

OPTIMIZATION OF DISTRIBUTED GENERATION INSTALLATION IN CILEDUG TASIKMALAYA FEEDER TO REDUCE POWER LOSS WITH GENETIC ALGORITHM (GA) METHOD

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Abstract

Distributed generation (DG) is a small-scale power plant that is generally located close to the load. The installation of DG can be an alternative to reduce power losses in the distribution system. In this study, the placement and capacity optimization of DG to Ciledug feeder is carried out. Optimization is carried out using the genetic algorithm (GA) method which aims to reduce power losses in the system. The simulation is divided into 2 stages. In the first simulation before the installation of DG, the power loss obtained was 755,807 kW, and the voltage profile experienced under voltage from bus 31 to bus 104. The second simulation will be carried out by adding DG to the network, the DG used amounted to 2, 3, and 4 DG units. The location and capacity of DG are searched using the genetic algorithm optimization technique. The optimization results using 2 DGs, showed that the DGs were connected at bus 95 and bus 97 with a capacity of 0.969 MW and 0.480 MW, respectively. The addition of 2 DGs to the network reduces the power loss to 398,899 kW. Next, the optimization results using 3 DGs, showed that DGs were connected at bus 96, bus 78, and bus 67 with a capacity of 0.977 MW, 0.977 MW, and 0.013 MW, respectively. The addition of 3 DGs to the network reduces the power loss to 236,920 kW. Finally, the optimization results using 4 DGs show that DGs are connected at bus 67, bus 80, bus 46, and bus 26 with a capacity of 0.951 MW, 0.799 MW, 0.616 MW, and 0.257 MW, respectively. The addition of 4 DGs to the network reduces the power loss to 141,465 kW.

Keywords: Distributed Generation, genetic algorithm, power loss

I. INTRODUCTION

Energy use Electrical has a very important role in driving every human activity, almost all sectors of life require electrical energy.

Tasikmalaya City is a growing area and consists of housing, shops, industry, schools, and universities. With this condition, PT PLN (Persero) UP3 Tasikmalaya as a provider of electrical energy services continues to strive to meet the electricity needs in Tasikmalaya City. But on the other hand, the rate of economic growth and population growth continues to increase causing a large demand for electrical energy, so there needs to be an effort to maintain the quality of electricity distribution.

Ciledug feeder (CLDG) is one of the repositories in the distribution system located in Tasikmalaya City. The Ciledug repeater has a long distribution channel, where the length reaches 40,463 meters. The distribution of electrical energy to the load will experience technical losses, namely power losses. Power losses exist starting from generation, transmission, and distribution [1].

Power losses that occur on distribution lines result in various impacts, including a decrease in the voltage profile on the distribution line, a low power factor that occurs can cause material losses due to the reduced power of the system in delivering electricity to consumers [2]. One alternative to solving the problem is to install distributed generation (DG) on the distribution network. Distributed generator (DG) is installed to inject voltage so that it affects power quality. In general, distributed generation (DG) is a generator that uses renewable energy, such as wind turbines, micro-hydro, and photovoltaic panels [3].

The many methods of installing distributed generation (DG) will make it difficult for operators to choose the right method. Because of this, a method for installing distributed

generation (DG) that produces the lowest power loss value is needed. In this research, the problem will be solved using the genetic algorithm (GA) method. The number of distributed generation (DG) installation methods will make it difficult for operators to choose the right method. Because of this, a method for installing distributed generation (DG) that produces the lowest power loss value is needed. In this research, the problem will be solved using the genetic algorithm (GA) method.

II. LITERATURE REVIEW

A. Distributed Generation

Distributed Generation (DG) is a power plant outside of the central generation system with a small capacity that is directly connected to the distribution network and is generally placed close to the load [4]. DG is often referred to as Embedded Generation, Dispersed Generation, Decentralized Generation, and on-site generation [4].

DG is a new thing in the power generation system that has a very significant impact on the conventional concept of centralized power generation. Currently, DG continues to experience development, DG is applied in various sectors such as industry, housing, and so on, and the use of DG is expected to reduce carbon emissions and dependence on fossil fuels as an energy source for electricity generation.

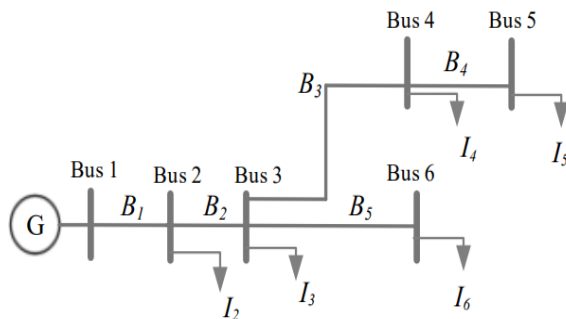
DG has great potential benefits, DG is used as a backup generator that provides energy sources to the power system during peak loads, reduces power losses, and can improve distribution system reliability [5].

The utilization of DG cannot be separated from technical problems. Currently, experts do not have a definite concept equation regarding DG including the concept of size/capacity limits and DG location placement.

Determining the installation location and capacity of DG is very important to reduce power loss and improve the voltage profile. Voltage values can increase when a DG with a large capacity is installed on a small load [6]. So, DGs with large capacities are better installed in areas with large loads.

B. Backward-Forward Sweep Load Flow

The backward-forward sweep load flow method is a method that in solving the power flow using the principle of Kirchoff's law. This method can provide a solution to the power flow problem by using two stages, namely backward sweep, and forward sweep. First, calculate the current flowing on the line, from the first bus to the last bus called the backward sweep stage. Second, calculate the voltage drop value at each channel bus by multiplying the previously calculated current value with the channel impedance value called the forward sweep stage. The following is an example of power flow calculation in a radial distribution network with the backward-forward sweep method.



Fgr 1. Example of Radial Distribution Network

For example, a power flow analysis will be carried out on the distribution network as shown in Fgr 2.9 using the backward-forward sweep method. The current equation injected at each bus is equal to:

$$B_5 = I_6 \quad (1)$$

$$B_4 = I_5 \quad (2)$$

$$B_3 = I_4 + I_5 \quad (3)$$

$$B_2 = I_3 + I_4 + I_5 + I_6 \quad (4)$$

$$B_1 = I_2 + I_3 + I_4 + I_5 + I_6 \quad (5)$$

After obtaining the above equation the formed BIBC matrix is as follows:

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{bmatrix} = \begin{bmatrix} 11111 \\ 01111 \\ 00110 \\ 00010 \\ 00001 \end{bmatrix} \begin{bmatrix} I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{bmatrix} \quad (6)$$

And the BIBC matrix can be simplified as follows:

$$[B] = [BIBC][I] \quad (7)$$

Then the equation for voltage drop on each bus is obtained as follows:

$$V_2 = V_1 - B_1 \cdot Z_{12} \quad (8)$$

$$V_3 = V_1 - B_1 \cdot Z_{12} - B_2 \cdot Z_{23} \quad (9)$$

$$V_4 = V_1 - B_1 \cdot Z_{12} - B_2 \cdot Z_{23} - B_3 \cdot Z_{34} \quad (10)$$

$$V_5 = V_1 - B_1 \cdot Z_{12} - B_2 \cdot Z_{23} - B_3 \cdot Z_{34} - B_4 \cdot Z_{45} \quad (11)$$

$$V_6 = V_1 - B_1 \cdot Z_{12} - B_2 \cdot Z_{23} - \dots - B_5 \cdot Z_{56} \quad (12)$$

From the above equation, a BCBV matrix can be formed which states that there is a relationship between bus voltage and line current. The BCBV matrix forms as follows:

$$\begin{bmatrix} V_1 - V_2 \\ V_1 - V_3 \\ V_1 - V_4 \\ V_1 - V_5 \\ V_1 - V_6 \end{bmatrix} = \begin{bmatrix} Z_{12} & 0 & 0 & 0 & 0 \\ Z_{12}Z_{23} & 0 & 0 & 0 & 0 \\ Z_{12}Z_{23}Z_{34} & 0 & 0 & 0 & 0 \\ Z_{12}Z_{23}Z_{34}Z_{45} & 0 & 0 & 0 & 0 \\ Z_{12}Z_{23} & 0 & 0 & 0 & Z_{36} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{bmatrix} \quad (13)$$

And the BCBV matrix can be simplified as follows:

$$[\Delta V] = [BCBV][B] \quad (14)$$

Then the equation for the ΔV matrix is obtained. The equation obtained is as follows:

$$[\Delta V] = [BCBV][BIBV][I] \quad (15)$$

$$[\Delta V] = [DLF][I]$$

By obtaining the BIBC, BCBV, and ΔV matrices we can calculate the voltage value on each bus. The equation to calculate the voltage value on each bus is as follows:

$$[V_i] = [V_i] - [\Delta V] \quad (16)$$

C. Power loss

In the process of transmission and distribution of electricity, power losses are often quite large. Power losses are the difference between the power generated or sent and the power that reaches the customer. Power losses have a big influence on the quality of power and voltage delivered to the load side.

Power losses are also caused by several factors, such as the distance of electrical energy distribution from the source, voltage drop, load imbalance, equipment diameter, and others. A loss situation in the electricity distribution network is a condition where an electricity distribution system experiences large power loss. Loss situation can be known by reviewing several areas that have high loading because in general, areas with high loading are likely to have large power losses.

D. Genetic Algorithm

GA works by randomly selecting individuals from a population. Changes in the environment will affect the lives of individuals. This causes individuals to adjust or adapt to their environment. Individuals who do not adapt will die and vice versa if they can adapt it will create a new generation.

To run the genetic algorithm, a code is needed that can represent a problem. The code is a chromosome consisting of genetic components called genes. A good chromosome will be selected through the manipulation of the material and properties of the chromosome genes. The information provided from the evaluation is the fitness value of each chromosome. GA has four basic working principles:

1. Encodes the problem parameters and does not work directly with them.
2. Searches for a solution to the problem from a population of candidate solutions, not just processing single solution.
3. Only considers the fitness function of each candidate solution to obtain the global optimum.

- Using rules in a probabilistic transition instead of a deterministic.

In the genetic algorithm, several parameters must be considered. The following are some of the parameters used in the genetic algorithm:

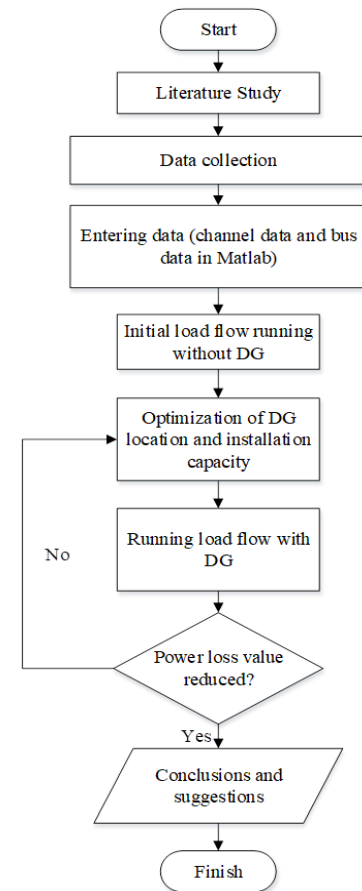
- Population size (POPSIZE), If the population size is small then the population does not provide enough material to cover the problem space which results in poor genetic algorithm performance. Using a large population can prevent convergence in the local region.
- Crossover probability (Pc), The crossover probability serves to control the frequency of the crossover operator. In the population, there is $P_c \times \text{POPSIZE}$, which is the structure of individuals who do crossover. The greater the value of the crossover probability, the faster the new structure is introduced in the population [7].
- Mutation Probability serves to increase population variation to determine the mutation value $P_m \times \text{POPSIZE} \times N$, N is the length of genes in one individual.

E. Genetic Algorithm Process

- Population Initialisation, First, in doing the initialization. In this process, an initial population is created where the number of chromosomes adjusts to the needs in solving the problem that will be done. In this initialization, we use binary numbers [8].
- Fitness Evaluation, evaluate the fitness value. This is done to find out how good the fitness value is resulting from the individual or chromosome that has been initialized. To find the fitness value, you can use the equation.
- Selection, the third is to select the results. In this process, we will look for parent candidates or parents to proceed to the next process by sorting the fitness value [9].
- Crossover, crossing chromosomes or mating between chromosomes. In the process of crossing two chromosomes, it is hoped that it will form a new chromosome that is better in value or fitness value than its parent. The occurrence of this crossover is based on the crossover possibility determined at the beginning.
- Mutation, performs the gene mutation process on the chromosome. The mutation performed is to replace a random gene with a new value and produce a chromosome with mutation results [7].
- Ethylism, performs the ethylism process. In the process, this process can copy chromosomes from the best chromosomes to a temporary population which will later be transferred to a new population.
- Population Switching performs population switching. The first initialized population will be replaced by the next generation. The new generation is the generation that has completed the process from initialization to ethyl. This new generation will be used again in the next iteration until a fitness value is found that is considered suitable and best from the results of the process of performing this genetic algorithm method or after reaching the maximum limit of generations that have been set at the beginning.

III. METHOD

A. Research Flowchart



Fgr 2. Research Flowchart

B. Research Support Data

In this research, the data obtained from PT PLN (Persero) UP3 Tasikmalaya is the main data in data management. The data obtained about the Ciledug (CLDG) feeder includes single line diagram, conductor data, and distribution transformer data in the Ciledug (CLDG) feeder distribution network.

Ciledug single-line diagram data, diagrams are important data in this study. The data will be used as a reference for making single-line diagram simulations in the software MATLAB. Conductor Data, Conductor specification data used in Ciledug (CLDG) is as shown in Tbl1 below:

No	Type of Conductor	R/KM	Xj/KM
1	AAAC 35mm ²	0,9217	0,379
2	AAAC 70mm ²	0,4608	0,3572
3	AAAC 150mm ²	0,2162	0,3305

Tbl 2 is a Tbl 1 of information about the type and cross-sectional area used, while the length and impedance of each conductor are shown in the following table:

$$P_{loss(i,j)} = real(S_i) \tag{22}$$

From equation (3.6), the total power loss can be calculated by summing up the power loss of each channel to get the following equation:

$$MinF_1(x) = \sum_{j=1}^n P_{loss(i,j)} \tag{23}$$

Where n is the number of branches of the distribution network and $(i,j) \in B$ means (i,j) are two points of a line of bus i and bus j

In this research, there are several constraints used, namely the DG power output limit and the allowable voltage limit at each bus. The allowable voltage limit at each bus should not exceed 5% of the source voltage, which is 20 kV. Meanwhile, the DG power constraint is 1 MW per unit. The following are the voltage constraint and DG power constraint equations.

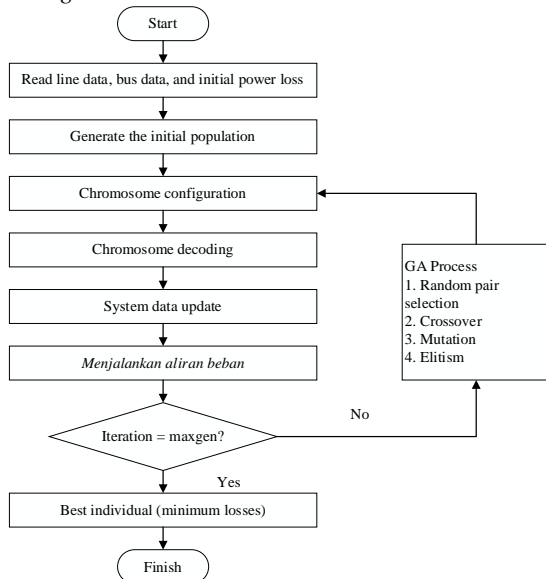
Constraint Voltage:

$$V_{min} \leq |V_i| \leq V_{max} \tag{24}$$

Constraint on DG active power injection:

$$\sum_{i=1}^{NDG} PDG(i) \leq 1MW / per\ unit \tag{25}$$

D. Flowchart of Optimization DG location and capacity Using GA

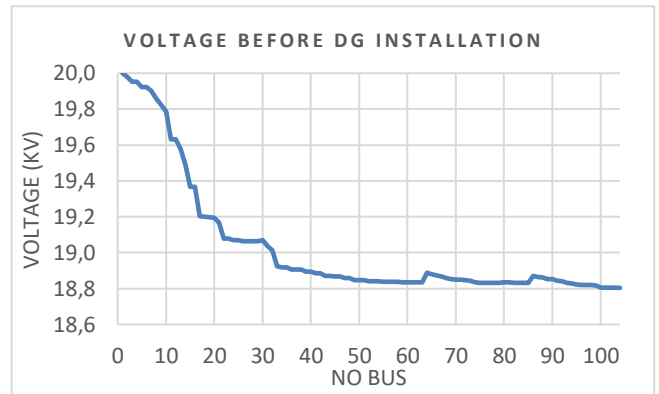


Fgr 4. Flowchart of Optimization GA

IV. RESULTS AND DISCUSSION

A. Initial Loss Calculation before DG installation

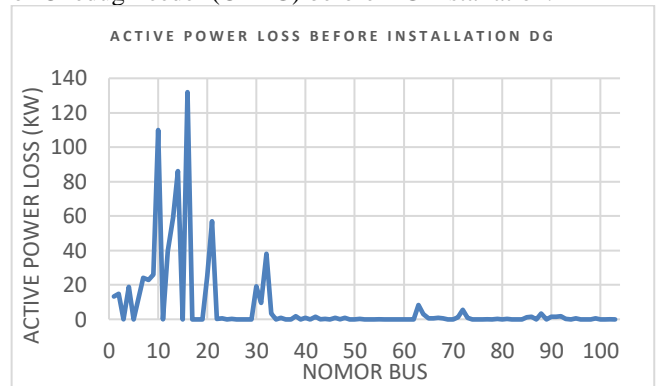
At this stage, a load flow analysis is carried out on the Ciledug (CLDG) feeder before the installation of DG. Some of the things observed are the voltage value at each bus and the power losses in the network when no DG is installed. Fgr 5 shows the voltage profile of Ciledug (CLDG) before DG installation.



Fgr 5. Voltage Profile Before DG Installation

From Fgr 5, bus 33 to bus 104 is under voltage because it does not meet the allowable voltage constraint requirements in the range of 0.95 pu to 1.05 pu. The following Fgr 3 displays a graph of the voltage profile of each bus of the Ciledug feeder (CLDG) before the installation of DG.

After the voltage value is known, the load flow calculation is carried out to find out how much active power loss is on the Ciledug feeder line before installing DG as follows. Fgr 6. displays a graph of active power loss per bus of Ciledug Feeder (CLDG) before DG installation.



Fgr 6. Active Power Loss Before DG Installation

From Fgr 6. is the result of load flow on the Ciledug (CLDG) feeder without DG installation. It is known that the total active power loss in the Ciledug (CLDG) distribution network is 755,807 kW.

B. Optimization allocation of DG

In this test, the system is given 2 DG, 3 DG, and 4 DG with the location and capacity-optimized using genetic algorithms. After the GA optimization process is complete, the location and capacity of DG are obtained. Furthermore, a comparison of power loss and voltage profile is carried out on the system conditions before and after DG is installed. The following Tbl6 shows the location and capacity of all DGs connected to the Ciledug (CLDG) feeder.

Tbl 4. GA Optimization Results for Allocation DG

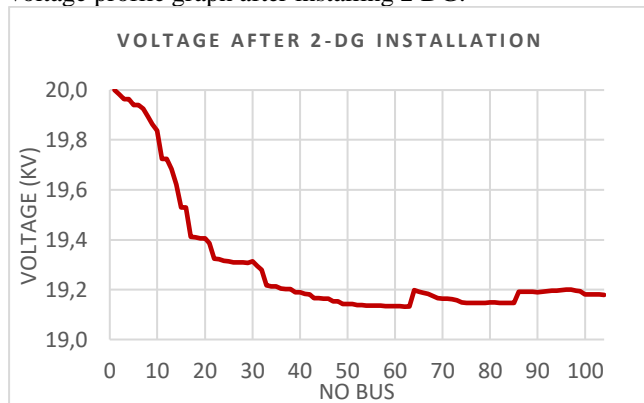
DG	Bus Location	Capacity (MW)
2	95	0,696
	97	0,48
3	96	0,977
	78	0,977

	67	0,013
	67	0,951
4	80	0,799
	46	0,616
	26	0,257

From Tbl6. The bus position and capacity of 2 DGs obtained are bus 95 with a capacity of 0.696 MW and bus 97 with a capacity of 0.480 MW. This means that the total power of 2 DGs that have been installed on the network is 1.176 MW, then the 3 DGs obtained are bus 96 with a capacity of 0.977 MW, bus 78 with a capacity of 0.977 MW, and bus 67 with a capacity of 0.013 MW. The total power of the 3 DGs that have been installed on the network is 1.967 MW. Furthermore, the 4 DGs obtained are bus 67 with a capacity of 0.951 MW, bus 80 with a capacity of 0.799 MW, bus 46 with a capacity of 0.616 MW, and bus 26 with a capacity of 0.257 MW. The total power of the 4 DGs that have been installed on the network is 2.623 MW. So that the total capacity of DG has met the constraint value of active power injection where the maximum limit is 1 MW / unit.

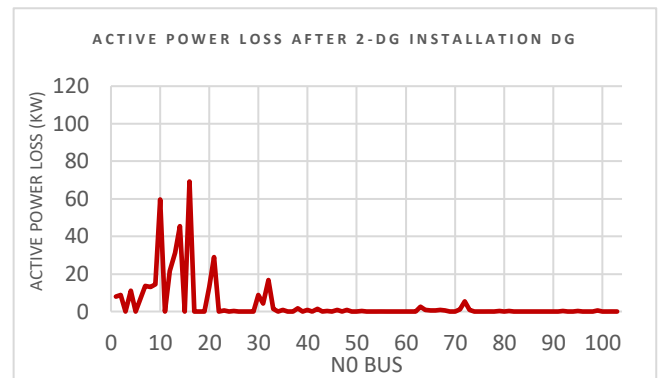
C. Analysis After 2-DG Installation

The installation of DG at Bus 95 and Bus 97 has the effect of improving the voltage profile of each bus. If the voltage results are plotted in the form of a graph, it will be seen that the voltage of each bus has increased compared to the previous condition. There are no more buses that experience under voltage. The following Fgr 7. shows the voltage profile graph after installing 2 DG.



Fgr 7. Voltage After 2-DG Installation

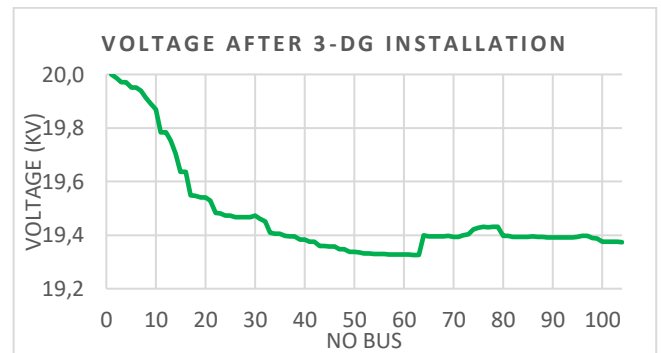
Load flow calculation results after the addition of 2 DGs in the distribution network of the Ciledug feeder (CLDG). GA optimization results for determining the location and installation of DG resulted in a decrease in active power loss to 398.199kW which was originally 755.807kW. The following Fgr 8. shows the active power loss graph after installing 2 DGs.



Fgr 8. Active Power Loss After 2-DG Installation

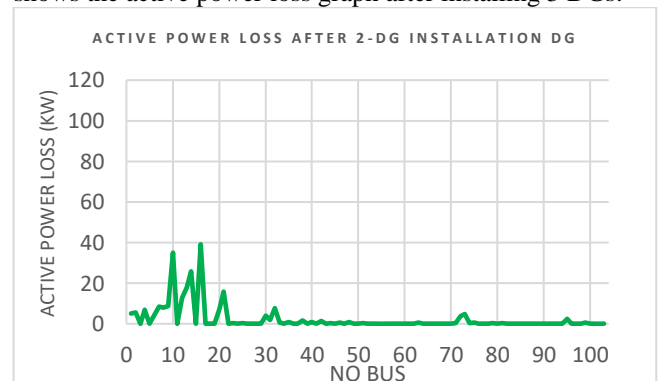
D. Analysis After 3-DG Installation

The installation of DG at bus 96, bus 78, and bus 67 has a significant impact on improving the voltage profile of each bus. Overall, the bus is at a level above 19.3 kV. If the voltage results are plotted in the form of a graph, the voltage increase of each bus will be seen compared to the previous condition. The following Fgr 9. shows the voltage profile graph after installing 3 DGs.



Fgr 9. Voltage After 3-DG Installation

Load flow calculation results after adding 3 DGs to the Ciledug distribution network (CLDG). The results of GA optimization for determining the location and installation of DG resulted in a decrease in active power loss to 236.920 kW which was originally 755.807 kW. The following Fgr 10. shows the active power loss graph after installing 3 DGs.

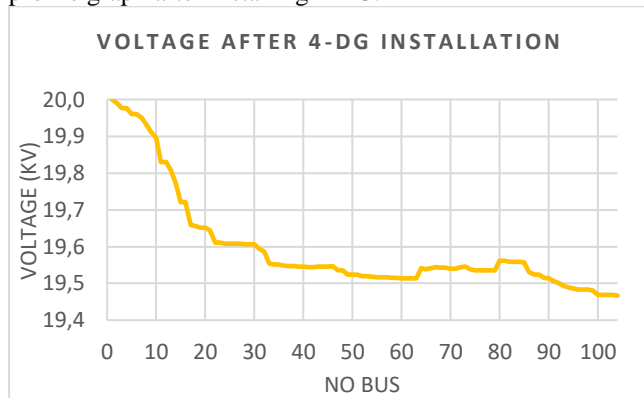


Fgr 10. Active Power Loss After 3-DG Installation

E. Analysis After 4-DG Installation

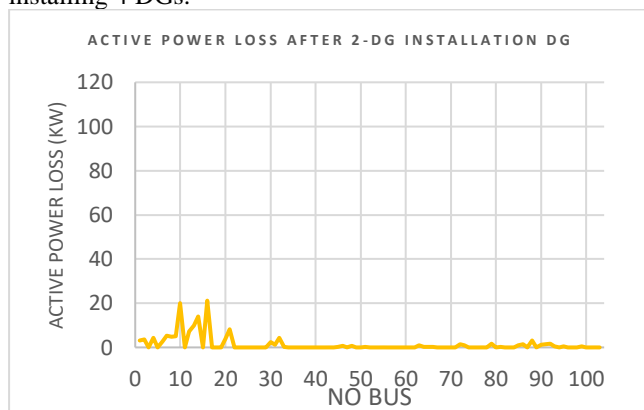
The installation of DG on Bus 67, Bus 80, Bus 46, and Bus 26 has a significant impact on improving the voltage profile of each bus. Overall, the bus is at a level above 19.4 kV. If the voltage results are plotted in the form of a graph,

the voltage increase of each bus will be seen compared to the previous condition. The following Fgr 11. shows the voltage profile graph after installing 4 DG.



Fgr 11. Voltage After 4-DG Installation

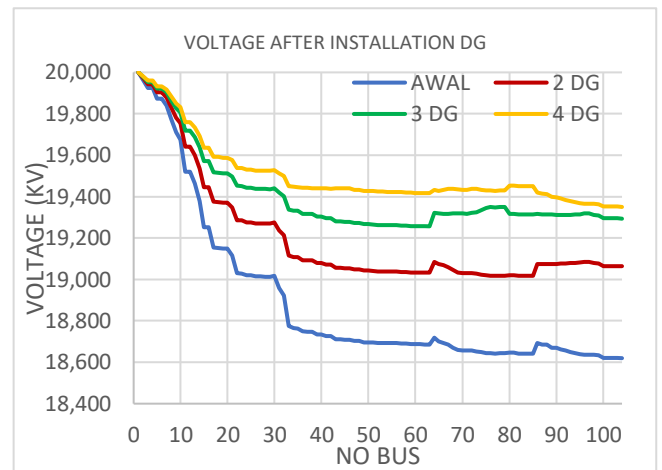
Load flow calculation results after the addition of 4 DGs in the distribution network of the Ciledug feeder (CLDG). The results of GA optimization for determining the location and installation of DG resulted in a decrease in active power loss to 141.465 kW which was originally 755.807 kW. The following Fgr 12. shows the active power loss graph after installing 4 DGs.



Fgr 12. Active Power Loss After 4-DG Installation

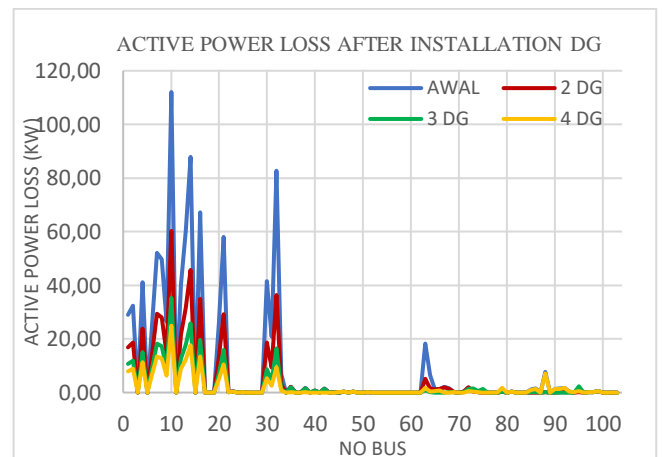
F. Analysis After and Before DG Installation

After the GA optimization process is complete, the location and capacity of DG are obtained. Furthermore, the installation of DG is carried out. This also means that the installation of DG on the Ciledug (CLDG) reinforcer has met the value of the voltage constraint used. The allowable voltage limit on each bus should not exceed 5% of the source voltage, which is 20 kV. The following Fgr 5 shows the comparison of voltage values when before and after DG.



Fgr 5. Voltage Comparison Before and After DG Installation

In Fgr 6, it can be seen that the installation of 2 DGs in the system has reduced active power losses to 398,807 kW, the installation of 3 DGs in the system has reduced active power losses to 236,92 kW, the installation of 4 DGs in the system has reduced active power losses to 141,465 kW, from 755,807 kW in the previous condition when the system has not been installed with DG. This proves that the installation of DG can effectively reduce the active power loss value. The following Fgr 6 shows a comparison graph of active power loss before and after DG is installed.



Fgr 6. Comparison of Active Power Loss Before and After DG Installation

G. Effectiveness of DG Installation

A comparison of the effectiveness of DG installation is carried out to determine how effective the installation of 2, 3, and 4 DG is in reducing active power losses considering the cost of building DG. The DG used in this study is photovoltaic (PV). Based on the guidelines issued by the Ministry of Energy and Mineral Resources entitled Financing of Solar Power Plants, the cost of building a solar power plant or PV array with a capacity of 1 MW is Rp42,268,500.00.

The development cost and effectiveness of installing 2, 3, and 4 DGs on active power loss reduction considering the DG development cost, can be calculated using the following equation:

Development Cost:

$$\text{Total DG Output} \times \text{Cost per MW} \quad (26)$$

Effectiveness of DG installation:

$$\frac{\text{Development Cost}}{\text{Active Power Loss Reduction Value}} \quad (27)$$

In the installation of 2 DGs located at buses 95 and 97 with a capacity of 0.696 MW and 0.480 MW, the total DG output is 1.176 MW. The installation of 2 DGs resulted in a decrease in active power loss of 357.608 kW to 398.199 kW or a decrease of 47.31%, which was originally 755.807 kW. The cost of installing 2 DG can be calculated as follows:

Installation Cost of 2 DG:

$$1,176 \times 42.268.500 = \text{Rp}49.707.756,00$$

Effectiveness of installation 2 DG

$$\frac{49.707.756}{357,608} = \text{Rp}139.000,68/\text{kW}$$

In the installation of 3 DGs located on buses 96, 78, and 67 with capacities of 0.977 MW, 0.977 MW, and 0.013 MW, the total DG output is 1.967 MW. The installation of 3 DGs resulted in a decrease in active power loss of 517.877 kW to 236.92 kW or a decrease of 68.63%, which was originally 755.807 kW. The cost of installing 3 DG can be calculated as follows:

Installation Cost of 3 DG:

$$1,967 \times 42.268.500 = \text{Rp}83.142.139,00$$

Effectiveness of installation 3 DG:

$$\frac{83.142.139}{517,877} = \text{Rp}160.231,69/\text{kW}$$

In the installation of 4 DGs located on buses 67, 80, 46, and 26 with capacities of 0.951 MW, 0.799 MW, 0.616 MW, and 0.257 MW, the total DG output is 2.623 MW. The installation of 4 DGs resulted in a decrease in active power loss of 614.342 kW to 141.465 kW or a decrease of 81.28%, which was originally 755.807 kW. The cost of installing 4 DG can be calculated as follows:

Installation Cost of 4 DG:

$$2,623 \times 42.268.500 = \text{Rp}110.870.275,00$$

Effectiveness of installation 4 DG:

$$\frac{110.870.275}{614,342} = \text{Rp}180.469,96/\text{kW}$$

From the above calculations, it is found that the installation of 2 DG has the best effectiveness towards reducing active power loss considering the cost of DG development, because to reduce active power loss by 1 kW only requires Rp139,000.68.

V. CONCLUSION

From the simulation of GA Optimization for determining the location of DG installation in the Ciledug distribution system (CLDG), the following conclusions can be drawn:

1. The total active power loss in the Ciledug (CLDG) distribution network without DG installation is obtained at 919.329 kW and there is Undervoltage on bus 31 to bus 104 because the allowable voltage limit on each bus cannot exceed 5% of the source voltage, which is 20 kV.
2. GA optimization results for location and capacity determination using 2 DGs are at bus 95 with a capacity of 0.696 MW and bus 97 with a capacity of 0.480 MW. Furthermore, using 3 DG, the results were obtained at bus 96 with a capacity of 0.977 MW, bus 78 with a capacity of 0.977, and bus 67 with a capacity of 0.013 MW. Finally, using 4 DGs, the results are obtained at bus 67 with a capacity of 0.951 MW, bus 80 with a capacity of 0.799 MW, bus 46 with a capacity of 0.616 MW, and bus 26 with a capacity of 0.257 MW.
3. The total active power loss in the distribution network of Ciledug (CLDG) after installation using 2 DGs is 475.366 kW. The total active power loss using 3 DG is 274.826 kW. The total active power loss using 4 DG is 202.713 kW.
4. The installation of 2 DGs has the best effectiveness in reducing active power loss considering the cost of building DGs, because to reduce active power loss by 1 kW only requires Rp139,000.68.

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