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Assessment of Grounding System to Reduce Potential Electrical Disturbances at Haji Regional General Hospital, East Java Province

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ABSTRACT

The grounding system in the Hospital is used to overcome when there is a touch voltage and step voltage on the transformer and also other equipment installed on the transformer. The process carried out in this study was carried out by measuring the grounding and processing the data used to determine the size and smallness of the touch voltage and Step voltage. The results of the calculation of the grounding resistance in the hospital obtained a value of 5,056 Ω which can cause a touch voltage with a value of 1014 V. The step voltage in humans weighing 50 Kg produces a value of 962,8 V and the step voltage for humans weighing 70 Kg produces a value of 1299 Volts. With the results of the values obtained, that the value has been in accordance with the standard of Step voltage based on IEEE 80-2013 with a value of 3,140 V with a duration of disturbance of 0,5 seconds.

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INTRODUCTION

Haji Regional General Hospital Surabaya is a Regional General Hospital located at Jalan Manyar Kertoadi, No. 4-6, Surabaya, East Java, Indonesia. As a government-owned hospital, RSUD Haji Surabaya provides various health facilities and services for the community, including a 24-hour Emergency Unit (UGD), various specialist polyclinics, inpatient facilities, laboratory, radiology, medical rehabilitation, pharmacy, and surgical services. This hospital also has special services for maternal and child health, including care during pregnancy and childbirth. With a vision of becoming a leading hospital that provides quality and affordable health services, RSUD Haji Surabaya is committed to providing quality and professional health services, increasing accessibility and affordability of health services.

The grounding system is installed on an object that has an electrical installation. The grounding system is installed into the ground with applicable regulations that use grounding made of copper-plated iron or pure copper (Pulungan *et al.*, 2022). The grounding system installed on the top of a building is called a lightning rod, which is connected to the electrical conductor wire and connected to the ground embedded in the ground (Hayyan *et al.*, 2019). Things that cause interference in the electrical installation system caused by interference by nature include animals, thunder, and plants, and internal interference, for example, damage to connecting cables, damage to connecting insulators, and other causes are human error factors (Harahap *et al.*, 2023).

The grounding system was not used when the power system still had a small capacity size. The reason at that time was because if there was a ground fault in the system, and where the magnitude of the fault current was equal to or less than 5 amperes, then in such conditions the arc would go out by itself. Electrical fault currents occurred more frequently, as the electric power system grew larger and was very dangerous for the system, because it could cause very high transient overvoltages. Therefore, experts then designed a system that made the power system no longer float. This system is then known as a grounding system (Tanjung, 2020).

The grounding system aims to secure electrical equipment and humans located around the fault by flowing the fault current to the ground, until a safe value is reached for all operating conditions, both normal conditions and when a fault occurs. When a fault occurs, the fault current that is flowed to the ground will cause a difference in voltage on the ground surface caused by the presence of soil resistance. The grounding system is useful for obtaining a potential voltage that is evenly distributed in a part of the structure and equipment, as well as for obtaining a return path for short circuit currents or fault currents to the ground that has low resistance. Because if the fault current is forced to flow into the ground with high resistance, it will cause a large voltage difference that can be dangerous (Anitasari *et al.*, 2024).

One factor in getting a small grounding resistance value is the location of the electrode to be planted. In the planning process of a type of grounding system, a grounding resistance measurement is required which will be a reference for the grounding system planning process (Faridha *et al.*, 2022). This will be useful in planning the grounding system because more current is flowed into the ground quickly when an electrical disturbance occurs because the grounding resistance value is small. In addition, the difference in soil types also greatly affects the grounding resistance itself. So it is very necessary to conduct a study and assessment that can see the extent of the influence of these parameters.

METHODS

From the block diagram in Figure 1, it can be explained that the study and assessment stage begins with a literature study, where the assessor will study the basic principles of grounding, and the grounding standards themselves. After studying the things needed for the study materials, it is continued to measure the grounding resistance and calculate the touch voltage and step voltage values at the Haji Regional General Hospital of East Java Province. After measuring and calculating, the data obtained can be analyzed and also compared with the values set in the PUIL in 2000.

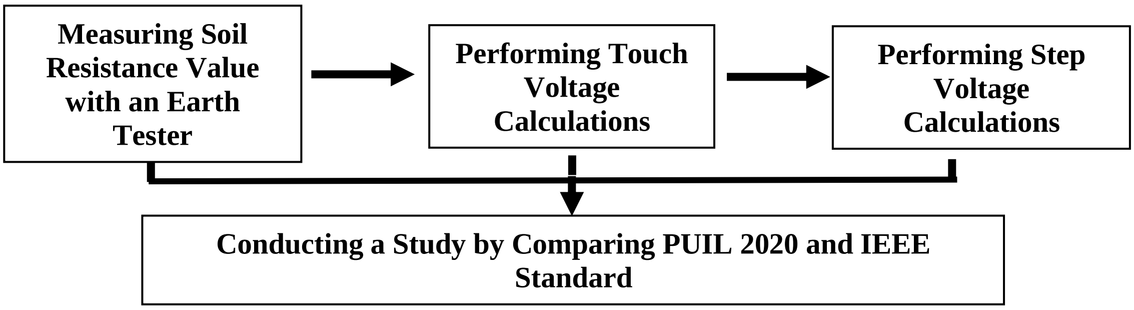

Figure 1. Block Diagram for the Process of Conducting a Study at Haji Regional Hospital

1. Measurement of Soil Resistivity

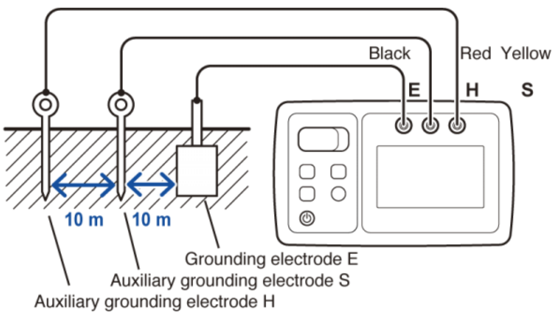

Figure 2. Soil Resistivity Measurement Circuit Using the Three Electrode Method

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Soil resistivity measurement using the three-electrode method, also known as the three-electrode Wenner method, is a common technique in geophysics and soil engineering to determine soil resistivity. The process begins with the preparation of equipment consisting of three electrodes: two current electrodes (H and S) and one potential electrode (E), as well as a soil resistivity measuring instrument such as an ohm-meter or a special soil resistivity instrument. The electrodes are placed in the ground with a certain configuration: the H and S electrodes are placed at a certain distance from each other along a straight line (Widagdo et al., 2023). Figure 2 is a Soil Resistivity Measurement Circuit Using the Three Electrode Method.

2. Determination of Touch Voltage and Step Voltage Criteria

Determining the criteria for touch voltage and step voltage is an important aspect in electrical safety, especially around high-voltage electrical installations. Touch voltage is the voltage that can be felt by a person when touching electrically charged equipment or surfaces, arising from the potential difference between the point touched and the surrounding ground. The criteria for touch voltage must meet safety standards as set by IEC 60479-1, taking into account the duration of contact and environmental factors such as humidity and surface type. Step voltage, on the other hand, is the voltage between two points on the ground surface that are one human step apart (about 1 meter), which occurs when an electric current flows through the ground and creates a potential gradient. The criteria for step voltage are also regulated by the same safety standards, taking into account the step distance and ground conditions.

In practice, the implementation of a good grounding system is essential to reduce touch and step voltages, and regular inspection and maintenance of electrical equipment and grounding systems are required to ensure safety (Ramadhani *et al*., 2021). The use of personal protective equipment (PPE) such as insulating shoes can also help protect against the risk of touch and step voltages. International standards such as IEC 60479-1 and IEEE Std 80 regulate the limits of touch and step voltages to ensure the safety of workers and the general public (Susanto, 2023). Electrical companies and related industries must comply with these standards in the design, installation and maintenance of their electrical installations. Thus, ensuring that touch and step voltages are within safe limits is a crucial step in managing electrical risks and maintaining safety in areas adjacent to electrical installations (Putra *et al.*, 2022).

$$E_s = \left(R_k + \frac{R_s}{2}\right) \times I_k \quad (1)$$

$$E_s = I_k\left(R_k + 1{,}5 \times R_g\right) \quad (2)$$

3. The Effect of Electric Current on the Body

The results of the study say that the average resistance in the human body is 1000 Ω, and the maximum electric current that can be considered safe for the body is 50 mA (Muljono *et al.*, 2019). Based on what is determined by Ohm's law (Ω), calculations can be made using the following formula (Yusmartato *et al.,* 2021).

$$V = I \times R$$

$$V = 50 \text{ mA} \times 1000 \text{ Ohm} = 50 \text{ Volt}$$

RESULTS AND DISCUSSION

The results of the interview with the person in charge of electricity at the Haji Regional General Hospital (RSUD) of East Java Province conducted on February 29, 2024, covered the following important things (Figure 3). This includes a comprehensive overview of the current condition of the electrical infrastructure and maintenance protocols (Table 1). In addition, this interview also revealed ongoing projects and future plans aimed at improving the reliability of electrical equipment at the hospital. The person in charge provided valuable insights into the challenges faced and the solutions being implemented. This information is important to understand the hospital's efforts to ensure electrical operations are in accordance with standards.

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Rod Type	: Copper Plated Iron
Rod Length	: 6 m
Rod Diameter	: 38,1 mm
Rod Thickness	: 2 mm
Mounting Design	: *Single ground rod*
Conductor Type of BC	: Copper without Isolation
Conductor Size of BC	: 35 mm

Figure 3. Interview with the Technical Team of Haji Regional Hospital, East Java

Table 1. Grounding Specifications at the East Java Hajj Regional Hospital

Data	PUIL 2000 Standart	Research Object	Criteria
Length of Copper-coated Iron rod	Minimum 1,5 m	6 m	**Good**
Diameter of Copper-coated Iron rod	Minimum 25 mm	1,5 inch (38,1 mm)	**Good**
Thickness of Copper-coated Iron	Minimum 2 mm	2 mm	**Good**
Cross-sectional area (BC)	Minimum 25 mm	35 mm	**Good**

1. Measurement results of Soil Resistivity

With the earth tester selector at the 20 Ω position, which means that the 20 Ω selector is the maximum measurement limit that can be read by the measuring instrument is 20 Ω (Carnolis & Surapati, 2017). After installing the auxiliary pegs and auxiliary cables. Measurement using an earth tester measuring instrument (Figure 4 and Table 2):

Brand : KYORITSU
Type : Digital Earth Tester model 4105A

Figure 4. Measuring Soil Resistivity with Earth Tester

Table 2. Grounding Measurement Results

Point	Measurement Value	Average Value	PUIL 2000 Standart	Criteria
1	0,15	0,72	≤ 5 Ω	**Good**
2	0,55			**Good**
3	0,45			**Good**
4	1,32			**Good**
5	1,31			**Good**
6	0,53			**Good**

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2. Fibrillation Current

Fibrillation current in the context of touch voltage is the electric current that flows through the body when a person touches a device or object that is exposed to electrical voltage. This current can cause ventricular fibrillation, a potentially fatal heart rhythm disturbance, due to the rapid and irregular contraction of the ventricles. Ventricular fibrillation interferes with effective blood flow, which can be fatal if not treated promptly. The safe limit of fibrillation current for humans is generally below 30 mA.

$$\mathrm{I_k} = \frac{\mathrm{k}}{\sqrt{\mathrm{t}}} \tag{3}$$

where,

I_k : Fibrillation Current (A)

k : 0,116 A for a body weight of 50 Kg and 0,157 A for a body weight of 70 Kg

$\sqrt{t}$: (0.5 seconds) Duration of ground fault

From the formula above, fibrillation can be determined for humans weighing 50 Kg and 70 Kg, where the results of the calculation of the fibrillation current value are used to calculate the touch voltage and step voltage values, the calculation of the fibrillation value is as follows:

a. Fibrillation for a human body weight of 50 kg

$$I_k = \frac{k}{\sqrt{t}} = \frac{0{,}116}{\sqrt{0{,}5}} = 0{,}164 \text{ A}$$

b. Fibrillation for a human body weight of 70 kg

$$I_k = \frac{k}{\sqrt{t}} = \frac{0{,}157}{\sqrt{0{,}5}} = 0{,}222 \text{ A}$$

3. Impact on Touch Voltage

Table 3. Touch Voltage Calculation Results

Point Measurement	Weight	Duration of Disturbance	Touch Voltage	IEEE Std 80-2013	Criteria
1	50 Kg		116,026 V		According to the standard
	70 Kg		222,049 V		According to the standard
2	50 Kg		116,095 V		According to the standard
	70 Kg		222,183 V		According to the standard
3	50 Kg		116,078 V		According to the standard
	70 Kg		222,149 V		According to the standard
4	50 Kg	0,5 Second	116,055 V	890 V	According to the standard
	70 Kg		222,106 V		According to the standard
5	50 Kg		116,053 V		According to the standard
	70 Kg		222103 V		According to the standard
6	50 Kg		116,092 V		According to the standard
	70 Kg		222,176 V		According to the standard

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The impact of touch voltage is a safety risk for humans because electric current can flow through the body when touching a faulty electrical device or installation. High touch voltage can cause serious injury or death. It is important to ensure safe and standard electrical installations to reduce this risk. Protection such as grounding and circuit breakers can help reduce touch voltage.

a. Touch voltage for Point 1

Touch voltage of a 50 Kg human:

$$E_s = I_k(R_k + 1{,}5 \times R_g)$$

$$E_s = 0{,}116\ (1000 + 1{,}5 \times 0{,}15) = 116{,}026\ \text{V}$$

b. Touch voltage of a 70 Kg human:

$$E_s = I_k(R_k + 1{,}5 \times R_g)$$

$$E_s = 0{,}222\ (1000 + 1{,}5 \times 0{,}15) = 222{,}049\ \text{V}$$

Based on the results of the touch voltage calculation on the grounding system, the calculation results show that at point 1 the grounding measurement shows a touch voltage for a maximum weight of 50 Kg of 116,026 V and for a maximum weight of 70 Kg of 222,049 V, the calculation has met the maximum touch voltage safety standard based on IEEE Std 80-2013 with a disturbance duration of 0.5 seconds where the maximum standard is 890 V (Table 3).

4. Impact on Step Voltage

Table 4. Calculation Results for Step Voltage

Point Measurement	Weight	Duration of Disturbance	Touch Voltage	IEEE Std 80-2013	Criteria
1	50 Kg		164,147 V		According to the standard
	70 Kg		222,199 V		According to the standard
2	50 Kg		164,541 V		According to the standard
	70 Kg		222,732 V		According to the standard
3	50 Kg		164,442 V		According to the standard
	70 Kg		222,599 V		According to the standard
4	50 Kg	0,5 Second	165,298 V	3140 V	According to the standard
	70 Kg		223,758 V		According to the standard
5	50 Kg		165,289 V		According to the standard
	70 Kg		223,744 V		According to the standard
6	50 Kg		164,521 V		According to the standard
	70 Kg		222,705 V		According to the standard

Step Voltage for Point 1

Step voltage with a maximum weight of 50 Kg:

$$E_s = (R_k + 6 \times R_g)I_k$$

$$E_s = (1000 + 6 \times 0{,}15)\frac{k}{\sqrt{t}}$$

$$E_s = (1000 + 0{,}9)\frac{0{,}116}{\sqrt{0{,}5}} = 164{,}147\ \text{V}$$

Step Voltage for Point 2

Step voltage with a maximum weight of 70 Kg:

$$E_s = (R_k + 6 \times R_g) I_k$$

$$E_s = (1000 + 6 \times 0{,}15) \frac{k}{\sqrt{t}}$$

$$E_s = (1000 + 0{,}9) \frac{0{,}157}{\sqrt{0{,}5}} = 222{,}199 \text{ V}$$

Based on the calculation, namely the calculation results of the step voltage on the grounding system, the calculation results show that at point 1 the grounding measurement shows a step voltage for a maximum weight of 50 Kg worth 164,147 V and for a maximum weight of 70 Kg worth 222,199 V. The calculation results have met the maximum step voltage safety standard based on IEEE Std 80-2013 with a disturbance duration of 0,5 seconds where the maximum standard is 3140 V (Table 4).

CONCLUSION

Based on the measurements and analysis of the data that has been done, it can be concluded that this study has succeeded in determining the value of grounding resistance, touch voltage and step voltage. The results show an average grounding resistance of 0.72 ohms, and these results have met the PUIL 2000 standard where the standard is less than 5 ohms. Furthermore, based on the results of the touch voltage calculation on the grounding system at the East Java Hajj Hospital, the calculation results show that at point 1 the grounding measurement shows a touch voltage for a maximum weight of 50 Kg of 116,026 V and for a maximum weight of 70 Kg of 222,049 V, these calculations have met the maximum touch voltage safety standard based on IEEE Std 80-2013 with a disturbance duration of 0,5 seconds where the maximum standard is 890 V. Then, based on the calculation results of the step voltage on the grounding system, the calculation results show that at point 1 the grounding measurement shows a step voltage for a maximum weight of 50 Kg worth 164,147 V and for a maximum weight of 70 Kg worth 222,199 V. The calculation results have met the maximum step voltage safety standard based on IEEE Std 80-2013 with a disturbance duration of 0.5 seconds where the maximum is 3140 V.

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