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Comparative Analysis of Earthing Resistance on Rod and Plate Electrodes for Improvement of Earthing Resistance Values

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ABSTRACT

The availability of a grounding system must have the smallest grounding resistance value. To obtain a grounding resistance value with a certain value is influenced by several factors such as: the shape of the grounding system, soil type, soil temperature, soil moisture, electrode diameter, soil electrolyte content and others. the ground surface, and in the form of plates or plates, all of which are designed to reduce grounding resistance. From the results of measurements and calculations, the value of grounding resistance is obtained from the measurement results above, indicating the depth of the grounding electrode is 1.5 m deep, at this depth the value of grounding resistance is 0.98 Ω. The rod electrode, while the plate electrode is 1.6 Ω. and the calculation of the ground resistance using Dwight's formula, the average value of the rod electrode is 0.9 Ω and the plate, the average value is 0.5 Ω. There is a difference between the results of calculations and measurements this is due to differences in the perception of the type of electrode used. It is < 1 Ω meets the requirements of PUIL, 2000, for wet and moist soil types.

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1. INTRODUCTION

Availability of the need for electricity and telecommunications equipment that is sufficient and modern must have elements of safety, comfort and have high quality and reliability. In securing an electric power system along with other electronic devices, it is necessary to install a grounding system. The availability of a grounding system must have the smallest grounding resistance value. To get the value of grounding resistance with a certain value is influenced by several factors such as: the shape of the grounding system, soil type, soil temperature, soil moisture, electrode diameter, soil electrolyte content and others. If without paying 33 n to these factors, it is very difficult to obtain the smallest grounding resistance value or the desired grounding resistance value, both from the short-term and long-term grounding resistance values, because evaluation of the grounding system must be carried out every 6 months (PUIL, 2000).

Research on the grounding system has been carried out, both in the form of the grounding system and by changing the electrolyte content in the soil by adding additives to the soil. the. However, research on a grounding system of two electrodes planted vertically against the ground, especially in a grounding system with a distance between the electrodes greater than the length of the electrode (S > L) is very rarely done, because the grounding system is very rarely used, because the system is less effective when viewed of the required land. If the grounding system can save the required land, it is likely that the grounding system will be effectively operated to meet the needs of a grounding system to secure electronic devices. Looking at the factors that affect the value of grounding resistance such as the diameter of the electrode and the addition of additives, it is very possible to do research by modifying the depth and diameter of the electrode in a grounding system of two electrode rods planted vertically against the ground with S > L to reduce the distance between the electrodes, so that it will be able to reduce the required land.

2. METHODS

Several researchers who have suggested about the grounding system as follows:

1. Grounding system is a conductor connection system that connects systems, equipment bodies and installations with the earth/ground so as to protect humans from electric shock, and secure installation components from the dangers of abnormal voltages/currents. Therefore, the grounding system is an essential part of the electric power system. The study was conducted to measure and compare the value of ground resistance in the reclamation area and non-reclamation beach in the housing area of Citra Land, PT. Ciputra Surya, JO. so that it will be easier in the design of the grounding system later. The type of electrode used in the measurement is a single rod electrode with a diameter of 0.15 m and a length of 1.4 meters, which is planted with a depth of 0.25/0.5/0.75/1 meter from the ground surface. Analog Earth Resistance Tester 3235. The measurement of the ground resistance value is carried out ten times so that the value obtained can be averaged so that the desired ground resistance value is obtained. Yield value the measurement of the grounding resistance of reclaimed land is 3.03 , while the non-reclaimed land is 5 . For the value of soil resistivity on reclaimed land is 0.455 while for non-reclaimed land it is 1.481.
2. The resistance of the earth is directly proportional to the magnitude of the resistance of the soil type. The resistance of the soil type itself is influenced by several things, namely soil structure, temperature, the effect of water content (humidity), and the influence of chemical content in the soil. This study is to analyze the decrease in the value of grounding resistance with the addition of additives in the form of gypsum without a mixture of soil and gypsum mixed with soil. The results showed that the value of grounding resistance with the addition of gypsum without a soil mixture had a higher value than the grounding resistance without the addition of additives. Ground resistance with the addition of gypsum mixed with soil on average can reduce the value of ground resistance by 153.56 ohms with 25% gypsum, 157.2 ohms with 75% gypsum and 169.91 ohms with 50% gypsum.
3. The planting of a grounding electrode is needed to improve the value of the grounding resistance. For a grounding electrode using solid copper (Copper rod) will improve the grounding resistance in the area around the point where the electrode is implanted so that the value of grounding resistance that meets the requirements is obtained. Sand and dry gravel soils have unique characteristics, because there are difficulties in installing grounding electrodes due to gravel obstacles, this will result in not being able to have sufficient electrode depth to get the expected grounding resistance value. The value of a good grounding resistance is < 1 according to the PUIL standard, 2000. To get a good grounding resistance value, a grounding electrode is planted using a solid copper rod with a certain diameter and depth that is most suitable for the type of sand and dry gravel. In this study, several positions of the depth of the grounding electrode were simulated. In dry sand and gravel soil conditions using solid copper grounding electrodes with a diameter of 5/8 inches, the grounding value is < 1 at a depth of 3.5 m.

The main purpose of grounding is to create a path that is low impedance (low resistance) to the earth's surface for electric waves and transient voltage. Lighting, electric current, circuit switching and electrostatic discharge are common causes of electrical surges or transient voltages. An effective grounding system will minimize these effects. According to (IEEE, 2007) the purpose of the grounding system is:

1. Limit the magnitude of the voltage to the earth so that it is within the permissible limits.
2. Provide a path for current flow which can provide detection of the occurrence of unwanted connections between the system conductors and earth. This detection will result in the operation of automatic equipment which cuts off the supply voltage from the conductor.

A. Characteristics of an Effective Grounding System

The characteristics of an effective grounding system include:

1. Well planned, all connections contained in the system must be connections that have been planned in advance with certain rules.
2. Visual verification can be done.
3. Avoid interference that occurs in the electric current from the device.
4. All metal components must be held / fastened by a grounding system, with the aim of minimizing electric current through conductive materials at the same electrical potential.

B. Equivalent Circuit

The equivalent circuit of one rod electrode is made with concentrated circuit elements as shown in Figure 2. The model is based on the fact that the ground impedance does not act as a pure resistance but also behaves as an inductance (L) and a capacitance (C).

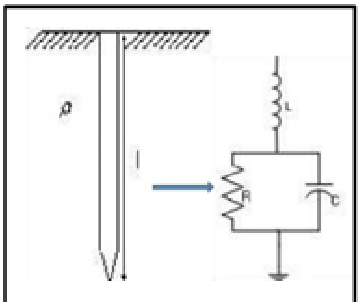

Figure 1. The equivalent circuit of the grounding system of the electrode rod

C. Grounded Parts

In an electrical installation there are four parts that must be grounded or often also called earthed.The four parts of this electrical installation are:

1. All installation parts are made of metal (conduct electricity) and can easily be touched by humans. This is necessary so that the potential of the metal that is easily touched by humans is always the same as the potential of the soil (earth) where humans stand so that it is not dangerous for humans who touch it.
2. The discharge section (bottom) of the lightning arrester. This is necessary so that the lightning arrester can function properly, which is to dispose of the electrical charge it receives from the lightning to the ground (earth) smoothly.
3. Lightning wire at the top of the transmission line. This lightning wire actually also functions as a lightning arrester. Because it is located along the transmission line, all the legs of the transmission line must be grounded so that lightning striking the lightning wire can be channeled to the ground smoothly through the legs of the transmission line pole.
4. The neutral point of the transformer or the neutral point of the generator. This is necessary in connection with the need for protection, especially regarding ground faults. In practice, it is desirable that the ground resistance of the above ground points does not exceed 4 ohms. Theoretically, the resistance of the ground or the earth is zero because the cross-sectional area of the earth is infinite. But in reality this is not the case, meaning that the grounding resistance is not zero. This is mainly due to the presence of contact resistance between the grounding device and the ground where it is installed (in the ground).

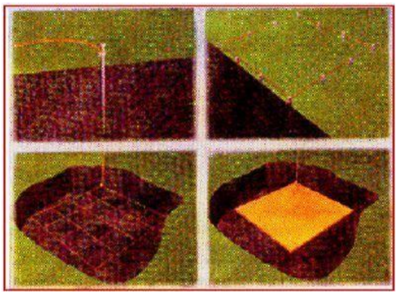
Figure 2. Types of grounding tools

From Figure 2. it appears that there are four grounding devices, namely:

1. Single grounding rod.
2. Double grounding rod. Consists of several single rods connected in parallel.
3. Grounding mesh, is a woven copper wire.
4. The grounding plate, which is a copper plate

The grounding resistance is not only caused by the contact resistance mentioned above, it is also caused by the connection resistance between the grounding device and the connecting wire. Another element that is part of the grounding resistance is the resistance from the ground around the grounding device which inhibits the flow of electric charge (electric current) coming out of the grounding device. The electric current that comes out of this grounding device faces parts of the ground with different resistance types.

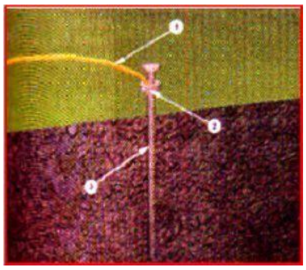

Figure 3. Ground rods and their accessories

For the same soil type, the resistivity is affected by the depth. The deeper the location, generally the lower the resistivity, because the composition is denser and generally wetter. Therefore, in installing a grounding rod, the deeper the installation, the better the results in the sense that a lower ground resistance will be obtained.

Figure 3. illustrates the grounding rod and its accessories, namely; (1) The ground conductor, (2) The connector between the conductor and the ground electrode, and (3) The ground electrode.

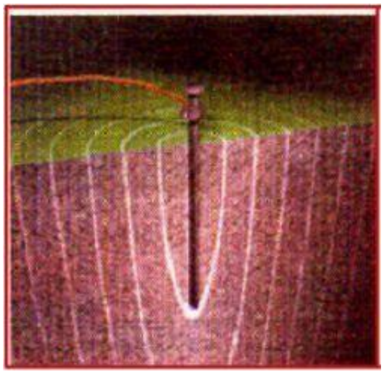
Figure 4. Ground rod and sphere of influence

While Figure 4. depicts the grounding rod and its sphere of influence in the soil. It appears that the deeper it is in the ground to a depth equal to the depth of the ground rod, and this circle of influence is getting closer to the ground rod. This is caused by variations in soil resistivity, as shown in the table below.

Table 1. Soil types of various types of soil and their grounding resistance

No	Type of soil	Type Resistance (Ohm)	Grounding Resistance (Ω)	
			Stem Depth Grounding	Ribbon Length Grounding(m)
1.	Humus	30	1053	1263
2.	Moist Soil	100	351710	402010
3.	Farmland	150	502515	603015
4.	Clay	300	663320	804020
5.	Sandy Clay	1000	33016510	4002010
6.	Sandy Moist Soil	400	-	1608040
7.	Sandy Dry Land	500	1608048	2001050
8.	Concrete 1 : 5	1000	33016510	4002010
9.	Moist Gravel	30000	10050030	1206030
10.	Dry Gravel	0	0	0
11.	Rocky Ground Rock	-	-	-

Table 1. shows the resistivity of various types of soil and grounding resistance at various depths and when using grounding strips of various lengths. From the table it can be seen that to obtain a grounding resistance of 6 in moist humus, it is sufficient that the grounding rod be driven to a depth of 5 meters but in dry sand the depth must be 165 meters.

Basically a grounding system is a device consisting of a required grounding electrode along with a grounding conductor. The grounding electrode can be a rod that is planted perpendicular to the ground or parallel to the ground, and a plate or plate, all of which are designed to reduce ground resistance. For this matter, it is necessary to first determine the material and the nature of the electrode, which in particular must have a high conductivity and low resistivity, so that current flows quickly into the ground. It should be noted that the electrode must be corrosion resistant. The rod electrode system is a resistance system that uses rods conductors planted perpendicular to the soil surface. Several electrode rods are planted together into the ground and then connected by conductors. The number of electrodes planted is adjusted to the needs of the grounding system itself. For conductor rods that are planted perpendicular to the ground surface, the effect of the shadow of the conductor must be taken into account, so that the electrode resistance and value are the same as a conductor completely buried in the ground. But the current through the conductor is half of the value entered in the fully embedded conductor. So the grounding resistance for an electrode rod that is planted perpendicular to the ground surface. The commonly used formula for single pegs was developed by Professor H.B. Dwight of the Massachusetts Institute of Technology are:

$$\rho = \frac{\pi . r^2 . R}{l} \quad \text{..........................(1)}$$

$$R = \frac{\rho}{2\pi L}\left(in \frac{4L}{a} - 1 \right) \quad \text{......................(2)}$$

Where :
ρ = average ground resistance (ohm-cm)
L = length of ground peg (cm)
a = cross-sectional radius of the peg (cm)
R = ground peg resistance (ohms)

Grounding of plate electrodes is a method by using plate-shaped electrodes with a minimum size of 0.5 m2 for copper. The minimum planting depth is 30 cm to 1.5 m below the soil surface. The ground resistance for the plate system is:

$$R = \frac{p}{4,2}\left(\frac{1}{WL} + \frac{0,16}{S}\right) \text{ohm} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where :

R = Earth resistance (ohms)

W = Width of plate (cm)

L = Plate length (cm)

S = Planting Depth (m)

To find out the accurate soil resistivity, direct measurements are needed at the location, because the actual soil structure is not as simple as expected and the locations are not the same.

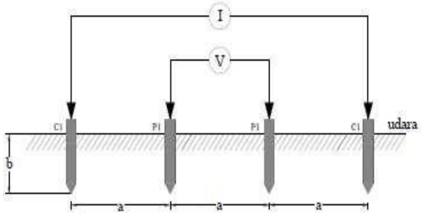

Figure 5. Four-Point Method

If the current I enters the ground through one of the electrodes and returns to the other electrode it is far enough away, so that the effect of the diameter of the conductor can be neglected.So:

$$\boldsymbol{\rho = R34.2.\pi.a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where :
A = distance between electrodes [m]
R34 = resistance between electrodes 3 and 4 [Ω]
ρ = soil resistivity [Ω-m]

The design equipment using Rod and Plate Electrode Grounding which will be designed is a development of External Grounding which functions to produce a grounding system with various forms of electrodes which is then designed to be an internal grounding system.

The thing that needs to be considered in the design of the grounding system is that there is no danger of step voltage and touch voltage. The intended criterion in making a grounding system is not the low price of ground resistance, but the avoidance of such hazards in the future. This is done to get a grounding resistance below 5 ohms. While the specifications of the tools used to measure grounding resistance are as follows:

1. Brand : KYORITSU
2. Type : Digital Earth Resistance Tester 4105A.
3. This tool serves to display the measured grounding resistance value with the ability to measure up to 1999 (ohms).

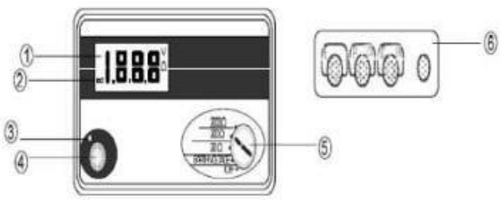

Figure 6. Earth Resistance Tester

1. LCD display of measuring values.
2. The battery symbol is low.
3. LED indicator (green).
4. Test button to lock.
5. Measurement Terminals.

3. RESULTS AND DISCUSSION

A. Measurement Results of Grounding Resistance on Rod Electrodes with a Depth of 150 cm

Table 2. Results of Earthing Resistance Measurements on Rod Electrodes with a depth of 150 cm

No	Depth of Soil	Measurement results	The calculation results ρ=resistance type	Calculation Result R = ground peg resistance (ohms)
1	20 cm	4,97	0,158	2,15
2	40 cm	3,62	0,111	1,35
3	60 cm	2,97	0,089	1
4	80 cm	1,98	0,059	0,81
5	100 cm	1,53	0,046	0,68
6	150 cm	0,98	0,029	0,49

From the data in table 2. above, it appears that there is a decrease in the value of the grounding resistance at each decrease in the depth of the grounding electrode. The value of the ground resistance is on average 2.1 (Ω). For moist and wet soil types. Meanwhile, from the calculation, the value of the decrease in grounding resistance has an average value of 0.92 (Ω). This shows that the average value of the decrease in ground resistance from the measurement results with the calculation results is almost the same.

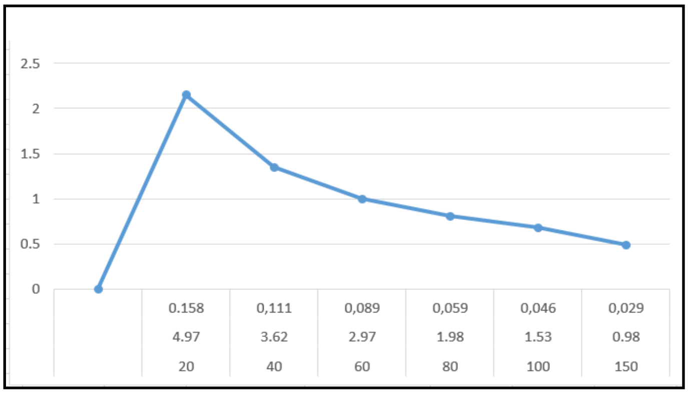

Figure 7. Graph of Calculation of the Rod Electrodes

B. Measurement Results of Grounding Resistance on Plate Electrodes with a Depth of 150 cm

Table 3. Measurement Results of Grounding Resistance on Plate Electrodes with a depth of 150 cm

No	Depth of Soil	Measurement results	The calculation results ρ=resistance type	Calculation Result R = ground peg resistance (ohms)
1	20 cm	5,3	1,06	0,45
2	40 cm	4,6	1,84	0,61
3	60 cm	3,8	2,28	0,68
4	80 cm	2,9	2,32	0,66
5	100 cm	1,9	1,9	0,52

6	150 cm	1,6	2,4	0,63

From the data in table 3. above, it appears that there is a decrease in the value of the grounding resistance at each decrease in the depth of the grounding electrode. The average value of the grounding resistance is 2.8 (Ω). for moist and wet soils. Meanwhile, from the calculation, the value of the decrease in grounding resistance has an average value of 0.5 (Ω). This shows that the average value of the decrease in ground resistance from the measurement results with the calculation results is almost the same.

Pada grafik perbandingan di bawah ini terlihat hasil perhitungan pada Elektroda Batang dan Plat.

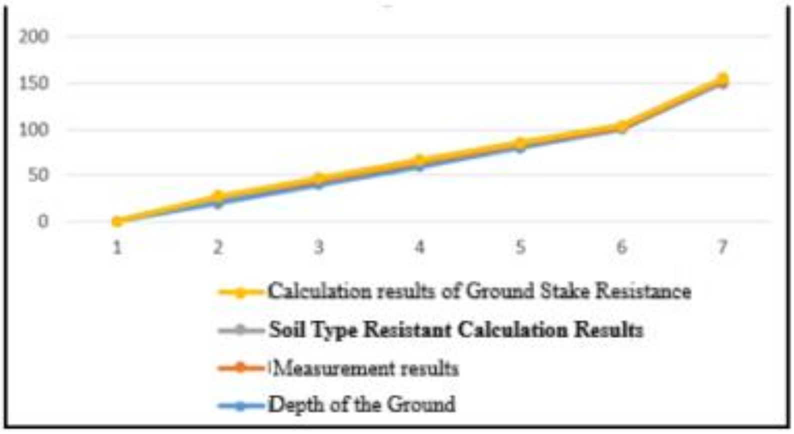

Figure 8. Calculation Graph on Plate Electrodes

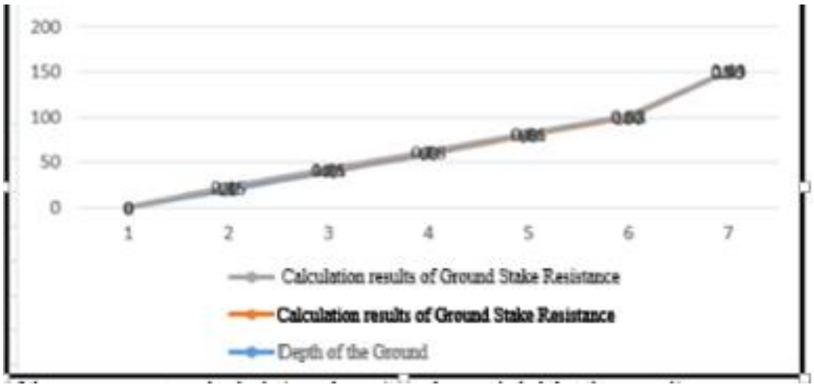

Figure 9. Comparison graph of calculation results on rod and plate electrodes

4. CONCLUSION

From the results of the measurements and calculations above, it can be concluded that the grounding resistance value in the above measurement results shows the depth of the grounding electrode is 1.5 m deep, at this depth the value of the grounding resistance is 0,98 on the rod electrode while the plate electrode is 1.6.

In the calculation of ground resistance using Dwight's formula, the average value for the rod electrode is 0.9 and for the plate, the average value is 0,5. There is a difference between the results of calculations and measurements this is due to differences in the perception of the type of electrode used. It is < 1 meets the requirements of PUIL, 2000, for wet and moist soil types.

The results of measurements in the field, as well as the results of calculations show that the resistance value is < 1 This is in accordance with the requirements for the value of the grounding resistance for buildings, even if electronic devices are installed there is no problem because the ground resistance has a value of < 1.

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