Improvement of Electrical Grounding System Using Bentonite

Ismujianto¹*, Isdawimah¹, Nuha Nadhiroh¹

¹Electrical Department, Politeknik Negeri Jakarta Kampus UI Depok, Indonesia

*ismujianto@elektro.pnj.ac.id

Abstract. Low grounding resistance ensure the proper operation of lightning protection system. The lower Rg value, the easier current flow through the earth without any obstacles. Lightning protection system can easily have mechanical and electrical damage. Mechanical correction can be done by cleaning the junction from corrosion, repairing the loose junction, or creating a new junction. On the other hand, electrical correction can be done by deepen the electrode and widen the area for lowering the grounding resistance. In this case the most influential in determining the value of Rg is ρ factor. Value of ρ affected by soil conditions, the more humid the soil gets smaller ρ. One of the ways to increase the soil moisture by adding bentonite to the soil. Bentonite is a natural clay containing the mineral montmorillonites; this consists of octahedral coordinated aluminium atoms sandwiched between tetrahedral coordinated silicon atoms. Consideration of using bentonite to improve the value of Rg because bentonite has various good properties including: very low and stable resistivity; abilities to absorb and retain large quantities of water; can swell up to 13 times its dry volume; low cost; it will not gradually leach out because it is part of the clay itself. The result show that the decrement of grounding resistance is around 16% - 48% (average 32%) with deviation standard is 8%.

1. Introduction

The quality of Rainfall Forecast in the dry season of 2010 is the worst. This is due to the strong La Nina phenomenon that affects the increase in the amount of rainfall during the dry season in Indonesia [1]. This means that the lightning density level also increases. Lightning density in Indonesia exceeds lightning density in other countries, which is around 180-260 days of thunder per year [2]. This happens because Indonesia is in the equatorial region which receives a large amount of insulation, where almost 70% of the area is a water that produce enormous steam, so that Indonesia is the most active convective area. This is very fulfilling the requirements for the formation of lightning, namely: the presence of moist air in a layer of 3 km thick, the presence of insulation that heats the surface of the soil and the air above it and an atmosphere that is convective unstable or there is a positive thermal buoyancy [3]–[5].

Lightning strikes, directly or indirectly, can endanger objects and living things, so that security is needed both externally and internally. An example of a lightning strike is the occurrence of an induced voltage which causes a decrease in pulse voltage and results in damage to the data sent [6]–[8].

In recent years, the ripple effects of lightning strikes on telecommunications stations have caused damage to the electrical equipment of the surrounding homes[9]. For example, in November 2017 there was an indirect lightning strike on the Jakarta communication channel of the Jakarta State Polytechnic Telecommunications laboratory which caused a fire.
This damage is mainly due to the potential of the increasing ground voltage from the station during lightning strikes. When the lightning current is released deeper into the ground, the voltage increase potential in the grounding mesh near the ground surface is found to be lower, and the voltage applied to the insulated wire of the embedded grounding wire increases. This causes overvoltage in the embedded earth wire insulation which can cause dielectric damage [10].

External safety uses three components, upper rod to catch lightning, bare conductor (BC) to channel lightning, and ground rod to spread lightning loads into the ground. While internal safety uses electronic equipment to reduce excessive voltage and current due to indirect strikes.

The physical condition of each component and the connection between the components used in the external safety must be in prime condition, so that lightning can be captured and channeled into the soil properly. Therefore, it is necessary to carry out routine inspections regarding the condition of the component. Inspection of the Upper rod and BC can be done visually because they are visible, while inspection of ground rod requires a Grounding Tester Meter. This tool is used to measure the grounding resistance value (R_g) of the ground rod and the overall lightning rod system.

This R_g value determines whether or not the lightning rod system has a very small R_g value (ideally zero), so that the lightning current can flow easily into the ground, without the any obstacle [11], [12].

Lightning protection systems can experience mechanical and electrical damage. Mechanical repairs are done by cleaning the connection from rust, repairing a broken connection, or making a new connection. While electrical are done reducing the value of grounding resistance (R_g) by deepening the planting of electrodes (Lrod), enlarging the cross-sectional area of the electrode (A_rod) and reducing soil resistivity (ρ). More significant results can be achieved when combining electrodes in the ground, because the connection cable also functions as an electrode grounding [13].

2. Grounding System

A. Lightning Strike Risk Measurement

In this paper, calculation of lightning strikes probability and protected area are using the Furse Strikerisk software. A building with lightning strikes probability over (1:100,000) requires a reliable lightning protection system in accordance with British Standard BS EN 62305-2 of 2012[14].

Lightning strike risk (R) for the building is the multiplication of average direct-lightning strike frequency in year (N_d). Lightning strike risk (R) of a building can be calculated using average frequency of direct strike per year (N_d), use of structure (A), type of construction (B), content or consequential effect (C), degree of isolation (D), type of terrain (E), as shown below:

\[
R = N_d \times A \times B \times C \times D \times E \quad (1)
\]

\[
N = 1/R \quad (2)
\]

Where N is probability of being struck. The value of N affects lightning protection level and protection angle (α). The farthest distance of lightning protection can be calculated using equation 3.

\[
X = \tan \alpha h \quad (3)
\]

B. Improving The Quality of Grounding System

The most effective method in improving the quality of the grounding system is to make the earth holding value (R_g) as small as possible, ideally 0 Ω. This R_s value depends on soil resistivity (ρ), length of earth electrode (L) and cross-sectional area (A) of earth electrode.

\[
R_s = \frac{\rho}{2\pi L} \left[ \ln \left( \frac{4L}{A} \right) - 1 \right] \quad (4)
\]

The value of R_g is strongly influenced by ρ[8]. The moister the soil conditions the smaller the value of ρ. Soil moisture can be increased in several ways, one of them is by adding bentonite to the soil. Bentonite is a natural clay containing the mineral montmorillonites, which mostly contains montmorillonite with minerals such as quartz, calcite, dolomite, feldspars, and other minerals.

Consideration of using bentonite to improve the value of R_g because bentonite has various good properties including: very low and stable resistivity; abilities to absorb and retain large quantities of
water; can swell up to 13 times its dry volume; low cost; it will not gradually leach out because it is part of the clay itself [15]–[17].

Furthermore, modifying the grounding rod system into mesh system may decrease the value of $R_g$ [18]. The value of $R_g$ for grounding mesh system can be calculated as below:

$$R_g = \frac{\rho}{2\pi L} \left[ \ln \left( \frac{8w}{0.5w + h} \right) - 1 \right]$$  \hspace{1cm} (5)

3. Method

A. Research Procedures

The research object is the existing lightning protection system on several building. In this paper, the condition of lightning protection system will be evaluated. The detail of structure must be collected and evaluated using Furse Strikerisk version 2.0 to get the information of lightning struck probability and the lightning protection area (X). On the other hand, not only visual checking of lightning rod but also $R_g$ measurement must be done. The research procedures are describe on Figure 1.

![Diagram of Lightning Protection Area Calculation](image)

**Figure 1.** Procedures of lightning protection area calculation

B. Research Method

The results of visual checking, $R_g$ measurement and software evaluation become the principal for improving the lightning protection system, mechanically and electrically. Mechanical correction
can be done by cleaning the junction from corrosion, repairing the loose junction, or creating a new junction. On the other hand, electrical correction can be done by deepen the electrode and widen the area for lowering the grounding resistance.

Modeling the improvement of $R_g$ is done by burying two ground rods at a certain depth, one of which is added with bentonite, as in Figure 2a. In addition, these two ground rods can be connected in parallel to obtain a smaller $R_g$ value. Measuring the value of $R_g$ uses a measuring instrument, Grounding Tester Meter, with various measurement positions, as shown in Figure 2b. Moreover, measurements are also made on various weather conditions that affect soil moisture.

![Image](image_url)

**Figure 2.** (a) Model of Improving Grounding Resistance (b) Position of grounding resistance measurement

4. **Result and Discussion**

A. **Result of Lightning Strike Risk Measurement**

In this part, we investigate the lightning protection requirement. The evaluation procedures of lightning protection system using Furse Strikrisk v2.0 are shown in Figure 3. On the menu “structure” (in Figure 3a.), number of thunderstorm days per years is identified using the information from Indonesian Agency for Meteorology, Climatology and Geophysics, Depok, which are regions of large ground flash density, has more than 100 thunderstorm days per years. The detail of structure must be input from the measurement of building “I” in Jakarta Polytechnic State (PNJ).

On furse strike risk v2.0, for deciding the lightning protection requirement, each function and the surrounding condition of building are under consideration, as shown in Figure 3b and 3c. The result as shown in Figure 3d, determined that building “I” urgently require a lightning protection system, due to the value of overall risk factor 1:525.
B. Result of $R_g$ Improvement

Carrying out the experiment procedure above, the following result can be shown in Figure 5. According to the results, it can be seen that bentonite addition method decrease the $R_g$ value down to the standard value. The result of the usage of bentonite is compared with the base case, whether using bentonite can perform better resistance value is presented on Figure 5c.
It can be seen that by adding bentonite to the rod grounding system has significant results on decreasing the value of $R_g$.

![Figure 5](image1)

**Figure 5.** Graphic of $R_g$ value on (a) Grounding Rod without Bentonite (b) Grounding Rod with Bentonite; (c) The comparison between 5a and 5b

Final part is examination of $R_g$ value improvement by adding bentonite. Decrement of grounding resistance as the result of the usage bentonite is describe on Figure 9. The decrement rate is about 16%-48% with average 32%and deviation standard is 8%. This experimental test shows a good decrement rate of grounding resistance.

![Figure 6](image2)

**Figure 6.** Decreament of $R_g$ as the result of the usage of bentonite
5. Conclusion

Based on the experimental result, the following conclusion can be drawn thus far. The building “I” urgently require a lightning protection system, due to the value of overall risk factor fall below 1:100,000 according to British Standard. The improvement of grounding system using backfill material can significantly decrease the value of $R_g$. Consideration of using bentonite to improve the value of $R_g$ because bentonite has various good properties including: very low and stable resistivity; abilities to absorb and retain large quantities of water; can swell up to 13 times its dry volume; low cost; it will not gradually leach out because it is part of the clay itself. The decrement rate is about 16% - 48% with average 32% and deviation standard is 8%.

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