Effect of distributed generation installation on power loss using genetic algorithm method

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Abstract. Injection of the generator distributed in the distribution network can affect the power system significantly. The effect that occurs depends on the allocation of DG on each part of the distribution network. Implementation of this approach has been made to the IEEE 30 bus standard and shows the optimum location and size of the DG which shows a decrease in power losses in the system. This paper aims to show the impact of distributed generation on the distribution system losses. The main purpose of installing DG on a distribution system is to reduce power losses on the power system. Some problems in power systems that can be solved with the installation of DG, one of which will be explored in the use of DG in this study is to reduce the power loss in the transmission line. Simulation results from case studies on the IEEE 30 bus standard system show that the system power loss decreased from 5.7781 MW to 1,5757 MW or just 27.27%. The simulated DG is injected to the bus with the lowest voltage drop on the bus number 8.

1. Introduction

The need for electric power is now increasing due to the increasing demand for load due to the rapid economic growth. This economic growth is driving the acceleration of the industrial world to use equipment that requires more electrical energy. Therefore, the supply and quality of electrical energy needs to be improved. Electrical energy supply that there is generally a conventional power plant. Conventional power plants are generally designed on a large scale, centralized, and built away from load centers requiring transmission and distribution networks to supply electricity. Conventional electric power system consists of three parts, ie generation, transmission and distribution associated with the load.

Long transmission and distribution networks from power plants to load centers result in greater power losses, so technical efforts are required to reduce such losses such as network shortening, reconductor, insertion of the substation, capacitor installation, automatic voltage regulator (AVR ), Replacement of connectors and so on.

In recent decades, distributed generation began to be developed in the developed countries to support the electricity needs of the country. Distributed generation is considered as an appropriate solution to overcome the shortage of energy supply and to overcome the problem of power distribution systems such as power loss, the balance of the system, and also address the critical load that is experiencing drop voltage.

This scattered plant is a small-scale plant connected to a local distribution system often called "Distributed Generation" (DG). DG characteristic is small scale usually between 50 kW to 400 MW, distributed and close to load center (closed to load), interconnection
With distribution system. This distributed generation can be environmentally friendly plant, can limit the construction of new transmission lines, reliably in response to changes in load, reducing the use of fossil fuels, the deregulation of the electricity market and a number of other advantages [1].

CIGRE has defined the Distributed Generation as all generating units with a maximum capacity up to 50 MW range and coupled to the distribution network [2]. IEEE defines Distributed Generation as a generation that generates energy in a smaller capacity than conventional power stations and can be mounted almost at any point of the power system. IEA (2002) defines Distributed Generation as units that generate energy on the consumer side or in a local distribution network [3].

Distributed Generation is often referred to as the on-site generation, dispersed generation, embedded generation, decentralized generation, or distributed energy. Basically, DG generate electrical energy from some small-capacity energy source and connected directly to the distribution network.

Pepermans, J. et al defines DG as a generator connected to the transmission network [4], distribution or on the customer side. International Council on Large Electric Systems (1999) defines DG as:

- The plant is not centered
- Usually connected to network distribution system
- Capacity between 50 kW to 100 MW.

In the definition of distributed generating (DG) capacity there are different definitions and currently the definitions are used as follows:
1. The Electric Power Research Institute defines DG as a generator with a capacity of a few kilowatts to 50 MW.
2. Gas Research Institute defines DG as a generator with a capacity of between 25 kW and 25 MW.
3. Preston and Rastler determine DG sizes ranging from a few kilowatts to over 100 MW.
4. Cardell defines DG as a generator with a capacity of between 500 kW and 1 MW.
5. International Conference on Large High Voltage Electric Systems (CIGRE) defines DG as a generator with a capacity of between 50 and 100 MW.
6. However there was a presentation on the capacity of DG differentiated as follows [5]:
   7. Micro (1W to 5 kW),
   8. Small (5 kW up to 5 MW),
   9. Medium (5 MW up to 50 MW),
   10. Large (50 MW up to 300 MW).

DG placement can be done in substations and distribution can also be installed on the buses that directly supply the load. Before installing the need to analyze the impact of DG placement for buses which different needs to be done to determine where to place the best.

Due to the distributed power plants are located near load centers, the distributed generation in addition to directly serve a load requiring additional electrical energy can also be interconnected to the electricity distribution network to optimize the reliability of the distribution network. Based on the benefits and advantages of these distributed generators, the authors will simulate the location optimization and distributed generating capacity of a power distribution network in its effect on the minimization of the distribution network losses. The power distribution network used for this study is IEEE 30 bus test distribution system and the optimization method used genetic algorithm.

2. Methodology

2.1. Power Flow Calculation

Power flow calculations are paramount in planning, operating and developing systems, to obtain the operating characteristics of the generation or transmission system in steady state. In the power flow calculation, the operating system is assumed to be in the 3 phase equilibrium conditions, so that the calculation can be represented by a series of one phase that exists [6]. Components of the system
(generation, transmission, load, transformer, etc.) Are represented by the equivalent circuit and a bus in
the system that are classified into 3 parts:
1. Reference bus / Slack bus / Swing bus that has voltage magnitude parameter |V| And the phase
   shrinkage voltage(0),
2. Generator bus / control voltage bus / P-V bus which has active power parameter (P) and voltage
   magnitude |V|,
3. Load bus / P-Q bus having active power parameter (P) and reactive power (Q).

Generally formulated with:

The Newton Raphson method is used to solve nonlinear algebraic equations simultaneously from some
unknown variables with a linear approximation.

In the power flow study, many methods can be used, but the common and widely used method is Newton
Raphson.

2.2. Newton Raphson method in Power Flow Calculation

The Newton Raphson method is used to solve nonlinear algebraic equations simultaneously from some
unknown variables with a linear approximation.

Generally formulated with:

In equation above bus 1 as reference bus. The Jacobian matrix provides a linear comparison between
the changes in the voltage angle ΔV₁^(i) and the voltage magnitude (ΔP₁^(i)) with changes in active power
(ΔP₁^(i)). and reactive power (ΔQ₁^(i)).

In the simplest form of equation (4) can be written as follows:
\[
\begin{bmatrix}
\Delta P \\
\Delta Q \\
\end{bmatrix} = \begin{bmatrix} H & N \\ J & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\
\Delta |V| \\
\end{bmatrix}
\]  

(5)

The number of Jacobian matrix elements of equation (5) is determined by 
\((2n - 2 - m) \times (2n - 2 - m)\) where \(n\) is the number of buses on the system, while \(m\) is the number of buses on the system voltage control.

The value of \(\Delta P_k^{(i)}\) and \(\Delta Q_k^{(i)}\) is the difference between the scheduled value and the calculated value of power residuals:

\[
\Delta P_k^{(i)} = P_k^{\text{sch}} - P_k^{(i)}
\]  

(6)

\[
\Delta Q_k^{(i)} = Q_k^{\text{sch}} - Q_k^{(i)}
\]  

(7)

Correction bus voltage magnitude and angle with the general iteration \((i + 1)\) is:

\[
\delta_k^{(i+1)} = \delta_k^{(i)} + \Delta \delta_k^{(i)}
\]  

(8)

\[
|V_k^{(i+1)}| = |V_k^{(i)}| + \Delta |V_k^{(i)}|
\]  

(9)

This process stops until convergence:

\[
|V_k^{(i+1)} - V_k^{(i)}| \leq \epsilon
\]  

(10)

2.3. Genetic Algorithm

In a genetic algorithm, a set of parameters (an individual) or in biology is called a chromosome for a problem in this case is an object function, formed or encoded in binary form. And in each generation, a number of individuals (population) are evaluated in parallel to their matching, as the price of the object to be minimized. New and improved populations are generated from the old through the application of genetic operators such as selection, crossover, and mutation.

Selection is a simple operator to get the new chromosome from the most powerful. Strings that have a stronger fitness value have a greater chance of being selected and can follow the operations of other operators.

Crossovers randomly select a pair of parent and form two offspring through the corresponding segment exchange from the parent. Implementation of crossover is done on the genes of the two parent chromosomes which result in the genes from the two different mains combined into their new offspring.

Mutation is a random change from the position of the string. In a binary string presentation, a simple change means 0 to 1 and vice versa.

Operations are repeated until the specified number of generations has been reached. Genetic structure of the algorithm in out line as shown in Figures 1-3.

2.4. Research Steps

The steps in this research were conducted in two steps, first to determine the location of DG placement and the second is to determine the optimum DG capacity.

1. The first step calculating the power flow to the system tested using Newton Raphson method to get the condition of the voltage profile on the system bus.

2. From this first step can be determined the location where DG will be paired on the system with the indicator refers to the voltage profile on the bus that decreased below 0.9500 pu.

From the second step of this optimization calculation can already determine the capacity of DG to be installed on the distribution system.
Figure 1. Flowchart calculation of power flow using Newton Raphson method

Figure 2. Flow chart of a genetic algorithm
3. Results and Discussion

3.1 Calculation Before Optimization
Calculation of power flow by using Newton Raphson method to show the voltage profile on each bus and line power loss obtained the Table 1.

| Bus Number | Voltage Profile (p.u.) | Bus Number | Voltage Profile (p.u.) | Bus Number | Voltage Profile (p.u.) |
|------------|------------------------|------------|------------------------|------------|------------------------|
| 1          | 1.0000                 | 11         | 0.9727                 | 21         | 0.9916                 |
| 2          | 1.0000                 | 12         | 0.9804                 | 22         | 1.0000                 |
| 3          | 0.9731                 | 13         | 1.0000                 | 23         | 1.0000                 |
| 4          | 0.9687                 | 14         | 0.9693                 | 24         | 0.9847                 |
| 5          | 0.9736                 | 15         | 0.9737                 | 25         | 0.9870                 |
| 6          | 0.9593                 | 16         | 0.9704                 | 26         | 0.9633                 |
| 7          | 0.9522                 | 17         | 0.9702                 | 27         | 1.0000                 |
| 8          | **0.9424**             | 18         | 0.9587                 | 28         | 0.9605                 |
| 9          | 0.9727                 | 19         | 0.9547                 | 29         | 0.9730                 |
| 10         | 0.9802                 | 20         | 0.9599                 | 30         | 0.9575                 |
Figure 4. Graph of the voltage profile before optimization

Figure 4 shows graphically the voltage profile that occurred after the power flow analysis before the optimization, it is seen that the bus number 8 voltage profile below 0.9500 pu. It shows that under these conditions it is necessary to maintain the voltage profile of the bus going back well above 0.9500 pu. So that on bus 8 which is a load bus that has the lowest voltage magnitude is selected as the main location of DG installation. It is also possible to install DG on another bus which also has low voltage magnitude, but still on bus 8 also installed DG.

Table 2. Results of power flow analysis for power losses

| Line | From bus | To bus | MW    | MVAR  |
|------|----------|--------|-------|-------|
| 1    | 1        | 2      | 0.5849| 1.7547|
| 2    | 1        | 3      | 0.6134| 2.3308|
| 3    | 2        | 4      | 0.5074| 1.4376|
| 4    | 3        | 4      | 0.1009| 0.4037|
| 5    | 2        | 5      | 0.2672| 1.0688|
| 6    | 2        | 6      | 0.8029| 2.4086|
| 7    | 4        | 6      | 0.1697| 0.6788|
| 8    | 5        | 7      | 0.2806| 0.6734|
| 9    | 6        | 7      | 0.0333| 0.0888|
| 10   | 6        | 8      | 0.2375| 0.9499|
| 11   | 6        | 9      | 0.0000| 0.5711|
| 12   | 6        | 10     | 0.0000| 0.4973|
| 13   | 9        | 11     | 0.0000| 0.0000|
| 14   | 9        | 10     | 0.0000| 0.2992|
| 15   | 4        | 12     | 0.0000| 0.3462|
| 16   | 12       | 13     | 0.0000| 2.2304|
| 17   | 12       | 14     | 0.0707| 0.1532|
| 18   | 12       | 15     | 0.1548| 0.2874|
| 19   | 12       | 16     | 0.1122| 0.2493|
| 20   | 14       | 15     | 0.0057| 0.0052|
| 21   | 16       | 17     | 0.0388| 0.0920|
| 22   | 15       | 18     | 0.1348| 0.2697|
| 23   | 18       | 19     | 0.0267| 0.0578|
| 24   | 19       | 20     | 0.0184| 0.0430|
| 25   | 10       | 20     | 0.1057| 0.2466|
| 26   | 10       | 17     | 0.0421| 0.1122|
| 27   | 10       | 21     | 0.0923| 0.2153|
| 28   | 10       | 22     | 0.1099| 0.2356|
| 29   | 21       | 22     | 0.1441| 0.2883|
Power losses that occur before optimization can be shown in Table 2. Where it can be seen that the lowest loss of active power occurs in channel number 20 ie from bus 14 to bus 15 of 0.0057 MW. While the highest occurred in channel number 6 that is from bus 2 to bus 6 of 0.8029 MW. Total active power loss is 5.7781 MW.

### 3.2. Determination of Optimal Capacity DG
For this optimization step the maximum capacity referred is from DG type, ie from the intermediate type whose maximum capacity is 50 MW.

| Bus Number | Voltage Profile (p.u.) | Bus Number | Voltage Profile (p.u.) | Bus Number | Voltage Profile (p.u.) |
|------------|------------------------|------------|------------------------|------------|------------------------|
| 1          | 1.0000                 | 11         | 0.9951                 | 21         | 0.9944                 |
| 2          | 1.0000                 | 12         | 0.9902                 | 22         | 1.0000                 |
| 3          | 0.9972                 | 13         | 1.0000                 | 23         | 1.0000                 |
| 4          | 0.9972                 | 14         | 0.9804                 | 24         | 0.9847                 |
| 5          | 1.0022                 | 15         | 0.9880                 | 25         | 0.9870                 |
| 6          | 0.9996                 | 16         | 0.9816                 | 26         | 0.9633                 |
| 7          | 1.0005                 | 17         | 0.9826                 | 27         | 1.0000                 |
| 8          | 1.0029                 | 18         | 0.9960                 | 28         | 1.0012                 |
| 9          | 0.9951                 | 19         | 1.0048                 | 29         | 0.9730                 |
| 10         | 0.9929                 | 20         | 1.0007                 | 30         | 0.9575                 |

Referring to Table 3 it can be seen that by injecting DG on three buses are buses 8, 7, and 19, indicates that DG increases the system voltage profile. We can see in table 3 that there is no voltage profile on any bus that is below the allowed standard limit of 0.9500 pu. We can also note on bus number 8 which previously experienced a decrease of 0.9424 pu, after the optimization using genetic algorithm to be 1.0029pu. All voltage profiles are within the permitted limits of between 0.9500 pu to 1.0500 p.u.
In Figure 5 we can see that after the treatment with the installation of DG, seen voltage profile on bus number 8 is to rise above 1.0029. This shows that by adding DG to the voltage dropped bus and several other buses, this can improve the voltage profile of the bus, as well as fix some of the buses that have decreased as well.

**Table 4.** Results of the power flow analysis for total load and power generation

| Bus Number | Load | Generation |
|------------|------|------------|
|            | MW   | MVAR       | MW   | MVAR   |
| 1          | 28,2100 | 60,9700 | -0,8231 | 2,3194 |
| 2          | 3,1200 | 1,5600    |       |        |
| 3          | 9,8800 | 2,0800    |       |        |
| 4          | 3,1200 | 1,5600    |       |        |
| 5          | 29,6400 | 14,1700 |       |        |
| 6          | -43,4939 | -22,9205 | 50,0000 | 55,5514 |
| 7          | 7,5400 | 2,6000    |       |        |
| 8          | 14,5600 | 9,7500   |       |        |
| 9          | 8,0600 | 2,0800    |       |        |
| 10         | 10,6600 | 3,2500   |       |        |
| 11         | 4,5500 | 2,3400    |       |        |
| 12         | 11,7000 | 7,5400  |       |        |
| 13         | 2,8600 | 0,9100    |       |        |
| 14         | 22,7500 | 14,5600 |       |        |
| 15         | 4,5500 | 2,9900    |       |        |
| 16         | 4,1600 | 2,0800    | 19,2000 | 6,4892 |
| 17         | 4,1600 | 2,0800    | 19,2000 | 6,4892 |
| 18         | 11,3100 | 8,7100  |       |        |
| 19         | 13,7800 | 2,4700   |       |        |
| Generations Power | 166.6938 | 53.0763 |

**Figure 5.** Graph of the voltage profile after optimization
From the results of this power flow analysis also found that the total generation, loading and loss of power (losses) on the network shown in Table 4 The total amount of power generation is $P_{gen} = 166.6938$ MW and $Q_{gen} = 33.0763$ MVAR. Total loading for is $P_{load} = 165.1181$ MW and $Q_{load} = 63.5628$ MVAR. While the total loss of power (losses) we need to see is the loss of active power only that is equal to $P_{loss} = 1.5757$ MW (27.27%). And it is seen that there is a decrease in power losses when compared with before the optimization of 5.7781 MW.

4. Conclusions And Suggestion

4.1. Conclusions

The results of the power flow analysis show that indicating the existence of a critical bus that is bus number 8. This indicates that the plant is in the system can not serve the load burden. So it should be understood that there should be an additional generator with DG installation. Installation of DG from the simulation result is bus 8. The improvement of voltage profile obtained is that all buses are within the permissible limits and nothing is below or above the standard value. From the installation of DG can also be known that the power losses on the channel on the system to decrease to 1.5757 MW or only 27.27% of the previous value of 5.7781 MW.

4.2. Suggestion

The suggestions that can be put forward for future research, use and planning are as follows:
1. This research may be used as a good basis for advanced research related to Distributed Generation, genetic algorithms, and other issues related to this study.
2. It is possible that the research will be used in the power system as a reference in planning the installation of DG to solve the problem of decreasing the voltage magnitude on the system and also can reduce the power losses.

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