table 1. Soil resistivity at alternating-current frequencies (commonly measured values)

Grounding Resistance: The sum of the grounding electrode's spreading resistance and the resistance of the grounding conductor.

Total Grounding Resistance: The total resistance of all grounding systems that can be measured at a given location and are included in the measurement.

Grounding Impedance (ZE): It is the alternating current resistance (at operating frequency) between a grounding system and the reference ground. The absolute value of this impedance is obtained by the parallel connection of the spreading resistances of the grounding electrodes and the impedances of conductors with a grounding effect, such as grounding conductors and cables.

Surge Grounding Resistance: The resistance effective between any point on a grounding system and the reference ground during the passage of lightning currents.

Potential Drift: The transfer of the rising potential of an earthing system to an area with a lower potential or to the reference earth zone via a conductor connected to that system (e.g., metal cable sheaths, PEN conductor, water pipes, railroad tracks). This creates a potential difference in the conductor relative to its surroundings.

Potential Regulation: The process of influencing the potential distribution by placing regulating electrodes around an earthing system to reduce step and touch voltages.

Potential Equalization: This involves eliminating potential differences between conductive parts. These arrangements are implemented by establishing a potential equalization line to eliminate potential differences between protective conductors and conductive structural parts or between different sections of a structure.

4. Sequence of Grounding Procedures

- Determining the location to be grounded
- Measuring the soil resistivity
- Calculating the soil spreading resistance
- Selecting the type of grounding electrode and installing the system

- Checking the connections
- Repeating the measurements

5. Methods for Calculating Ground Resistance:

There are various methods for calculating ground resistance. Some of these include **the Laurent, Koch, Sverak, and Schwarz methods**. One of the most prominent methods is the Schwarz method. **In this method, the resistances of horizontal conductors and vertical rods, as well as the mutual resistances between them, are taken into account.**

Network Grounding Resistance:

$$R_g = \frac{\rho}{\pi l_c} \left[\ln \left(\frac{2l_c}{\sqrt{d_1 h}} \right) + \frac{k_1 l_c}{\sqrt{A}} - k_2 \right] \quad (1)$$

Grounding Resistance of Rods:

$$R_k = \frac{\rho}{2\pi n_p l_k} \left[\ln \left(\frac{8l_k}{d_2} \right) - 1 - \frac{2k_1 l_k}{\sqrt{A}} (\sqrt{n_p} - 1)^2 \right] \quad (2)$$

Mutual Resistance Between Grid Conductors and Network:

$$R_m = \frac{\rho}{2l_c} \left[\ln \left(\frac{2l_c}{l_k} \right) + \frac{k_1 l_c}{\sqrt{A}} - k_2 + 1 \right] \quad (3)$$

Grounding Resistance

$$R = \frac{R_g R_k - R_m^2}{R_g + R_k - 2R_m} \quad (4)$$

ρ : Soil resistivity

lc : The total length of the conductors that make up the network

l_k : Rod length

n_p : Number of rods

k_1 and k_2 : Schwarz constants

A : Network area

d_1 : The diameter of the conductors that make up the network

h : Burial depth

d_2 : Rod diameter

The Schwarz constants are determined using the following formulas. Using the values obtained, the constants k_1 and k_2 for the burial depth of the grounding system are determined by interpolation.

$h_i = 0$	$k_1 = -0.04x + 1.41$	$k_2 = 0.15x + 5.50$
$h_i = \frac{1}{10}\sqrt{A}$	$k_1 = -0.05x + 1.20$	$k_2 = 0.1x + 4.68$
$h_i = \frac{1}{6}\sqrt{A}$	$k_1 = -0.05x + 1.13$	$k_2 = -0.05x + 4.40$

$$X = \frac{\text{Long Side of the Network}}{\text{Short Side of the Network}} \quad (5)$$

$$F_1 = k_{1_1} - k_{1_2} \quad (6)$$

$$k_1 = k_{1_1} - \frac{F_1 * h}{h_i} \quad (7)$$

$$F_2 = k_{2_1} - k_{2_2} \quad (8)$$

$$k_2 = k_{2_1} - \frac{F_2 * h}{h_i} \quad (9)$$

6. Ground Resistance Tester (megohmmeter) (Toprak Megeri)

This is a measuring instrument used to measure soil resistivity. It has four terminals: two are used for current, and the other two are used for voltage. According to the Wenner method—(one of the most commonly used methods)—four electrodes are driven into the ground at equal intervals. The two outermost electrodes serve as current electrodes, while the two middle electrodes serve as voltage electrodes. The electrodes are driven vertically into the ground to a depth of 20–30 cm. The current electrodes are connected to the current terminals of the megohmmeter, and the voltage electrodes are connected to the voltage terminals.

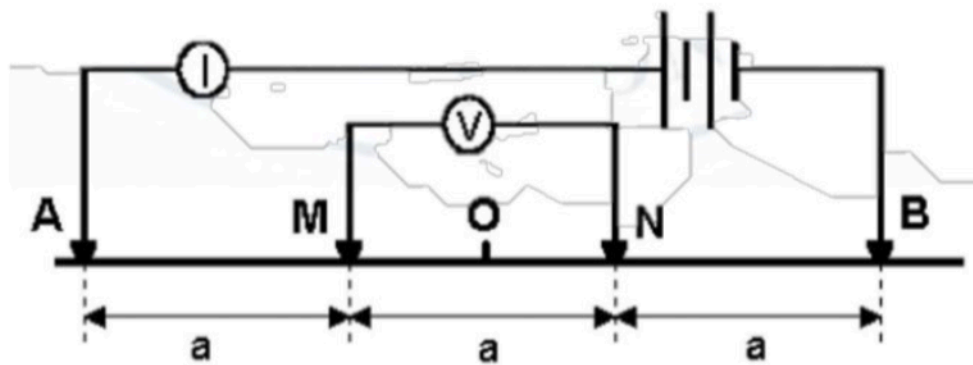


Figure 3: Wenner array

The soil megger (**soil resistance meter**) gives the soil resistance (R) at point O. The soil resistivity is calculated using the obtained resistance value. The formula for calculating resistivity using the Wenner method is given in Equation 10.

$$\rho = 2\pi a R \quad (10)$$

ρ = Apparent resistivity of the soil ($\Omega \cdot m$)

a = Equal distance (m) between the electrodes

R = Measured grounding test resistance (Ω)

