The University of Jordan
School of Engineering
Electrical Engineering Department

EE 449
Instrumentation and Control Lab

EXPERIMENT 1
EARTHING AND GROUND RESISTANCE

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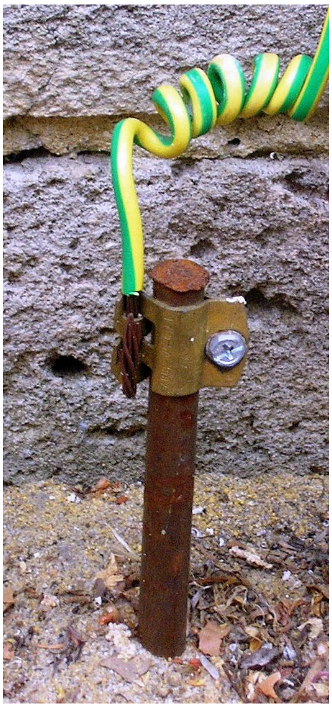
EXPERIMENT 1
EARTHING AND GROUND RESISTANCE

OBJECTIVES

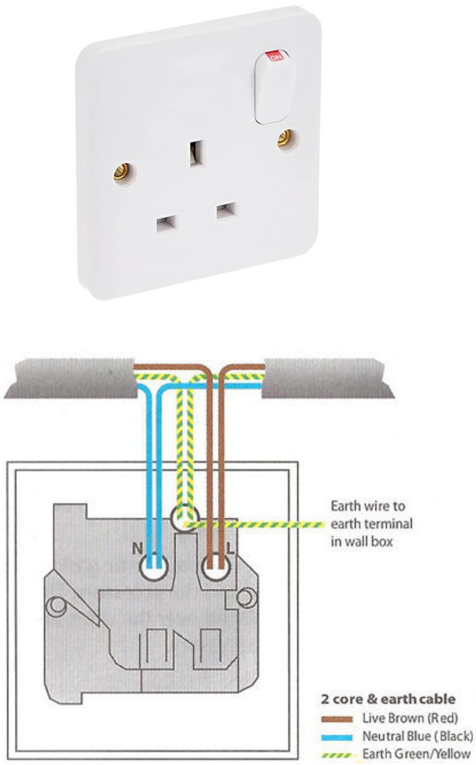
1. To understand the importance of earthing/grounding in practical systems.
2. To understand the meaning of ground resistance.
3. To be able to measure ground resistance using proper testing equipment.

DISCUSSION

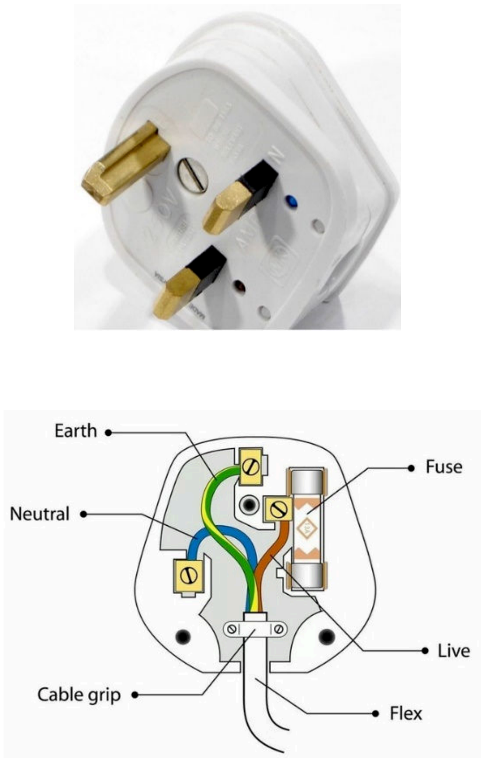
Regulations require that electrical systems employ appropriate grounding for safety and proper equipment operation. That is why equipment in an electric distribution system (transformers, circuit breakers, etc) are connected to the ground. In addition, buildings, radio towers and telecommunication equipment are grounded to protect against lightning strikes. Furthermore, homes have a ground/earth wire connected to the ground. The conductive surfaces of home appliances (your fridge, toaster, microwave, etc) are connected to this earth wire for safety against faults. These are collectively known as *earthing systems* (UK and IEC terminology) or *grounding systems* (US terminology).



Earthing rod (typically solid copper or steel with copper outer layer) driven into the ground

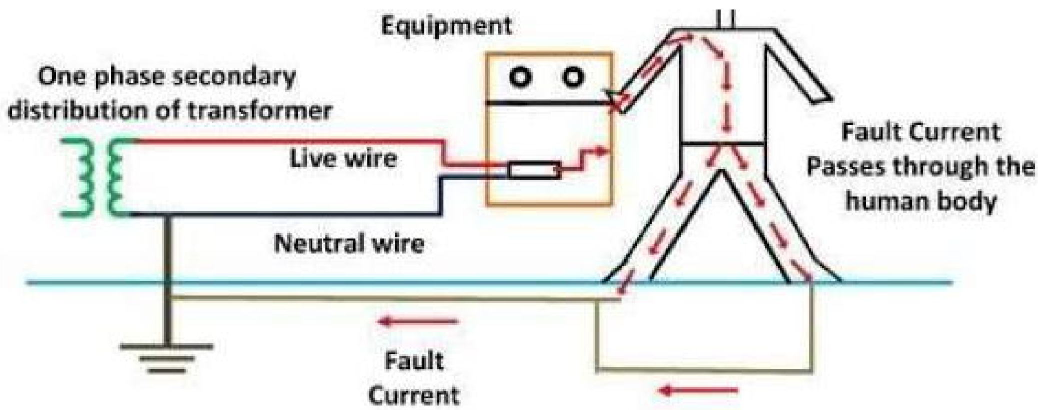


MK-type electric socket. The socket has three pins, with the top pin being the earth terminal. This pin is connected by a green-and-yellow wire to the earthing rod.

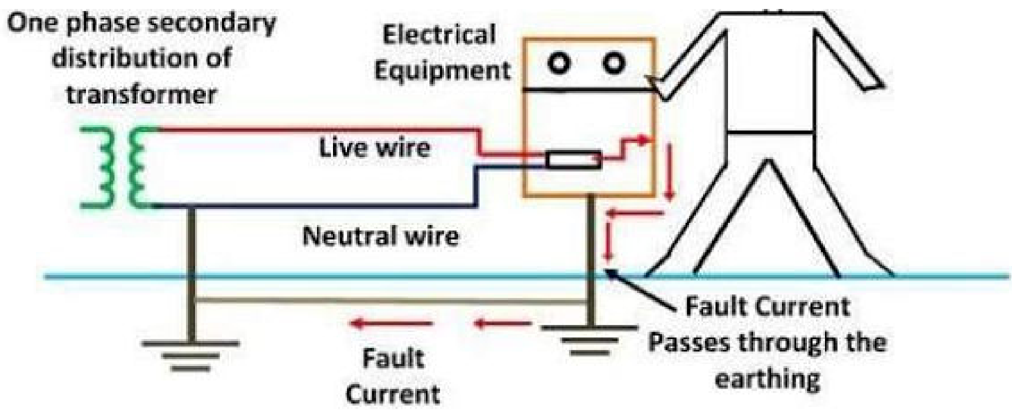


MK-type mains plug (Type G), commonly used in the UK. The top wire (green-and-yellow) is the earth wire connected to the chassis or metal structure of an appliance for safety.

The reason for grounding the conductive surfaces of home appliances through the earth wire in your home is to allow a fault current from the live wire to go through the chassis of the appliance then the ground (hopefully tripping the appropriate circuit breaker), rather than going through the human body as shown below. Regulations for earthing systems may vary between countries, but most follow the International Electrotechnical Commission (IEC) recommendations.



Electrical system **without** earthing



Electrical system **with** earthing

Earthing also prevents static buildup (say due to friction of wind blowing onto a radio mast), and helps protect against power surges caused by nearby lightning strikes. In the case of a surge, a lightning arrester installed on the roof of tall buildings, diverts the excess current to the earth before it can cause damage. Additionally, earthing sometimes serves to reduce electromagnetic interference (EMI) for communication devices.

Sometimes, you will see the words *earthing* and *grounding* used to make a distinction between the practice of connecting equipment frames and enclosures to earth (referred to as *earthing*) versus connecting the neutral point of a three-phase power system (in the star configuration) to earth (called *grounding*). This later practice of connecting neutral to ground is useful to stabilize voltage and facilitate protection in the power grid. Either way, both earthing and grounding require making a connection to earth utilizing a grounding rod.

In this experiment, you want to measure the *ground resistance*, which is the resistance of the grounding rod to which your equipment is connected to earth. Ideally, this resistance should be as small as possible, so that we maintain the potential of the earth on the system being grounded. This provides a low impedance path for any fault current to flow through, and hence, energy can be easily dissipated from a site into the surrounding soil.

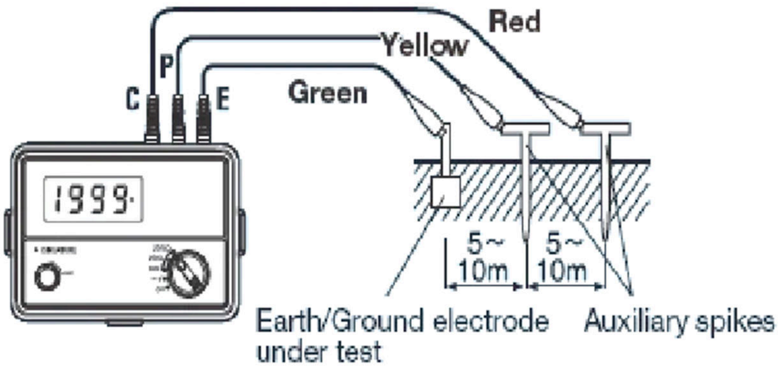
Soil resistivity plays a key role when designing an effective grounding system. Local soil resistivity varies based on the soil type and varies seasonally. Soil resistivity is affected by the moisture, mineral and dissolved salt content of the soil. The table below lists some typical soil resistivity values.

Soil type	**Soil resistivity (Ω-m)**	
	Minimum value	Maximum value
Clay, cinders	5	165
Loam with sand and gravel	10	1350
Gravel, sand, stones	600	4500

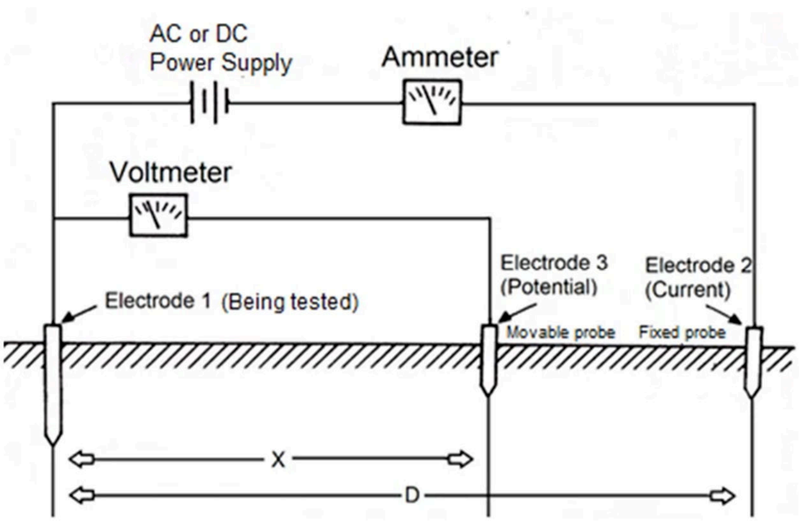
Notice the wide variation is soil resistivity values in the above table, the reason for which is that soil resistivity is highly dependent on its moisture content. When soil is completely dry, its resistivity is extremely high (acting as an insulator), but when moisture content reaches 25% of the wight, resistivity drops significantly.

The *fall-of-potential* method is a widely used testing technique to measure earth resistance of grounding systems. In such test, special electrical equipment, such as the PE-331 device shown below is used.

The testing device has three terminals labeled: C (current probe, red), P (potential probe, yellow), and E (earth probe, green). First, the earthing rod to be tested is disconnected from its system to ensure accuracy. Then, this earthing rod is connected to the earth probe (E) of the testing device. Next, two earth stakes are driven into the soil in a direct line, away from the earthing rod, with *proper spacing* (see below). The outer stake is connected to the current probe (C), while the middle stake is connected to the potential probe (P) of the testing device (see the figure below).



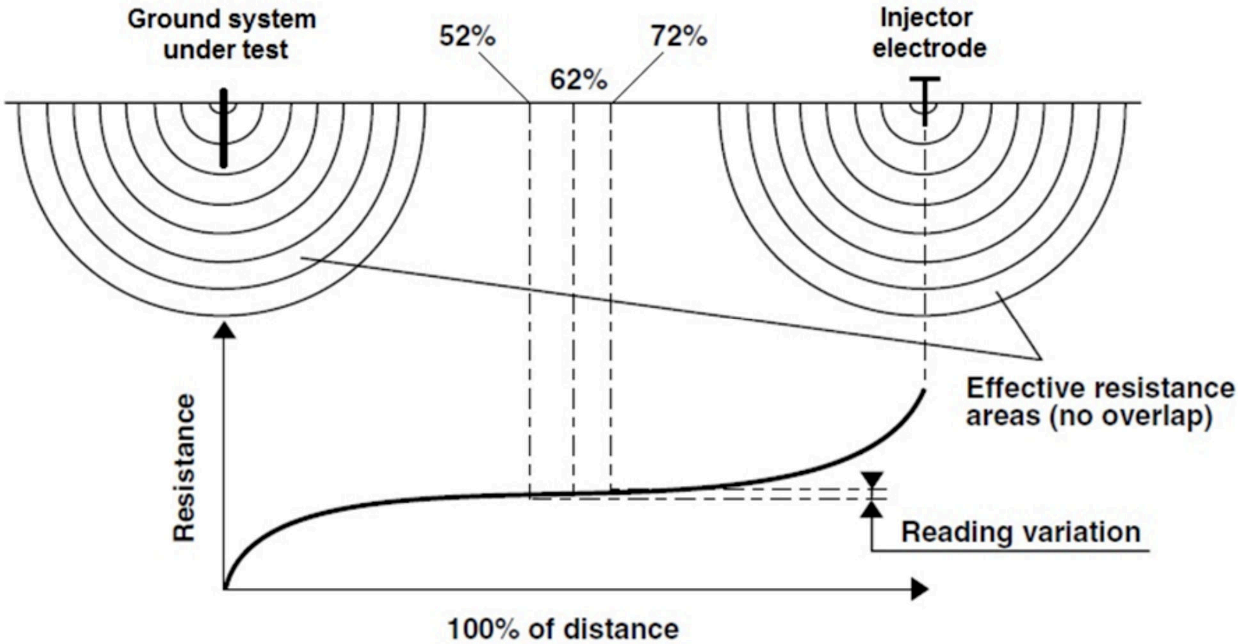
When pressing START, the device injects a known current between the outer stake (current probe, C) and the earth probe (E), while the drop in voltage potential is measured between the potential probe (P) and the earth probe (E). Using Ohm's Law ($V = I \times R$), the testing device can calculate the ground resistance (the resistance between the potential probe (P) and the earth probe (E)).



To ensure accuracy of the measurement, the current probe (C) must be placed outside the sphere of influence of the earthing rod (E). The table below shows a guide for appropriate distance (D) from the current probe (C) to earthing rod (E), which depends on the depth of the earth rod into ground.

Depth of earthing rod	Distance (D) to current probe
1 m	20 m
2 m	25 m
3 m	30 m
6 m	40 m

The figure below shows how the ground resistance value measured by the fall-of-potential method changes as the distance (X) between the movable potential probe (P) and the earth probe (E) is varied. When this distance (X) is between 52% and 72% of the distance (D), the resistance value stays almost constant, and represents the most accurate value for the ground resistance.



That is why sometimes the value at distance X = 62% × D is taken to be the actual measurement (called 62% rule), while at other instances, three values are taken (e.g., at X = 52%, 62%, and 72% of the distance D) and then averaged to find the ground resistance. Taking three measurements also helps verify that there is a stable plateau in the resistance curve between 52% and 72%, which indicates that the distance D (between the earth probe (E) and the current probe (C)) was selected properly.

In practical systems, the target ground resistance is 5 Ω or less for general systems, and 1 Ω or less for industrial and power grid applications, with a single electrode providing 25 Ω or less on its own. If the ground resistance obtained by a single earthing rod is not small enough, a longer earthing rod can be driven deeper into the ground. Doubling the depth of the rod in the ground can sometimes reduce the ground resistance by up to 40%. In addition, soil conductivity enhancement materials (such as bentonite clay, carbon-based conductive cement, graphite-based materials, etc) can be added around the earthing rod to improve ion flow, and hence improve ground resistance. Alternatively, multiple earthing rods can be driven into the ground and then connected into a grid to provide a much smaller overall ground resistance.

PROCEDURE A: GOOD WEATHER

1. Use a fall-of-potential testing device to test the *short* earthing rod (which is driven about 50 cm into the ground). Place the earth probe (E) on the rod, and place the current probe (C) at a distance of **D = 22 meters** from the earth probe. Now place the potential probe (P) at different distances (X) from the earth probe (E) to read the resulting ground resistance. Fill the table below with the measured values. Remember to select a proper ohm rang on the testing device, and take all distance measurements on a straight path between the earth probe (E) and the current probe (C).

Distance (X) between potential probe (P) and earth probe (E)	Percentage of distance (X) to distance (D), i.e., X/D	Measured ground resistance value (Ω)
0.5 m	2%	
1.1 m	5%	
2.2 m	10%	
3.3 m	15%	
4.4 m	20%	
5.5 m	25%	
7.7 m	35%	
9.9 m	45%	
11.4 m	52%	
13.6 m	62%	
15.8 m	72%	
17.6 m	80%	
18.7 m	85%	
19.8 m	90%	
20.9 m	95%	
21.5 m	98%	

2. Plot (**by hand**) the measured ground resistance values versus the percentage of distance (X) to overall distance (D) (i.e., X/D).

3. Does the measured curve resemble the expected theoretical curve?

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4. Determine the average ground resistance for this short rod from the three readings at 52%, 62%, and 72% of the distance ratio (X/D)?

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PROCEDURE B: RAINY DAY

1. Repeat the above fall-of-potential test for the same *short* earthing rod after you have poured some tap water on and around the rod (simulating rain on a winter day). One or two liters of water should be enough. Keep the distance **D = 22 meters** between the earth probe (E) and the current probe (C). Fill the table below with the new ground resistance readings.

Distance (X) between potential probe (P) and earth probe (E)	Percentage of distance (X) to distance (D), i.e., X/D	Measured ground resistance value (Ω)
0.5 m	2%	
1.1 m	5%	
2.2 m	10%	
3.3 m	15%	
4.4 m	20%	
5.5 m	25%	
7.7 m	35%	
9.9 m	45%	
11.4 m	52%	
13.6 m	62%	
15.8 m	72%	
17.6 m	80%	
18.7 m	85%	
19.8 m	90%	
20.9 m	95%	
21.5 m	98%	

2. Plot (**by hand**) the measured ground resistance values versus the percentage of distance (X) to overall distance (D) (i.e., X/D).

3. Determine the average ground resistance for this short rod (on a rainy day) from the three readings at 52%, 62%, and 72% of the distance ratio (X/D)?

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4. Comment on the difference between the results in this procedure and results of the previous procedure A (without using water)?

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5. Why did extra moisture change the ground resistance value? Explain the science behind this.

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PROCEDURE C: OTHER EARTHING ROD

1. Repeat the above fall-of-potential test, but for the other *longer* earthing rod (which is driven about 120 cm into the ground). **No need** to pour any water. Maintain similar distance **D = 22 meters** between the earth probe (E) and the current probe (C). Fill the table below with the new readings by varying the distance (X) between the potential probe (P) and the earth probe (E).

Distance (X) between potential probe (P) and earth probe (E)	**Percentage of distance (X) to distance (D), i.e., X/D**	**Measured ground resistance value (Ω)**
0.5 m	2%	
1.1 m	5%	
2.2 m	10%	
3.3 m	15%	
4.4 m	20%	
5.5 m	25%	
7.7 m	35%	
9.9 m	45%	
11.4 m	52%	
13.6 m	62%	
15.8 m	72%	
17.6 m	80%	
18.7 m	85%	
19.8 m	90%	
20.9 m	95%	
21.5 m	98%	

2. Plot (**by hand**) the measured ground resistance values versus the percentage of distance (X) to overall distance (D) (i.e., X/D).

3. Determine the average ground resistance for the long rod from the three readings at 52%, 62%, and 72% of the distance ratio (X/D)?

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4. Comment on the difference between the results in this procedure and the previous results of procedure A?

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5. Suggest methods that can be used in practice to reduce ground resistance (when needed).

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