Optimal distributed generation placement to reduce power loss using Particle Swarm Optimization method

M G Firmansyah*, Y Mulyadi, H Hasbullah and A Saripudin

Department of Electrical Engineering Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Jawa Barat, Indonesia

*giri@student.upi.edu

Abstract. In electrical power systems, distribution networks have considerable power losses compared with the other parts of electrical power systems. This caused by the distance of power plant to the load center. The high value of power losses causing disadvantage for the electricity provider company. This study aims to reduce power losses in the MLBC feeder distribution network by erecting the distributed generation. The optimal location for erecting distributed generation sought by using the Particle Swarm Optimization (PSO) method. Before distributed generation erected in MLBC feeder distribution network, the power losses’ value is 128.1 kW. Locating the most optimum location for erecting the distributed generation is using the particle swarm optimization method, bus 13 on the MLBC feeder distribution network was the optimum location for distributed generation erection. Hence, the loss value from load flow simulation is 67.5 kW or 60.6 kW for power loss reduction after distributed generation installed on bus 13.

1. Introduction
As technology advances, electrical energy became a primary need in people's lives. Electrical energy generated on a large scale, centralized and located far from the load in general. It requires a transmission and distribution network to distribute electricity. Transmission and distribution network have a long structure that has impact on power losses and voltage drops. The power losses cause the efficiency of a network reduced, while voltage drops cause damage to consumer's electrical equipment. Therefore, installing a Distributed Generation will anticipate the effect.

Distributed Generation is a small-scale generator located near to the load center. Installation of distributed generation has positive impact. Reliability of the network, voltage profile and power quality will increase, while power losses can be reduced by installing distributed generation. Erecting distributed generation to the worst voltage profile in a system can cause positive impact to the system [1].

In this research, Particle Swarm Optimization method is used to obtain the smallest power losses value. Particle Swarm Optimization is a population-based stochastic algorithm for optimization which is based on social-psychological principles [2]. The simulation is done using ETAP and MATLAB software, so the optimal location of distributed generation can be obtained and the power losses can be reduced.
2. Methods
In 1995, James Kennedy and Russell Eberhart put forward a new method for completing nonlinear functions. Particle Swarm Optimization is similar to a Genetic Algorithms, in that the system is initialized with a population of random solution [3]. The basic of this algorithm inspired by social animals. This social relationship is a natural process for communicating with each other in groups that seek food and migrate together to a group such as groups of birds, bees and so on. When one group member gets the desired path, the other members will follow quickly [4].

In multi-variable optimization such as particle swarm optimization, a herd is considered to have a certain size and a random position for each particle in a multidimensional space. Each particle in the particle swarm optimization is considered to have two characters, that is position and speed. Each of these particles moves in a certain multidimensional space and each particle will remember the best position that the previous particle has passed. Each particle contained in a multi-dimensional space of the particle swarm optimization will transmit its best position to the other particles so that each particle will adjust its position and speed according to the information received regarding that position. Particle swarm optimization is an algorithm for finding minimum or maximum function values based on new populations. Particle swarm optimization has advantages in finding complex non-linear optimization values. This algorithm is proven to be able to find the best solution for optimization problems.

In this particle swarm optimization algorithm, it will use a several numbers that will used as a candidate location for connecting a distributed generation and realized into a data. A general flow of data analysis carried out in this research can be seen in Figure 1. This research begins with conducting literature studies and field studies to obtain the knowledge base needed in research. After that, a problem was raised to become a topic that would become the object of research. The minimum loss value after the installation of distributed generation is the purpose of this study. Furthermore, observations and data collection were carried out to support the research. After the data is collected, the data is processed using ETAP 16.0 and MATLAB r2017a software to get the desired results.

![Research flowchart](image)

**Figure 1.** Research flowchart.

The stages of the Particle Swarm Optimization program are as follows.

- Determine the swarm size, value, and particle speed randomly.
- Evaluate objective function from each particle.
- Determine Pbest and Gbest value.
• Calculate the particle speed from previous iteration by using this equation.

\[ V_j(i) = \theta V_j(i-1) + c_1 r_1 [P_{bestj} - X_j(i-1)] + c_2 r_2 [G_{bestj} - X_j(i-1)] \]  

(1)

where \( i \) is iteration, \( j \) is integer (1, 2, 3, 4, ..., N), and \( r_1 \) and \( r_2 \) are random values.

• Determine particle position and next iteration by using this equation.

\[ X_j(i) = X_j(i-1) + V_j(i) \]  

(2)

where \( X_j \) is next iteration particle’s position and \( V_j \) is next iteration particle’s speed.

• Evaluate again objective function from next iteration.

• Renew the value of Pbest and Gbest.

• Check whether the solution for optimization has been optimal or not. If it is optimal, the algorithm process will stop, but if not, the algorithm will return to step number 4.

3. Results

3.1. Load flow simulation before installation of distributed generation

Malangbong-Coklat feeder using a 20 kV distribution voltage that supplied from Malangbong substation. One-line diagram of Malangbong-Coklat feeder is shown in Figure 2. Afterwards, a power-flow simulation was performed using Newton-Raphson method using MATLAB r2017a software.

![Figure 2. One-line diagram of Malangbong-Coklat feeder’s.](image)

Table 1. Load flow simulation results before installation of distributed generation.

| No | Power          | kW   | Information         |
|----|----------------|------|---------------------|
| 1  | Total Power    | 3243.5 | Malangbong Substation |
|    | Injected       |      |                     |
| 2  | Power Loss     | 128.1 |                     |
Malangbong-Coklat has 38 buses that connected by 37 lines, there also 71 distribution transformator. The result load flow simulation is shown at Table 1. The total power supplied by Malangbong Substation in Malangbong-Coklat feeder is worth 3,243.5 kW, and the power loss value of the Malangbong-Coklat feeder is worth 128.1 kW.

3.2. Capacity of distributed generation
The capacity of the distributed generation to be installed is obtained from the total load that’s connected to the Malangbong-Coklat feeder. Based on Table 1, the total of load connected on Malangbong-Coklat feeder is 3,243.5 kW.

The distributed generation that will be installed in this simulation has power capacity of 4.7 MVA with a power factor of 0.85. To find the active power to be supplied can be calculated by Equation (3).

\[ P = S \cos \phi = 4.7 \times 10^6 \times 0.85 = 4.0 \text{ MW} \]  

(3)

The real power that will be supplied to the distribution network by a distributed generation is equal to 4.0 MW. This value is applied so the capacity of the distributed generation is not fully used.

3.3. Locating the optimal placement of distributed generation
Distributed Generation will be installed on one of the 38 buses on Malangbong-Coklat feeders. The optimal location of distributed generation installation will be sought using the Particle Swarm Optimization (PSO) method.

Table 2 displays bus data on Malangbong-Coklat distribution network that will be processed into input data in the MATLAB application. Meanwhile, Table 3 shows the line data of Malangbong-Coklat distribution network. It consists of from-to bus, line name, length, and the line impedance.

| Bus Number | Transformer | kW  | kVAR | Total kW | Total kVAR |
|------------|-------------|-----|------|----------|------------|
| Bus 2      | -           | -   | -    | -        | -          |
| Bus 3      | LMBD        | 38.4| 23.9 | 113.8    | 70.7       |
|            | LMBB        | 75.4| 46.8 |          |            |
| Bus 4      | BLBD        | 71.9| 44.6 | 418.6    | 259.5      |
|            | SPLL        | 159.3| 98.8 |        |            |
|            | BLB         | 187.4| 116.1|        |            |
| ...        | ...         | ... | ...  | ...      | ...        |
| Bus 36     | TON         | 41.6| 25.8 | 41.6    | 25.8       |
| Bus 37     | CGE         | 29.2| 18.1 | 29.2    | 18.1       |
| Bus 38     | RDUG        | 63.8| 39.6 | 63.8    | 39.6       |
| **Total**  | **3,441.8** | **2,133.8** |      |          |            |

| From Bus | To Bus | Line | Length (km) | R   | Xj  |
|----------|--------|------|-------------|-----|-----|
| 1        | 2      | E274 | 0.274       | 0.07252| 0.02611|
| 1        | 4      | G5998| 1.58750     | 2.48317|
| 2        | 3      | A257 | 0.285       | 0.28587| 0.30620|
| ...      | ...    | ...  | ...         | ...   |     |
| 35       | 36     | A264 | 0.29366     | 0.03146|
| 35       | 37     | A312 | 0.34705     | 0.03718|
After the bus and line data are processed, simulation of locating the optimal location of distributed generation can be done, the graph of power losses value after installation distributed generation, the location and capacity of installation of distributed generation that installed.

![DF Placement Optimization with the PSO Method](image)

**Figure 3.** Objective function graph to iteration in locating the optimal location of distributed generation simulation.

After 10 times of iterations, it was found that the optimal location for installing distributed generation is on bus 13. The objective function is the value of power loss after the installation of a distributed generation on bus 13 that is equal to 67.5 kW. Rating is the capacity of a distributed generation installed on bus 13 which is equal to 4 MW. While the number of particles is the number of particles used in the particle swarm optimization algorithm.

### 3.4. Load flow simulation after installation of distributed generation

Load flow simulation after installation of a distributed generation on bus 13 still using the Newton-Raphson method. After simulating the installation of distributed generation, the load flow simulation results obtained as shown in Table 4.

| No | Power | kW   | Information             |
|----|-------|------|-------------------------|
| 1  | Total Power Injected | 1881 | Malangbong Substation Distributed Generation |
|    |                  | 1450,746 |                        |
| 2  | Power Loss     | 67.5 | -                       |

### 4. Conclusions

The value of power losses in Malangbong-Coklat distribution network is equal to 128.1 kW. This power loss can be reduced by the installation of a distributed generation on the Malangbong-Coklat distribution network. After the load flow simulation and locating the optimum location for the installation of distributed generation using particle swarm optimization method, it was found that the most optimum location for distributed generation installation was bus 13 located in the Cibiuk area. Installation of distributed generation on bus 13 results in reduced power loss from before the installation of distributed generation. The power loss after installation of distributed generation is 67.5 kW, reduced by 60.6 kW or 47.3% from before the installation of distributed generation.
References

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