Reliability impact and assessment of distributed generation integration

R D N Sidik*, Y Mulyadi and B Trisno
Department of Electrical Engineering Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No.207 Bandung, Indonesia 40154

*rizaldaffa@student.upi.edu

Abstract. Distribution network is a part of an electric power system that has more intensity of failure than other parts of the power system. This is due to the close distribution network at the load which results in more factors that can be the cause of the failure. The more interference, the worse the reliability index. One effort to improve the feeder reliability index is by connecting Distributed Generation (DG) to feeders. In this study the effect of DG on the reliability index of Malangbong Chocolate (MLBC) feeders will be observed. MLBC is a power secondary substation in the district of Garut in West Java province, Indonesia. The method used in this study is to simulate the reliability of MLBC feeders before and after connecting with DG using the ETAP Power System 16.0 software. The results of the two simulations are then compared to see the effect of DG on the system reliability index. The results show that the SAIFI values before and after using DG connected to bus 4 and bus 5, are 3.8865 and 1.1802 per customer respectively. Whereas the value of SAIDI are 4.3079 and 1.1079 hours per customer in one year respectively. So it can be concluded, the use of DG on feeders can improve the reliability index of the system.

1. Introduction
The distribution network is the final part of the electric power system that carries electric power from the transmission line to each user. The distribution network has more interference intensity than other parts of the power system [1]. This is due to the proximity of the distribution network to the load, thus providing more factors causing disruption [2]. The more interference, the worse the system reliability index.

To determine the level of reliability of the distribution feeder, the reliability index parameter is used. Reliability indices that are commonly used in distribution networks are SAIFI (System Mean Disruption Frequency Index), SAIDI (System Mean Disruption Duration Index), and CAIDI (Average Customer Disruption Duration Index) [3].

One solution to improve the distribution network reliability index is Distributed Generation (DG) [4]. DG is a generator that is connected directly to the distribution network so that no new transmission line construction is needed [5]. In several previous studies it was stated that the application of DG is one of the most economical solutions to overcome the problem of electricity load growth, increased line power loss, and increased voltage drop [6-8].

This study focused on the impact of DG on the reliability index on Malangbong Chocolate feeders, which are power secondary substations in the district of Garut in West Java province, Indonesia. This research uses data from Indonesia Electricity Company in the district of Garut.
reliability index is simulated using ETAP 16.0 software. The most commonly used reliability index to show the reliability of electric power, and used in this study, are SAIFI and SAIDI [9].

2. Reliability index

2.1. SAIFI (System Average Interruption Frequency Index)
SAIFI is a reliability index that related to how many times interruption happens in one period of time. SAIFI can be defined by this equation [9]:

\[
SAIFI = \frac{\sum_i \lambda_i N_i}{N_t}
\]  

Notes:
\( \lambda_i \) = Failure rate (interruption per year)
\( N_i \) = Number of customers that have black out.
\( N_t \) = Number of customers that connected to feeder.

2.2. SAIDI (System Average Interruption Duration Index)
SAIDI is a reliability impact related to how long the blackout happens in one period of time. SAIDI can be defined by this equation [9]:

\[
SAIDI = \frac{U_i N_i}{N_t}
\]  

Notes:
\( U_i \) = Interruption duration (Hours)
\( N_i \) = Number of customers that have black out.
\( N_t \) = Number of customers that connected to feeder.

3. Methodology
This research was conducted using secondary data from PLN in Garut district. The data used are one-line diagrams from MLBC distribution feeder, conductor specifications, and interrupt recapitulation. The data is then used to make a one-line diagram of the MLBC feeder in ETAP 16.0 software and run a reliability assessment to obtain a reliability index.

3.1. Data input
This research is used data one-line diagram MLBC feeder, interruption recapitulation during 2018, and the number of loads that connected to MLBC feeders. Table 1 shown interruption data from 2018.

| No | Date       | Rec-sogoh | Duration (minutes) |
|----|------------|-----------|-------------------|
| 1  | 01/06/2018 | S.BBTS    | 60                |
| 2  | 01/06/2018 | S.BBTS    | 84                |
| 3  | 01/11/2018 | S.BBTS    | 6                 |
| 4  | 19/2/2018  | S.BBTS    | 47                |
| 5  | 17/4/2018  | S.BBTS    | 160               |
| 6  | 20/4/2018  | GH.WBK    | 202               |
| 7  | 27/4/2018  | S.BBTS    | 19                |
| 8  | 05/04/2018 | S.BGP     | 94                |
Table 1. Cont.

| No | Date       | Rec-ssogh | Duration (minutes) |
|----|------------|-----------|--------------------|
| 9  | 05/09/2018 | R.BLB     | 46                 |
| 10 | 05/12/2018 | S.BBTS    | 15                 |
| 11 | 13/5/2018  | S.BBTS    | 34                 |
| 12 | 14/5/2018  | S.CWNI    | 64                 |
| 13 | 25/7/2018  | S.CWNI    | 5                  |
| 14 | 26/7/2018  | S.NBK     | 29                 |
| 15 | 08/03/2018 | S.NBK     | 95                 |
| 16 | 08/03/2018 | R.BLB     | 101                |
| 17 | 25/8/2018  | R.BLB     | 88                 |
| 18 | 09/03/2018 | S.CWNI    | 35                 |
| 19 | 20/9/2018  | S.BBTS    | 26                 |
| 20 | 25/9/2018  | S.BBTS    | 20                 |
| 21 | 10/08/2018 | S.BBTS    | 51                 |
| 22 | 10/10/2018 | R.BLB     | 13                 |
| 23 | 23/10/2018 | R.BLB     | 18                 |
| 24 | 23/10/2018 | GH.WBK    | 116                |
| 25 | 24/10/2018 | S.BBTS    | 13                 |
| 26 | 25/10/2018 | R.BLB     | 0                  |
| 27 | 11/06/2018 | S.BBTS    | 62                 |

Total interuption | 1503

3.2. Simulation using ETAP 16.0
The simulation is done by entering the following data: the number of loads connected to the feeder, the number of customers, and the conductor specifications. Feeder configurations made are the same as radial one-line diagram configurations. Figure 1 shows the MLBC feeder in the ETAP software.
MLBC distribution feeders supply electricity to 72 distribution transformers with a total load and number of customers 2.8 MW and 30,862 customers respectively. Figure 2 shows a simple model of one-line diagram of MLBC feeders. MLBC feeders have 5 main busses each connected to different loads. Table 2 shows the number of loads and customers connected to each bus.

Figure 1. MLBC one-line diagram in ETAP 16.0.

Figure 2. Simple MLBC one-line diagram.
Table 2. Load ad customers data.

| NO | BUS | Load (kW) | Customers |
|----|-----|-----------|-----------|
| 1  | BUS 1 | 114.73 | 631 |
| 2  | BUS 2 | 2738.91 | 11640 |
| 3  | BUS 3 | 2402.65 | 11314 |
| 4  | BUS 4 | 894.12 | 4736 |
| 5  | BUS 5 | 448.41 | 2541 |
| TOTAL | | 2853.64 | 30862 |

Based on table 2, the total load connected to MLBC feeders is 2.8 MW, therefore the DG capacity that used in this research is 4 MVA.

In a study conducted by Ngaopitakkul et al, it was concluded that DG capacity and placement influence the reliability of feed distribution [5](Ngaopitakkul et al., 2013). The focus of this research is the impact of DG placement on the reliability of MLBC feeders.

DG placement is shown in figure 2 where the MLBC feeder has 5 main buses connected to the load. To determine the DG installation point, there are several things to consider, namely:

- Interruption location.
- Feeders configuration.
- Number of loads and customer connected.

After considering those points, the DG installation will be simulated with three different scenarios:

- One unit DG connected to one bus
- One unit DG connected between two bus.
- Two unit DG connected to two different bus.

4. Results and discussions

The simulation results are displayed in table number 3-5. Table 3 for the condition of one DG unit connected to one bus, table number 4 for the condition of one DG unit connected between two buses, and table number 5 for the condition of two DG units connected to two buses.

This study uses the SPLN 68-2 standard on reliability indexes for spindle configuration with Recloser. Based on these standards, the system is said to be reliable if the SAIFI value is less than 2.4 interruptions per year and the SAIDI value is less than 12.8 hours per year.

Table 3. One unit DG connected to one bus results.

| No | BUS | SAIFI(f/cs.yr) | SAIDI(hr/cs.yr) | CAIDI (hr/f) |
|----|-----|----------------|-----------------|--------------|
|    | without DG | 3.8865 | 4.3079 | 1.108 |
| 1  | 1   | 2.5817 | 2.1388 | 0.828 |
| 2  | 2   | 1.9866 | 1.7215 | 0.867 |
| 3  | 3   | 1.5171 | 1.3804 | 0.910 |
| 4  | 4   | 1.4428 | 1.3140 | 0.911 |
| 5  | 5   | 1.2545 | 1.1743 | 0.936 |

The simulation of MLBC feeders reliability index before connected to DG shows that SAIFI 3.8865 interruption per customer in one year and SAIDI 4.3079 hours per customer in one year.
DG simulation with the first scenario shows that the smallest reliability index is when DG is connected to bus number 5. In this condition, the reliability index decreases a lot with a SAIFI value of 1.2545 per customer in one year and SAIDI of 1.1743 hours per customer in one year. This happens because most disruptions occur near the MLBC substation, so that when the disturbance occurs, the feeder has a backup supply from DG that is connected to the bus.

Table 4. One unit DG connected between bus results.

| No | BUS | SAIFI (f/cs.yr) | SAIDI (hr/c.yr) | CAIDI (hr/f) |
|----|-----|----------------|----------------|-------------|
| 1  | 2   | 3.2162         | 3.8304         | 1.191       |
| 2  | 3 and 4 | 2.6598      | 3.3397         | 1.256       |
| 3  | 3 and 5 | 2.8446         | 3.4415         | 1.210       |
| 4  | 4 and 5 | 2.2423         | 2.5935         | 1.157       |

Table 4 shows the simulation results of DG installation between two buses. It appears that the installation of DG affects the reduction in SAIFI and SAIDI values of the MLBC feeder. The biggest decrease is when DG is connected between bus 4 and bus 5 with SAIFI 2,224 interruptions per year and SAIDI 2.5935 hours per interruption. This is because on bus 4 there are BBO SSO (Sectionalizer) buses and CWNI SSO which have a high failure rate in 2018. BBTS SSO has a failure rate of 1,083 failures per year and CWNI SSO has a failure rate of 0.25 failures per year. So, if there is a disruption to the SSO BBTS and SSO CWNI, the electricity supply will not be interrupted because it gets electricity supply through the connected DG.

Table 5. One unit DG connected between bus results.

| No | BUS | SAIFI (f/cs.yr) | SAIDI (hr/cs.yr) | CAIDI (hr/f) |
|----|-----|----------------|----------------|-------------|
| 1  | 2   | 1.9319         | 1.6775         | 0.868       |
| 2  | 3 and 4 | 1.4623       | 1.3363         | 0.914       |
| 3  | 3 and 5 | 1.3881         | 1.2700         | 0.915       |
| 4  | 4 and 5 | 1.1997         | 1.1303         | 0.942       |
| 5  | 2 and 3 | 1.5171         | 1.3804         | 0.910       |
| 6  | 2 and 4 | 1.4428         | 1.3140         | 0.911       |
| 7  | 2 and 5 | 1.2545         | 1.1743         | 0.936       |
| 8  | 3 and 4 | 1.4428         | 1.3140         | 0.911       |
| 9  | 3 and 5 | 1.2545         | 1.1743         | 0.936       |
| 10 | 4 and 5 | 1.1802         | 1.1079         | 0.939       |

Table 5 is the simulation result of DG installation between two buses. It appears that the installation of DG affects the reduction in the value of SAIFI and SAIDI for MLBC feeders. The biggest decrease is when DG is connected to bus 4 and bus 5 with a value of SAIFI 1,1802 disruptions per year and SAIDI 1,1079 hours per interruption. This condition occurs because in bus 4 there is a SSO BBTS (Sectionalizer) which has a high failure rate of 1,083 failures per year. Whereas on bus 5 there is a CWNI SSO which has a failure rate of 0.25 failures per year. So if there are disturbances in the SSO BBTS and
SSO CWNI, the electricity supply will not be interrupted because it receives an electricity supply from DG that is connected to each bus.

5. Conclusions

From the results of research and analysis can be concluded as follows:

- Distributed Generation installations on the MLBC feeder bus affect the feeder reliability index.
- Installing DG on an MLBC feeder can significantly reduce the system's reliability index.
- The scenario of installing two DG units on different buses gets the biggest decrease in the reliability index compared to the other two scenarios.
- The optimal DG position is on buses 4 and 5, where the reliability index value gives the best results.

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