Distributed Generators Presence Impact to the Overall System Performance

Z Pane, S Suherman* and R Sipahutar
Electrical Engineering Department, Universitas Sumatera Utara, Indonesia

*suherman@usu.ac.id

Abstract. The presence of distributed generators (DG) are potentially reducing electrical losses, improving power quality and generating economic benefits. However, miss locating DG leads to system degradation including power quality, reliability, system control, losses and power regulation. This paper reports system analysis of distribution network in Dolok Sanggul as three DGs present. ETAP simulation was employed. The study reveals that Parilitan micro hydro generator produces excessive power. The optimum power is supposed to be 2234.079 kW instead of 7500 kW. By reducing the DG power, the active power losses are reduced from 941 kW to 233 kW, while the reactive power losses are reduced from 628 kVar to 455 kVar.

1. Introduction
Distributed generator (DG) is a power source directly connected to distributed network in customer side. Distributed generator installation is aimed at increasing power source, reducing losses, stabilizing voltage and improving power quality. Distributed generator location and size depend on the goal whether for voltage stabilization or losses reduction [1].

Its permitted maximum capacity depends on the network load. Methods in determining generator location and size have been using mathematical analysis [2], genetic algorithm (GA) [3], artificial bee colony [3] and other method. Newton-Raphson [4] has been used to present power flow solution [5]. The size of DG is classified as micro to large DG as shown in Table 1 [6].

| Table 1. DG classification. |
|-----------------------------|
| Capacity | Power (MW) |
| Micro     | <5 kW      |
| Small     | 5 kW - 5 MW|
| Medium    | 5 MW - 50 MW|
| Large     | 50 W - 500 MW|

DG are made up by the following technologies [7]:
- Internal Combustion Engines (ICE)
- Gas Turbine
- Combined Cycle Gas Turbines (CCGT)
- Micro turbines
In order to operate in a stable voltage, voltage in customer side should be in range of normal operation with +5% /-10% acceptable variations. Otherwise, customer equipment is inefficient [8] and easily broken. DG influences voltage profile. Figure 1 illustrates the impact.

The power from sender is represented by equation:

\[ S_0 = P_0 + jQ_0 \]

so the current equation is (Abdel-Akher, et al., 2011):

\[ \bar{I} = \frac{S_0}{U_0} = \frac{P_0-jQ_0}{U_0} \]  \hspace{1cm} (1)

In customer side, power is \( S_1 = P_1 + jQ_1 \) and the current:

\[ \bar{I} = \frac{S_1}{U_1} = \frac{P_1-jQ_1}{U_1} \]  \hspace{1cm} (2)

The voltage loss is defined as:

\[ \Delta U = \left| \frac{(RP_1 + XQ_1) - j(XP_1 - RQ_1)}{U_1} \right| \]  \hspace{1cm} (3)

For low power flow, equation s simplified to be:

\[ \Delta U \approx \frac{RP_1 + XQ_1}{U_1} \]  \hspace{1cm} (4)

The impact DG presence as in Figure 1b causes Equation to be:

\[ \Delta U \approx \frac{RP_1 + XQ_1}{U_1} \]

\[ \Delta U = \frac{R(P_1 - P_{DG}) + X(Q_1 - Q_{DG})}{U_1} \]  \hspace{1cm} (5)

---

- Fuel Cells
- Solar Photovoltaic (PV)
- Wind power
- Small Hydropower (SHP)
- Solar Thermal

---

a. Normal system
b. System with DG

Figure 1. Impact of DG presence.

Voltage profile swings as transmission parameter changes. Figure 2 shows voltage profile sample of DG presence. If $\Delta U$ is larger than 5%, system is unstabilized.

Figure 2. Impact of DG presence on voltage.

DG could help dealing with losses. As depicted in Figure 3 DG should generate power when losses minimum ($L_{\text{min}}$): $P_{DG,L\text{min}}$. The minimum loss is approximated by using Equation [9]:

$$L = \frac{(P_L-P_{DG})^2+(Q_L+Q_{DG})^2}{U^2} R$$  \hspace{1cm} (6)

This paper reports the analysis of DG impact on Dolok Sanggul Distribution network, and finding a solution to the emerged problem.
2. Research methods

Research is started by collecting data source and load within distribution network of 20 kV in Dolok Sanggul which has 3 DGs: PLTMH Aek Silang 750 kW, PLTMH Aek Sibundong 750 kW, and PLTMH Parlilitan 7500 kW. Total load 5058.54 kVA

This paper considers the most influential DG, which is in Parlilitan. One line diagram model of Dolok Sanggul Network is analysed (not shown). In general, the power and voltages are shown in Table 2.

By using the existing data, the stability index is calculated by using Equation:

$$L_j = \frac{1}{V_i^4} \left[ (P_iX - Q_iR)^2 + V_i^2 (P_iR + Q_iX) \right]$$  (7)

The stability index is employed to calculate the optimal capacity by using the following Equation:

$$P_{DG,j} = \frac{1}{2X^2} \left[ RV_i^2 + 2X^2 \left( P_{L,j} + \sum_{k \neq i,j}^{N} P_{j,k} \right) - 2Q_jRX \right]$$  (8)

The optimized DG performances are recalculated and compared to existing network.
**Table 2. Existing Data of Dolok Sanggul Network**

| Parameters                              | Quantity |
|-----------------------------------------|----------|
| Active power losses (∑kW)              | 941      |
| Reactive power losses (∑kVAR)           | 628      |
| Active power of GI (kW)                 | -3834    |
| Reactive power of GI DS (kVAR)          | 2400     |
| Active power Parlilitan (kW)            | 7500     |
| Reactive power Parlilitan (kVAR)        | 0        |
| Active power Aek Silang (kW)            | 750      |
| Reactive power Aek Silang (kVAR)        | 563      |
| Active power Aek Sibundong (kW)         | 750      |
| Reactive power Aek Sibundong (kVAR)     | 0        |
| \(V_{min}\) (%)                        | 95.16    |
| \(V_{max}\) (%)                        | 108.93   |
| \(\sum S_{beban}\) (kVA)              | 5058.54  |

3. **Results and discussion**

After analysing the stability index as well as DG capacity, the optimum size of DG Parlilitan is:

\[
P_{DGj} = \frac{1}{2X^2} \left[ R V_i^2 + 2X^2 \left( P_{Lj} + \sum_{k \neq i,j} N \right) - 2Q_{ij}RX \right]
\]

\[P_{DGj} = 2234.079\ kW\]

By reducing DG parlilitan from 7500 kW to 2234.079 kW, the performances increase. Figure 4 shows the performance of power and voltage comparison between existing system and the optimized DG capacity.

The active power losses are reduced from 941 kW to 233 kW, while the reactive power losses are reduced from 628 kVAR to 455 kVAR.

The existing system produces voltage swing from 95.16% to 108.93%, while the optimized version reduce voltage variation to be from 95.47% to 103.25%.

4. **Conclusions**

Distributed generator (DG) is potentially increasing voltage stability and reducing losses. However, miscalculation on its position and capacity degrades network stability.

In case of Dolok Sanggul distribution network, by optimizing the highest capacity DG out of 3 DGs, the optimum power is 2234.079 kW instead of 7500 kW.

DG power reduction results active power losses reduction from 941 kW to 233 kW, and reactive power losses reduction from 628 kVAR to 455 kVAR.

The voltage swing from maximum to minimum reduces from 13.77% to about 7.78%.
Figure 4. Performance comparison of before and after optimization.

References

[1] S Prabha, D R, Jayabarathi T, Umamageswari R and Saranya 2015 “Optimal location and sizing of distributed generation unit using intelligent water drop algorithm,” Sustain. Energy Technol. Assessments 11 106–113.

[2] S N Kefayat, M, Ara A L and Niaki 2015 “A hybrid of ant colony optimization and artificial bee colony algorithm for probabilistic optimal placement and sizing of distributed energy resources,” Energy Convers. Manag. 92 149–161.

[3] and S K G Singh, R K 2010 “Optimum Allocation of Distributed Generation Based on Nodal Pricing for Profit, Loss Reduction and Voltage Improvement Including Voltage Rise Issue,” in International Journal of Electric Power and Energy System 32.

[4] W D S Grainger, John J 1994 Power System Analysis (Mc-Graw-Hill, Inc).

[5] and H E-K Abdel-Akher, M, A A Ali, A M Eid 2011 “Optimal Size and Location of Distributed Generation Unit for Voltage Stability Enhancement,” in Energy Conversion Congress and Exposition (ECCE).

[6] Israfil 2012 “Optimal DG Allocation in Distributin System Employing Modified Artificial Bee Colony Algorithm to Reduce Losses and Improve Voltage Profile,”.

[7] F A Viawan 2006 “Steady State Operation and Control of Power Distribution Systems in the Presence of Distributed Generation,” p. Chalmers University of Technology.
[8] A H R and R F A IM Dunia, Suherman 2018 “Measuring the power consumption of social media applications on a mobile device,” *J. Phys. Conf. Ser.* **978** (1) 12104.

[9] P Kundur 1993 *Power System Stability and Control* (Newyork: McGraw-Hill, Inc).