Analysis of the Soiling System on Peatland at the Distribution Substation of PT PLN (Persero) ULP Bagan Siapi Api

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Abstract

The grounding system is an important component in the reliability and safety of the electric power distribution system. This study aims to analyze the performance of the grounding system at the distribution substation owned by PT. PLN (Persero) ULP Bagan Siapi Api, especially on peatland. The data collection method was carried out by measuring the grounding resistance using the Fall-of-Potential method with a Digital Earth Tester. The study was conducted on two types of soil, namely peatland and barren land, to compare their resistance values. The measurement results showed that peatland has a very low resistance, with an average of 1.25 Ω using a single electrode (single rod), far below the maximum limit set by the 2011 PUIL standard of 5 Ω. Meanwhile, the barren land showed a high resistance (14.30 Ω) which could only be reduced to meet the standard by adding electrodes in parallel. These findings conclude that the peatland in the Bagan Siapi Api area actually supports an effective and efficient grounding system, contrary to the general assumption that peatland has a high resistance. These results can be the basis for making technical policies for installing grounding systems in similar areas.

Keywords: ***Peatland, Grounding, Fall-of-Potential, PUIL 2011***

Introduction

Electricity is a very important basic need of the community. The availability of electricity supports the smooth running of various daily activities and encourages the development of the industrial sector (Adrianus et el., 2015). The transmission line functions as a means to distribute the flow of electrical energy starting from the power plant, then

distributed through transmission and distribution networks until finally accepted by consumers (Hikmatul et el., 2025). Conductors used in medium-voltage air ducts are typically made of materials such as aluminum or copper alloys, which have a certain resistance (Pristisal et el., 2025). The distribution system itself is divided into two, namely, the medium voltage distribution line that uses a voltage of 20 kV and the low voltage distribution system that uses a voltage of 220/380 V (Pristisal et el,. 2025). As one of the key elements in the electric power system, the Medium Voltage Overhead Line (SUTM) serves as the connecting line between substations and customer loads (Pristisal et el., 2025).

Electricity distribution carried out by PT PLN ULP Bagan Siapi Api often experiences disruptions caused by several factors, one of which is the lack of optimal performance of the grounding system on the distribution transformer. The soil conditions in the Bagan Siapi Api ULP work area vary greatly, ranging from coastal soils, watery/swampy peatlands, and mixed barren soils. Each soil type has different resistivity values, the resistivity range of soil generally ranges from 10 to 5000 ohm-meters, depending on the conditions and soil type in the location (Hikmatul et el., 2025). The value of grounding resistance is strongly influenced by soil resistivity, as the two have a comparable relationship - the greater the resistivity of the soil, the higher the resistance of the soil (Hikmatul et el., 2025). In other words, several grounding systems on distribution transformers owned by PT. PLN (Persero) is not good because of the environmental conditions.

Research Methodology

The first step that the author took was to calculate the *value of grounding* resistance using the Earth Tester *measuring tool* with *the Fall-of-Potential* method according to the actual conditions in the field. The measurement uses 2 configurations, namely by using 1 electrode rod and using 2 electrode rods. Then the author compares the measurement results of the measuring instrument with the calculation using a formula. The following is the basis for doing the calculations that the author used in writing this journal:

The calculation of grounding resistance for the planting depth of one electrode rod can use the following equation:

$$R = \frac{\rho}{2 \times \pi \times L} x \left(ln \frac{4 \times L}{a} - 1 \right)$$

And for the calculation of grounding resistance for the planting distance of two electrode rods can use the following equation:

$$R = \frac{\rho}{4.\pi.L} x \left(ln \frac{4L}{a} + \ln \frac{4L}{s} - 2 + \frac{s}{2L} - \frac{s^2}{16L^2} + \frac{s^4}{512L^4} \right)$$

an insert transformer. The following table lists the types, lengths, and cable sizes of low-voltage distribution networks.

Information:

R = Resistance of the electrode rod

L = Length of electrode rod into the ground (m)

ρ = Soil type resistance (Ω.m)
α = Electrode rod radius (m)
s = Planting distance between the two electrodes (m)
ln = Natural logarithm

Results and Discussion

Result

The total length *of* the Bagan Siapi Api ULP feeder is 317.127 kms. The number of transformers is spread across 404 pieces and the peak load is in the range of 25 mW. For complete data, you can see the *following single line diagram*.

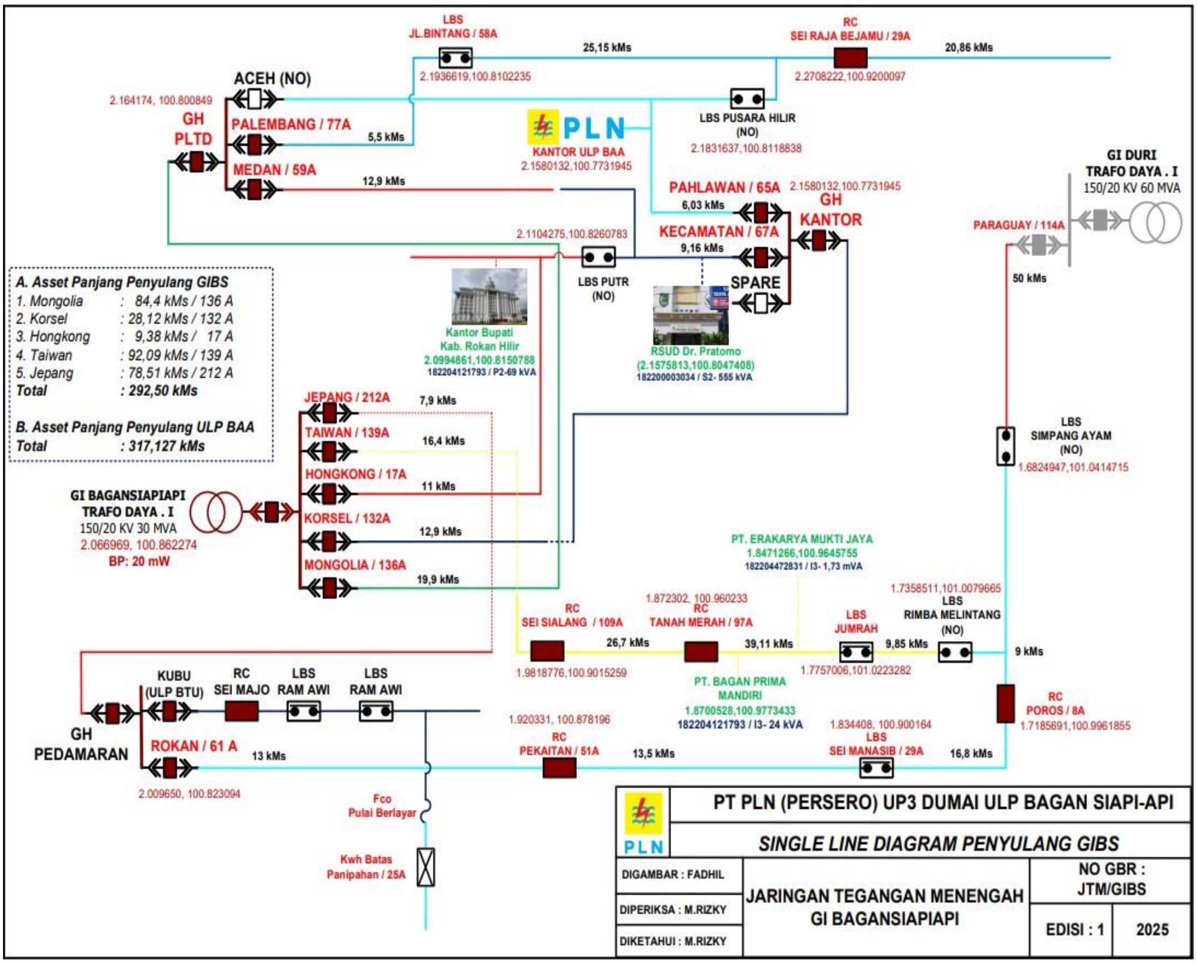

Figure 1. **Single Line Diagram**

The analysis carried out by the author includes several schemes, which are as follows:

1. Scheme 1
   Grounding resistance value was tested on 3 transformers on peatland using *an Earth Tester* measuring instrument with a configuration of 1 *ground rod*.
2. Scheme 2
   Testing of grounding resistance values on 3 transformers in barren land using measuring instruments
   Earth Tester with 1 *ground rod configuration*.
3. Scheme 3
   Testing of grounding resistance values on 3 transformers in barren land using measuring instruments
   Earth Tester with 2 *ground rod configuration*.

4. Scheme 4
   Compare the measurement results using a measuring instrument with the results of formula calculations.

Schemes 1, 2 and 3 were measured by the authors to measure the value of grounding resistance in transformers BAA 002, BAA 039, BAA196 for peatland areas, and transformers TPL 007, TPL 029, TPL 063 for barren land areas. In barren land areas, the author made measurements by increasing the number of stem groundings to 2.

The following is a picture of the measurement of the value of grounding resistance using *the Earth Tester*.

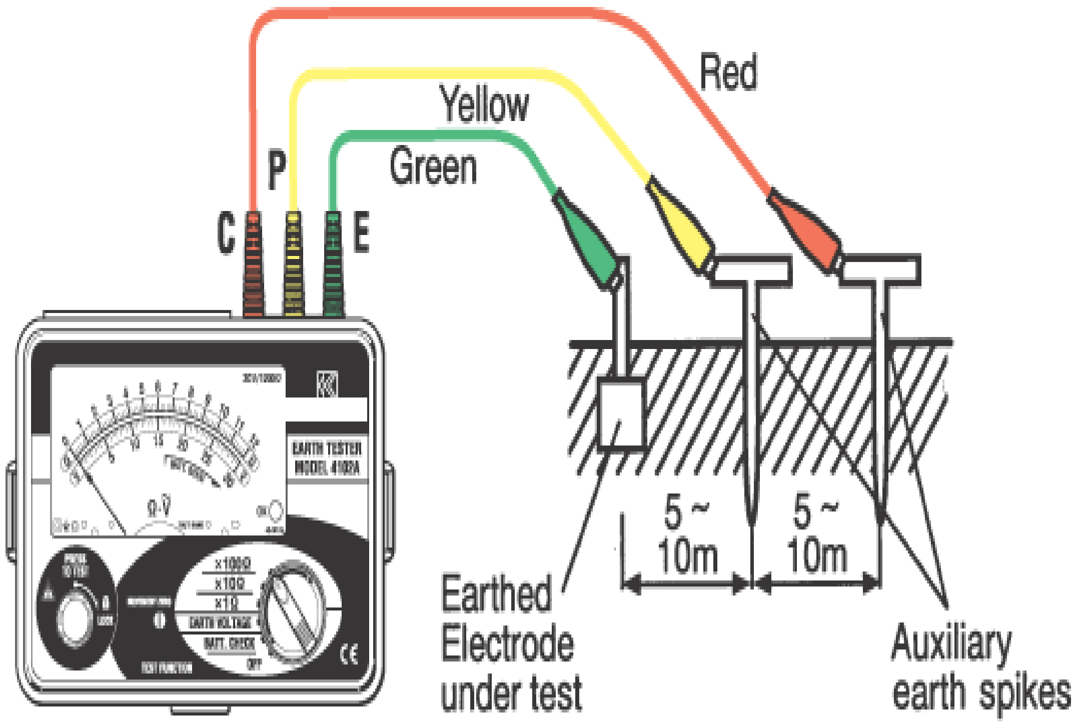

Figure 2. Testing Network

Table 1. Measurement Results Using Earth Tester

NO	GARDU	SOIL TYPE	NUMBER OF WHEELS	MEASUREMENT RESULTS (Ohms)	NUMBER OF WHEELS	MEASUREMENT RESULTS (Ohms)
1	TPL 063	BARREN	1	13.08	2	1.52
2	TPL 029			14.89		1.21
3	TPL 007			14.94		3.83
Average			14.30		2.19	
1	BAA 002	PEAT	1	1.13	-	-
2	BAA 039			0.66		
3	BAA 196			1.97		
Average			1.25		-	

4.1 Analysis

Table 1 is the result of measuring the resistance value of transformer grounding on peatland and barren land. The data obtained is real data from measurements in the field using *the Earth Tester measuring tool* with the same grounding system configuration, which includes the length of the electrode, the type and size of the electrode to the depth of electrode planting. The only difference is that in scheme 3 it uses a configuration of 2 electrode rods, where the electrodes are installed in parallel with a distance of 3 meters.

From the data obtained, it can be used as a reference for the analysis of the value of grounding resistance as a whole according to the condition of the soil type in the Bagan Siapi Api ULP.

1. Scheme 1
   The distribution transformer is located on peatland, where the soil condition has a high moisture content throughout the year which is not affected by the season. With the configuration of 1 electrode rod, the calculation of the resistance value obtained is very small, which ranges from 0.66 – 1.97Ω. This value is far below the maximum limit of the 2011 PUIL standard.
2. Scheme 2
   The distribution transformer is located in barren land, where the soil condition has a very low moisture content. However, in some locations there is mixed barren soil. Soil conditions are greatly affected by rainfall. With the configuration of 1 electrode rod, the calculation of the resistance value obtained is quite large, which ranges from 13.08 – 14.94Ω. This value does not meet the 2011 PUIL standard.
3. Scheme 3
   The soil condition is the same as the condition of scheme 2, but in this scheme the measurement uses a configuration of 2 electrode rods installed in parallel with a distance of 3 meters. The results of the calculation of the detention value dropped to 1.21 – 3.83 Ω. This value meets the 2011 PUIL standard.
4. Scheme 4
   In this scheme, the author will calculate the grounding resistance value using a formula for both the configuration of 1 electrode rod and 2 electrode rods, which the author then uses as a reference for analysis.

4.2 Account

In addition to using *the Earth Tester measuring tool*, the authors also use formula equations to calculate the value of grounding resistance. The following is the calculation that the author uses according to the formula that the author listed above:

1. Calculation of Detention Values on Peatlands
   The resistivity of swamp/wet soil ranges from 3 – 15 Ω.m, we assume using the lowest value which is 3 Ω.m.
   Known:
   $\rho = 3\ \Omega.m$
   $L = 2.9m$
   $\alpha = 0.008\ m$
   $\mu = 3{,}14$

1. Hitung $\frac{4L}{a}$:

$$\frac{4 \times 2{,}9}{0{,}008} = \frac{11{,}6}{0{,}008} = 1450$$

2. Hitung $\ln(1450)$:

$$\ln(1450) \approx 7{,}279$$

3. Hitung $\ln(1450) - 1$:

$$7{,}279 - 1 = 6{,}279$$

4. Hitung $\frac{\rho}{2\pi L}$:

$$\frac{3}{2\pi \times 2{,}9} = \frac{3}{18{,}22} \approx 0{,}1647$$

5. Hitung nilai akhir:

$$R = 0{,}1647 \times 6{,}279 \approx \boxed{1{,}033\ \Omega}$$

2. Calculation of Detention Value in Mixed Barren Land
   a. Configuration of 1 Electrode Rod

   The resistivity of barren soils mixed with clay ranges from 15 – 100 Ω.m, we assume using a value close to 40 Ω.m.

   Known:

   ρ = 40 Ω.m

   L = 2.9m

   α = 0.008 m

   μ = 3,14

1. Hitung $\frac{4L}{a}$:

$$\frac{4 \times 2{,}9}{0{,}008} = \frac{11{,}6}{0{,}008} = 1450$$

2. Hitung $\ln(1450)$:

$$\ln(1450) \approx 7{,}279$$

3. Hitung $\ln(1450) - 1$:

$$7{,}279 - 1 = 6{,}279$$

4. Hitung $\frac{\rho}{2\pi L}$:

$$\frac{40}{2\pi \times 2{,}9} = \frac{40}{18{,}22} \approx 2{,}198$$

5. Hitung nilai akhir:

$$R = 2{,}198 \times 6{,}279 \approx \boxed{13{,}8\ \Omega}$$

   b. Known 2 Electrode Rod
   Configuration:

   ρ = 40 Ω.m

   L = 2.9m

α = 0.008 m
μ = 3,14
s = 3 m

1. Hitung logaritma:

- $\ln\left(\frac{4L}{a}\right) = \ln\left(\frac{11,6}{0,008}\right) = \ln(1450) \approx 7,279$
- $\ln\left(\frac{4L}{s}\right) = \ln\left(\frac{11,6}{3}\right) = \ln(3,867) \approx 1,352$

From the results of the calculation of the data above, both the configuration of 1 electrode rod and 2 electrode rods assumes that each type of soil has the same resistivity value.

2. Hitung suku lainnya:

- $\frac{s}{2L} = \frac{3}{2\times 2,9} = \frac{3}{5,8} \approx 0,517$
- $\frac{s^2}{16L^2} = \frac{9}{16\times(2,9)^2} = \frac{9}{134,56} \approx 0,0669$
- $\frac{s^4}{512L^4} = \frac{81}{512\times(2,9)^4} \approx \frac{81}{512\times 70,71} = \frac{81}{36204} \approx 0,00224$

3. Jumlahkan semua suku di dalam kurung:

$$7,279 + 1,352 - 2 + 0,517 - 0,0669 + 0,00224 \approx 7,083$$

4. Hitung bagian depan:

$$\frac{40}{4\pi \times 2,9} = \frac{40}{36,48} \approx 1,096$$

5. Hitung nilai akhir:

$$R = 1,096 \times 7,083 \approx \boxed{7,77\ \Omega}$$

Table 2.
Results of Grounding Resistance Calculation of Single Electrode Configuration

SOIL TYPE	RESISTANCE TYPE LAND (Ω.m)	PLANTING DEPTH (m)	PRISONER GROUNDING (Ω)
PEAT	3	2,9	1,033
MIXED BARREN	40	2,9	13,8

Table 3.
Results of Calculation of Grounding Resistance of Two Electrode Configuration

SOIL TYPE	SOIL TYPE RESISTANCE (Ω.m)	PLANTING DISTANCE (m)	PLANTING DEPTH (m)	PRISONER GROUNDING (Ω)
MIXED BARREN	40	3	2,9	7,77

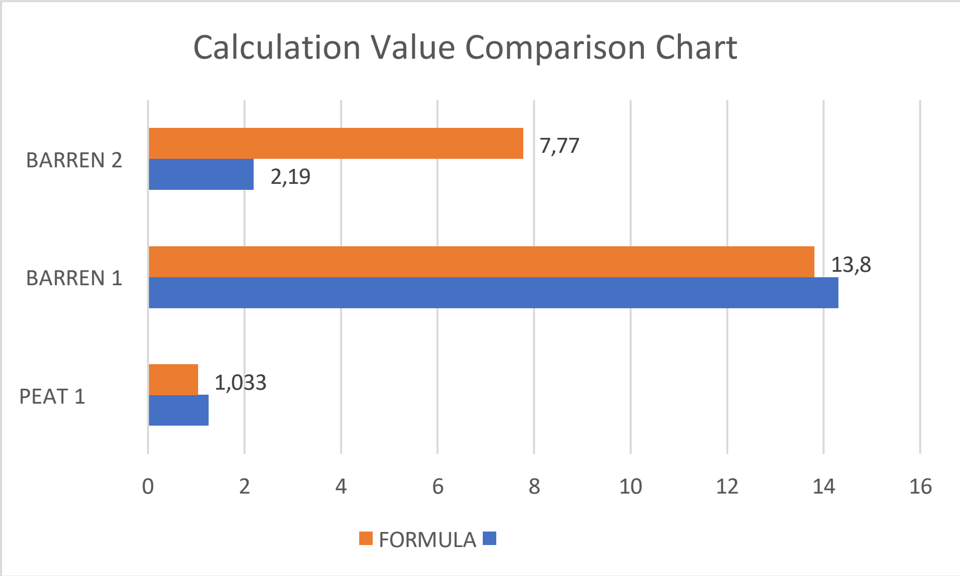

Figure 3. Comparison Chart of Detention Values

Conclusion

Based on the tests that have been carried out using *the Earth Tester* and compared using manual calculations, the following conclusions can be drawn:

1. The resistance value of the grounding on peatlands with a high moisture content has a resistance value of 1.25Ω.
2. The value of grounding resistance on high barren land is influenced by *the* large resistivity value of the soil. With the configuration of 1 electrode rod, it can be seen from the test results using measuring instruments and formula calculations, the grounding resistance value ranges from 13.08 – 14.94 Ω far below the PUIL 2011 standard.
3. By applying the configuration of 2 electrode rods on barren land, it has been proven to be effective in reducing the value of grounding resistance without having to add certain treatments. This condition occurs because in some barren lands there is mixed soil that can affect the calculation value.
4. The difference in resistance values between measurements using *Earth Tester* and using formulas is influenced by the absence of in-depth testing related to *the resistivity* of the soil type being tested and only using *resistivity value estimation*.

Proposed Improvements

After analyzing and drawing conclusions, the author provides a few suggestions for improvement so that the resistance value of the transformer grounding in ULP Bagan Siapi Api can be improved, of course this cannot be done instantly considering the length of the network is quite wide and the number of transformers is large. However, it would be better if it was done gradually so that every improvement implemented could be evaluated. The following are suggestions for improvement that the author can convey:

1. Checking and measuring the grounding value of all distribution substations, especially on barren land for maintenance.
2. The application of a configuration of 2 electrode rods installed in parallel on the transformer grounding system in barren land, considering that this method is quite effective in lowering the grounding resistance value.

3. The use of copper grounding cables, so that the excess current that occurs in the transformer can be transmitted better than the use of aluminum cables.

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