Analysis of impact installation of Distributed Generation in a 20 kV distribution system

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Abstract. This study aims to determine the effect of the installation of Distributed Generation (DG) on the value of voltage drop and real power losses in the distribution network of 20 kV Gunung Dukuh feeder (GNDH). In addition, this study also aims to determine the optimal distribution location of Distributed Generation (DG) to get the best voltage drop and power losses. The background of this research is that the voltage drops and power losses are common in GNDH feeders at PT. PLN (Persero) Cimahi area. The voltage value on the GNDH feeder is sometimes still below the standards set by PLN. This will certainly cause the load not to work optimally and can even cause damage to the electricity load and in the end will be very detrimental to all parties, both the electricity consumer and PT. PLN (Persero). Based on the characteristics of DG directly connected to the distribution system, there is no need for a transmission system to deliver electricity. This is certainly very influential on the decrease in the voltage drop and the value of power losses. The method used in this research is power flow simulation using ETAP 16.0.0 software and analysis after getting simulation results. The findings of this study are the simulation results prove that the installation of DG affects the decrease in voltage drop and power losses in GNDH feeder, before installation of DG the voltage drop in GNDH is 10.1% and the value of power losses before DG installation is amounted to 446.5 kW. After the DG installation simulation, the optimal installation of two DGs is found on the TM 36 bus and the TM 42 bus with a decrease in the voltage drop to 1.18% and a power loss value to 117.2 kW.

1. Introduction
Electrical energy is one of the very important energies for humans to support all their activities. This is what causes dependence on electrical energy is increasing, while the availability of electrical energy sources that are not proportional to the number of needs [1]. To meet the availability of electrical energy, electricity distribution which consists of a generation system, transmission system, and distribution system is required. In general, large-scale conventional power plants from PLTA, PLTU, PLTG, PLTP, PLTB and so on are called centralized power plants [2]. Centralized or conventional power plants are usually located far from the center of the load so that they need a transmission system and a distribution system to deliver electricity. In the distribution of electrical energy, the distance between the plant and the load is quite far, causing a reduction in power, because at the time of distribution from the generator to the load there is a voltage drop and power losses [3].
Voltage drops and power losses are common in the Gunung Dukuh feeder or commonly referred to as the GNDH feeder at PT. PLN (Persero) Cimahi area. It certainly will disrupt service load, the load cannot work optimally even can cause damage to the electricity load and in the end will be very detrimental to all parties, both the electricity consumer and PT. PLN (Persero) [4].

Previous studies suggest that one way to minimize voltage drops and power losses in distribution systems is to install Distributed Generation (DG) at the right location and in the right size [5]. Distributed Generation (DG) can be defined as a small-scale power plant with capacities from several kilowatts to tens of megawatts connected to the distribution system and located close to the load center [6-8].

Based on the characteristics of the Distributed Generation (DG) which is connected directly to the distribution system, there is no need for a transmission system to transmit electrical energy. This is certainly very influential on the decrease in the voltage drop and the value of power losses. So that it can be considered the installation of Distributed Generation (DG) in the future to increase the efficiency of the distribution system.

2. Methods

2.1. Research flow
The flow of research on the analysis of impact installation of distributed generation in a 20 kV distribution system is shown with the research flow diagram in Figure 1.

![Figure 1. Research flowchart.](image)

2.2. Research locations and objects
The location of data collection in this study is at PT. PLN (Persero) Distribution of West Java Cimahi Area, located on Jl. Jend. H. Amir Machmud No. 675 Cimahi with the object of research is the Gunung Dukuh (GNDH) feeder connected to the Lagadar substation.

2.3. Research supporting data
In this study, the data obtained from the PLN Cimahi Area will be the main data for data processing, including the one-line diagram, distribution transformer data and introductory data contained in the GNDH feeder distribution network.

2.4. Data processing methods
The data in this study were simulated using the ETAP (Electrical Transient Analyzer Program) software version 16.0.0. ETAP is a software that serves to simplify the needs of electric power system simulations. This software can operate offline to run power system simulations, or online to control the system in real-time. ETAP has several supporting features for various types of simulation conditions,
one of which is Load Flow Analysis or also called power flow analysis. Power flow analysis is a study that displays the results of power flow performance in certain circumstances. The purpose of power flow analysis is to determine the active and reactive power flow in the channel, voltage profile, and power losses in the system.

The flow of using ETAP 16.0.0 for research on the analysis of impact installation of distributed generation in a 20 kV distribution system, in particular, the effect on the voltage drop and the GNDH feeder power losses is as follows:

2.4.1. Making one-line diagram. The first step in using ETAP 16.0.0 is the creation of a one-line diagram system by entering the GNDH feeder data that has been collected.

2.4.2. Entering parameters. In making One Line Diagram on ETAP 16.0.0, it is necessary to include parameters to support the simulation, such as power grids, cables, buses, transformers, lumped load and synchronous generators used.

2.4.3. Running load flow. After the parameters are entered, the next step is to run a load flow simulation.

After simulating one-line diagram of GNDH feeder, the author adds synchronous generator as DG (Distributed Generation) which is connected to the bus on the One Line Diagram of GNDH feeder, then re-running the power flow simulation (running load flow) then press the load flow analyzer or report tools manager to get the simulation results.

In this research, two scenarios are carried out to get the value of voltage drop and power losses as well as the optimal point of DG (Distributed Generation) installation on GNDH feeders. The first scenario is the installation of one DG (Distributed Generation) unit on selected buses while the second scenario is the installation of two DG units on two different buses. The simulation process is shown by the simulation flow diagram in Figure 2.

![Figure 2. Simulation flowchart.](image-url)
3. Results and discussion

3.1. Simulation results of GNDH feeder distribution network without DG

After simulating the power flow or running load flow of GNDH feeder before connecting with DG, the highest voltage drop value obtained from the report manager can be seen in Table 1.

| Device ID | Type   | Condition       | Rating/Limit | Unit | Operating | % Operating | Phase Type |
|-----------|--------|-----------------|--------------|------|-----------|-------------|------------|
| Bus TM 71 | Bus    | Under Voltage   | 20.000       | kV   | 17.98     | 89.9        | 3-Phase    |

Based on Table 1 obtained an operating voltage of 17.98 kV on the bus TM 71, the operating voltage is the lowest operating voltage from the simulation results, this shows that the highest voltage drop occurred on the bus. The operating voltage can also be referred to as the receiving voltage (Vr). Based on the results of calculations using equation 1, the voltage drop value is 2.02 kV or in percent form using equation 7, the voltage drop value is 10.1%.

The results of power losses obtained based on the simulations that have been carried out obtained the value of real power losses of 446.5 kW or 0.446 MW, to be clearer about the results of the value of real power losses can be seen in Table 2.

| Source (Swing Buses) | Power Losses (MW) |
|----------------------|-------------------|
|                      | 5.475             |
| Apparent Losses      | 0.0446            |

Based on the GNDH feeder simulation results before connecting with DG, the voltage drops and power losses that do not meet PLN standards are obtained, because the distance from the source (substation) to the bus TM 71 is the farthest. This is following equations 6 and 10 where distance is one of the factors that influence the voltage drop value.

3.2. Determination of DG capacity

Based on data obtained from the PLN Cimahi area, it is known that the total measured power distribution network of GNDH feeders is 6876,751 kVA or 6,876751 MVA with a power factor of 0.85. Therefore, the DG capacity value of 5,845 MW ≈ 6 MW is determined.

3.3. Simulation results of installing one DG unit on selected buses

In this simulation, one DG unit is connected to one bus. DG is placed at several points of the GNDH feeder bus to determine changes in voltage drop results and power losses. Following is the determination of the DG installation location on selected buses:

- DG installation on bus TM 17
- DG installation on bus TM 36
- DG installation on bus TM 42
- DG installation on bus TM 71
- DG installation on bus TM 73

For more details on the layout of the bus points on the one-line diagram of the GNDH feeder can be seen in Figure 3. The selection of the DG installation location on the buses above is because each bus represents certain conditions on the GNDH feeder, including:

- The closest distance from the source (substation).
- Position in the middle of the feeder.
- Position in one branch.
- Being on the edge of the branching.
- Position at the tip of the feeder.

The simulation of DG installation on selected buses in GNDH feeder is done by adding a synchronous generator as DG to the One Line Diagram created in ETAP 16.0.0 software. For example, for more details, DG installation on the bus TM 17 can be seen in Figure 3.

![Figure 3. Installation of a DG unit on bus TM 17.](image)

After simulating the power flow and getting the voltage drop and power losses on the GNDH feeder, the simulation is performed again on other buses that have been selected using the same capacity DG. After the simulation of DG installation on selected buses, the voltage drop values are as shown in Table 3 below:

| No | Installation of DG | Voltage Drop (%) |
|----|--------------------|------------------|
| 1  | Without DG         | 10,1             |
| 2  | Bus TM 17          | 8,21             |
| 3  | Bus TM 36          | 1,96             |
| 4  | Bus TM 42          | 1,81             |
| 5  | Bus TM 71          | 4,23             |
| 6  | Bus TM 73          | 3,45             |

For more details about the effect of DG installation on voltage drop at the selected bus point can be seen in Figure 4.

![Figure 4. GNDH feeder voltage drop bar diagram with installation of one dg unit.](image)
From the results of DG installation on selected buses, it is found that the voltage drops on bus TM 36, 42, 71, and 73 shows relatively small values with the acquisition of these values already meeting the standard values set by PLN. While the value obtained from the installation of DG on the bus TM 17 shows results that are not much different from the voltage drop value without using DG and still do not meet the standards set by PLN, this is because the location of the bus TM 17 is close to the source (substation). This causes the power supply sourced from DG to experience a large voltage drop because the distance from the bus TM 17 to the tip of the feeder is quite far as the distance from the GI to the feeder tip.

For the results of the value of power losses obtained after DG installation simulations on selected buses on GNDH feeders can be seen in Table 4.

Table 4. Value of power losses simulation results installation of one DG unit.

| No | Installation of DG | Power Losses (kW) |
|----|-------------------|--------------------|
| 1  | Without DG        | 446.5               |
| 2  | Bus TM 17         | 349.4               |
| 3  | Bus TM 36         | 138.9               |
| 4  | Bus TM 42         | 135.8               |
| 5  | Bus TM 71         | 266.1               |
| 6  | Bus TM 73         | 229.4               |

For more details about the results obtained from simulations that have been carried out regarding the value of the lowest power losses obtained by installing DG at the selected bus point can be seen in Figure 5.

![Power Losses Bar Chart](image)

Figure 5. GNDH feeder power losses value bar diagram by installing one DG unit.

From the results of DG installation on selected buses, it was found that the value of power losses on the bus TM 36, 42, 71, and 73 showed relatively small values. While the value obtained from the installation of DG on the TM 17 bus shows results that are not much different from the value of power losses without using DG, this is because the location of the bus TM 17 is close to the source (substation). This also causes the power supply sourced from DG to experience large power losses because the distance from the bus TM 17 to the tip of the feeder is quite far as the distance from the GI to the feeder tip.

After analyzing the results that have been obtained from the simulation of installation of one DG unit on selected buses, the optimum DG installation location is obtained to obtain the lowest voltage drop and power loss values as shown in Figure 5 and Figure 6, namely in bus TM 42 point with a voltage drop value of 1.81% and a power loss value of 135.8 kW. This is because the location of the bus TM 42 is almost in the middle of the feeder, so that when the power supply coming from the main source (substation) experiences a voltage drop and power losses, at the tip of the feeder there is no significant voltage drop due to the network getting an additional source from DG installed in the center of the feeder.
3.4. Simulation results of installing two dg units on two different buses

In this simulation, two DG units are connected on two different buses. The previous DG capacity of 6 MW was divided into two DG units, each of which had a capacity of 3 MW. The division into two DG units is carried out by placing each DG unit on a different bus.

The installation simulation of two DG units connected by two different buses to the GNDH feeder is done by adding two synchronous generators as DG to the One Line Diagram created in ETAP 16.0.0 software. For example, for more details, the installation of two DG units on the bus TM 17 and the bus TM 36 bus can be seen in Figure 6.

After simulating the power flow and getting the voltage drop and power losses on the GNDH feeder, the simulation is carried out again with other installation schemes that have been created using DG with the same capacity.

After simulating the installation of two DG units connected to two different buses in the GNDH feeder, the voltage drop values can be seen as shown in Table 5.

| No | Installation of DG                  | Voltage Drop (%) |
|----|-------------------------------------|------------------|
| 1  | Without DG                          | 10.1             |
| 2  | Bus TM 17 and Bus TM 36             | 1.96             |
| 3  | Bus TM 17 and Bus TM 42             | 1.42             |
| 4  | Bus TM 17 and Bus TM 71             | 3.61             |
| 5  | Bus TM 17 and Bus TM 73             | 2.84             |
| 6  | Bus TM 36 and Bus TM 42             | 1.18             |
| 7  | Bus TM 36 and Bus TM 71             | 1.18             |
| 8  | Bus TM 36 and Bus TM 73             | 1.18             |
| 9  | Bus TM 42 and Bus TM 71             | 1.81             |
| 10 | Bus TM 42 and Bus TM 73             | 1.81             |
| 11 | Bus TM 71 and Bus TM 73             | 3.36             |

For more details about the results of the lowest voltage drop value obtained from the installation of two DG units connected by two different buses can be seen in Figure 7.
Figure 7. GNDH feeder voltage drop bar diagram with installation of two DG units.

For the results of the value of power losses obtained after simulating the installation of two DG units on two different buses on GNDH feeders, see Table 6.

Table 6. Value of power losses results of installation simulation of two DG units.

| No | Installation of DG     | Voltage Drop (%) |
|----|------------------------|------------------|
| 1  | Without DG             | 446.5            |
| 2  | Bus TM 17 and Bus TM 36| 128.5            |
| 3  | Bus TM 17 and Bus TM 42| 119.6            |
| 4  | Bus TM 17 and Bus TM 71| 219.0            |
| 5  | Bus TM 17 and Bus TM 73| 191.1            |
| 6  | Bus TM 36 and Bus TM 42| 117.2            |
| 7  | Bus TM 36 and Bus TM 71| 126.5            |
| 8  | Bus TM 36 and Bus TM 73| 123.2            |
| 9  | Bus TM 42 and Bus TM 71| 132.8            |
| 10 | Bus TM 42 and Bus TM 73| 132.2            |
| 11 | Bus TM 71 and Bus TM 73| 221.9            |

For more details about the results obtained from simulations that have been carried out regarding the value of power losses by installing two DG units connected by two different buses can be seen in Figure 8 below.

Figure 8. Bar diagram of GNDH feeder power loss by installing two DG units.

After analyzing the results that have been obtained from the simulation of installing two DG units on two different buses, it is found that the most optimal DG installation location is to obtain the lowest voltage drop and power loss values as shown in Figure 8, namely on the bus TM 36 and bus TM 42 with a voltage drop value of 11.18% and a value of power losses of 117.2 kW. This is because the location of
the bus TM 36 and bus TM 42 is almost in the middle of the feeder so that when the electricity supply from the main source (substation) experiences a voltage drop and power losses, in the middle to the tip of the feeder there is no voltage drop significant because the network gets an additional source of DG installed on the bus TM 36 and bus TM 42, besides the distance between the bus TM 36 and the bus TM 42 also affects the voltage drop and power losses due to the distance between the two close together so that all parts of feeders GNDH accepts power supplies with very low voltage drops and power losses.

4. Conclusion
From the results of the analysis of impact installation of distributed generation in a 20 kv distribution system that has been carried out, it can be concluded that simulation results prove that the installation of Distributed Generation (DG) affects the decrease in voltage drop and power losses in GNDH (Gunung Dukuh) feeders. The voltage drop in the GNDH feeder before DG installation is 10.1%. Whereas after simulating the installation of one DG unit there was the greatest decrease if DG was installed on the TM 42 bus with a voltage drop of 1.81%. In addition to the simulation results after the installation of two DG units, the largest voltage drop occurred when DG was installed on the TM 36 bus and TM 42 bus with a voltage drop value of 1.18%. The value of power losses in GNDH feeders before DG installation is 446.5 kW. Whereas after simulating the installation of one DG unit there was the greatest decrease if DG was installed on the TM 42 bus with a value of power losses of 135.8 kW. Besides, for the simulation results after the installation of two DG units, the greatest reduction in power losses when DG is installed on the TM 36 bus and TM 42 bus with a power loss value of 117.2 kW. The value of voltage drops and power losses will decrease the most when two DG units are installed namely on the TM 36 bus and the TM 42 bus, then the optimal DG installation location is on the TM 36 bus and the TM 42 bus.

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