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Decreasing Ground Potential Rise by Lessening Soil Resistance in Arrester Grounding System

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ABSTRACT

One of the requirements for a safe soil construction installation is a low soil resistance value in accordance with standards, including those applicable in Indonesia, namely PUIL 2000 and PUIL 2011 with a value of 0 Ω to 5 Ω, including the value of soil resistance in grounding arrester at LA distribution substations 0031. Because the objective of the arrester is to drain the lightning surge voltage in order to safeguard the distribution substation, it must have a good and standard grounding system, ideally with a resistance below 5. With the initial measurement of the grounding system having a value of 11.5 Ω, a study is required to reduce the value of the soil resistance, from a series of analytical calculations and soil types, so that a decrease in soil resistance is obtained which is considered the PUIL standard, namely 3.4 at arrester ground resistance. The smaller the resistance value obtained, the smaller the Ground Potential Rise (GPR) effect at the Distribution Substation.

Keywords :
Grounding arrester, Decrease in ground resistance ,PUIL, Distribution Substation, GPR.

1. INTRODUCTION

A grounding system is required to safeguard power generation installations, power distribution and distribution systems, and electrical equipment installations against lightning voltage surges, including at distribution substations (Batista et al., 2021), where the soil problem exists, a system often employed in the field of electricity attempts to preserve continuous system operation and protect electrical equipment and persons who are near electrical disturbances (Putra et al., 2022b). In the distribution system to distribute electric power from power centers (sources) to power users (consumers), an electric power network channel system is needed (Putra & Harlian, 2021). This network system is comprised of a 150 kV transmission line that is supported by a substation and distributed via feeders that include 20 kV medium voltage overhead lines (SUTM) (Salam et al., 2017), subsequently transformed through 20 kV distribution substations to a 380/220 volt low voltage system (Putra et al., 2021). Throughout its operation, the electric power distribution system is a component that is frequently disrupted (Li et al., 2021). Apart from technical disruptions or the equipment itself, these disturbances

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also include non-technical disturbances from the outside or natural disturbances, such as a lightning strike (Camara et al., 2020). To prevent disturbances and damage in 20 kV distribution substations, a good grounding system is required, with a resistance value ranging from 0 and 5 ohms (Ω) under the PUIL 2000 standard (Rizki & Putra, 2020 and PUIL, 2000), High ground resistance causes the reflected current wave to travel to metal electrical equipment if the reflected current wave exceeds the electrical distribution equipment's insulator breakdown voltage (Arias Velásquez & Mejía Lara, 2019) so the lightning current will cause damage to the equipment (Ali et al., 2020). On the grounds of initial measurements indicating that the arrester grounding system installation at the LA 0031 distribution substation exceeds the PUIL (General Electrical Installation Requirements) standard value, it is necessary to reduce the value of the soil resistance to protect against lightning damage in addition to protecting the equipment at the LA 0031 distribution substation installation. Obviously, electricity with a good and standard grounding system protects humans or electrical operators in adjacent areas from the dangers of contact voltages and step voltages induced by lightning, which is indicated by the formation of Ground Potential Rise (GPR) at that location (Salam et al., 2017 and Putra et al., 2022a). Decreasing the soil resistance to the soil of this system is an attempt to connect part of the open conducive equipment with the ground and is useful for obtaining a uniform potential voltage 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 which has low resistance (Hossain et al., 2021).

2. RESEARCH METHOD

In order to perform field observations for research on lowering soil resistance in the arrester grounding system at the 20 kV distribution substation LA 0031, the researcher selected research locations and conducted field observations. The initial measurement was then conducted using the Earth Tester Digital 4015 A and the 3-point approach (Faudzi et al., 2020). The original measurement results were then assessed and analyzed in order to lower the soil resistance utilizing multiple rod electrodes and the driven rod as well as U.dwight methods (IEEE Std 81, 2012), when using the cymgrd program to analyze the Ground Potential Rise (GPR) (Salam et al., 2017).

- For one electrode rod implanted perpendicularly.

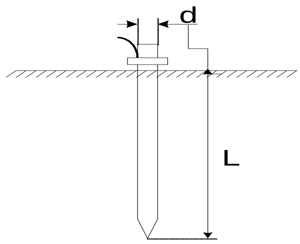

Figure 1. The rod electrodes are implanted perpendicularly

$$R_{bt} = \frac{\rho}{2\pi L} \ln\left(\frac{2L}{r}\right) \quad (1)$$

- Two electrodes are implanted perpendicularly (placed anywhere)

$$R_{bt} = \frac{\rho}{2\pi L} \ln\left(\frac{2L}{\sqrt{a.r}}\right) \quad (2)$$

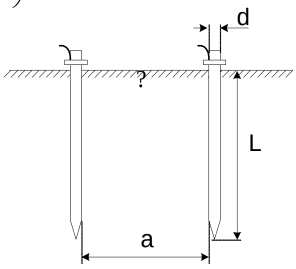

Figure 2. Two electrode rods are implanted perpendicularly

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- For four electrode rods implanted perpendicularly (placed anywhere)

$$R_{bt} = \frac{\rho}{2\pi L}\ln\left(\frac{2L}{\sqrt[4]{2^{1/2}a^3 r}}\right) \quad (3)$$

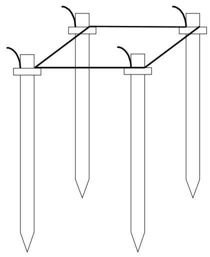

Figure 3. Four electrode rods are implanted perpendicularly

3. RESULTS AND DISCUSSIONS

Initial data from the measurement of ground resistance in the arrester grounding system at the 20 kV LA 0031 distribution substation indicate that the acquired ground resistance value is more than the PUIL 2000 or PUIL 2011 standard of 5 5 Ω, or 11.5 Ω.

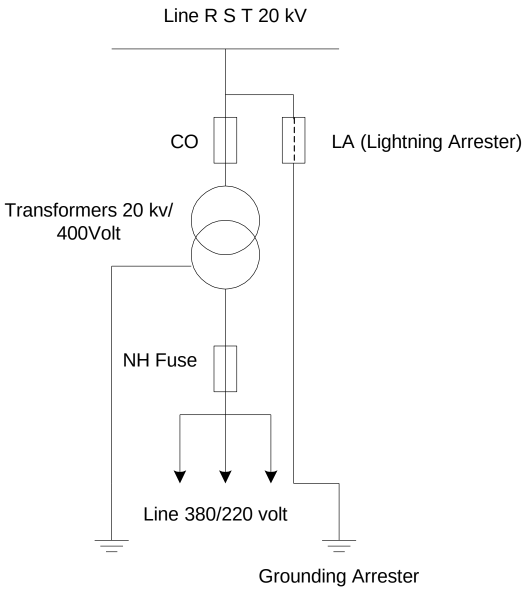

Figure 4. Single Line Diagram of 20 kV Distribution Substation LA 0031

Table 1. Arrester Ground Resistance Value Exceeds Standard Value

Substation	Location		Ground Resistance (Ω)
	Soil Type	Village	Arrester Distribution Substation 20 kV
LA.0031	Farm Soil	Pagar Agung	11.5

According to UB. Dwight, the quantity of soil resistance from one rod, two rods, three rods, four rods, or five rods or more electrodes is as follows: Therefore, after obtaining measurement results with a soil value that exceeds the standard (maximum 5 Ohm), we will compute it based on the ground conditions at the time the tower was constructed. According to the calculation results, the 20 kV distribution substation LA 0031 has an issue with its soil resistance. According to the results of measuring the arrester ground resistance using the 3-point or pin method when the rod electrode is implanted in clay soil and the soil resistance value exceeds the maximum permitted standard (5 Ohm), the soil has a resistivity value between 20 and 100 Ohm meters (maximum value of field resistivity).

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According to the results of a calculation employing UB. Dwight's equation (1), the soil resistance value for a single soil electrode implanted in clay/wet soil during the rainy season is as follows:

Table 2. Field Parameters

Parameter	Value	Unit
ρ : Farm soil type resistance	20 s.d 100	Ωm
ρ : Assumed soil resistivity	40	Ωm
L : Embedded stem length	3	m
d : Electrode rod diameter	0,0162	m
r : Electrode rod radius	0,0081	m

Table 3. Comparison of Arrester Soil Resistance Results.

Soil Resistance (Ω)		
PUIL 2000 Standard	Measurement Result	Calculation results
5	11,5	14,03

From the results of the initial calculation analysis regarding the soil resistance in the arrester grounding system at the 20 kV LA 0031 distribution substation, the results obtained were greater than the results of field measurements, namely 14.03 Ω, whereas the results of measuring the arrester soil resistance at the beginning showed a value of 11.5 Ω. This phenomenon is caused by the humidity in the measurement location, which is a result of the rainy season. In comparison to the PUIL 2000 standard, the results of measurements and calculations are still far from standard; thus, it is important to improve by decreasing the soil resistance to the standard value of 0 to 5 Ω. As a means of decreasing the soil resistance, a parallel rod electrode is put in addition to the existing rod electrode.

3.1 Adding 1 Electrode Rod

Before conducting direct field testing and based on the results of initial calculations and measurements, the first analysis is to reduce the earthing resistance in the arrester grounding system of the 20 kV LA 0031 distribution substation by estimating the calculation using equation (2) of the UB method. Dwight calculated the value of soil resistance by adding one 3-meter-long rod, resulting in two soil electrode rods with a resistance of 7.75 Ω.

3.2 Adding 3 Electrode Bars

After completing an estimated calculation with two ground electrode rods, the results are still beyond the PUIL 2000 standard limitations; consequently, the analysis of the calculation test is proceeded by adding electrodes to the calculation of four soil electrode rods using equation (3). Based on the results of the calculation analysis utilizing four buried soil electrodes, the soil resistance value value is calculated to be 4.61 Ω ; with this construction, the soil resistance value has met the tolerance limit or standard from PUIL 2000.

Table 4. Soil Resistance Value Calculation Results

PUIL 2000 Standard	Soil Resistance Value Calculation Results (Ω)		
	1 Electrode Bar	2 Electrode Bar	4 Electrode Bars
5	14,03	7,75	4,16

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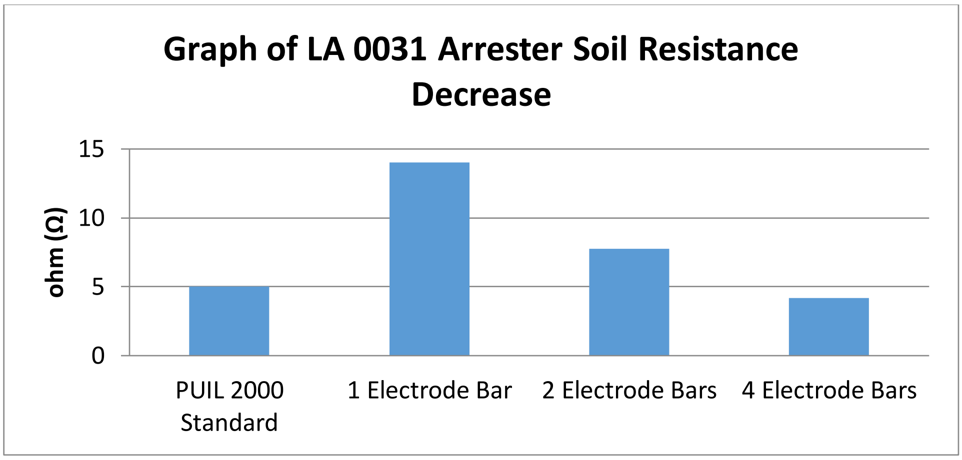

Figure 5. Graph of decreasing grounding resistance with calculations

Figure 5 illustrates a reduction process starting with the usage of two ground electrode rods and a reduction in soil resistance according to PUIL 2000 requirements when four soil electrode rods are placed in damp field soil.

Table 5. Field Measurement Result Soil Resistance Value

PUIL 2000 Standard	Field Measurement Result Soil Resistance (Ω)		
	1 Electrode Bar	2 Electrode Bars	4 Electrode Bars
5	11,5	5,55	3,4

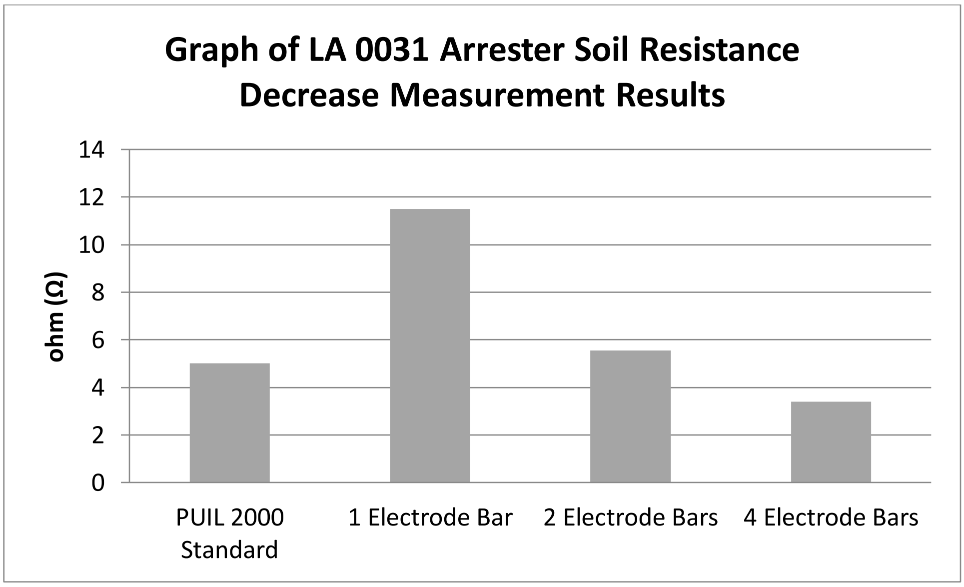

Figure 6. Graph of decreasing soil resistance with field measurements.

As a consequence of measuring soil resistance in the field, the value of soil resistance decreased as the number of implanted rod electrodes increased. The smallest measurement value is 3,4, which has reached the safe tolerance range and PUIL 2000 standard. The gap between the calculated and measured values is due to the low soil resistivity value, which is a result of the humid circumstances during the rainy season. The humidity factor, in addition to the number of electrodes installed, influences the decrease in soil resistance value.
From the measurement data with 4 soil electrodes at a depth of 3 meters it can be simulated using the cymgrd application to find out the distribution of the Ground Potential Rise (GPR) that occurs as a result

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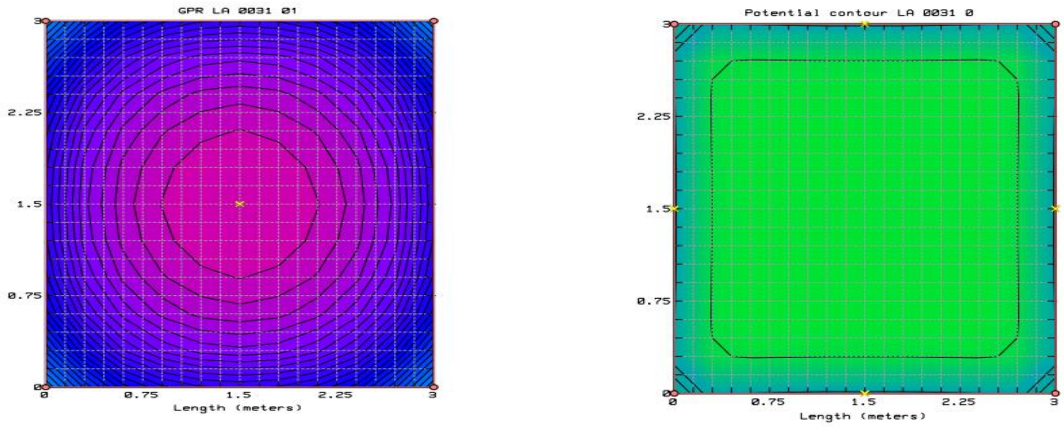
of fault currents caused by lightning, fault currents are assumed to be 100 Amperes. From the cymgrd simulation, the GPR data, touch voltage and step voltage are obtained which are shown in the following table:

Table 6. Comparison of GPR Values

Research Description	GPR	Touch Voltage	Step Voltage
	Volt (V)		
Pre-Repair	771.417	207.96	339.69
Post-Repair	35.914	207.96	339.69



(a) (b)

Figure 7. Electrical Voltage Distribution Contours at Ground Level Substation Location LA0031

Based on the simulation results using the cymgrd application, if there is a fault current from a lightning strike, the potential touch voltage on the distribution substation equipment is 207.96 volts and the step voltage is 339.69 volts, while the GPR voltage value before repairing the ground resistance value in the arrester grounding system is 771,417 volts, with the improvement in the addition of rod electrodes, the GPR voltage value dropped to 35,914 volts, which can be seen clearly in Figure 7 (a) the distribution of very high GPR voltage is marked with a pink contour, while in Figure 7 (b) the distribution of the GPR voltage is very small, namely 35,914 volts around the 20 kV distribution substation is safe for living things and humans.

4. CONCLUSION

From the results of research on decreasing soil resistance in the arrester grounding system at the 20 kV distribution substation LA 0031, it is concluded that the value of grounding resistance will decrease with the addition of grounding rod electrodes; the greater the number of electrodes used, the lower the value of grounding resistance; this is demonstrated by the use of grounding rod electrodes. The original grounding resistance value was 11.5 Ω, and it fell to 3.4 Ω when the number of rod electrodes was increased to four. In addition to the number of rod electrodes, the humidity or water component in the ground is a factor that causes the value of grounding resistance to decrease. This is clear from the utilization of four electrode rods. After conducting actual measurements, the calculated value of grounding resistance, 4.61 Ω, is reduced to 3.4 Ω, yielding a grounding resistance value of 3.4. Whenever a fault current occurs, the decrease in ground resistance is followed by a fall in the GPR voltage.

5. ACKNOWLEDGEMENTS

With the assistance of PT. PLN (Persero) ULP Lembayung – Lahat, this research was able to obtain data that met expectations. In the future, it is recommended that research be conducted during the dry season, when the phenomenon of increasing ground resistance values due to reduced soil moisture factor will occur.

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