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Design Optimization of Distance Grid and Ground Rod in the Earth System

Deni Almanda[1*], A I Ramadhan[2]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Indonesia

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ABSTRACT

One of the main factors in securing an electric power system is the earthing system. The earthing system in the generating unit is closely related to the switchyard. Switchyard earthing system design is done by adjusting the grid distance and ground rod length to get the most optimal quality and cost combination. The definition of optimal conditions in this case is limited to circumstances where there is a combination of quality that does not exceed the technical tolerance threshold and has cost efficiency. The design of the switchyard earthing system was taken as a case study. Technical standards are carried out based on IEEE Std 80-2000. Calculations for obtaining technical parameters and costs are carried out one-by-one in the range of grid spacing and length of certain ground rods to determine the optimum point using MATLAB-GUI as a programming tool and MATLAB R2011a as a tool mathematical computing. Calculation results and analysis concluded that the grid distance of 23 m and the length of the 6 m ground rod is the best choice in the optimization of this earthing system by meeting the safety quality criteria for earth resistance is Rg = 0.13806 Ω less than 0.5 Ω with a minimum cost of Rp. 1,220,104,730.

INTRODUCTION

Earthing system or commonly referred to as a grounding system is a security system for devices relating to soil type resistance, earthing resistance also has a large effect on the size of the soil type resistance, the higher the grounding resistance value the higher the soil type resistance. Measurement of soil type resistance is usually done by the three point method and the four point methodv[1-6].

The earthing system is one of the main factors in securing an electric power system. The design of the switchyard earthing system is quite complex. There are three main things that need to be considered, namely quality, cost, and procurement [7-9]. The problem is that the improvement in security quality is generally followed by an increase in costs that must be incurred. This is what underlies the existence of optimization steps to obtain the most effective and efficient combination of security quality and cost. In addition, consideration must be given to the availability and price of goods recommended in the technical design. This study focuses on optimizing the design of the switchyard earthing system in terms of the distance of the grid conductor and the length of the ground rod [10-12].

Case in the field, grid distance and ground rod length are determined directly whereas optimization can be done by adjusting the grid distance and ground rod length by following the rule that the earth resistance times the maximum grid current is less than the tolerance touch voltage (Rg. IG <Es_tol), voltage The mesh is smaller or equal to the tolerance touch voltage (Em ≤ Es_tol) and the actual step voltage is smaller or equal to the tolerance step voltage (El ≤ El_tol). If these three conditions are met then the objective of obtaining the optimization of the grid distance and ground rod length in the earthing system is achieved both in terms of quality and cost [13-14].

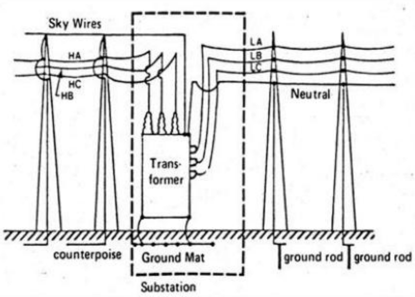

Fig. 1. Illustration of Structure of the Earthing System

* Corresponding author.
E-mail address: deni.almanda@ftumj.ac.id
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Optimization

Optimization is the results achieved in accordance with the wishes, so optimization is the achievement of the results according to expectations effectively and efficiently. Much optimization is also defined as a measure by which all needs can be met from the activities carried out [15-16].

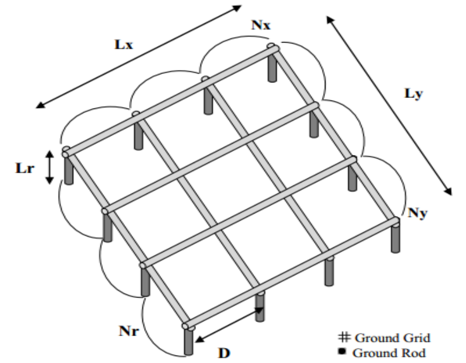

Fig. 2. Earthing System Layout Design

By referring to Figure 2 above, to get the optimal design, it can be done by fulfilling the following minimum cost functions:

$$B(N_x, N_y, N_r, L_r) = (N_r . L_r . C_{ri}) + (N_r . C_r) + (C_{ci} + C_c).\left((N_x + 1). L_y + L_x . (N_y + 1)\right) \quad (1)$$

From the cost function above, to get the minimal cost function influenced by grid distance, equation (1).

$$B(D, L_r) = \left(2\left(\frac{L_y + L_x}{D}\right). L_r . C_{ri}\right) + \left(2\left(\frac{L_y + L_x}{D}\right). C_r\right) + (C_{ci} + C_c).\left(\left(\frac{L_x . L_y}{D} + L_y\right) + \left(\frac{L_y . L_x}{D} + L_x\right)\right) \quad (2)$$

Wherein:

N_r : total ground rod
N_x : total grid conductor in X direction
N_y : total grid conductor in Y direction
L_r : length of each ground rod (m)
C_{ri} : ground rod installation fee (rupiah/m)
C_r : cost of rod conductor material (rupiah/rod)
L_c : length of the grid conductor
C_{ci} : grid conductor installation costs (rupiah/m)
C_c : grid conductor material costs (rupiah/m)
L_x : length of conductor X direction (m)
L_y : length of conductor Y direction (m)
D : grid conductor distance (m)

EXPERIMENTAL METHOD

An optimization method is a method which is carried out analytically by comparing the value of more than one measurement parameter with the usage cost to determine the optimum point. The optimization method uses MATLAB-GUI as a programming tool and MATLAB R2011a as a mathematical computing tool based on ANSI / IEEE Std 80-2000 [17].

RESULTS AND DISCUSSION

Initial Parameter Data

The optimization of the earthing system is based on the influence of the grid spacing and the length of the ground rod in finding the optimal earthing system value in terms of safety and the total cost to be incurred. The data that need to be included in determining the optimization of the earthing system design are obtained from IEEE Std 80-2000 [17] and the Cilacap Adipala Power Plant Data with a Tolerance Touch Voltage of 240 V as contained in the contract documents. In this case study the data used are 777.8 MVA X" generator d = 21.4%, 800 MVA transformer voltage 22/500 kV, X_t = 16.19%, then the If value of the 500 kV voltage side fault is as follows:

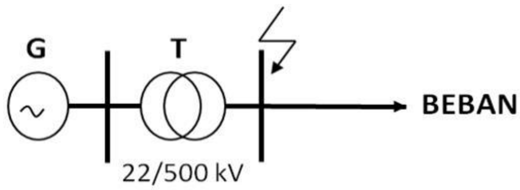

Fig. 3. Single Line Switchyard Diagram 500 kV

To run the program, the initial parameter data will be used as input in the analysis of earthing system optimization in the Matlab program. Before the program reads the input data, the program first reads the length of the ground rod, which was first included in the Matlab program.

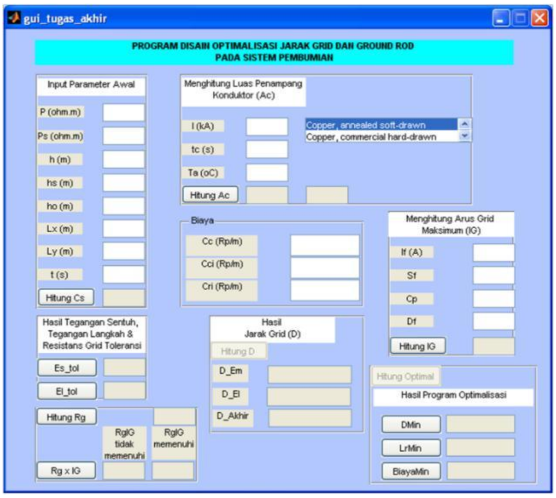

Fig. 4. Initial Display of Optimization Design Program

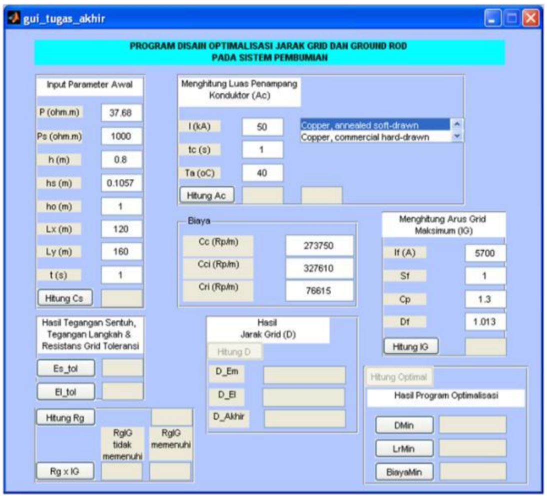

Fig. 5. Initial Parameter Input Program Display

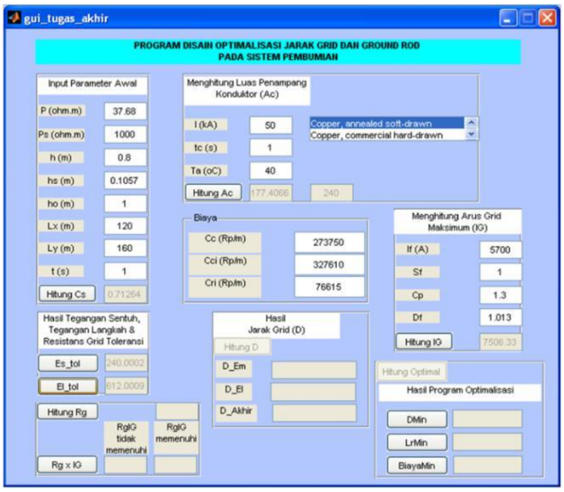

Fig. 6. Program Display Results of Initial Parameter Calculation

The conductor used in the design of this earthing system is Copper, annealed soft-drawn, obtained from the calculation of the grid conductor size 177,4066 mm^2, then conductors with a cross-sectional area of 240 mm^2. The reduction factor (Cs) value equals 0.71264 is used to calculate the touch voltage and tolerance step voltage. The touch tolerance value is 240,0002 V and the tolerance step voltage is 612,0009 V. As for the maximum grid current with a disturbance current rms value of 5.7 kA, the maximum grid current value is 7506.33 A.

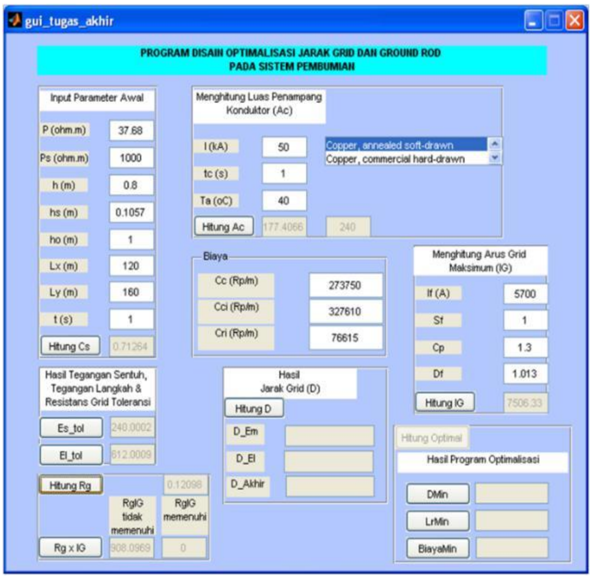

Fig. 7. Display of the Earthing System Optimization Calculation Program

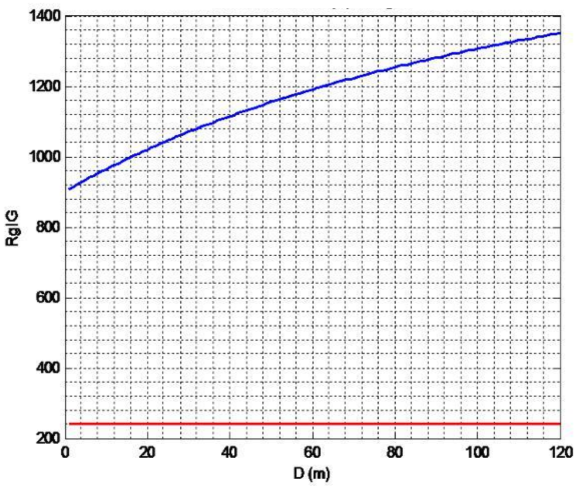

Fig. 8. Grid Distance Graph (D) against RgIG

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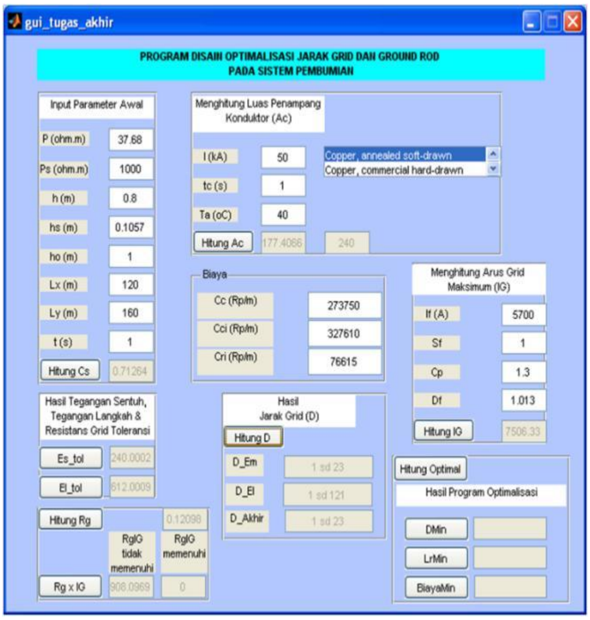

Fig. 9. Display Program Distance Range Grid Results

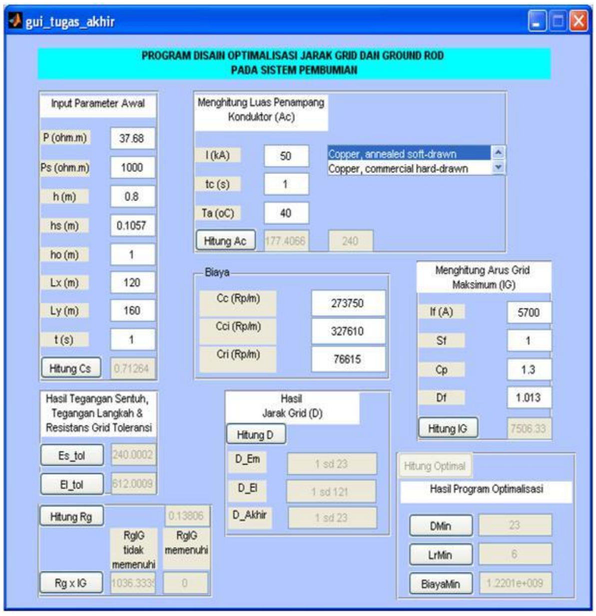

Fig. 12. Display of Optimized Program Results

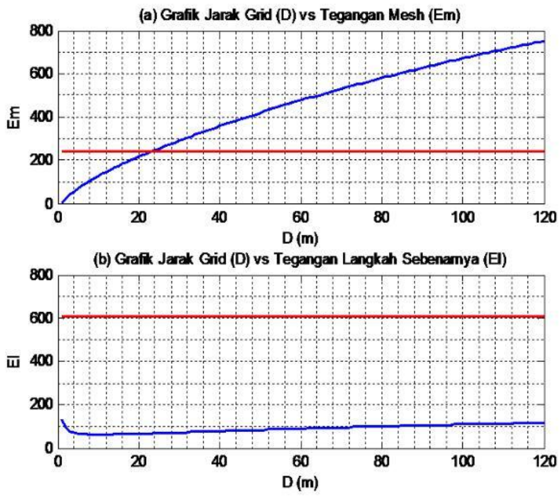

Fig. 10. (a) Effect of Grid Distance on Em, (b) Effect of Grid Distance on El

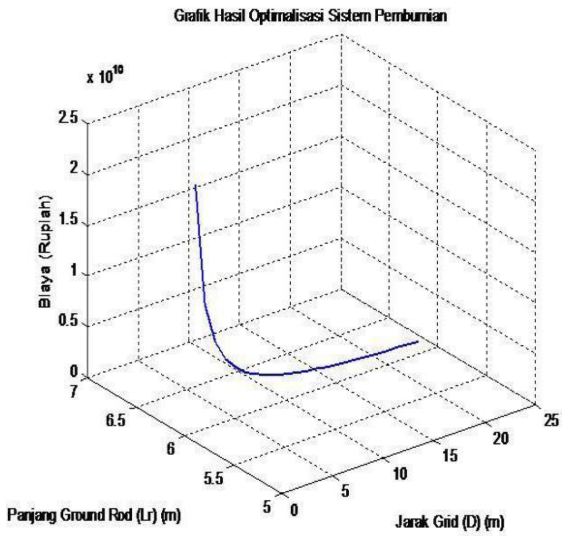

Fig. 13. Graph of Results of Earthing System Optimization Program

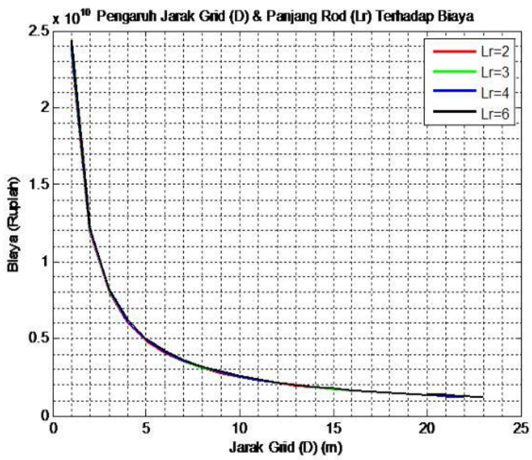

Fig. 11. Graphic Effect of Ground Rod Length on grid distance and cost

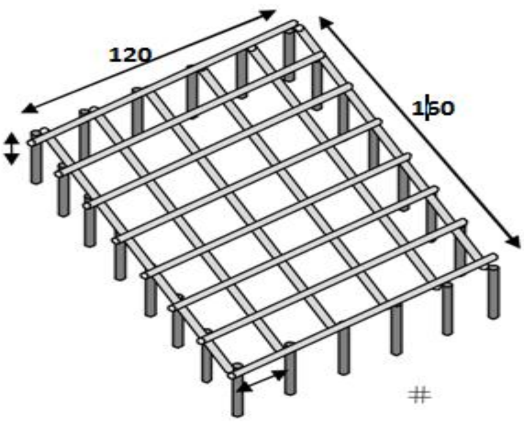

Fig. 14. Lay Out Grid Optimization Results

CONCLUSION

Based on the results of the optimization program using Matlab GUI and Matlab R2011a, it can be concluded that the grid distance of 23 m and the length of the 6 m Ground rod provides the most optimal grounding system design results, with a safety quality for Earthing Resistance (Rg) of 0.13806Ω smaller than The maximum limit of Earthing Resistance is 0.5 Ω (IEC 60694) and the value of the mesh voltage is smaller than the touch tolerance voltage (Em = 239.1854 V <Es_tol = 240,0002 V) and the tolerance step voltage is more than Rp. 1,220,104,730, while the cost of a combination of grid conductor distance and ground rod length obtained from the most optimal design results: Rp. 1,220,104,730.

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