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Experimental Analysis for Different Rod Configurations of Grounding System

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Abstract: Generally, grounding systems secure electrical equipment and people by channeling fault currents to the ground. The location of the electrode is crucial for a small grounding resistance value. Measurements are required to determine the resistance value. Earthing resistance value is affected by planting depth and electrode location. This paper investigates the relationship between electrode arrangement and electrode depth for a low-resistance earthing system. Also conducted in this paper is the determination of soil types found in Universiti Tun Hussein Onn Malaysia (UTHM) based on the measurement of resistivity values. The installation of this grounding system was conducted in Tun Fatimah's residential college at UTHM with different methods which are a single grounding rod, two parallel grounding rods and three parallel grounding rods. Each of these methods is planted at a different depth particularly 1.5, 3.0 and 4.5 meters. The performance of an earthing system is determined by factors such as electrode depth, soil conditions, soil types and installation types. It is found that the resistance value for the depth of 3 rods planted with the single grounding rod method (4.5 meters) is 0.612 ohms while the resistance value for the depth of 1.5 meters with the three parallel grounding rod method is 1.8 ohms. Thus, it can be concluded that the deeper the electrode, the lower the ground resistance. Deeper electrode implantation significantly reduces the resistance value compared to parallel implantation.

Keywords: Grounding Rods, Soil Conditions, Electrode, UTHM

1. Introduction

Grounding is basically known as a safety measure to help prevent people from accidentally encountering electrical hazards [1]. In the electrical system, the grounding system are the circuits used to connect electrical devices to the ground. Grounding of electrical installation is primarily concerned with the safety aspect of equipment and use. Grounding is important in providing a reference voltage (zero potential ground potential) against which all other voltages in a system are established and measured. An effective ground connection also minimizes the susceptibility of equipment to interface as well as reduces the risk of equipment damage due to lightning. If the grounding system is installed

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correctly, it should allow enough current to flow under fault conditions. The protective device should be installed correctly so that the rise in potential during fault conditions combined with fault clearance can minimize the risk of electrocution to individuals near the site of damage to equipment. To get the best grounding system, the low earth resistance must be archived. For an electrical engineer, this is one of the biggest encounters. Based on various electrical engineering standards, the limiting ground resistance that should be achieved for a given installation varies according to certain conditions [2]. Usually, engineers will just use their experiences or trial-and-error techniques to decide on a suitable grounding electrode system. However, such practice sometimes will lead to high cost and practical differences as either the system is less designed, needs more grouping electrodes or is over-designed wasting material and labor.

There are several types of grounding systems that can be made in 4 forms that are often used in the installation of grounding systems. To make an earthing installation with an earthing resistance value that complies with the regulations, several techniques can be performed such as paralleling, adding depth or increasing the cross-sectional area of the course. By doing grounding with this technique, it will be able to help to produce a safe grounding. There are many ways to obtain a standard earthing resistance value, which should be carried out in a suitable (legal) way and not contain non-legal elements that could be harmful in the future. This installation system is used as an alternative to reduce the grounding resistance value. There are four types of grounding rods such as single, parallel, multiple rods, and grounding plate [3-4].

Grounding technology was introduced to prevent lightning strikes on equipment, ensuring a proper grounding system. The problem that is always faced when installing a grounding system is not being able to identify the correct method to install the grounding system safely and accurately. Resistance testing is done before construction to facilitate installation. Calculating the best method saves time and energy. This paper aims to collect data on the number of parallel electrodes and electrode depth for the best grounding system, using case studies and grounding resistance tests. This information is used as a reference for engineers and researchers. This paper also aims to investigate the relationship between electrode arrangement and electrode depth for the best grounding system at Universiti Tun Hussein Onn Malaysia (UTHM). It will determine the types of soil and analyze and compare the measured resistivity values with calculations. The grounding test is carried out at the field site in front of Tun Fatimah's residential college.

2. Materials and Methods

The process flow chart for the entire project is shown in Figure 1. This project is implemented in 3 phases. The flow chart illustrates the steps that need to be implemented to successfully design and analyze the type of earthing system installation method. The project started by designing the grounding rod in Phase 1 followed by physical work to plant the rod with the appropriate rod depth in the next phase. Next, the work of taking data and analyzing the data is carried out. This work uses a model 4105a earthing resistance meter to measure soil resistance and uses the single rod and parallel rod electrode installation methods. A copper ground rod was installed for measuring purposes. Deep electrode rods were planted at a depth of 1.5, 3.0 and 4.5 meters.

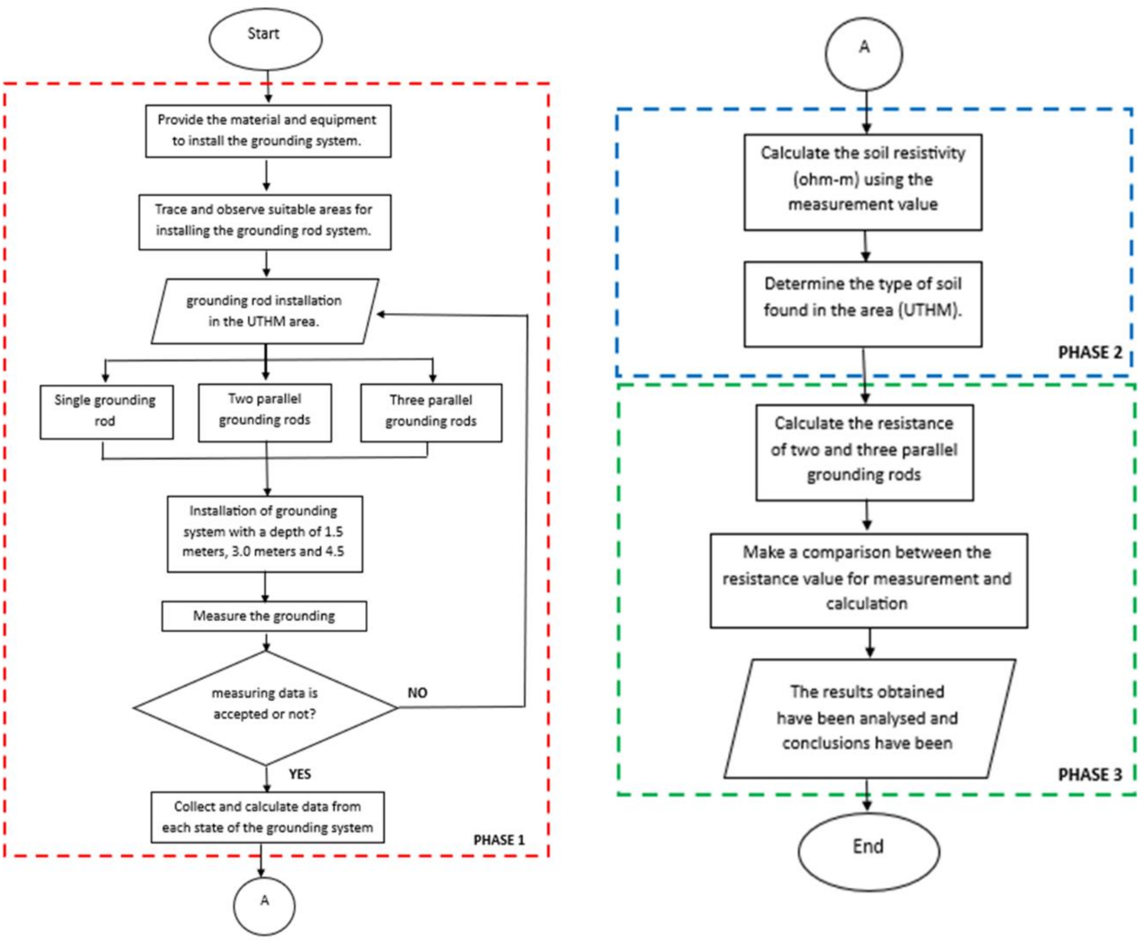

Figure 1: Flowchart of Project

2.1 Tools and Materials

The tools and materials shown in Table 1 are used to measure the object of study. In this case, this equipment is very important to the success of the project to follow the measurement standard of the grounding rod system. Materials for making an earthing system in Tun Fatimah's residential college. UTHM are as shown in Table 2. The table shows the specifications of the materials used to perform the grounding installation for this project.

Table 1: Research tools and materials

No	Tool and Material	Specification	Quantity	Unit
1	Earth Tester Kyoritsu	Model 4105a	1	Unit
2	Auxiliary electrode	Iron	2	Unit
3	Measurement cable (red)	1.5 mm	15	Meter
4	Measurement cable (yellow)	1.5 mm	10	Meter
5	Measurement cable (green)	1.5 mm	5	Meter
6	Tape measure	3 m	1	Unit
7	Hammer	2 kg	1	Unit
8	Pliers	500 grams	1	Unit

Table 2: Rod grounding material

No	Tool and Material	Specification	Quantity	Unit
1	Copper rod electrodes	1.5 m / 5ft	9	Unit
2	Ground rod coupler	12 mm	7	Unit
3	Clamp rod small	12 mm	3	Unit
4	Earth chamber	PVC Link	3	Unit
5	Earthing cable	16 mm	60	Meter
6	Cable coupler	Plastic	4	Unit

2.2 Methods

To obtain measurement data, Figure 2 shows the schematic diagram for the measurement Grounding System. The Kyoritsu 4105a Digital Earth Tester is turned on for the purpose of checking the battery voltage. If the screen looks clean without the low battery symbol, the battery is in good condition. After that, the BC grounding cable to be measured needs to be checked. If the BC earthing cable is dirty it should be cleaned first, with a clean cloth/sandpaper, so that the clamp on the probe cable can directly touch the clean copper surface and avoid errors in the meter reading. It is important to mention that the Earth Tester has three wires including red, yellow, and green wires. The distance between additional electrodes is determined to be a minimum of 5 meters and a maximum of 10 meters. The green wire must also be connected to the grounding that has been installed. Grounding (earth resistance) should be measured by turning the Selector Switch gauge to the 200-ohm or 2000-ohm position depending on the condition of the soil in the local area to be measured. Next, the person in charge should press the "PRESS TO TEST" button to find out the grounding resistance. The earth resistance value is displayed on the meter display. The resistance value that appears on the Earth Tester screen is noted. After the value has been recorded, return the position of the "PRESS TO TEST" button to the initial position.

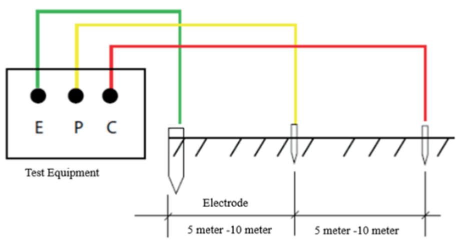

Figure 2: Measurement Grounding System

This test examines resistance reduction using multiple electrode rods arranged in parallel. Correct ground electrode spacing is essential for effective auxiliary electrodes, as incorrect spacing causes spheres of influence to cross and resistance does not decrease. Measurements were made by placing additional electrodes (P, C) at different positions, with depths of 5 feet, 10 feet, and 15 feet. After that, the measured resistance value is taken 3 times for ten consecutive days by changing the yellow wire to 3 points which are Z1, Z2 and Z3 as Figure 3.

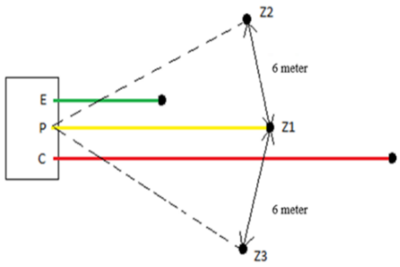

Figure 3: Different point for cable yellow

2.3 Equations

The single rod method was the very common method that has been used for generations. It is a very simple grounding system design among other methods where they just use a single electrode rod with various sizes depending on the desired grounding resistance. The methods used in reducing the R-value of the grounding rod electrode [5] are increasing the number of grounding rods, extending the size of the grounding rod, making soil treatments, using special grounding rods and finally, the combination method.

The method used is British Standard 7430/2011 on the Code of practice for protective earthing of electrical installation and British Standard 7430/2011 on the Code of practice for earthing [6]. The formula for the value of grounding with vertically planted rod electrodes is written. Equation 1 shows the relationship between the grounding resistance and the size (depth and radius in meters) of the electrode.

$$R = \frac{\rho}{2\pi L}.[\ln(\frac{8L}{d}) - 1] \quad \text{(Eq. 1)}$$

Where: R = Earthing resistance for a single rod (Ohms)
ρ = Soil resistivity (Ohm-meter)
L= Electrode length (meters)
d= Diameter of the electrode (meters)

The method used is IEEE Standard 142 Grounding of Industrial and Commercial Power Systems [7]. The formula for grounding values with rod electrodes planted vertically is written. Equation 2 shows the relationship between the grounding resistance and the size (depth and radius in meters) of electrode.

$$R = \frac{\rho}{2\pi L}.[\ln(\frac{4L}{a}) - 1] \quad \text{(Eq. 2)}$$

Where: R = Earthing resistance for a single rod (Ohms)
ρ = Soil resistivity (Ohm-meter)
L= Electrode length (meters)
a= Electrode radius (meters)

To reduce earthing resistance, a parallel connection equation is used with the distance between the electrodes having to be at least twice the length, which can be calculated using the following formula [8]. Equation 3 shows the relationship between the grounding resistance of the electrode arranged in parallel with the reference electrode.

$$\frac{1}{R\ total} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{RN} \quad \text{(Eq. 3)}$$

Where: R total = Total grounding resistance for pin electrode(Ω)
R1 = Earthing resistance for the first pin electrode (Ω)
R2 = Earthing resistance for the 2^{nd} pin electrode (Ω)
RN = Earthing resistance for the Nth post electrode (Ω)

3. Results and Discussion

3.1 Results

A case study at the University Tun Hussein Onn Malaysia investigated the relationship between parallel electrode arrangement and appropriate electrode depth for the best grounding system. Three readings were taken three times and for 10 consecutive days, with electrode depths of 1.5 meters, 3.0 meters, and 4.5 meters. Table 3 shows the average value for 10 consecutive days of the measurement grounding system.

Table 3: Measurement grounding system

Electrode installation depth (m)	Single grounding rod (ohm)	Two parallel grounding rods (ohm)	Three parallel grounding rods (ohm)
1.5	5.246	2.481	1.800
3.0	1.422	0.677	0.492
4.5	0.612	0.285	0.190

Each depth of soil has a different resistance value. In this case, the humidity of the water affects the resistance value. This soil resistance value is calculated using the resistance value of one grounding rod for each depth as a reference as shown in Figure 4. In this case, the humidity of the water affects the resistance value. After the calculation is completed, the electrode is removed from the soil to see the condition of the soil as shown in Figure 5 which shows the condition of wet soil. The underground layer in the installation area of the earthing system is wet, supported by soil resistance calculations and site observations. This is because the selected area is near water catchment areas and drains.

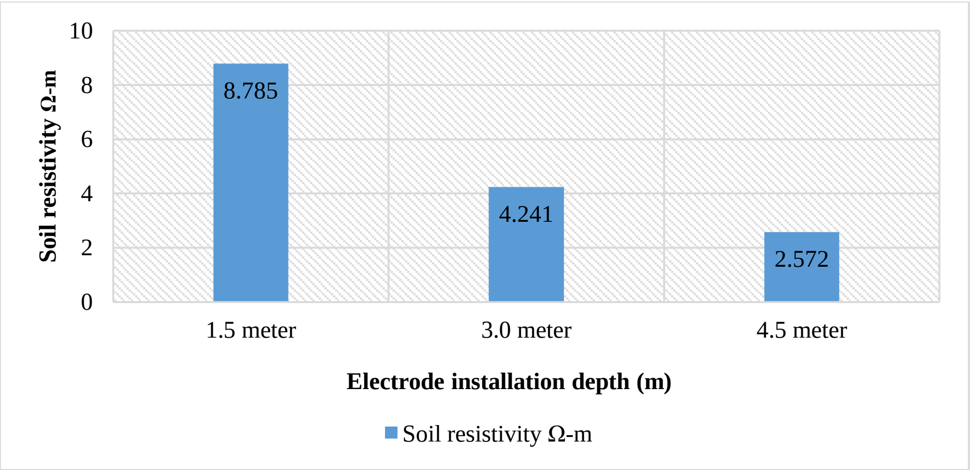

Figure 4: Calculated value for soil resistivity

Figure 5: Wet soil conditions

The ground resistance value was obtained from the calculation by using the measurement information of the resistance value for the single grounding rod method as a reference. With this, research has identified that each depth has a different soil resistance value [9]. Figure 6 shows the value of soil resistance in the project site where the grounding system is installed. So, the selection of soil type for each soil layer is determined by the soil resistance value that has been calculated. The type chosen is the type of native land of the sea and clay.

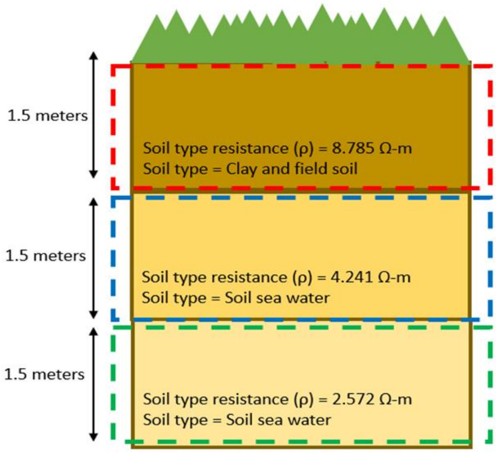

Figure 6: Soil layer after being calculated

The calculation of the resistance value is made to make a comparison between the measurement and the calculation to facilitate the evaluation before the construction of the grounding system. Table 4 shows the calculation grounding system.

Table 4: Calculation grounding system

Electrode installation depth (m)	Single grounding rod (ohm)	Two parallel grounding rods (ohm)	Three parallel grounding rods (ohm)
1.5	5.246	2.623	1.749
3.0	1.422	0.711	0.474
4.5	0.612	0.306	0.204

Grounding rods play a critical role in electrical systems by providing a safe path for electrical currents to dissipate into the ground. Measurement and calculation are important aspects of designing and implementing an effective grounding system for electrical installations. Figures 7, 8 and 9 show the difference in resistance values found through measurement and calculation.

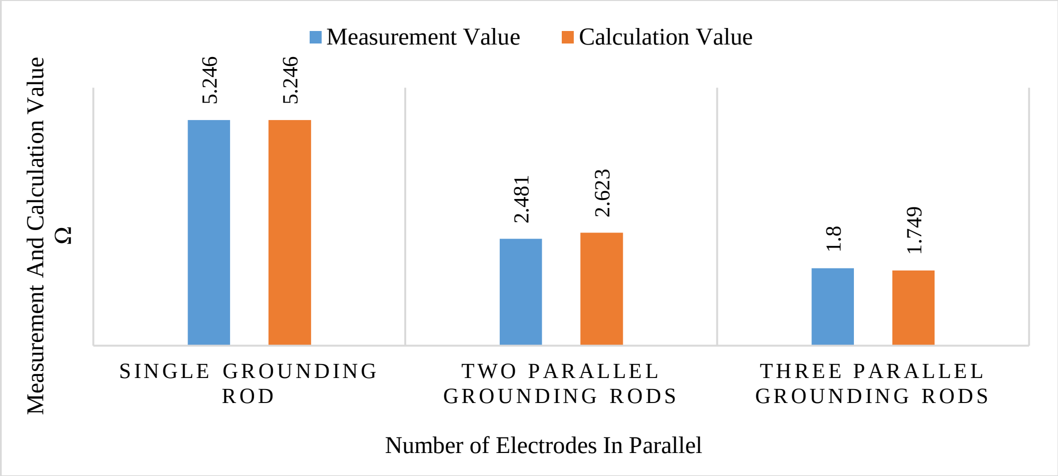

Figure 7: Measurement and Calculation Value Results for a depth of 1.5 meters

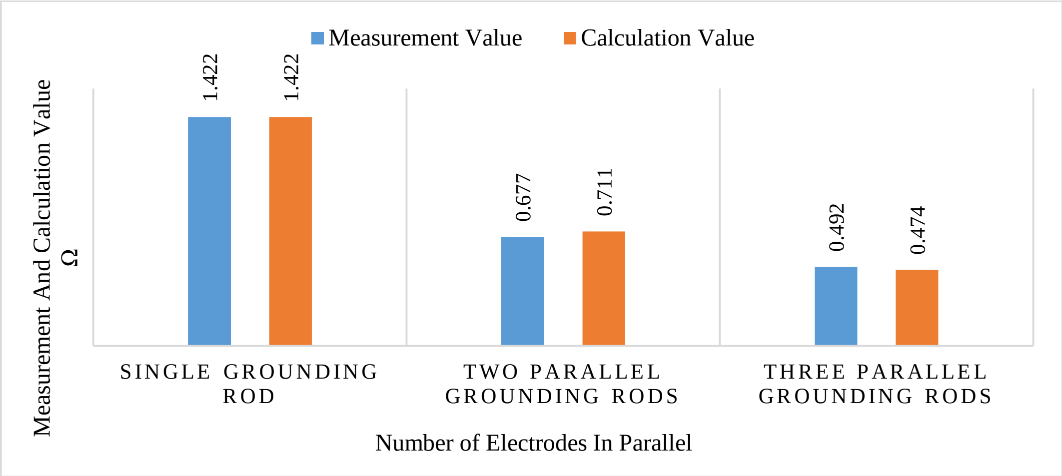

Figure 8: Measurement and Calculation Value Results for a depth of 4.5 meters

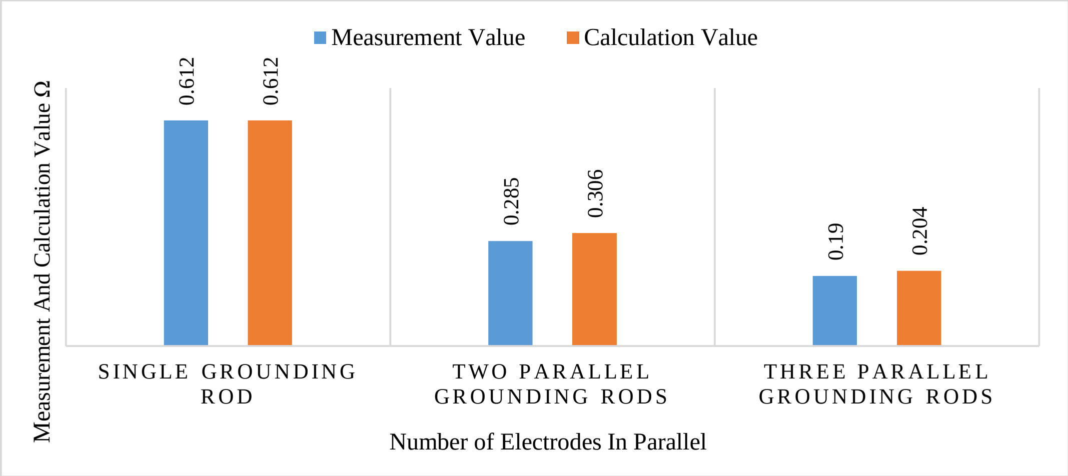

Figure 9: Measurement and Calculation Value Results for a depth of 4.5 meters

3.2 Discussions

From all the results and analysis that have been made, it is concluded that the performance of the grounding system can be determined through the depth of the electrode planted into the ground, the condition of the soil, the type of soil, the specification of the installation type electrode and so on. Calculation of ground resistance is very important to design a proper grounding system. In this paper, soil resistance is determined by using the resistance value of a single grounding rod as a reference. The deeper the electrode is planted the lower the soil resistance value. The results also show that the deeper the electrode depth, the lower the soil resistance obtained.

Next, the method of planting electrodes is very important to reduce the resistance value. In this paper, the electrodes are planted in parallel which are single grounding rods, two parallel grounding rods and three parallel grounding rods. The results show that the more electrodes planted in parallel, the lower the soil resistance obtained [10]. The results of this work are proven through manual calculations to provide accurate and excellent results. Finally, the conclusion found in this work shows that planting the electrodes deeper still greatly reduces the resistance value compared to planting the electrodes in parallel. Figure 10 shows the conclusion of the entire work in this paper.

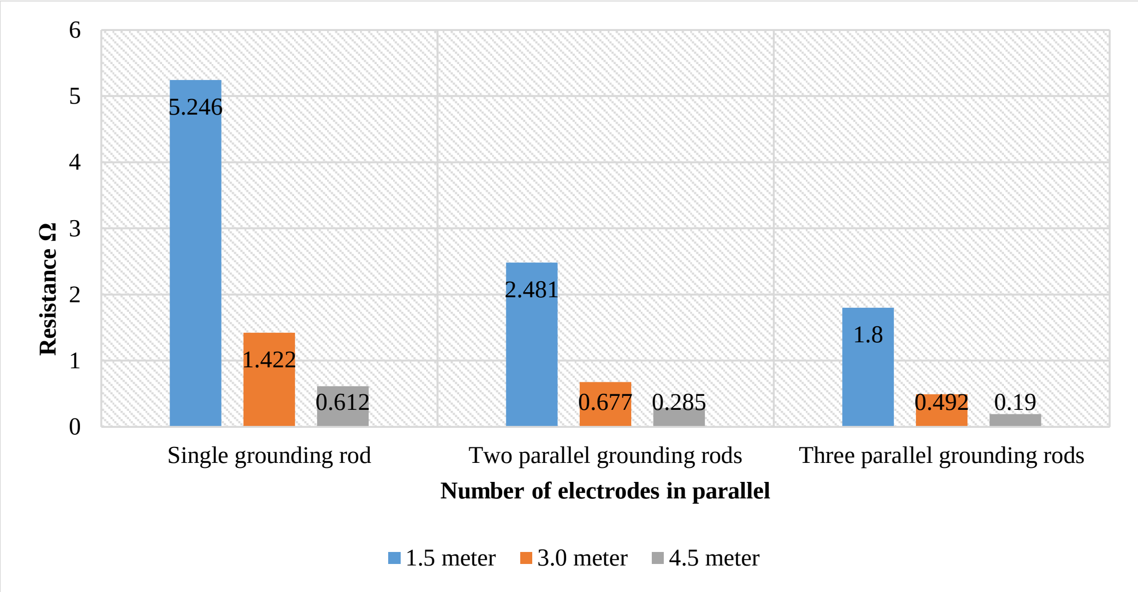

Figure 10: Grounding system measurement results for all types of grounding rod.

4. Conclusion

It is concluded that the performance of the grounding system can be determined through the depth of the electrode planted into the ground, the condition of the soil, the types of soil, and the specification of the installation type electrode. The comparison has been made of various factors that cause the resistance value to be low to design a proper grounding system. From the analysis, it has been proven that each soil depth has a different soil resistance value. It is proven that the electrode method planted vertically 3 meters deep has a lower resistance value than the electrode method planted in 3 parallel points 1.5 meters deep. In this case, the electrode installation method is very important because it will produce different resistance values.

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