

Resistance Of The Grounding System In Residential Houses In Preventing The Hazard Of Electric Shock To Humans Using Soil Treatment

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ABSTRAK

Sengatan listrik merupakan risiko fatal di lingkungan domestik yang menuntut sistem pembumian (grounding) yang efektif. Karena resistansi yang tinggi dapat melemahkan fungsi proteksi, optimasi melalui penggunaan bahan aditif menjadi fokus utama penelitian ini. Studi ini mengevaluasi pengaruh kedalaman penanaman batang elektroda pada jenis tanah basah dan kering menggunakan komposisi campuran bahan aditif. metode yang digunakan yaitu metode tiga titi dengan media tanam dalam pipa PVC. Hasil Pengujian pada penelitian ini perlu adanya perbaikan pada penanaman batang elektroda secara minimum sekurang-kurangnya 1 meter didalam tanah dan dengan hasil yang maksimal dan efektif disarankan 2,44 meter (8 kaki) ke dalam tanah. serta pada tanah kering batang elektroda perlu di tanam hingga 3,5 meter untuk mendapatkan nilai resistansi dibawah 5 Ω sesuai dengan standar PUIL.

Kata kunci: Pentanahan perumahan, Resistansi, Sengatan Listrik, Bahan aditif

ABSTRACT

Electric shock is a fatal risk in domestic environments that require an effective grounding system. Because high resistance can weaken the protective function, optimization through the use of additives is the main focus of this study. This study evaluates the effect of electrode rod planting depth on moist and dry soil types using a mixture of additives. The method used is the three-point method with planting media in PVC pipes. Test results in this study require improvements in the minimum electrode rod planting of at least 1 meter in the ground and with maximum and effective results it is recommended to be 2.44 meters (8 feet) into the ground. And in dry soil the electrode rod needs to be buried up to 3.5 meters to get a resistance value below 5 Ω according to PUIL standards.

Keywords: Residential grounding, Resistance, Electric shock, Additives.



1. INTRODUCTION

The Need For Electrical Power Will Continue To Grow In The Future, Demonstrating Rapid Development, Related To Needs In The Industrial Sector And The Low-Voltage Consumer Sector (**Mubarok et al., 2022**). While Equitable Distribution Of Electricity Offers Advantages, It Also Poses Potential Safety Risks To Humans. Electricity Can Be Harmful Because It Can Cause Electric Shock, Potentially Endangering Humans (**Anwar, 2021**)(**Andini et al., 2016**). Grounding Systems For Residential Electricity Consumption Are Often Overlooked Or Rarely Used, But For Buildings With High Electricity Consumption, They Are Essential, Even Mandatory (**Yuliadi et al., 2022**). Electricity Has Become a Basic Necessity in Modern Life, but Its Use Also Carries Significant Risks, Particularly Electric Shock. In Indonesia, Cases Of Electric Shock Are Still Frequently Reported, Whether Caused By Short Circuits, Insulation Damage, Or Protection System Failure. One Of The Most Basic And Effective Preventative Measures Is The Implementation Of a Proper Grounding System In Residential Electrical Installations (**Pratiwi et al., 2024**)(**Juniardi et al., 2021**). The grounding system can be implemented by planting electrode rods at a certain depth so that the grounding impedance is small. The distance of the electrode's depth into the ground, the type of soil, and the electrode configuration can affect the grounding resistance value. The ability to flow current to the ground is better so that the fault current does not flow and does not damage the equipment (**Rahman et al., 2018**). The provisions on the grounding system are contained in the PUIL (General Requirements for Electrical Installations) of 2000 that the applicable standard for grounding resistance should not exceed 5Ω ($\leq 5 \Omega$). However, in areas with a fairly high soil resistivity, the maximum standard is (10Ω) (**PUILL, 2000**)(**IEEE, 2013**). The value of the grounding resistance value is influenced by several factors, namely the type of soil, the size and type of electrode used, the depth of electrode planting. Meanwhile, the soil resistivity is influenced by soil composition, temperature, water content (humidity), and chemical content in the soil (**Harahap et al., 2021**)(**Deni, 2018**). In grounding locations with very high soil resistance, with little water content, dry and rocky soil conditions, it becomes a problem in implementing the grounding system. Due to these soil conditions, the depth of the grounding electrode is limited, resulting in a high grounding resistance. One way to achieve low grounding resistance and resistivity is through chemical soil treatment, which involves adding additives(**Kasim et al., 2016**). One widely researched approach is the use of additives in the soil where the electrode rods are embedded. These additives aim to increase the conductivity of the soil around the electrodes, thereby accelerating the flow of current to the ground and reducing the total resistance of the grounding system (**Tessa et al., 2022**)(**Tessal et al., 2021**). Some commonly used additives are bentonite, charcoal, and salt. Based on this description, the author conducted research using a mixture of bentonite, charcoal, and salt to reduce grounding resistance using rod electrodes through 3-inch PVC pipes. This study aimed to analyze the effectiveness of various additive mixtures in reducing grounding resistance in residential installations and their impact on improving human safety from the dangers of electric shock (**Debit et al., 2021**).

2. METHOD

This research was conducted experimentally with a quantitative approach by taking grounding resistance data for residential grounding systems. The research was conducted using a three-point method, using 2 auxiliary electrode rods and 1 measuring electrode rod. Measurements were made with a 3-inch PVC pipe planting medium by inserting moist and dry soil types using a mixture of additives in the form of salt and bentonite with varying composition percentages. The test was influenced by the depth of the electrode rod planted into the soil starting from a

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depth of 30 cm, 50 cm, 70 cm, 90 cm and 120 cm. The test method can be seen as in the image below:

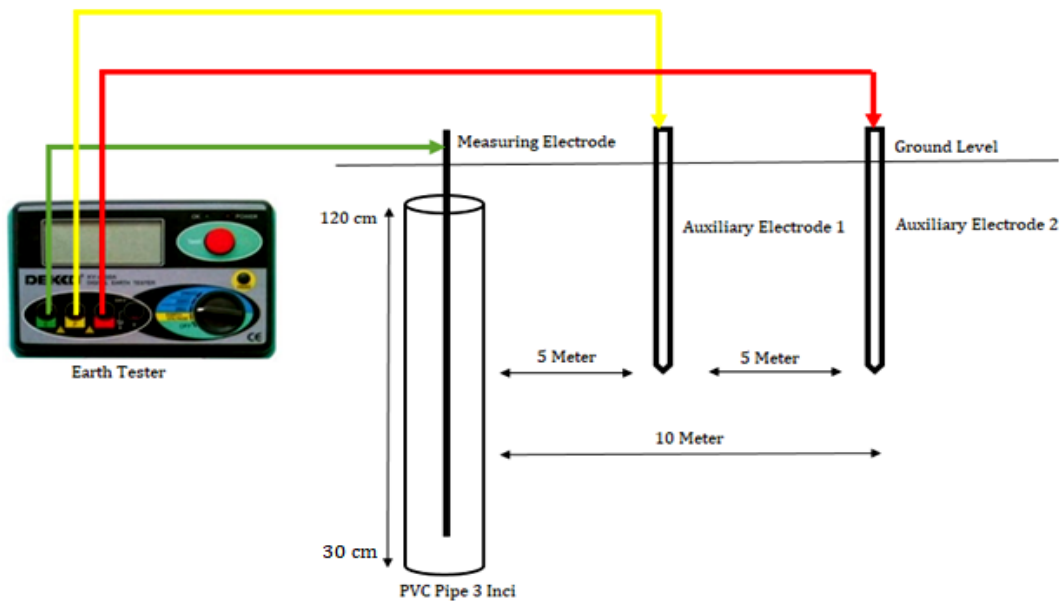


Figure 1. How to measure grounding using the three-point method

As for calculating the soil resistance value and soil type resistance, the following parameters can be used (**IEEE, 2013**):

$$R = \frac{\rho}{2\pi i} \text{ atau } \rho = 2\pi l R \quad (1)$$

Where: R : Earth Resistance (Ω), ρ : Soil resistivity (Ω -cm), l : Electrode length (cm) To measure grounding resistance in housing, it can be shown in Figure 2 below.

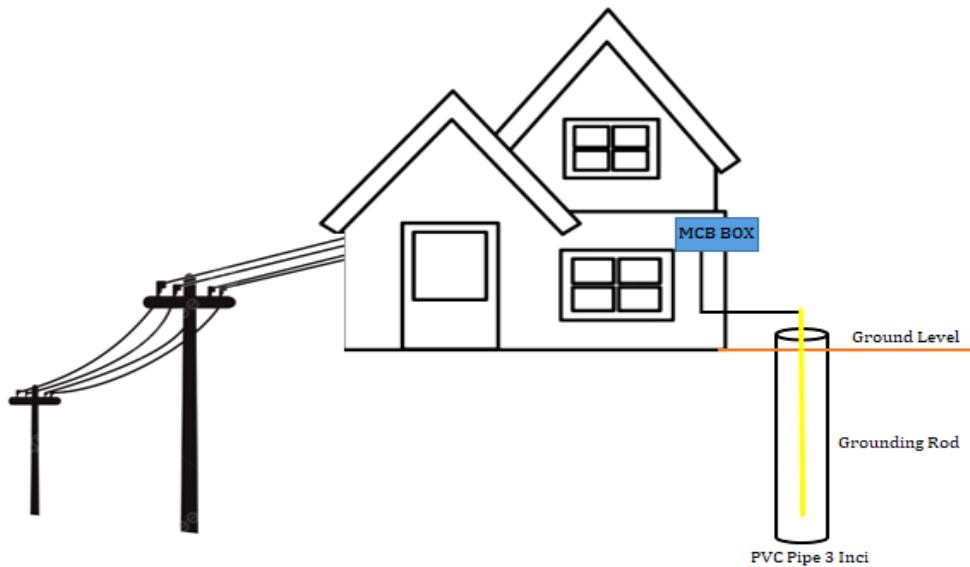


Figure 2. Method of Measuring Resistance of Residential Grounding System

Measurement of grounding resistance in residential grounding systems is carried out by preparing a 3-inch PVC pipe with a pipe length of 1.5 meters. Next, prepare 2 auxiliary electrodes and 1 measuring electrode, each 1.5 meters long, and the distance between the auxiliary electrode and the measuring electrode is 5 meters. then insert the type of moist soil and the type of dry soil into each pipe, where the additives have been mixed in the form of salt and bentonite with a percentage that has been varied. Measurements are carried out by taking samples of the grounding resistance value influenced by the depth of the electrode rod planting starting from a depth of 30 cm, 50 cm, 70 cm, 90 cm and 120 cm. The measurement results are compared with the maximum resistance value of $\leq 5 \Omega$ according to PUIL 2013. The measurement stages can be shown in the research flow diagram below:

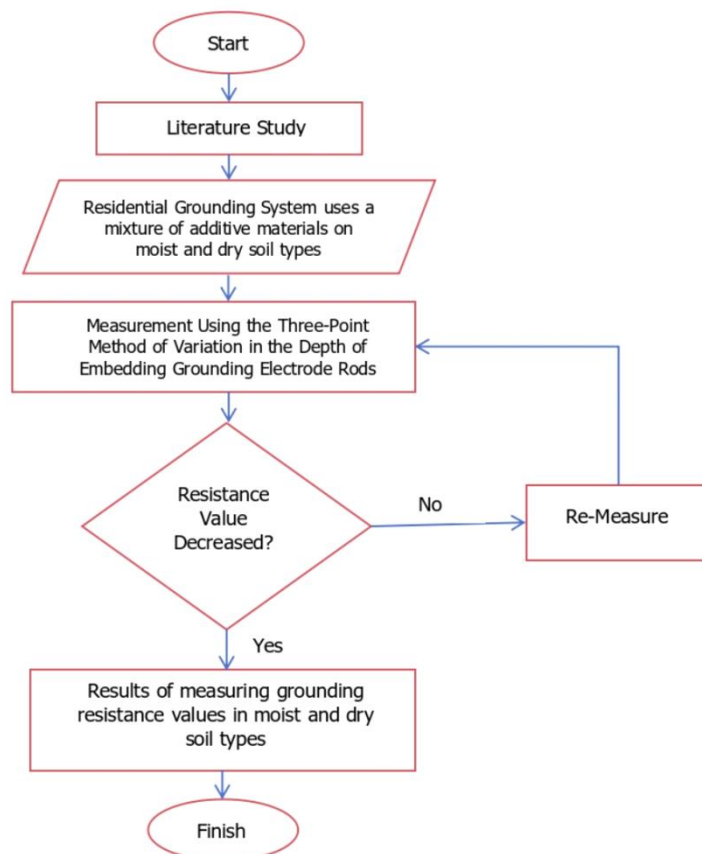


Figure 3. Research Flow Diagram

A grounding system is a conductor that functions to channel excess current into the earth and protect humans from electric shock. A good grounding system must have the lowest possible resistance value. Several factors can affect the resistance value of a grounding system, including soil resistivity, humidity, temperature, conductor dimensions, and the depth of the conductor. The General Regulations for Electrical Installations (PUIL) establish standard resistance values for various power system station sizes. The provisions stipulated in PUIL 2000 are as follows:

- 1) For large power stations (≥ 10 kilovolts), the R value must be ≤ 25 ohms.
- 2) For small power stations (≤ 10 kilovolts), including transmission towers, the R value must be ≤ 10 ohms.
- 3) For electrical and electronic equipment, the R value must be ≤ 5 ohms.
- 4) For lightning protection systems, the R value must be ≤ 25 ohms.

The effect of adding additives such as salt and bentonite in this study, additives such as salt can work by increasing the number of free ions in the soil. Increased Conductivity: Water in the soil will dissolve salt, creating a very strong electrolyte. This makes it easier for electric current to flow through the soil. Can perform Instant Resistivity Reduction: Salt provides a very fast and significant resistance reduction effect. However, it has the disadvantage that salt is corrosive to copper/steel electrodes and is easily washed away by rainwater (leaching), so the value is unstable in the long term and requires regular refilling.

Bentonite additives are a type of natural clay that has hygroscopic properties (absorbs water). Thus, it maintains humidity and is able to absorb water up to several times its original weight and retain it for a long time. Because moist soil has a lower resistance than dry soil, bentonite maintains the stability of the grounding value. Expands the Contact Surface: When wet, bentonite swells and fills the cavity between the electrode and the surrounding soil, thereby increasing the effective contact surface area. Has Long-Term Stability. Unlike salt, bentonite is not easily lost and is not corrosive, so it is more durable and protects the electrode. As for the combination of the two types of salt and bentonite additives, namely Salt reduces resistance by increasing chemical conductivity, while bentonite reduces it by maintaining moisture and improving physical contact of the electrode with the soil.

Based on the General Requirements for Electrical Installations (**PUIL, 2013**), the depth of planting the grounding electrode rod is generally set to reach a soil layer that has constant moisture to obtain a low resistance value.

- 1) Minimum Depth: The electrode rod should be buried at least 1 meter below the ground surface. However, for more effective and stable results, many technicians recommend a minimum depth of 2.44 meters (8 feet) if the soil conditions allow.
- 2) Maximum Resistance Value: According to PUIL 2011, the safe total earthing resistance value of the system must be 5 ohms. If this value is not achieved at the standard depth, the electrodes must be buried deeper or installed in parallel.
- 3) Soil Conditions: Electrode placement is greatly influenced by soil resistivity. In dry or sandy soils, rod electrodes often need to be buried to a depth of 3.5 meters or more to achieve resistivity values below 5 ohms.
- 4) Distance Between Electrodes: If using more than one electrode rod (parallel system), the minimum distance between rods is 1.8 meters or equivalent to the length of the electrode planted.

3. RESULTS AND DISCUSSION

In this study, the measurement of grounding resistance values in housing was carried out using the three-point method. This measurement was carried out using a 3-inch PVC pipe medium with a pipe length of 1.5 meters. using 2 auxiliary electrodes and 1 measuring electrode each 1.5 meters long, and the distance between the auxiliary electrode and the measuring electrode is 5 meters. Prepare the type of moist soil and the type of dry soil to each pipe, where the additives have been mixed in the form of salt and bentonite with a percentage that has been varied. The measurement was carried out by taking samples of the grounding resistance value influenced by the depth of the electrode rod planting starting from a depth of 30 cm, 50 cm, 70 cm, 90 cm and 120 cm. The measurement results were compared with the maximum resistance value of $\leq 5 \Omega$ according to PUIL 2013, can be shown in Figure 4 below:

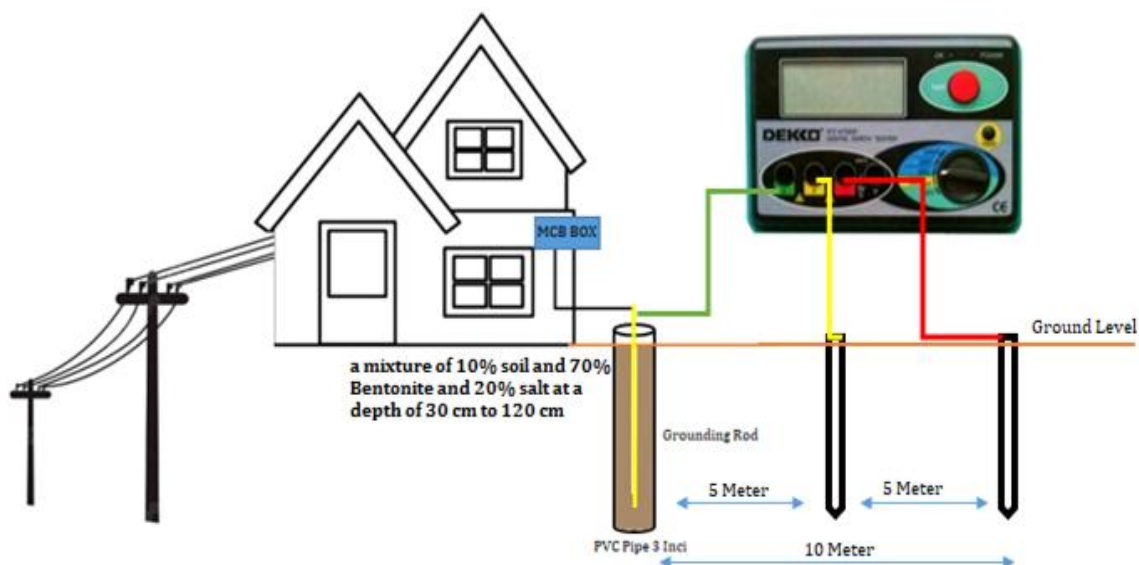


Figure 4. Measurement of the depth of the grounding resistance value in residential homes in moist soil conditions using a variety of additive materials

The measurement results with varying additive compositions in five different pipes can be seen in Table 5 below:

Table 1. Results of Resistance Measurements The Effect of Grounding Electrode Depth on Residential Grounding Systems with a Mixture of Additives on Moist Soil

Pipe	Percentage of mixed ingredients on a scale of 100 (%)			Results of Resistance (Ω)				
	Moist Soil (%)	Bentoni te (%)	Salt (%)	30 cm	50 cm	70 cm	90 cm	120 cm
1	10	70	20	10,7	9,7	8,8	7,9	7,1
2	10	60	30	11,4	10,5	9,6	8,7	7,6
3	10	50	40	11,9	11	10,1	9	8,1
4	10	40	50	12,3	11,4	10,5	9,6	8,7
5	10	30	60	13,1	12	11,1	10,2	9,3
5	10	30	60	13,1	12	11,1	10,2	9,3

Table 1 shows the results of measuring the resistance of the residential grounding system with the influence of the depth of electrode rod planting by mixing the type of moist soil using bentonite and salt additives with varying composition percentages. The measurement results are seen in pipe 1 and pipe 2 with a depth of 30 cm - 120 cm experiencing a fairly large decrease in resistance, namely from 10.7 Ω down to 7.1 Ω , in testing pipe 1, and in testing pipe 2 also experienced a decrease, namely 11.4 Ω down to 7.6 Ω .

Based on the results of residential grounding resistance measurements as in Table 1 above, a large decrease in grounding resistance value can be seen in the tests on pipe 1 and pipe 2. This can be shown in Figure 5 below:

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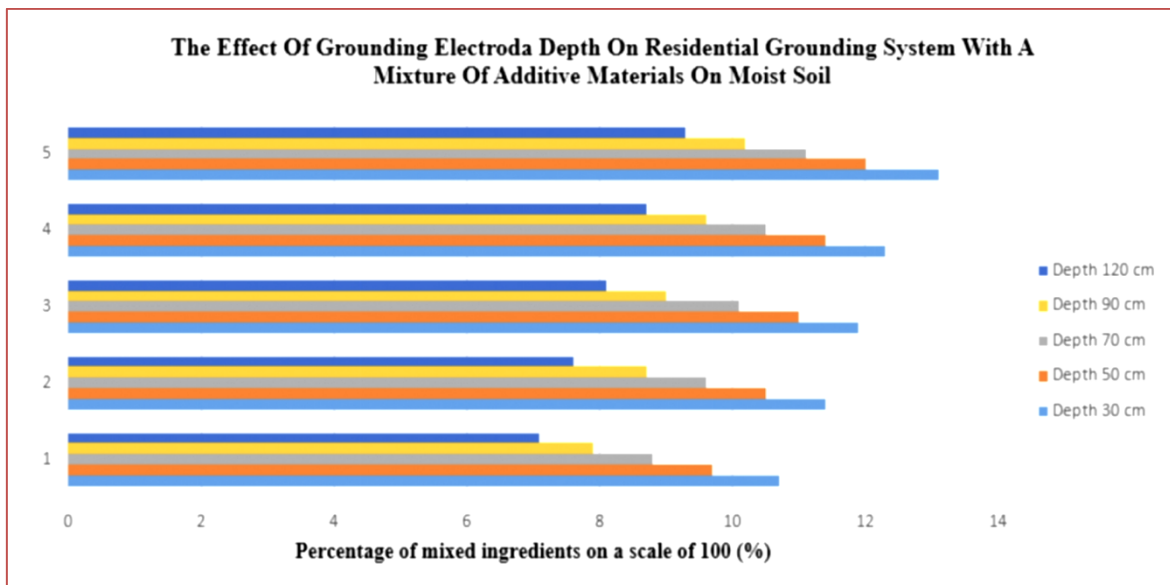


Figure 5. Comparison Chart of Resistance Measurements of The Effect of Grounding Electrode Depth on Residential Grounding Systems with a Mixture of Additives on Moist Soil

Figure 5 Comparison graph of resistance measurements for residential grounding systems shows that the measurement results on pipe 1 and pipe 2 with a depth of 30 cm - 120 cm experienced a fairly large decrease in resistance, namely from 10.7 Ω down to 7.1 Ω , in testing pipe 2 also experienced a large decrease, namely from 11.4 Ω down to 7.6 Ω . measurements on pipe 3 decreased resistance value by 11.9 Ω down to 8.1 Ω , on pipe 4 decreased by 12.3 Ω down to 8.7 Ω and on pipe 5 the resistance value decreased slightly by 13.1 Ω down to 9.3 Ω .

The second test still uses the three-point measurement method, the difference is that it uses dry soil with a mixture of bentonite and salt additives varied, measurements are carried out to obtain the grounding resistance value with the influence of the depth of the electrode rod planting, starting from a depth of 30 cm, 50 cm, 70 cm, 90 cm and 120 cm, as shown in Figure 6 below:

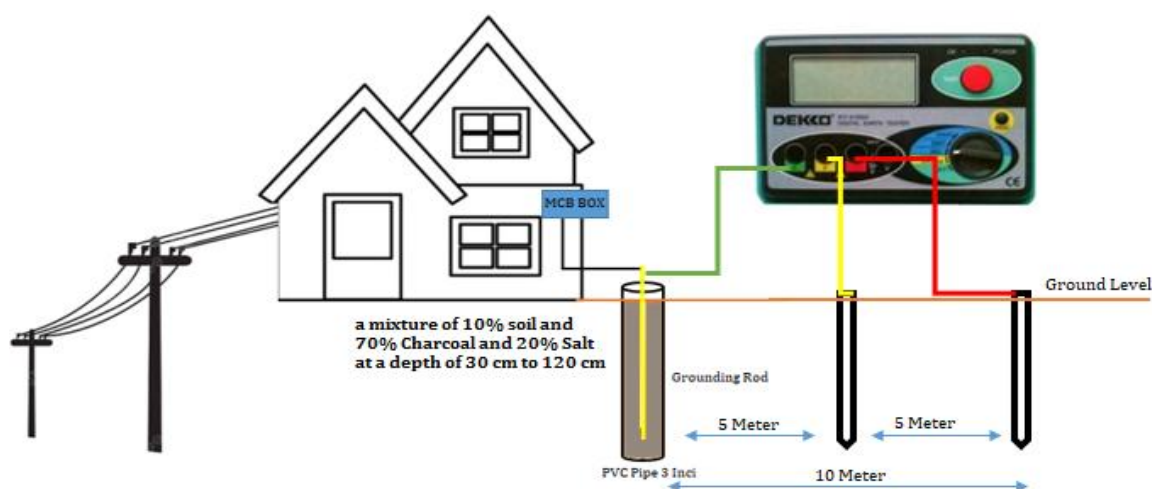


Figure 6. Measurement of the depth of the grounding resistance value in residential homes in dry soil conditions using a variety of additive materials

The measurement results with varying additive compositions in five different pipes can be seen in Table 6 below:

Table 2. Resistance Measurement Results The Effect of Grounding Electrode Depth on Residential Grounding Systems with a Mixture of Additives On Dry Soil

Pipe	Percentage of mixed ingredients on a scale of 100 (%)			Results of Resistance (Ω)				
	Dry Soil (%)	Bentonite (%)	Salt (%)	30 cm	50 cm	70 cm	90 cm	120 cm
1	10	70	20	13,2	12,1	11,2	10,3	9,4
2	10	60	30	13,8	12,6	11,7	10,9	9,9
3	10	50	40	14,3	13,2	12,3	11,4	10,5
4	10	40	50	15	13,7	12,9	12	11,2
5	10	30	60	15,6	14,2	13,4	12,5	11,7

Table 2 Results of the second test on dry soil, measuring the resistance of the residential grounding system with the influence of the depth of electrode rod planting by mixing the type of moist soil using bentonite and salt additives with varying composition percentages. The measurement results are seen in pipe 1 and pipe 2 with a depth of 30 cm - 120 cm experiencing a fairly large decrease in resistance, namely from 13.2 Ω down to 9.4 Ω , in testing pipe 1, and in testing pipe 2 also experienced a decrease, namely 13.8 Ω down to 9.9 Ω .

The second test still uses the three-point measurement method, the difference is that it uses dry soil with a mixture of bentonite and salt additives varied, measurements are carried out to obtain the grounding resistance value with the influence of the depth of the electrode rod planting, starting from a depth of 30 cm, 50 cm, 70 cm, 90 cm and 120 cm, This can be shown in Figure 7 below:

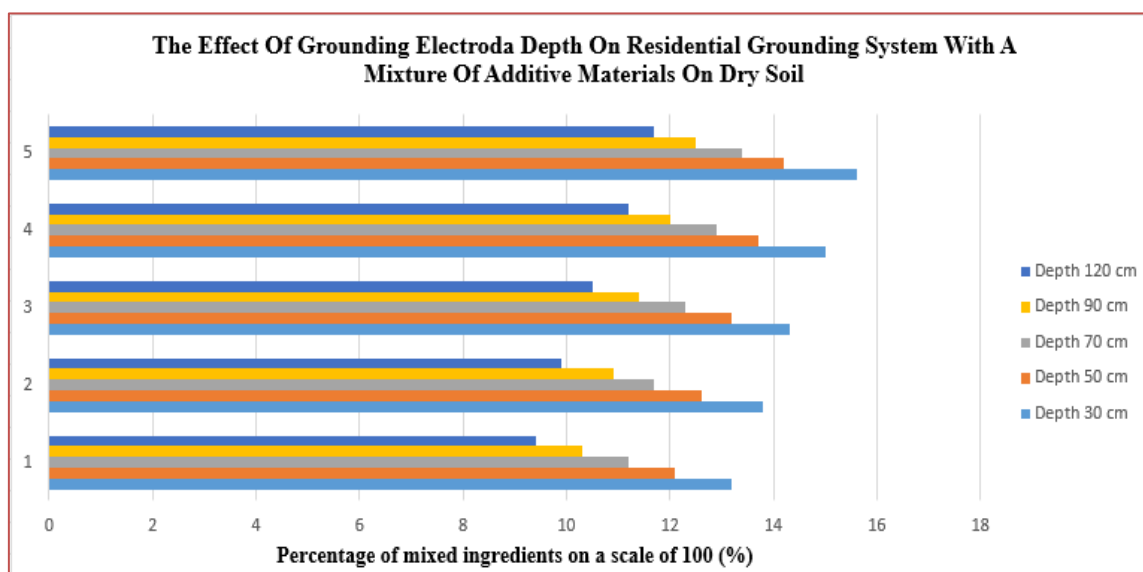


Figure 7. Comparison Chart of Resistance Measurements of The Effect of Grounding Electrode Depth on Residential Grounding Systems with a Mixture of Additives on Dry Soil

Figure 7 A comparison graph of resistance measurements for residential grounding systems shows that measurements from a depth of 30 cm to 120 cm showed a significant decrease in resistance, from 13.2 Ω to 9.4 Ω in pipe 1. Pipe 2 also experienced a significant decrease, from 13.8 Ω to 9.9 Ω . Measurements on pipe 3 showed a decrease in resistance from 14.3 Ω to 10.5 Ω , on pipe 4 a decrease of 15 Ω to 11.2 Ω , and on pipe 5 a slight decrease, from 15.6 Ω to 11.7 Ω .

4. CONCLUSION

Based on the results of measuring the grounding resistance value in the residential grounding system, with the influence of the depth of the grounding electrode rod and soil resistivity in wet and dry soil types using a mixture of bentonite and salt additives, it can be concluded that in the first test with wet soil types, the resistance value in pipe 1 and pipe 2 with a depth of 30 cm - 120 cm experienced a fairly large decrease in resistance, namely from 10.7 Ω down to 7.1 Ω , in testing pipe 1, and in testing pipe 2 also experienced a decrease, namely 11.4 Ω down to 7.6 Ω . and in testing dry soil types, the resistance value of pipe 1 and pipe 2 was obtained with a fairly large decrease in resistance, namely from 13.2 Ω down to 9.4 Ω , in testing pipe 1, and in testing pipe 2 also experienced a decrease, namely 13.8 Ω down to 9.8 Ω . These conditions still do not meet the maximum resistance standard, but can be improved by increasing the electrode depth and maintaining stable soil resistivity with the use of a better additive mixture.

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