Analysis of the impact of distributed generation injection to stability of 20 kV distribution network system

T Sucita* and Y Mulyadi
Department of Electrical Engineering Education, Indonesia University of Education, Bandung, Indonesia
*tasmasucita@upi.edu

Abstract. This study took a case study at PT. PLN (Persero) APJ Area Bandung with the subject raised is the installation of Distribution Generators on the distribution line of 20 kV. The purpose of this study was to determine the effect of generator installation Distribution of stability on a system of 20 kV distribution with load conditions is considered balanced. The reason for conducting this research is to find out how far DG can maintain stability on each bus. The method used in this study is to compare the results of the simulation of power flow and short circuit interference using ETAP Power System software. The results obtained from the power flow simulation before installation DG voltage drop at the end of the line. While the three phase short circuit fault current before the DG installation at the beginning of the line is x. After installation of DG with an injection of 50% power DG obtained a voltage drop at the end of the line of y and a fault current at the beginning of the line of z. While the injection of 90% of the power obtained by the voltage drop at the end of the line is v and the fault current at the beginning of the line is w. The results of the study show that with the injection of DG can increase the voltage profile on the line. Likewise, the interference current has increased, but it can be overcome by placing the location of the DG from the fault site.

1. Introduction
Large-capacity power plants are generally located far from the load center, so that a long transmission and distribution channel is needed. This causes a large voltage drop and power losses. On the other hand, the limited resources of fossil fuels which have many problems with the environment and the high operational costs of transmission systems and distribution systems encourage the development of small-scale power generation systems close to the load center. This system must be integrated with the grid system through a distribution network known as Distributed Generation. Generally Distributed Generation (DG) utilizes technology from renewable energy sources such as solar energy, wind energy, small-scale hydropower and can also use ICE (Internal Combustion Engine) technology [1].

In the past few years, the use of DG has had its own influence on the electric power system. The International Council on Large Electric System defines DG characteristics as a scale between 50 kW to 100 MW, distributed and close to the load center (closed to load), usually connected to a distribution network [2]. The plant is environmentally friendly, limiting the construction of new transmission networks, reliable in responding to load changes, reducing the use of fossil fuels. Some research on the impact of DG installation on electric power systems shows that DG has an impact on improving the voltage profile and decreasing power losses at the load center [3]. The method applied to the DG is almost the same as the use of capacitors to reduce power losses.
The main problem in this research is "how does the impact of injection of distributed generation on system stability, especially changes in voltage profile and short circuit fault currents on a 20 kV distribution network?"

2. Method
The procedure of the research steps is carried out as follows:

- Make a distribution system model at ETAP before adding DG.
- Enter data from field observations.
- After a complete and perfect model, simulates the flow of power.
- Set the location of the interference then simulate a short circuit current interference.
- Record the results of the simulation of power flow and short circuit interference before injection.
- Add DG to the distribution system model that has been created by first determining the location and injection capacity of DG.
- Re-simulate power flow and short circuit current interference.
- Record the results of the simulation of the power flow and the disturbance of short circuit current after the DG injection is recorded.
- Perform several simulations by varying the location and the amount of injection power DG.
- Analysis of data on short circuit current disturbances that have been recorded.
- Conclusion.

The process of simulation and analysis of this research can be seen in figure 1.

![Research flow chart](image-url)
Figure 2 is a case example of a single line distribution system diagram of 20 kV (North Bandung Substation).

Power grid impedance data, impedance at DG, conductors used, and data on power flow in the distribution channel of 20 kV NDJ-NDO feeders in Bandung area before and after injection of DG, can be seen in table 1.

Table 1. NDJ feed source impedance – NDO Bandung area.

| No | Side source of 20 kV | Reactance (%) | Reactance of 100% (Ω) | Reactance (Ω) |
|----|---------------------|----------------|-----------------------|---------------|
| 1  | Transformer 3 BDG UTR | 12.497 | 6.666 | 0.833 |
| 2  | Bengkok (Injection of 50%) | 9.988 | 177.778 | 17.756 |
| 3  | Bengkok (Injection of 90%) | 12.497 | 98.765 | 12.343 |

Size of Conductor of data distribution 20 kV NDJ feeder - NDO Bandung area can be seen in table 2.

Table 2. Delivery data for NDJ feeders - NDO Bandung area.

| No | Name of Line | Distance (Km) | Size of Conductor (Mm²) | Total Impedance R (Ω) | X (Ω) | sequence (+/-) R (Ω) | sequence (0) X (Ω) |
|----|--------------|---------------|-------------------------|-----------------------|-------|----------------------|---------------------|
| 1  | NDJ - UNP    | 0.521         | 3 X 150mm²              | 0.107                 | 0.054 | 0.185                | 0.163               |
| 2  | UNP - BCAS   | 0.521         | 3 X 150mm²              | 0.107                 | 0.054 | 0.185                | 0.163               |
| 3  | BCAS - TSB   | 1.203         | 3 X 240mm²              | 0.150                 | 0.117 | 0.331                | 0.035               |
| 4  | TSB - HHS    | 2.388         | 3 X 150mm²              | 0.492                 | 0.248 | 0.850                | 0.745               |
| 5  | HHS - CTB    | 0.438         | 3 X 150mm²              | 0.090                 | 0.046 | 0.156                | 0.137               |
| 6  | CTB - HVD    | 0.166         | 3 X 150mm²              | 0.034                 | 0.017 | 0.059                | 0.052               |
| 7  | HVD - BCAJ   | 0.355         | 3 X 240mm²              | 0.069                 | 0.054 | 0.153                | 0.016               |
| 8  | BCAJ - BM    | 0.413         | 3 X 150mm²              | 0.085                 | 0.043 | 0.147                | 0.129               |
| 9  | BM - BBR     | 0.135         | 3 X 240mm²              | 0.017                 | 0.013 | 0.037                | 0.004               |
| 10 | BM - CL      | 0.18          | 3 X 150mm²              | 0.037                 | 0.019 | 0.064                | 0.056               |
| 11 | CL - KTKS    | 0.19          | 3 X 150mm²              | 0.039                 | 0.020 | 0.068                | 0.059               |
| 12 | KTKS - BCAD  | 0.23          | 3 X 150mm²              | 0.047                 | 0.024 | 0.082                | 0.072               |
| 13 | BCAD - BB    | 0.416         | 3 X 150mm²              | 0.086                 | 0.043 | 0.148                | 0.130               |
| 14 | BB - BKS     | 0.064         | 3 X 240mm²              | 0.008                 | 0.006 | 0.018                | 0.002               |
| 15 | BB - EEP     | 0.318         | 3 X 150mm²              | 0.066                 | 0.033 | 0.113                | 0.099               |
| 16 | EEP - DKL    | 0.14          | 3 X 300mm²              | 0.014                 | 0.013 | 0.035                | 0.039               |
| 17 | DKL - DPZ    | 0.31          | 3 X 240mm²              | 0.039                 | 0.030 | 0.085                | 0.009               |
| 18 | DPZ - ABT    | 0.22          | 3 X 150mm²              | 0.045                 | 0.023 | 0.078                | 0.069               |
| 19 | ABT - GLL    | 0.335         | 3 X 150mm²              | 0.069                 | 0.035 | 0.119                | 0.105               |
| 20 | GLL - BIPA   | 0.387         | 3 X 150mm²              | 0.080                 | 0.040 | 0.138                | 0.121               |
3. Results and discussion

3.1. Results

The case study in this study is the distribution channel of 20 kV NDJ NDO Bandung area. The bus used for injection research case research is based on observations of researchers is the TM HHS bus. The TM HHS bus has a load of 67 kW, a total channel length of 4,633 km from the main harrow. Simulations on this bus are carried out with two scenarios, namely injection of 50% and 90% of DG capacity of 3600 kW. The location of injection of DG bus TM HHS can be seen in figure 3.

Figure 3. Injection of DG to bus TM HHS.

3.1.1. Voltage profile on the TM HHS bus. Power flow simulation is carried out after DG is injected on the network with 50% each of DG capacity or 1800 kW and 90% of DG capacity or 3240 kW. The simulation results of power flow on NDJ-NDO feeders after DG injection on the TM HHS bus are described in table 3.

Table 3. Voltage Profile before and after DG Injection on the TM HHS bus.

| No  | Bus         | Voltage Profile (kV) | Drop Voltage (%) |
|-----|-------------|----------------------|------------------|
|     |             | Without DG | Injection of DG | Without DG | Injection of DG |
|     |             |           | 50% 90% |           | 50% 90% |
| 1   | Bus TM NDJ  | 19,84     | 19,916 | 19,958 | 0.8 | 0.42 | 0.21 |
| 2   | Bus TM UNP  | 19,804    | 19,892 | 19,945 | 0.98 | 0.54 | 0.275 |
| 3   | Bus TM BCAS | 19,771    | 19,871 | 19,935 | 1.145 | 0.645 | 0.325 |
| 4   | Bus TM TSB  | 19,722    | 19,843 | 19,925 | 1.39 | 0.785 | 0.375 |
| 5   | Bus TM HHS  | 19,595    | 19,771 | 19,903 | 2.025 | 1.145 | 0.485 |
| 6   | Bus TM CTB  | 19,572    | 19,748 | 19,88 | 2.14 | 1.26 | 0.6 |
| 7   | Bus TM HVD  | 19,564    | 19,739 | 19,871 | 2.18 | 1.305 | 0.645 |
| 8   | Bus TM BCAJ | 19,553    | 19,714 | 19,845 | 2.235 | 1.43 | 0.775 |
| 9   | Bus TM BM   | 19,537    | 19,697 | 19,829 | 2.315 | 1.515 | 0.855 |
| 10  | Bus TM BBR  | 19,537    | 19,697 | 19,828 | 2.315 | 1.515 | 0.86 |
| 11  | Bus TM CL   | 19,531    | 19,691 | 19,823 | 2.345 | 1.545 | 0.885 |
| 12  | Bus TM KTKS | 19,526    | 19,696 | 19,817 | 2.37 | 1.52 | 0.915 |
| 13  | Bus TM BCAD | 19,52     | 19,68 | 19,811 | 2.4 | 1.6 | 0.945 |
| 14  | Bus TM BB   | 19,51     | 19,669 | 19,801 | 2.45 | 1.655 | 0.995 |
| 15  | Bus TM BKS  | 19,51     | 19,669 | 19,801 | 2.45 | 1.655 | 0.995 |
| 16  | Bus TM EEP  | 19,504    | 19,664 | 19,795 | 2.48 | 1.68 | 1.025 |
| 17  | Bus TM DKL  | 19,502    | 19,662 | 19,793 | 2.49 | 1.69 | 1.035 |
| 18  | Bus TM DPZ  | 19,499    | 19,658 | 19,79 | 2.505 | 1.71 | 1.05 |
| 19  | Bus TM ABT  | 19,497    | 19,657 | 19,788 | 2.515 | 1.715 | 1.06 |
| 20  | Bus TM GLL  | 19,497    | 19,657 | 19,788 | 2.515 | 1.715 | 1.06 |
| 21  | Bus TM BIPA | 19,497    | 19,657 | 19,788 | 2.515 | 1.715 | 1.06 |
Figure 8 shows the change in voltage profile on the power system at DG injected on the TM HHS bus with a capacity of 50% and 90% power from DG.

![Voltage Profile](image)

**Figure 4.** Changes in DG injection voltage profile on TM HHS buses.

Each injection provides an improvement in the stress profile of the entire system. The bigger the DG injection, the voltage profile increases as shown in Figure 4 where 50% injection of DG capacitance provides voltage improvement on TM NDJ bus at the beginning of the channel to 19.916 kV until the voltage at the end of the channel becomes 19.657 kV, and injection 90% of DG capacity provides repair of the voltage at the start of the channel to 19,958 kV until the voltage at the end of the channel becomes 19,788.

3.1.2. **Three phase short connect interference after of DG injection on TM HHS bus.** The simulation results of short circuit interference in the 3 phase system after DG installed on the TM HHS bus can be seen in Table 4.

| No | Disturbance Point | Short Circuit Interference Flow (kA) |
|----|-------------------|-------------------------------------|
|    |                   | Without DG  | 50%  | 90%  |
| 1  | Bus TM NDJ        | 13.43       | 14.08| 14.14|
| 2  | Bus TM UNP        | 12.45       | 13.09| 13.16|
| 3  | Bus TM BCAS       | 11.52       | 12.15| 12.21|
| 4  | Bus TM TSB        | 10.03       | 10.65| 10.71|
| 5  | Bus TM HHS        | 7.35        | 7.92 | 7.79 |
| 6  | Bus TM CTB        | 6.99        | 7.51 | 7.57 |
| 7  | Bus TM HVD        | 6.86        | 7.37 | 7.42 |
| 8  | Bus TM BCAJ       | 6.46        | 6.91 | 6.96 |
| 9  | Bus TM BM         | 6.18        | 6.60 | 6.64 |
| 10 | Bus TM BBR        | 6.12        | 6.53 | 6.51 |
| 11 | Bus TM CL         | 6.07        | 6.47 | 6.37 |
| 12 | Bus TM KTKS       | 5.95        | 6.34 | 6.38 |
| 13 | Bus TM BCAD       | 5.82        | 6.19 | 6.23 |
| 14 | Bus TM BB         | 5.59        | 5.94 | 5.97 |
| 15 | Bus TM BKS        | 5.57        | 5.91 | 5.94 |
| 16 | Bus TM EEP        | 5.43        | 5.75 | 5.79 |
| 17 | Bus TM DKL        | 5.38        | 5.71 | 5.74 |
| 18 | Bus TM DPZ        | 5.27        | 5.58 | 5.62 |
| 19 | Bus TM ABT        | 5.17        | 5.47 | 5.5  |
| 20 | Bus TM GLL        | 5.02        | 5.30 | 5.33 |
| 21 | Bus TM BIPA       | 4.86        | 5.13 | 5.15 |
Based on the simulation data with the ETAP program, it shows that there is a change in the fault current on the bus after the injection of DG. With 50% injection, the fault current on the TM NDJ bus at the beginning of the channel has increased from 13.43 kA to 14.05 kA, while by injection 90% of DG capacity has increased from 13.43 kA to 14.13 kA. The change in the magnitude of three phase short circuit fault currents on all buses after DG injection on TM HHS buses can be seen in figure 10.

3.2. Discussion
The discussion of the findings of this study can be explained as follows.

3.2.1. Impact of DG injection on the voltage profile
- In general DG injection on a 20 kV distribution network has the effect of decreasing the voltage drop so that the voltage profile on the channel is experienced. This condition can occur because each DG injection scenario on the channel changes the loading current on the channel. So that with a fixed value and a fixed receptor, the smaller loading current makes the voltage drop value smaller. The greater the DG power is injected, the lower the voltage drop on the channel so that the voltage profile will rise.
- DG injection point also has an effect on the value of voltage drop. It can be seen from the injection results on the TM HHS bus which is 4.633 km from the substation, with 90% injection the voltage drop value at the end of the channel is 1.06%. So that the closer the injection point DG to the end of the channel, the lower the voltage drop at the end of the channel.

3.2.2. Impact of DG injection on three phase short circuit disruption
- Based on several research results it has been known that one of the shortcomings of the interconnection system between the plants in the transmission system is the increase in the flow of short circuit faults. As with the distribution system, DG injection on the channel will result in an increase in short circuit fault currents on the channel.
- In general DG injection on a 20 kV distribution network system results in an increase in the large three-phase short circuit fault current. This condition can occur because when DG has not been installed in the system, the magnitude of the three phase short circuit fault only comes...
from the substation transformer impedance and the equivalent impedance of the source to the point of disturbance. Whereas after DG installed, the large impedance of DG and equivalent impedance DG towards the point of interference were taken into account. The load that was originally supplied from the power grid, with the presence of DG, the load will get a supply from the DG. The next impact is a decrease in channel impedance. In accordance with Ohm's law, the smaller the impedance, the greater the current.

4. Conclusion
Based on the findings of the research results, it can be concluded as follows.

- By giving DG injection on the distribution channel of 20 kV it will give a significant decrease in voltage drop on the channel so that the voltage profile on the channel increases. The increase in voltage profile clings to the DG injection point and the amount of injection power from DG.
- The increase in the average voltage value of the feeder is directly proportional to the amount of DG power injection in the feeder.
- With the injection of DG on the distribution channel of 20 kV, the short circuit fault current will be greater than without using the DG injection. The increase in three phase fault current depends on the amount of injection power from DG.
- The amount of the short circuit current that occurs at a point depends on the location of injection site DG. The farther the fault location of the DG injection, the smaller the interference current received due to the impedance of the output.

The recommendations of the research results are as follows.

- Further research can use more data so that the trend can be clearer.
- In addition, if you are still using ETAP software, use the latest version and the library for delivery used must be in accordance with the real conditions so that the results can be close to the actual results.
- To increase the research data, a simulation and calculation of power losses, one phase to ground short circuit, two phase, two phase to ground, and calculation of protection relay on the channel can be added. So the research results will be more accurate.

References
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