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GENETIC ALGORITHM-BASED OPTIMIZATION OF DISTRIBUTED GENERATOR PLACEMENT IN DISTRIBUTION NETWORKS TO MINIMIZE POWER LOSSES

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Abstract

An increase in electrical energy can lead to an increase in power losses and a decrease in voltage in the system. One of the efforts made to reduce power losses that occur in the distribution network is by placing the optimal Distributed Generation (DG) in the right location. Installation of DGs with suboptimal capacity and placement location can result in greater active power losses and further reduce voltage stability. This study discusses the optimization of DG placement in the electric power distribution network using genetic algorithm methods that are known to be effective in solving complex optimization problems. The IEEE 33 bus distribution system, which is a standard system frequently employed in power flow research, was the subject of the case study. The Newton-Raphson method is a commonly used iterative method for power flow analysis due to its accuracy in calculating power flow in electrical networks. The research findings indicate that the most suitable location for two DG units with an injection power of 6,626 MW is on buses 3 and 4. The placement of this DG has the potential to substantially mitigate power losses within the distribution network. The placement of two DG units on buses 3 and 4 results in a more significant improvement in system power losses than the placement of DG units on other buses. Power losses of buses 3 and 4 experienced power losses of 67724.69 MW, while system losses were reduced by 1137621.21 MW, or 5.61 percent.

Keywords: *Optimization, Distributed Generation (DG), Genetic Algorithms, Newton Raphson Method, Power Losses.*

I. INTRODUCTION

Electrical energy is a very important form of energy in human life today. Increasing population growth has many impacts, especially in the electrical energy sector. This causes the demand for electrical energy to increase. This increase in demand can result in increased power losses and voltage drops in the system [1]. One way to reduce power losses in the distribution network is to place Distributed Generation (DG) which is also called distributed generation plants located in load centers [2].

DG can be defined as a small-scale power plant, which is directly connected to the distribution network. DG is a power plant that produces electrical energy from renewable energy sources, such as wind turbines, microhydro, biomass, photovoltaic (PV), and fuel cells[3]. The increasing deployment of DG units in the distribution network has led to increased attention to DG placement and capacity optimization [4].

Installation of DGs with non-optimal capacity and placement location can result in greater active power losses and further reduce voltage stability [5, 6]. The optimal placement of DGs in the distribution network is influenced by several key factors [7]. First, the integration of DG units significantly improves the voltage profile and reduces channel losses, as demonstrated by various optimization methods, including Genetic Algorithms (GA)[8, 9].

GA is one of the metaheuristic methods to determine solutions to a problem optically by using a search procedure that resembles the biological evaluation process of living things[8]. The application of GA-based optimization techniques has been proven to significantly reduce power losses in distribution networks, especially with high DG penetration. Additionally, GA enables efficient convergence towards optimal solutions, making it the preferred method for complex multi-bus networks[10].

In this study, we will simulate the optimization of DG placement on the IEEE 33 bus distribution system to reduce losses using the GA method.

II. LITERATURE RIVIEW

A. Distribution system

The distribution system has a very important function in the electric power system, namely to distribute electric power from the substation to the load centers to the customer. The distribution of electric power in the distribution system is classified into 2 parts based on the working voltage level, namely the primary distribution system and the secondary distribution system[11].

The electric power distribution system in Indonesia is generally of the radial type. The radial system distribution network is characterized by the existence of one transmission line of electric power starting from the source of the substation to the customer. A radial distribution system consists of one or more distribution transformers and has branches towards the load[4, 7].

B. Distributed Generation (DG)

Distributed Generation (DG) is one of the solutions in terms of equitable distribution of electrical energy. DGs are installed to inject active power (P) and/or reactive power (Q) to improve the voltage profile, improve reliability or otherwise improve the state of the distribution system[12]. These plants are spread across the entire electric power system that is close to the load [13].

The advantage of having DG when compared to centralized power generation is the application of small generators, usually with a capacity of 5 kW to 10 MW, which are placed in locations close to electrical energy consumers to provide the required electrical power[13]. DG generates electrical energy from several energy sources that are small capacity and are directly connected to the distribution network [2, 11].

DG has two main functions, namely it is a unit to anticipate the occurrence of a power grid disconnection or stand-by unit and is a power supply unit at peak load hours or peak units. Based on its generation capacity[9], DG can be grouped as follows:

Table 1. DG classification by Generation capacity

DG CLASSIFICATION	GENERATION CAPACITY
Micro DG	1 Watt – 5 kW
Small DG	5 kW – 5 MW
Medium DG	5 MW – 50 MW
Large DG	50 MW – 300 MW

C. Power Flow

Before optimizing the distribution system, it is necessary to conduct a power flow study. Power flow studies are the process of determining the value of the power flowing within an electric power system [14]. Power flow studies are the process of determining the value of the power flowing within an electric power system. This study can be carried out using manual methods or using the help of software which basically this study still uses the main factors, namely Bus Voltage, Power Factor, Current and Power Flow from generation to load on the electric power system that is analyzed[8].

There are 4 methods used in calculating power flow, namely the Gauss-Seidel Method, Newton Raphson Method, and Fast Decoupled Method. The most commonly used methods are the Gauss-Seidel method and the Newton Raphson method. In this study, Newton Raphson's method was used to calculate the power flow.

Newton Raphson's method uses the Taylor series to approximate the power flow function. The power flow function is a nonlinear function that determines the power flow in a power system. This method calculates the magnitude of the voltage and the voltage phase angle on each power system bus. In the analysis of power flow using the Newton Raphson method, the amount of electricity is used in units of magnitude per unit (p.u)[15].

Basically, Newton Raphson's method works by making a preliminary estimate for the value of the bus voltage. Then, this method uses the power flow equation to calculate the gradient of the power flow function. The power flow function gradient shows the direction and magnitude of the change in power flow if the bus voltage is changed[16]. Newton Raphson's method then uses the gradient of the power flow function to calculate the change in bus voltage. This change in bus voltage is then used to calculate the bus voltage value in the next iteration. This process is repeated until the bus voltage value in the next iteration does not change again, or until a certain tolerance is reached[17].

D. Coordination Equations in the Operation of Power Systems

The loss of active power in a network can be calculated based on the relationship between the power generated by different units. This relationship is called the Kron equation[1]**.**

$$P_L = \sum_{j=1}^{n_g} \sum_{i=1}^{n_g} b_{ij} P_i P_j + \sum_{i=1}^{n_g} b_{i0} P_i + b_{00} \quad (1)$$

Equation (1) can be expressed in the form of the following matrix:

$$P_L = P_g^T \boldsymbol{B} P_g + P_g^T \boldsymbol{B}_0 + \boldsymbol{B}_{00} \quad (2)$$

Where

$$B = [b_{ij}]$$

$$B_0 = [b_{i0}]$$
$$B_{00} = b_{00}$$
$$P_g^T = \left[p_1 p_2 \cdots p_{n_g}\right]$$

The $\boldsymbol{B}, \boldsymbol{B_0}, \boldsymbol{B_{00}}$ in equation (2) is a matrix that describes the power losses in the network. This matrix is calculated based on the method described in . In general, the value of this matrix varies depending on the value of the load and generation. However, this matrix can be calculated under normal system operating conditions, i.e. when there is no change in load and generation[13].

E. Genetic Algorithm

GA is one of the metaheuristic methods to determine solutions to a problem optically by using a search procedure that resembles the biological evaluation process of living things[18]. As for some of the technical terms in the GA method[19], namely:

1. Chromosome

Each individual in a population is called a chromosome which is a representation of the solution and each is evaluated for its degree of resilience by a predefined function [15].

2. Crossover

Crossovers are operators of genetic algorithms that involve two parents to form new chromosomes[15].

3. Mutation

Mutation is the process of randomly changing the values of one or more genes in a chromosome [20].

4. Selection Operator

Selection operation is the process of selecting two individuals or chromosomes as parents for the next generation. Chromosome selection is carried out with the aim of finding chromosomes that have the best fitness value among other chromosomes to be used as parents in the next generation[13].

5. Stop Condition

The stop condition is a process that states the state of the generation stop in the GA process. The stop condition is an important factor in GA. The right stop condition can help GA to find the optimal solution in a reasonable time[8].

III. RESEARCH METHODS

In the research flow chart as shown in figure 1, the selection of the IEEE 33 bus dataset was carried out by collecting and summarizing information from various relevant literature sources. The data obtained includes the network impedance and the load on each bus. Once the data is selected, the next step is to formulate the DG placement scenario. Then determining the DG placement scenario, the Genetic Algorithm (GA) method is used to optimize DG placement. Evaluation is carried out to ensure that the placement is optimal; if not, the optimization process using GA is repeated. If it is optimal, the results obtained include DG capacity, DG location, power losses per bus, and total power losses. The results are then analyzed to obtain a better understanding and draw conclusions based on the analysis.

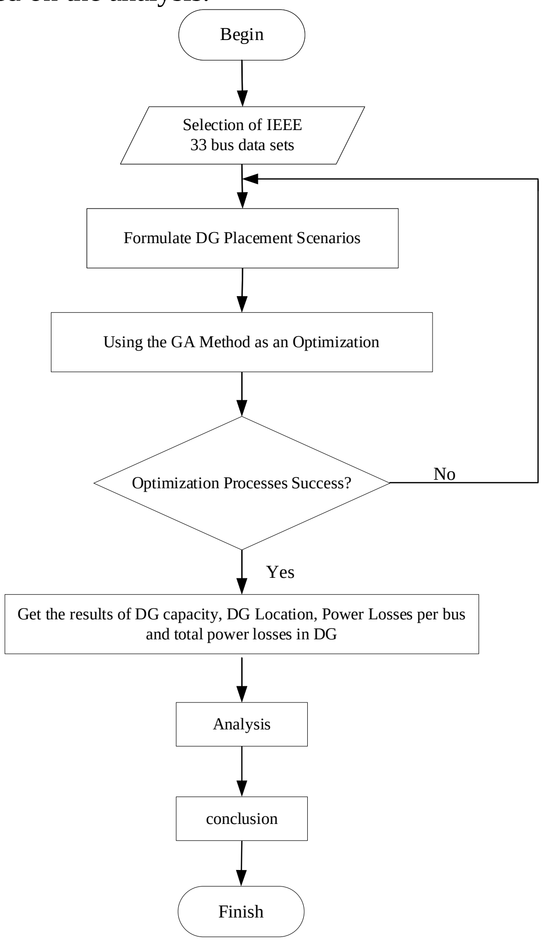

Figure 1. Research Flow Diagram

IV. RESULT AND DISCUSSION

A. DG Placement on Test Distribution System Bus

In this study, two scenarios were carried out on the test distribution system, 2 DG units were placed on the selected buses, namely on buses 3 and 4, buses 3 and 6, 6 and 26 then on buses 4 and 26.

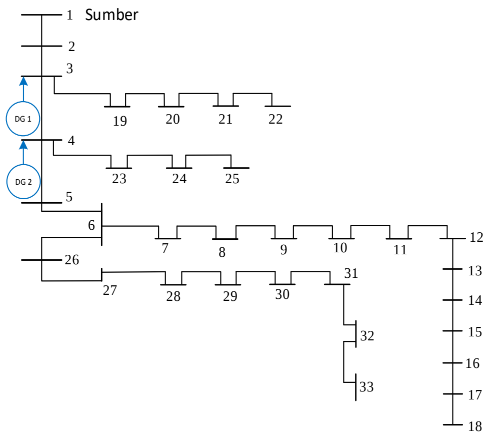

Figure 2. Placement of 2 DGs on buses 3 and 4

Figure 2 shows the placement of 2 DGs on 2 different buses, i.e. on buses 3 and 4 in the test distribution system. This configuration is the result of an optimization process that uses the GA method, with the main goal of minimizing power losses in the system. The reason for choosing the bus is because buses 3 and 4 have a large total load of 1440 MW with a load connected to the bus which is 0.78% of the total load of the test distribution system, so the placement of DG on this bus is expected to help reduce the load on the main channel and reduce power losses.

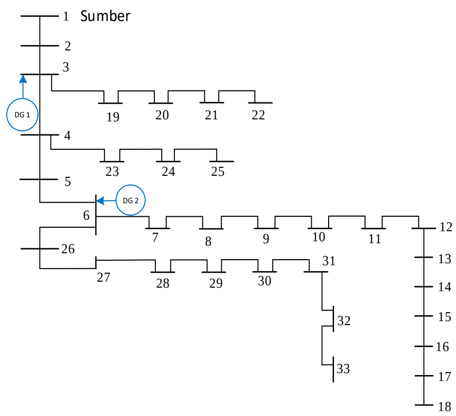

Figure 3. Placement of 2 DGs on buses 3 and 6

Figure 3 shows the placement of 2 DGs in the test distribution system, where DG 1 and DG 2 are placed on buses 3 and 6. The selection of this bus as the location for the DG placement is based on several considerations, namely bus 3 is located on the main branch that supplies several loads, namely buses 19, 20, 21 and 22. The placement of DG here can reduce power losses on the branch and bus 6 is located on a branch that has many derivative branches.

The total load on buses 3 and 6 is 1445 MW with the load connected to the bus which is 0.78% of the total load of the test distribution system. The placement of DG on the bus is expected to help reduce the load on the main channel and reduce power losses.

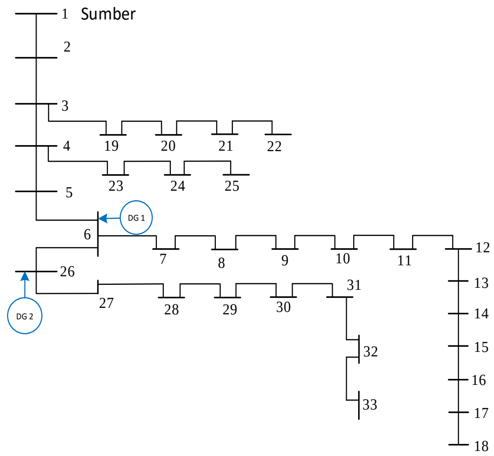

Figure 4. Placement of 2 DGs on buses 6 and 26

Based on Figure 4, it can be seen that DG 1 is placed on bus 6 and DG 2 is placed on bus 26. The reason for placing DG on this bus is the same as in the previous scenarios, where Bus 6 and 26 are located on branches that supply some load and have many derivative branches as can be seen in Figure 12. The total load on buses 6 and 26 is 1885 MW with the load connected to the bus is 0.72% of the total load of the test distribution system. By placing DG on this bus, it is hoped that it can help reduce system power losses.

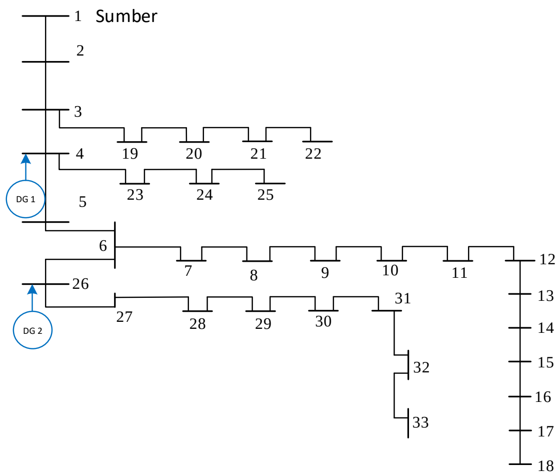

Figure 5. Placement of 2 DG on buses 4 and 26

Figure 5 shows the placement of 2 DGs on Bus 4 and bus 26 in a test distribution system. The reason for choosing the placement of DG on this bus is the same as the previous scenario, namely because these buses are candidates who meet the criteria for DG placement, where these buses are located in a system with a total electrical load of 1880 MW. The load connected to these buses is relatively large, which is 0.72% of the total load of the distribution system, so it is expected that the placement of DG on these buses can compensate for the load on the main network and reduce power losses.

Table 2. Placement of 2 DGs on the Test Distribution System

Lokasi DG	Kapasitas DG perbus (MW)		Kapasitas Total DG (MW)	Total Rugi Daya (MW)	Perbaikan Daya Sistem (MW)	Perbaikan Rugi Daya (MW)	perbaikan rugi daya (%)
3 DAN 4	BUS 3 5,234	BUS 4 1,392	6,626	1205345,9	67724,687	1137621,21	5,61%
3 DAN 6	BUS 3 0,523	BUS 6 1,426	1,949	1205345,9	44707,209	1160638,69	3,70%
6 DAN 26	BUS 6 0,143	BUS 26 1,281	1,424	1205345,9	38358,89	1166987,01	3,18%
4 DAN 26	BUS 4 0,014	BUS 26 1,281	1,281	1205345,9	26674,3032	1178671,59	2,21%

The buses selected as the DG placement location will generate power that will be injected into the test distribution system and also have different power losses. Based on the simulation results, it can be seen that the power injected on Buses 3 and 4 is 6.626 MW with a power loss of 67724.67 MW. When DG was placed on this bus, there was a repair of system power loss of 1137621.21 MW or 5.61%.

From the results of this scenario, the most optimal placement of 2 DGs is on bus 3 and bus 4. This is because bus 3 and bus 4 contributed a large power loss repair compared to other buses, namely 1137621.21 MW or 5.61%.

V. CONCLUSION

Based on the objectives of the research, it can be concluded as follows:

1) For the simulation on the bus distribution system of the 2 DG placement test, the most optimal is on buses 3 and 4 with an injected power of 6.626 MW.

2) The results of the simulation of the placement of 2 DG on buses 3 and 4 resulted in a power loss of 67724.69 MW with a power loss improvement of 1137621.21 MW or 5.61%.

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