

Ground type resistance earthing system using bar electrodes

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ABSTRACT

Providing a return line for short-circuit currents or fault currents to a low-resistance ground, a grounding system is useful for achieving a uniform potential voltage over a given area of buildings and equipment. Because a large voltage difference can occur if a fault current is forced to ground against high resistance. Placement of the electrode to be planted is one of the elements to obtain a low grounding resistance value. Grounding resistance measurements, which will serve as a guide for the grounding system design process, are required during the planning stage for certain types of grounding systems. The problem is how the grounding resistance is affected by the buried depth of the rod conductor and the soil-type resistance. Therefore, it is very important to conduct research and testing to determine the extent to which these parameters influence. The experimental results of measuring resistance on dry and wet soils are on dry soil 30 cm obtained 98.48 Ω , 60 cm obtained 37.07 Ω , 90 cm obtained 20.52 Ω , 120 cm obtained 19.77 Ω , and for wet soil at a depth of 30 cm obtained 43.34 Ω , 60 cm obtained 22.21 Ω , 90 cm obtained 15.43 Ω , 120 cm obtained 11.66 Ω .

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1. INTRODUCTION

Grounding is one of the important components in the electric power system to ensure security, equipment safety, environmental safety, and the safety of people around (Nazari et al., 2021). Grounding must comply with all relevant standards and specifications to obtain the desired results (Hasan & Hameed, 2020). However, in this case, variations often occur in topics related to this standard, such as the depth of application of the grounding pin or electrode, which prevents the value of the grounding resistance from reaching the required value of 5 as specified in PUIL 2000.

Grounding electrodes can be installed either vertically (perpendicular/rod) or horizontally (parallel/grid) to the ground (Schweigert et al., 2019). To achieve the permissible grounding resistance, the grounding electrode must be immersed in the earth at a certain depth (Poljak & Roje, 2020). The depth of the pole or electrode, the type of electrode, and the type of soil where the electrode is installed all have a significant influence on the size of the grounding resistance, while the resistivity of the soil varies greatly depending on the type of soil, soil layer, soil moisture, and soil temperature. The amount of electrolytes in the soil has an impact on the resistivity of the soil as well (Santoso & Wijatmoko, 2023).

In addition to providing a return line for short-circuit currents or low-resistance ground fault currents, grounding systems are useful for achieving a uniform potential voltage over a specific area of buildings and equipment.

Because a large voltage difference can occur if a fault current is forced to ground against high resistance (Reffin et al., 2019). Placement of the electrode to be planted is one of the elements to obtain a low grounding resistance value (Clark et al., 2021). Grounding resistance measurements, which will serve as a guide for the grounding system planning process, are

required for some types of grounding systems. The problem is how the grounding resistance is affected by the buried depth of the rod conductor and the soil-type resistance (Hardi et al., 2023) (Alipio et al., 2019). Therefore, it is very important to carry out research and testing to determine how much influence this characteristic has (Arifin, 2021). Previous research used rod electrodes only 100 cm long, in this study the rod electrodes were increased in length to 120 cm.

Based on these reasons, the author tries to compile this final report with the title "Planning the Effect of Soil Type Resistance on Grounding Systems Using Bar Electrodes at the Electrical Engineering Building Site of UNIMAL".

2. RESEARCH METHOD

Research Flow

The research flow that will be used by the author in this research method is as follows:

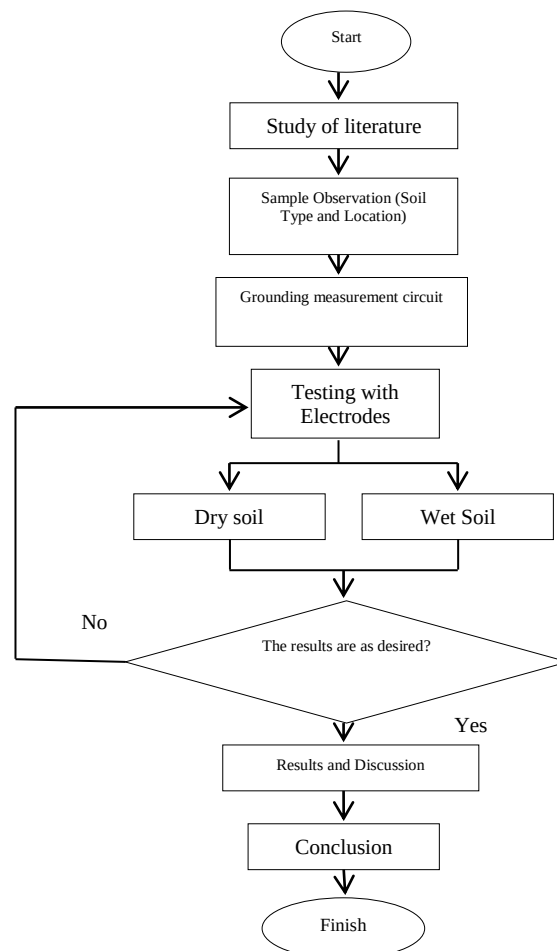


Figure 1. Flowchart

Research Methods

The method used in carrying out this research is experimental: (a) A literature study is a technique for studying the theory needed from dictionaries to support and relate to the final assignment taken (Ali et al., 2020). (b) Interaction with managers, leaders, and experts in their industry where questions and answers are exchanged. (c) Field study is a technique of collecting information and collecting information directly from research subjects where information is collected by looking directly to get more accurate information for this final project.

Grounding Resistance Measurement Method

The author uses a juxtaposition technique using two electrodes to assess the grounding resistance (Nti et al., 2020). The author contrasts the findings of determining the value of grounding resistance to the type of soil in this final project research (Moradi, 2020). In this final project, the author implanted electrodes using various types of soil, including sand, rock, moist soil, and dry soil. In this measurement, an earth tester is used to measure using two electrodes.

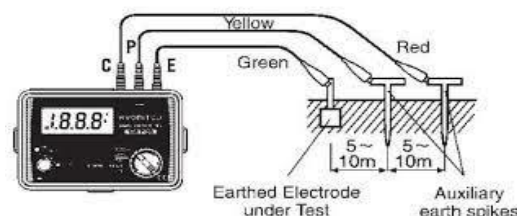


Figure 2. Soil resistivity measurement

Measurement Series

In the series of soil resistivity measurements, it can be determined using two-rod electrodes connected to the Earth Resistance Tester (Zhang et al., 2020).

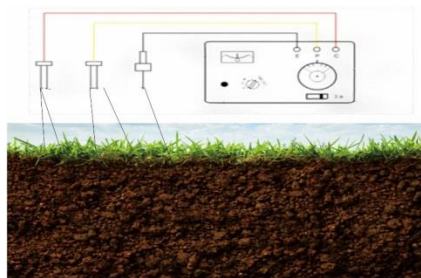


Figure 3. Measurement Circuit

Data Collection

If at the testing stage, the tool is good and there are no problematic components, then continue at this stage, namely data collection (Camara et al., 2020). Data collection is done to be processed and then analyzed.

Time and Location

This research was conducted starting from December 2022 to January 2023. Starting from planning, implementation, and research and up to the preparation of research reports. As for the location of this research, it is located in the yard of the Electrical Engineering Department at Malikussaleh University which is on Jalan Batam, Gampong Blang Pulo, Muara Satu District, Lhokseumawe City

3. RESULTS AND DISCUSSIONS

Data Collection

Data collection is an activity to find data in the field that will be used to answer research problems. The validity of data collection and the qualifications of data collectors are needed to obtain quality data. Data collection was taken directly from the field which is located in the backyard of the Electrical Engineering Department Building, Malikussaleh University, data collection using an earth tester, megger as a measuring tool, and rod electrodes that were stuck into the ground starting from a depth of 30 cm to 120 cm.

After the rod electrodes are implanted into the ground using various types of soil, including sand, rock, moist soil, and dry soil to see the comparison. After that, measurements are taken using a Mega Ohm Meter or commonly called a Megger which is a measuring tool that functions to measure the insulation resistance of an installation or to find out whether the conductor of an installation has a direct connection, whether between phase and phase or with zero or with Grounding, here is a picture of measurements using a megger.



Figure 4. The measurement process using a Mega Ohm Meter (Megger)

Data and Measurement Results

In the implementation of the final project entitled "Planning the Effect of Soil Type Resistance on Grounding Systems Using Bar Electrodes at Unimal Electrical Engineering Building Sites" which aims to determine the effect of different soil types with rod electrodes installed in parallel. The type of depth on the electrode when planting starts from 30 cm to 120 cm.

Table 1. Dry soil resistance value					
No	Measuring Time	Dry Soil Resistance Value			
		Depth			
		30 cm	60 cm	90 cm	120 cm
1	Wednesday 08-03-2023	84,8	31,0	20,1	19,1
2	Thursday 09-03-2023	105,7	32,7	20,00	19,7
3	Friday 10-03-2023	148,3	42,0	26,9	23,2
4	Saturday 11-03-2023	79,0	34,1	19,1	18,8
5	Sunday 12-03-2023	83,1	55,5	23,3	20,3
6	Monday 13-03-2023	98,0	34,3	18,8	19,7
7	Tuesday 14-03-2023	90,5	30,5	15,5	17,6
8	Rata-rata	98,48	37,07	20,52	19,77

Based on the data in Table 1. The dry resistance value taken in one week, it is found that the soil dry resistance value varies due to the type of soil or soil moisture and the depth of planting. From these data, we can find out that the deeper the electrode is implanted, the smaller the resistance. The experiments were carried out from Wednesday to Tuesday with the depth of electrode embedding also having different resistance values. This was due to changes in soil moisture from Wednesday to Tuesday. The following is a graph of the dry soil resistance values based on the data obtained.

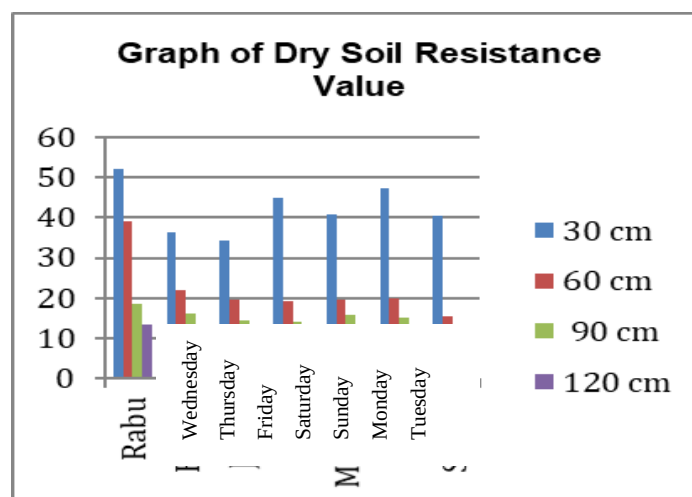


Figure 5. Graph of dry soil resistance value

Based on Figure 5, the resistance value graph of dry soil experiments conducted from Wednesday to Tuesday shows a high resistance value if the depth of the rod electrode is implanted at a depth of 30 cm with an average resistance value of 98.48Ω , then the resistance value decreases at a depth of 60 cm with an average resistance value of 37.07Ω , and if the rod electrode is implanted at a depth of 90 cm the resistance value decreases to an average of 20.52Ω , and the lowest resistance value is 19.77Ω obtained from the results of implanting a rod electrode 120cm deep using dry soil. It can be interpreted that the deeper the electrode is planted the smaller the resistance value and the better the resulting grounding.

Table 2. Wet soil resistance value

No	Measuring Time	Wet Soil Resistance Value Depth			
		30 cm	60 cm	90 cm	120 cm
1	Wednesday 08-03-2023	52,1	39,2	18,6	13,55
2	Thursday 09-03-2023	36,2	22,1	16,3	11,79
3	Friday 10-03-2023	34,4	19,7	14,33	10,71
4	Saturday 11-03-2023	45,0	19,3	14,23	11,71
5	Sunday 12-03-2023	40,8	19,6	15,90	11,41
6	Monday 13-03-2023	47,4	20,1	15,2	11,90
7	Tuesday 14-03-2023	40,5	15,5	13,5	10,6
8	Rata-rata	43,34	22,21	15,43	11,66

Based on the data in Table 2. Wet resistance values were taken in one week, and data on dry soil resistance values are obtained which vary due to the type of soil or soil moisture and the depth of planting. From these data, we can find out that the deeper the electrode is implanted, the smaller the resistance. However, this value is smaller when compared to dry soil types, wet soil has a lower resistance value than dry soil. This is due to the reception of the electrode going well or it can be called good grounding rather than dry ground. The experiments were carried out from Wednesday to Tuesday with the depth of electrode embedding also having different resistance values. This was due to changes in soil moisture from Wednesday to Tuesday. The following is a graph of the dry soil resistance values based on the data obtained.

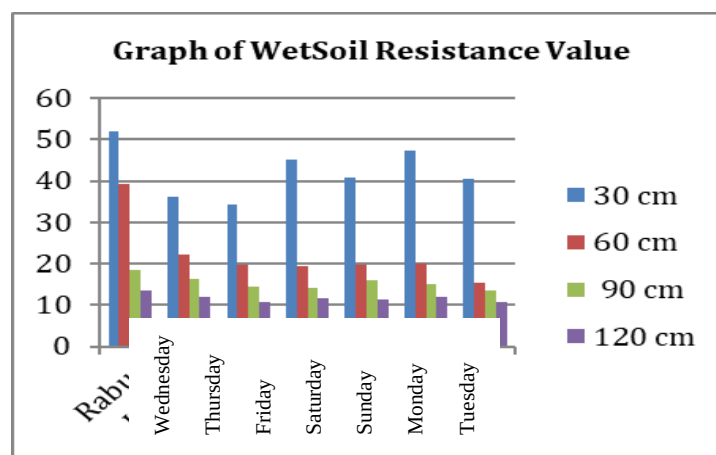


Figure 6. Graph of wet soil resistance value

Based on Figure 6 Graph of Wet Soil Resistance Value experiments conducted from Wednesday to Tuesday on wet soil types show a smaller resistance value than previously using dry soil. Experiments carried out by implanting rod electrodes at a depth of 30 cm obtained an

average resistance value of 43.34 Ω , then the resistance value decreased at a depth of 60 cm with an average resistance value of 22.21 Ω , also if the rod electrode was implanted at a depth of 90 cm the resistance value decreases with an average of 15.43 Ω , and the lowest resistance value is 11.66 Ω obtained from the results of implanting a rod electrode as deep as 120 cm using wet soil types. This means that the deeper the electrode is planted the smaller the resistance value and the better the resulting grounding. The lowest resistance value is 10.6 Ω obtained in the experiment on Tuesday on wet soil types.

Calculation of Grounding Resistance Based on Obtained Data

To be able to analyze the effect of soil type on the value of grounding resistance, the authors make calculations based on the data obtained at the time of measurement. Calculations are performed as follows

To determine the effect of soil type on the value of grounding resistance, a soil resistivity value is needed based on the first measurement data. Because the first measurement data is data obtained from measuring grounding resistance with variations in the depth of implanting rod electrodes. The depth of the electrodes used starts from 30 cm, 60 cm, 90 cm, and 120 cm. Where the electrode used is a rod electrode which has a length of 120 cm and a diameter of 0.006 m. The following is the calculation of the value of soil type resistance:

Calculations on dry soil with a depth of 30 cm on Monday can be calculated using the following formula:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 0,30 \times 94,8}{\ln\left(\frac{4 \times 0,30}{0,006}\right) - 1} \\ \rho &= \frac{127,2\pi}{25(\ln(200) - 1)} \\ \rho &= \frac{127,2\pi}{25 \ln(200) - 25} \\ \rho &= 37,18 \Omega\end{aligned}$$

Calculations on dry soil with a depth of 60 cm on Monday:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 0,60 \times 31}{\ln\left(\frac{4 \times 0,60}{0,006}\right) - 1} \\ \rho &= \frac{37,2\pi}{\ln(4 \times 100) - 1} \\ \rho &= \frac{18,6\pi}{10 \ln(20) - 5} \\ \rho &= 23,41 \Omega\end{aligned}$$

Calculations on dry soil with a depth of 90 cm on Monday:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 0,90 \times 20,1}{\ln\left(\frac{4 \times 0,90}{0,006}\right) - 1} \\ \rho &= \frac{18,09\pi}{50 \ln(600) - 50} \\ \rho &= 21,06 \Omega\end{aligned}$$

Calculations on dry soil with a depth of 120 cm on Monday:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 1,20 \times 19,1}{\ln\left(\frac{4 \times 1,20}{0,006}\right) - 1} \\ \rho &= \frac{127,2\pi}{25 \ln(800) - 25}\end{aligned}$$

$$\rho = 25,33 \Omega$$

Based on dry soil calculations, the resistance values varied starting from a depth of 30cm to produce a resistance value of 37.18 Ω , a depth of 60 cm to produce a resistance value of 23.41 Ω , a depth of 90 cm to produce a resistance value of 21.06 Ω and finally, to a depth of 120 cm to produce resistance value 25.33 Ω . Based on the calculated values above, we can see that the deeper the rod electrode is implanted, the lower the resistance value, but at a depth of 120 cm the resistance value increases to 25.33 Ω .

This happens because each layer of soil has different humidity, acidity-base properties, texture, and mineral content, in other words, even though the rod electrode is plugged deep into the soil, if the soil does not have good characteristics according to the factors above, the resistance value will not change. Good. Then re-testing is needed to get good soil for grounding. Next, the resistance value will be calculated for wet soil types with data taken from Monday.

Calculations on wet soil with a depth of 30 cm on Monday can be calculated using the following formula:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 0,30 \times 43,34}{\ln\left(\frac{4 \times 0,30}{0,006}\right) - 1} \\ \rho &= \frac{1563\pi}{50 \ln(200) - 50} \\ \rho &= 22,84 \Omega\end{aligned}$$

Calculations on wet soil with a depth of 60 cm on Monday:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 0,60 \times 39,2}{\ln\left(\frac{4 \times 0,60}{0,006}\right) - 1} \\ \rho &= \frac{1176\pi}{50 \ln(20) - 25} \\ \rho &= 29,60 \Omega\end{aligned}$$

Calculations on wet soil with a depth of 90 cm on Monday:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 0,90 \times 18,6}{\ln\left(\frac{4 \times 0,90}{0,006}\right) - 1} \\ \rho &= \frac{837\pi}{25 \ln(600) - 25} \\ \rho &= 19,48 \Omega\end{aligned}$$

Calculations on wet soil with a depth of 120 cm on Monday:

$$\begin{aligned}\rho &= \frac{2 \cdot \pi \cdot L \cdot R_t}{\ln\left(\frac{4L}{a}\right) - 1} \\ \rho &= \frac{2 \times 3,14 \times 1,20 \times 13,55}{\ln\left(\frac{4 \times 1,20}{0,006}\right) - 1} \\ \rho &= \frac{813\pi}{25 \ln(800) - 25} \\ \rho &= 17,97 \Omega\end{aligned}$$

Based on wet soil calculations, the resistance values vary starting from a depth of 30cm to produce a resistance value of 22.84 Ω , a depth of 60cm to produce a resistance value of 29.6 Ω , a depth of 90 cm to produce a resistance value of 19.48 Ω and finally, to a depth of 120 cm to produce a resistance value resistance 17.97 Ω . Based on the calculation value above, we can see that the deeper the rod electrode is implanted in the soil, the smaller the resistance value, this is

different from the calculation of the specific resistance value of dry soil, where at a depth of 120 cm the resistance value increases, in wet soil the resistance value stabilizes. up to 17.97 Ω . This happens because the wet soil layer has good conductivity which can spread the electric current well into the soil. Therefore, soil that has high humidity and is wet can reduce high surges of electricity.

Discussion of Measurement Results

Based on Figures 5 and 6, the resistance value graphs for wet soil and dry soil show differences which can be seen from the soil resistivity value. Dry soil has greater resistance than wet soil. In addition, the depth of the electrode also affects the resulting resistance value, for example, a 30 cm electrode depth produces a greater resistance value compared to 60 cm, 90 cm, and 120 cm resistance values. Moisture in the soil also affects the resistance value, it can be seen that on different days with the same depth the resistance value is different, this is due to the soil moisture which changes every hour and every day. Therefore all the resistance values taken are summed up to get the average resistance value for that soil type.

From the manual calculations that have been done, there are slight differences that occur in data collection directly from the field. The results of manual calculations have a lower value than the value measured directly using implanted rod electrodes. This can occur due to several factors, one of which is the quality of the calculation or measuring instrument and also the accuracy in calculating and retrieving data in the field. The resistance value obtained using a rod electrode implanted at a depth of 120 cm is 10.6 Ω so the resistance value obtained will decrease if it is implanted deeper. A good resistance value for Grounding is 5 Ω or even less than that value.

So in planning the effect of soil-type resistance on the grounding system using rod electrodes at the UNIMAL Electrical Engineering Building location, we need a resistance value of 5 Ω or even less than that value, so we can predict this value by calculating the resistance value.

Is known:

$$L_1 = 120 \text{ cm}$$

$$L_2 = ?$$

$$N_1 = 10,6 \Omega$$

$$N_2 = 5 \Omega$$

So to find the value of L_2 or what depth we need to get a resistance value of 5 Ω . We can use the following cross-multiplication formula:

$$\frac{L_1}{N_1} = \frac{L_2}{N_2}$$

$$\frac{120 \text{ cm}}{10,6 \text{ cm}} = \frac{L_2}{5 \Omega}$$

$$\frac{120}{53} = \frac{L_2}{5}$$

$$\frac{600}{53} = \frac{L_2}{5}$$

$$3000 = 53 L_2$$

$$L_2 = \frac{3000}{53}$$

$$L_2 = 56 \frac{32}{53}$$

$$L_2 = 56,603 \text{ cm}$$

So to get a value of 5Ω we have to increase the depth by 56.603 cm, then the length of the electrode needed is: $120\text{ cm} + 56.603\text{ cm} = 176.603\text{ cm}$

To calculate an estimate and get a 5Ω resistance value for dry soil types, you can use the following formula:

$$\begin{aligned}\frac{L_1}{N_1} &= \frac{L_2}{N_2} \\ \frac{120\text{ cm}}{15,55\text{ cm}} &= \frac{L_2}{5\Omega} \\ \frac{120}{\frac{311}{20}} &= \frac{L_2}{5} \\ \frac{2400}{311} &= \frac{L_2}{5} \\ 12000 &= 311 L_2 \\ L_2 &= \frac{3000}{53} \\ L_2 &= 38 \frac{182}{311} \\ L_2 &= 38,58\text{ cm}\end{aligned}$$

So to get a value of 5Ω we have to increase the depth by 38.58 cm, then the length of the electrode needed is: $120\text{ cm} + 38.58\text{ cm} = 158.58\text{ cm}$.

So to get a resistance value of 5Ω , it is necessary to implant a rod electrode into the soil for a minimum length of 158.58 cm above the soil surface with a soil type with high humidity (wet).

4. CONCLUSION

The conclusions from the results of the Planning Research on the Effect of Soil Type Resistance on the Grounding System Using Rod Electrodes at the UNIMAL Electrical Engineering Building Location, namely Planting rod electrodes to get a resistance value of 5Ω for dry soil types can be planted to a depth of 158.58 cm and for wet soil with a depth 176.60 cm. It can be concluded from the two types of soil, namely dry soil and wet soil, that wet soil has a higher resistance value than dry soil. The resistance decreases with the depth of the electrode embedding and the distance between the electrode embedding layers. This study does not address soil moisture. For further research, soil moisture parameters can be added.

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