Jurnal Teknologi Elekterika, 2024, Volume 21 (2): 73-80 e- ISSN 2656-0143

# Analysis of Improvement of Distribution Substation Earthing Resistance Values at PT. PLN (Persero) ULP Karebosi

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*Abstract*

**The grounding system at the distribution substation is an essential component closely related to maintaining the reliability of the electrical system. In this regard, this study aims to examine the impact of applying certain grounding methods to improve grounding resistance values at the distribution substation. The research was conducted over five months, from January 15, 2024, to June 15, 2024, at the Pannampu feeder managed by ULP Karebosi. MATLAB GUI was used to theoretically calculate using the Dwight equation related to grounding resistance (Ω) and soil resistivity (Ωm). The results of this study show that the measured grounding resistance values after applying the multiple grounding rod method decreased by 52.49% for the grounding electrode of the lightning arrester GD. KPPKU, 49.45% for the grounding electrode of the transformer body and PHB-TR GD. KPPKU, and 48.94% for the grounding electrode of the lightning arrester GD. KPPDK, which had grounding resistance values of 5.43Ω, 5.44Ω, and 8.42Ω before reconfiguration.**

***Keywords: Earthing resistance, Distribution substation, Multiple Grounding Rod, Panampu Feeder, MATLAB.***

## I. Introduction

The social conditions in modern society heavily depend on the availability of electrical energy. Therefore, the state-owned electricity company (PLN) as the sole supplier of electrical energy in Indonesia is deemed necessary to maintain the stability, quality, and continuity of the electricity produced to meet the community's needs. PT PLN (Persero) is one of the state-owned enterprises that operates in the electricity sector, providing energy to serve the needs of every individual in Indonesia [1]. To meet these needs, mitigation efforts are required to address potential disturbances that may arise in equipment, ensuring the reliability of the electrical system. Mitigation can be defined as a series of efforts to analyze the causes and address issues to normalize disturbances [2].

One important aspect of maintaining the reliability and continuity of the electricity system is ensuring the reliability of distribution substations. A Distribution Substation is a facility that contains or consists of medium voltage switching equipment, distribution transformers, and low voltage switching equipment to supply electrical power to customers at both medium and low voltage levels [3].

In a distribution substation, there are several key components, one of which is the transformer. A transformer is a device used to transform voltage, either by stepping it up or down from the distribution transformer [4]. Commonly used distribution transformers include 20kV / 400V three-phase and single-phase transformers, as well as configurations using three single-phase transformers. The phase-to-phase voltage in the low voltage network system is 380 V [5].

In addition to distribution transformers, the Low Voltage Switchgear (PHB-TR) is another key component of a distribution substation. PHB-TR is a combination of one or more Low Voltage Connecting Devices along with control equipment, measuring instruments, protection devices, and interconnected control systems. All components are assembled with a complete wiring and mechanical system in its supporting parts [6].

In addition to ensuring the reliability of distribution substations, one of the main factors in securing electrical circuits is grounding. If effective safety measures are implemented, there must be a well-designed grounding system [7]. A grounding system connects conductors, equipment bodies, and installations to the ground, providing protection for individuals from electric shocks and safeguarding installation components from abnormal voltage or current hazards [8].

The grounding system installation can operate effectively if it meets certain requirements, such as creating a low impedance path to ground for personnel and equipment protection, utilizing an effective circuit, and being capable of withstanding and dissipating surge currents [9].

One of the standard guidelines for grounding resistance values used in Indonesia is established by the National Standardization Agency in PUIL 2000. It states that in overhead line networks, in addition to at the source and consumer, the PEN conductor must be grounded at least at each branch end longer than 200 m. Similarly, for outdoor installations, the PEN conductor must be grounded. The total grounding resistance of the entire system should not exceed 5 Ω; in areas with very high soil resistivity, it may reach up to 10 Ω [10].

Several methods are recommended to reduce and improve poor grounding resistance values. These include the addition of multiple grounding rods, where increasing the number of electrodes installed in the system helps distribute the voltage that occurs at the ground surface during a fault more evenly [11]. Other methods include extending the length of the grounding rod, implementing soil treatment where certain additives are incorporated into the soil to effectively lower its resistivity and, consequently, the surface voltage [12]. Additionally, the use of specialized grounding rods and combination methods can also be employed.

After considering the advantages and disadvantages of the aforementioned methods, and based on the grounding resistance values at ULP Karebosi, particularly at the KPPKU and KPPDK distribution substations, which do not yet meet applicable standards, this study aims to examine the effect of applying the multiple grounding rod method to improve grounding resistance values at the distribution substation.

For planning the improvement of grounding resistance values, a MATLAB GUI is utilized to facilitate the calculation and analysis of the results from grounding resistance reconfiguration. The Graphic User Interface (GUI) is one of the many features provided by MATLAB, serving as an application interface that contains tasks, commands, and program components to make it easier for users to operate MATLAB. The purpose of creating this GUI is to develop a simple and practical program for users [13].

## II. Research Methodology

### *A. Place and Time of Research*

Research on Reconfiguration of Distribution Substation Grounding Resistance using the Multiple Grounding Rod Method at PT. PLN (Persero) ULP Karebosi will be carried out in approximately 5 months from 15$^{th}$ January 2024 to 15$^{th}$ June 2024.

### *B. Research Procedures*

The procedure for this activity can be carried out in a structured and systematic manner to make it easier to carry out and direct, the following steps are taken:

1. Initial Observations
2. Collect data on earth resistance values, soil type, electrode length, electrode diameter and electrode depth according to the points that have been found based on initial observations and searches contained in the previous literature review.
3. Ensure completeness of data
4. Carry out calculations and analysis of the data that has been obtained

5. Carry out corrective actions based on the results of calculations and analysis
6. Observe and measure the earthing resistance value after corrective action is taken
7. Draw conclusions
8. Provide solutions or suggestions

The steps and methods for this activity are depicted in Figure 1, the activity procedure flowchart below.

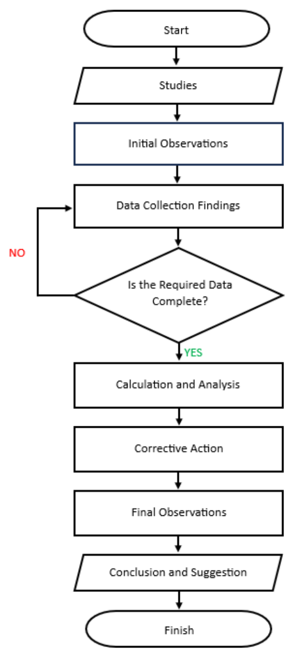


Figure 1. Activity Procedure Flowchart

*C. Data Collection Techniques*

The data collection method used in this research is as follows.

1. Literature
   This data collection method aims to obtain standard grounding resistance values that are applicable, as well as the locations of each substation along the feeder.
2. Observation
   This data collection method aims to obtain grounding resistance values, soil types, grounding resistance measurements, electrode diameters, electrode lengths, and electrode depths.
3. Interview
   This data collection method aims to gather network topology data and historical condition data that may potentially hinder the research.

*D. Data Processing / Analysis Techniques*

It has been explained previously that there are 3 types of methods used in this research, namely literature, observation and interviews. From the search results data obtained, the data is then used to process and analyze the results using the Dwight formula with the help of Matlab software. After knowing the results that have been obtained, the author can draw conclusions and provide solutions so that these incidents can be minimized.

## III. Results and Discussion

*A. Results of activities*

Based on the research objectives to be achieved and related to repressive steps that can be taken to suppress and improve earthing resistance values that are poor and do not meet applicable standards. So it is necessary to measure the earth resistance value first to see the actual condition of the earth resistance value at the external distribution substation at the Panampu Feeder which is one of the 34 feeders under the care of ULP Karebosi.

To obtain accurate soil resistivity values, direct measurements must be conducted at the locations designated for the grounding system, as the actual soil structure is more complex than anticipated, with different locations exhibiting varying resistivity values [14]. A common challenge in measuring soil resistivity is that the soil composition is not homogeneous throughout the entire volume, varying both vertically and horizontally [15].

The collection and measurement of earth resistance value data is carried out at three earthing points at the distribution substation, namely at the neutral point earthing, lightning arrester earthing, and transformer body and PHB-TR earthing using the Kyoritsu KEW 4105A Earth Tester, while still paying attention to safety factors by using equipment. complete personal protective equipment (PPE) and learn how to use tools correctly.

The measurement results of the distribution substation earthing resistance values at the Panampu feeder before reconfiguration

Table 1. Results of measuring the earthing resistance value ……….of the distribution substation for the outer pair of the ………..Panampu feeder before reconfiguration

| No. | Substation Name | Grounding Type | Earthing Resistance (Ω) |
|---|---|---|---|
| 1. | KPPPS | Neutral Point Electrode | 1,88 |
| | | LA Electrode | 7,81 |
| | | Transformer Body & PHB-TR Electrodes | 1,88 |
| 2. | KPCDK | Neutral Point Electrode | 3,95 |
| | | LA Electrode | 3,76 |
| | | Transformer Body & PHB-TR Electrodes | 3,76 |
| 3. | ULDC 1 | Neutral Point Electrode | 6,82 |
| | | LA Electrode | 21 |
| | | Transformer Body & PHB-TR Electrodes | 9,2 |
| 4. | KPPMB | Neutral Point Electrode | 1,78 |
| | | LA Electrode | 1,49 |
| | | Transformer Body & PHB-TR Electrodes | 2,05 |
| 5. | KPPKU | Neutral Point Electrode | 13,9 |
| | | LA Electrode | 5,43 |
| | | Transformer Body & PHB-TR Electrodes | 5,44 |
| 6. | KPPKU 1 | Neutral Point Electrode | 14,61 |
| | | LA Electrode | 6,1 |
| | | Transformer Body & PHB-TR Electrodes | 5,97 |
| 7. | KPPBB | Neutral Point Electrode | 1,83 |
| | | LA Electrode | 12,79 |
| | | Transformer Body & PHB-TR Electrodes | 1,82 |
| 8. | KPPDK | Neutral Point Electrode | 2,54 |
| | | LA Electrode | 8,42 |
| | | Transformer Body & PHB-TR Electrodes | 19,4 |
| 9. | TN 1 | Neutral Point Electrode | 1,33 |
| | | LA Electrode | 2,84 |
| | | Transformer Body & PHB-TR Electrodes | 2,85 |
| 10. | KPPSG | Neutral Point Electrode | 0,85 |
| | | LA Electrode | 1,5 |
| | | Transformer Body & PHB-TR Electrodes | 1,08 |
| 11. | KPPPC | Neutral Point Electrode | 2,98 |
| | | LA Electrode | 3,43 |
| | | Transformer Body & PHB-TR Electrodes | 2,17 |
| 12. | ULAZ 3 | Neutral Point Electrode | 3,13 |
| | | LA Electrode | 3,44 |
| | | Transformer Body & PHB-TR Electrodes | 2,89 |

*B. Description of Activities*

1. Discussion

The data that will be used in calculating repair planning at the distribution substation of the outer pair of Panampu feeders using rod electrodes using the Multiple Grounding Rod method is presented in table 2 below.

Table 2. Table of Input Data for Planning Calculations

| No. | Data Type | Amount | Unit |
|---|---|---|---|
| 1. | L (electrode length) | 2,5 | meters |
| 2. | d (elevtrode diameter) | 0,016393 | meters |
| 3. | s (distance between electrode) | 5 | meters |
| 4. | n (number of electrodes) | According to the needs | rod |

To calculate the resistance of a rod or pipe electrode to the ground in ohms (Ω), the following equation is given.

$$R = \frac{\rho}{2\pi L}\left[log_e\left(\frac{8L}{d}\right) - 1\right] \qquad (1)$$

The combined resistance of electrodes in parallel can be expressed by the following equation.

$$R_t = \frac{1}{n}\frac{\rho}{2\pi L}\left[log_e\left(\frac{8L}{d}\right) - 1 + \frac{L}{s}log_e\left(\frac{1{,}78n}{2{,}718}\right)\right] \quad (2)$$

The formula for soil resistivity can be calculated and expressed using the following equation.

$$\rho = \frac{2\pi LR}{ln\left(\frac{8L}{d}\right) - 1} \qquad (3)$$

The following is an example of a planning calculation for improving the value of earth resistance at the distribution substation for the outer pair of the Panampu feeder. To be able to calculate the appropriate earthing resistance value, the soil resistance value at each distribution substation must be calculated first. The soil resistance value can be calculated and expressed using the following equation (3).

a. LA earthing at the KPPPS distribution substation

$$\rho = \frac{2x3{,}14x2{,}5x7{,}81}{\ln\left(\frac{8x2{,}5}{0{,}016393}\right) - 1}$$

$= 20{,}079\ \Omega m$

b. LA earthing at the KPPDK distribution substation

$$\rho = \frac{2x3,14x2,5x8,42}{ln\left(\frac{8x2,5}{0,016393}\right)-1}$$
$= 21,648\ \Omega m$

After the soil resistivity value has been obtained, the soil resistivity value is entered into equation (2) to see the number of earthing electrodes required to achieve the applicable standard earthing resistance value, this equation refers to the BS 7430:2011 Code of Practice for Books. Protective Earthing of Electrical Installation, where this equation takes into account various influencing factors such as soil resistivity, electrode length, electrode diameter, and distance between electrodes. The calculation takes sample data on the earthing equipment of the Panampu feeder distribution substation in January 2024:

a. LA earthing at the KPPPS distribution substation

$$R_t = \frac{1}{2}\frac{20,079}{2x3,14x2,5}\left[log_e\left(\frac{8x2,5}{0,016393}\right) - 1 + \frac{2,5}{5}log_e\left(\frac{1,78x2}{2,718}\right)\right]$$
$= 3,991\ \Omega$.

b. LA earthing at the KPPDK distribution substation

$$R_t = \frac{1}{2}\frac{21,648}{2x3,14x2,5}\left[log_e\left(\frac{8x2,5}{0,016393}\right) - 1 + \frac{2,5}{5}log_e\left(\frac{1,78x2}{2,718}\right)\right]$$
$= 4,303\ \Omega$.

Calculation of soil resistivity values and calculations for planning improvements to resistance values at the distribution substation of the outer pair of Panampu feeders using rod electrodes using the Multiple Grounding Rod method are presented in full in table 3 below.

Table 3. Calculation Results of Soil Resistance Values and Earthing Resistance Values of Panampu Feeder Distribution Substations After Repair

| Substation Name | Grounding Type | Earth Resistance before repair (Ω) | $\rho$ (Ωm) | $R_t$ (Ω) | n (btg) |
|---|---|---|---|---|---|
| KPPPS | LA | 7,81 | 20,079 | 3,991 | 2 |
| ULDC1 | Neutral Point | 6,82 | 17,534 | 3,485 | 2 |
| | LA | 21,0 | 53,990 | 4,608 | 5 |
| | Trafo Body & PHB-TR | 9,20 | 23,653 | 4,702 | 2 |
| KPPKU | Neutral Point | 13,9 | 35,736 | 4,889 | 3 |
| | LA | 5,43 | 13,960 | 2,775 | 2 |
| | Trafo Body & PHB-TR | 5,44 | 13,986 | 2,780 | 2 |
| KPPKU1 | Neutral Point | 14,61 | 37,562 | 3,940 | 4 |
| | LA | 6,10 | 15,683 | 3,117 | 2 |
| | Trafo Body & PHB-TR | 5,97 | 15,349 | 3,051 | 2 |
| KPPBB | LA | 12,79 | 32,883 | 4,499 | 3 |
| KPPDK | LA | 8,42 | 21,648 | 4,303 | 2 |
| | Trafo Body & PHB-TR | 19,4 | 49,877 | 4,257 | 5 |

The above ground resistance value calculations were processed and the results analyzed using the Dwight formula with the help of Matlab software as shown in Figure 2 below.

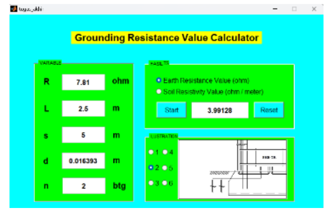


Figure 2. Calculation of Grounding Resistance Values Using Matlab Software

2. Earthing System Maintenance and Repair

Based on the description in the discussion above, if there is a grounding point whose grounding resistance value does not meet the applicable standards, then it must be handled immediately before it causes damage to the equipment and can disrupt the continuity of the load supply.

The improvement method to be used is the multiple grounding rod technique, which involves adding more grounding rods configured in a straight line, with the distance between electrodes set to twice their effective length. The distribution substations being studied are KPPKU and KPPDK. The work steps taken before carrying out maintenance and repairs to the earthing system are:

a. Prepare a working permit from ULP Karebosi
b. The HAR Team carries out JSA (Job Safety Analysis) where JSA is carried out to analyze equipment that wants to be maintained and repaired
c. The HAR Team prepared the test equipment and materials needed based on the JSA results

d. Report to ULP Karebosi that the HAR Team wants to carry out maintenance and repairs on earthing equipment
e. After receiving permission from ULP Karebosi, the entire Team held a briefing and prayed together so that they would be given safety and make their work easier.
f. After that, the HAR Team delimited the work area and installed K3 signs.
g. After that, the process of maintaining and repairing the earthing system of the Panampu feeder distribution substation can begin by determining the connection point and opening access to the connection point on the PHB-TR stand.
h. Install additional ground rods at predetermined points.
i. Connect the connecting conductor with an additional ground rod that will be paralleled.
j. Connect the other side of the connecting conductor to the ground rod using a double bolts tap connector or compression connector (CCO).
k. Ensure that each connection point is installed properly, so that electricity distribution can be maximized
l. Carry out measurements after maintenance and repair activities to ensure that the earthing resistance value is in normal condition.

After carrying out maintenance and repairs to the earthing system at the earthing electrode of the KPPKU and KPPDK distribution substations, it is necessary to re-measure the earthing resistance value after repair to ensure that the earthing resistance value is in normal condition and in accordance with applicable standards. The measurement results table after repair is shown in table 4 below.

Table 4. Results of measuring the earthing resistance value of the distribution substation for the outer pair of the Panampu feeder after repairs

| No. | 1. | | 2. |
|---|---|---|---|
| Substation Name | KPPKU | | KPPDK |
| Grounding Type | LA Grounding Electrode | Transformer Body & PHB-TR Grounding Electrode | LA Grounding Electrode |
| Earth Resistance Measurement Before Repair (Ω) | 5,43 | 5,44 | 8,42 |
| Calculation of Earthing Resistance Before Repair (Ω) | 2,775 | 2,780 | 4,303 |
| Measurement After Repair (Ω) Week-1 | 2,540 | 2,760 | 4,140 |
| Measurement After Repair (Ω) Week-2 | 2,780 | 2,850 | 4,490 |
| Measurement After Repair (Ω) Week-3 | 2,420 | 2,650 | 4,280 |

The results of measuring the earthing resistance value of the distribution substation for the outer pair of the panampu feeder after the above improvements can also be presented in a graph of the relationship between the calculation and measurement of the earthing resistance value shown in figures 3, 4, and 5 below.

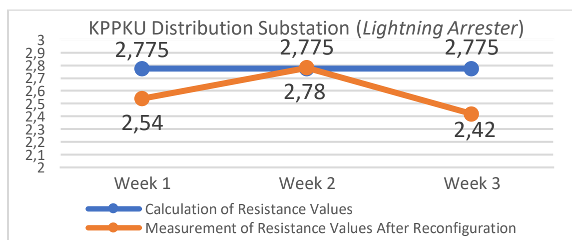


Figure 3. Graph of the Relationship Between Calculation of Detention Values Before and After Reconfiguration of KPPKU

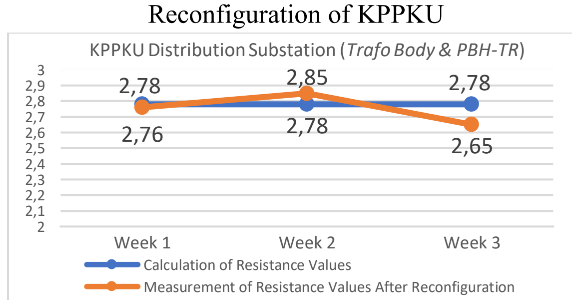


Figure 4. Graph of the Relationship Between Calculation of Detention Values Before and After Reconfiguration of KPPKU

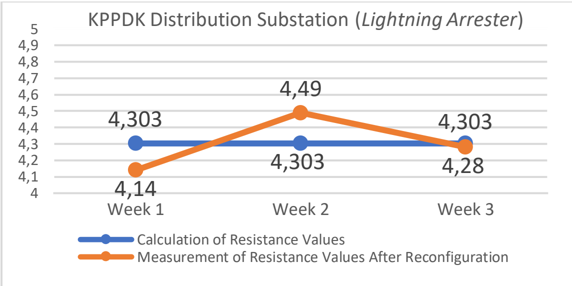


Figure 5. Graph of the Relationship Between Calculation of Resistance Values Before and After Reconfiguration of KPPDK

In table 4 and figures 3, 4, and 5 above show the results of measuring the earth resistance value after carrying out corrective action which was measured periodically over a period of three weeks. It can be seen that the measured earth resistance value has decreased with an average decrease amounting to 52,49% of the previous value at the ground electrode of the lightning arrester at the KPPKU distribution substation which was originally valued at 5,43Ω to 2,58Ω if averaged, at the ground electrode of the transformer body and PHB-TR at the KPPKU distribution substation experienced an average decrease in value of 49,45% from the previous value which was originally 5,44Ω to 2,75Ω if averaged, and the ground electrode of the lightning arrester at the KPPDK distribution substation experienced an average decrease in value of 48,94% from the previous value which was originally 8,42Ω becomes 4,3Ω when averaged.

# IV. Conclusion

The conclusions that can be drawn from writing this thesis are as follows.

1. The multiple grounding rod method has a significant influence in efforts to improve the earthing resistance value at distribution substations, this can be proven by the decrease in the earthing resistance value of the lightning arrester KPPKU from the initial value of 5,43Ω to 2,58Ω (52,49%), the value of the earthing resistance of the transformer body and PHB-TR decreased. KPPKU from the initial value of 5,44Ω to 2,75Ω (49,45%), and the ground resistance value of the lightning arrester decreased. KPPDK from the initial value of 8,42Ω to 4,3Ω (48,94%) after the reconfiguration was carried out.
2. The multiple grounding rod method can be applied by increasing the number of grounding rods using an electrode configuration forming a straight line with a minimum distance between electrodes that is twice the effective length.


# Acknowledgement

I would like to express my deepest gratitude to PT. PLN (Persero) ULP Karebosi and all parties who have provided continuous support, direction and guidance during the process of writing this journal. Thank You.


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