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THE EFFECT OF DISTRIBUTED GENERATION (DG) PLACEMENT ON ELECTRICITY RELIABILITY

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Abstract

The continuity of the supply of electric power is becoming a greater demand from consumers. Feeder MRA05 GI Mrica Banjarnegara supplies electrical energy for parts of Banjarnegara Regency until 2020 has 4 distributed generations, namely PLTMH Sigebang 500 KW, PLTMH Kincang 320 KW, PLTMH Adipasir 320 KW, PLTMH Rakit 500 KW. Based on recorded data in 2020, the MRA05 feeder experienced 15 blackouts/year, with a total outage duration of 38.68 hours/year, of course it was enough to disrupt the continuity of the distribution of electrical energy to consumers. This research discusses the magnitude of the reliability index (SAIFI, SAIDI, CAIDI) when the DG is not installed and installed. The calculation of the magnitude of the reliability index was carried out using the Reliability Index Assessment (RIA) method, the calculation results were compared with the results of the ETAP 12.6.0 software simulation. The reliability index is based on the RIA method when DG is not installed, the SAIFI value is 2.96228 interruptions/year, the SAIDI value is 9.1185 hours/year, the CAIDI value is 3.078 hours/interruption, When DG is installed, the SAIFI value is 2.96228 disturbances/ year, the SAIDI value is 7.567 hours/year, the CAIDI value is 2.5546 hours/interruption.

Keywords— *Distributed Generation (DG), reliability index, ETAP 12.6.0*

INTRODUCTION

Feeder MRA05 GI Mrica Banjarnegara supplies electrical energy for the Rakit Banjarnegara District area, in 2020 there were 15 blackouts, with a total outage duration of 38.68 hours. As of 2020, Feeder MRA05 has 4 Distributed Generation (DG) units of the type of Micro-hydro Power Plant (PTMH), namely PLTMH Sigebang 500 KW, PLTMH Kincang 320 KW, PLTMH Adipasir 320 KW, PLTMH Rakit 500 KW.

DG is defined as a generator with a maximum capacity of up to 50 MW and distributed to the distribution network [1]. One of the advantages of having DG in a distribution network system is that it can help increase the reliability of the distribution network [2]. The reliability of the distribution network can be seen in the size of the reliability index on the network [3].

One of the methods to calculate the magnitude of the reliability index on the distribution network can use the Reliability Index Assessment (RIA) method. Functionally the RIA method will comprehensively record failures that occur in the equipment, then identify these failures, and analyze these failure modes, so that reliability indices will be produced on the distribution network [4].

Based on this background, the authors tried to conduct this study aiming to determine the effect of DG on the reliability index of MRA05 feeders using the RIA method and simulation using ETAP 12.6.0 software.

RESEARCH METHODS

1. Research Steps

This study aims to determine the magnitude of the reliability index on the MRA05 feeder when the DG condition is not installed and installed using the RIA method and ETAP simulation. The steps of this research are as follows:

a. Data collection

The data needed in this study were obtained from PT. PLN (Persero) Rayon Banjarnegara includes single line diagrams, distribution transformer data, blackout data in 2020 and other complementary data. In addition, there is also data from the literature on component failure rates and conductor impedances.

Table 1. Failure rate of distribution system components[5]

Component	Failure Rate	Repair Time (jam)
SUTM	0,2/km/year	3
SKTM	0,07/km/year	10
PMT	0,004/ units/year	10
Load switch	0,003/ units/year	10
Disconnect switch	0,003/ units/year	10
Back cover	0,005/ units/year	0,25
Cable connector	0,001/ units/year	15
Distribution transformer	0,005/ units/year	10
Network protector	0,005/ units/year	0,25
Low voltage rail	0,001/ units/year	10

Table 2. MRA05 feeder distribution transformer

No	Load Point	Location	Capacity (kVA)
1	load1	sigebang	50
2	load2	sigebang	50
3	load3	tapen	50
4	load4	lengkong	50
5	load5	lengkong	50
6	load6	lengkong	25
7	load7	lengkong	25
8	load8	lengkong	50
9	load9	lengkong	50
10	load10	lengkong	25
11	load11	badamita	50
12	load12	badamita	25
...	....	....	.....
143	load143	pingit	25
144	load144	pingit	50
145	load145	rakit	25
TOTAL			**6180**

Table 3. Channel length data on the MRA05 feeder

No	Component	Conductor length (km)
1	Line 1	0,25
2	Line 2	2,2
3	Line 3	0,15
4	Line 3.1	0,35
5	Line 3.2	0,6
6	Line 4	0,15
7	Line 5	0,3
8	Line 6	0,45
9	Line 6.1	0,35
10	Line 7	0,6
.....	....	......
.....	....	......
201	Line Kincang	0,35
202	Line Adipasir	0,35
203	Line Rakit	0,35
TOTAL		**87,563**

Table 4. MRA05 feeder loading data

Substation	Feeder	Current Rating (A)	Load Current (A)
Mrica	MRA05	400	175

From table 4 it can be used to determine the amount of loading used in the simulation with the following calculations.

$$\frac{\sqrt{3}VI_{load}}{S_{total\ trafo}} x\ 100\%$$
$$\%trafo = \frac{\sqrt{3}x x 20kV x 175\ A}{6180\ kVA} x100\%$$
$$\%trafo = \frac{6062}{6180} x100\%$$
$$\%trafo = 98\%$$

So that in the simulation the load used is 98% of the capacity of each distribution transformer.

Table 5. Blackout data on the MRA05 feeder

No	Date	Outage Time (hours)	Customer goes out
1	11 January 2020	5,28	11764
2	13 January 2020	3,23	11764
3	04 February 2020	2,25	11764
4	01 March 2020	3,58	11764
5	10 March 2020	3,23	11764
6	01 april 2020	4,17	11764

7	16 april 2020	0,65	11764
8	11 July 2020	1,47	11764
9	15 juli 2020	2,53	11764
10	26 juli 2020	1,63	11764
11	05 september 2020	0,80	11764
12	19 Octoberr 2020	3,67	11764
13	25 Octoberr 2020	1,25	11764
14	19 novemebr 2020	1,10	11764
15	26 December 2020	3,38	11764
TOTAL		**38,68**	

In table 5 above, the causes of blackouts were mostly caused by non-technical factors such as environmental, natural and other non-technical factors, namely 73.33%, while 26.67% were caused by component failures.

b. Depiction On ETAP 12.6.0

An overview of the MRA05 network on ETAP 12.6.0 is shown in Figure 1.

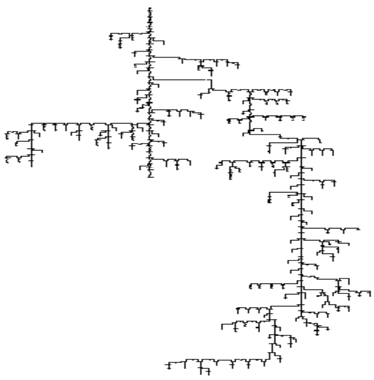


Figure 1. Depiction of MRA05 on ETAP 12.6.0

RESULTS AND DISCUSSION

1. When the DG condition is not installed

In this condition it is assumed that when there is a disturbance to the feeder, the PMT will trip, so that the load supply from the substation or substation to all load points is cut off, then all load points will be extinguished.

2. Calculations using the RIA Method

- Bus Failure Rate 3

The failure rate on bus 3 is influenced by the failure rate of bus 2, as well as the failure rate of the component going to bus 3, the component going to bus 3 is 0.25 SUTM and 1 ABSW. So the failure rate of bus 3 can be calculated as follows.

$\lambda_{LP} = \sum_{i=K} \lambda\text{i}$

$\lambda_3 = \lambda_2 + 0{,}25x\,\lambda_{SUTM} + \lambda_{ABSW}$

$\lambda_2 = 0 + 0{,}25x0{,}2 + 0{,}003$

$\lambda_2 = 0{,}053\ gangguan/tahun$

- Annual Bus Interruption Period 3

The duration of the disturbance on bus 3 is affected by the duration of the disturbance on bus 2, as well as the duration of the disturbance on the components that go to bus 3, the components that go to bus 3 are 0.25 SUTM and 1 ABSW. So the duration of bus 3 interruption can be calculated as follows.

$\mathrm{U_i} = \sum_{i=K} \lambda_i \; x \; r_j$

$\mathrm{U_3} = U_2 + \lambda_{Pmt1} x \; MTTR_{pmt1} +$

$0{,}25 \; x \; \lambda_{SUTM} \; x \; MTTR_{SUTM} + \lambda_{ABSW} \; x \; MTTR_{ABSW}$

$\mathrm{U_3} = 0 + (0{,}25x0{,}2x3) + (0{,}003x10)$

$\mathrm{U_3} = 0{,}18 \; hours/year$

The results of the calculation of the failure rate and annual disturbance duration above are summarized from all load points shown in Table 6.

Table 6. Summary of failure rate and annual disturbance duration at all load points

No.	Load Point	λ_i (f/year)	U_i (h/year)	L_i (KW)	N
1	Bus 1	0	0	0	0
2	Bus 2	0	0	0	0
3	Bus 3	0,053	0,18	0	0
4	Bus 4	0,493	1,5	0	0
5	Bus 5	0,523	1,59	0	0
6	Load-1	0,602	1,89	41,65	65
7	Load-2	0,722	2,25	41,65	47
8	Load-3	0,562	1,77	41,65	65
9	Load-4	0,785	2,46	41,65	141
10	Load-5	0,915	2,85	41,65	120
....	.....	.....	.....	....	....
....	.....	.....	.....	....	.....
149	Load-143	4,9446	15,00	20,825	65
150	Load-144	4,9546	15,03	41,65	65
TOTAL					**11764**

After the failure rate, annual disturbance time, power at the load point (Li) the number of customers (N) at each load point is obtained, then the SAIFI, SAIDI, CAIDI, ENS and AENS indexes can be calculated.

a. *System Average Interruption Frequency Index* (SAIFI)

$$\mathrm{SAIFI} = \frac{\sum \lambda_i N_i}{N_i}$$

$$\mathrm{SAIFI} = \frac{\sum((0x0) + (0x0) + \cdots + 4{,}9546)}{11764}$$

$$\mathrm{SAIFI} = 2{,}96228 \text{ interruption/year}$$

b. *System Average Interruption Duration Index* (SAIDI)

$$\mathrm{SAIDI} = \frac{\sum U_i N_i}{N_i}$$

$$\mathrm{SAIDI} = \frac{\sum((0x0) + (0x0) + \cdots + (15{,}03x65))}{11764}$$

$$\text{SAIDI} = 9{,}1185\ hours/year$$

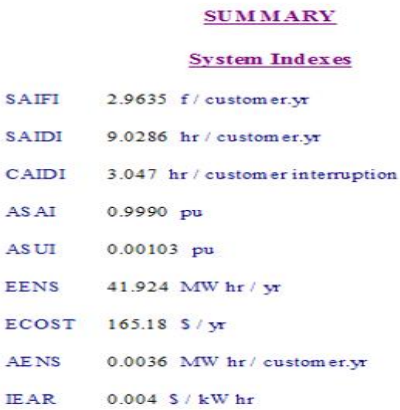
c. *Customer Average Interruption Durtion index* (CAIDI)

$$\text{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}} = \frac{9{,}1185}{2{,}96228}$$
$$= 3{,}078\ \text{jam/gangguan}$$

d. *Energy Not Supplied* (ENS)

$$\text{ENS} = \sum La(i).Ui$$
$$\text{ENS} = \sum 41{,}65x1{,}89 + 41{,}65x18{,}11562{,}25 + \cdots + 20{,}825x15 + 41{,}65x15{,}03$$
ENS =42,1842 MWh/year

3. Simulation Results on ETAP


SUMMARY

System Indexes

SAIFI	2.9635 f / customer.yr
SAIDI	9.0286 hr / customer.yr
CAIDI	3.047 hr / customer interruption
ASAI	0.9990 pu
ASUI	0.00103 pu
EENS	41.924 MW hr / yr
ECOST	165.18 $ / yr
AENS	0.0036 MW hr / customer.yr
IEAR	0.004 $ / kW hr

Figure 2. Simulation result reliability index

From Figure 2 it can be seen the reliability index of the MRA05 feeder where the SAIFI value is 2.9635 disturbances/year, the SAIDI value is 9.0286 hours/year, the CAIDI value is 3.047 hours/interference, the ENS value is 41.924 MWh/year, the AENS value is 0 ,0036 MWh/customer.

4. When the DG condition is installed

In this condition it is assumed that when there is a disturbance to the feeder, the PMT will trip, so that the load supply to the load point will be cut off, but in this condition not all load points on the feeder go out. The load point that restarts is caused by the presence of DG which can operate islanded system, with DG operating islanded system, DG will act as a replacement load supplier to connect DG to the load point and to separate the off load point from the load point to be supplied by DG with this islanded system scenario. DG cannot supply the load to the feeders as a whole, DG will only supply the load according to the load point in the islanded system scenario. Based on the single line diagram in the ETAP simulation, the islanded system scenario can be seen in table 7 below

a. *System Average Interruption Frequency Index* (SAIFI)
The magnitude of the SAIFI value when the DG is installed is the same as the SAIFI value when the DG is not installed, this is because in this feeder, one feeder only has one PMT, so wherever there is a disturbance in the feeder, the PMT will trip and all load points will turn

off. So that the presence of DG does not affect the SAIFI value, therefore the SAIFI value when DG is installed remains the same as when DG is not installed, i.e.

$$\mathrm{SAIFI} = \frac{\sum \lambda_i N_i}{N_i}$$

$$\mathrm{SAIFI} = 2{,}96228 \text{ interruption/year}$$

b. *System Average Interruption Duration Index* (SAIDI)

To be able to find the magnitude of the SAIDI value, first look for the duration of the disturbance at the load point in table 7 when DG operates an islanded system. because with DG operating an islanded system this causes the load point that should go out when the PMT trip becomes on, so the duration of the disturbance for the load point in table 8 when DG operates an islanded system I assume is 0 hours/year. So that the duration of the disturbance (U) at the load point in table 8 is only affected by the duration of the disturbance between the PMT trip and DG starting to operate the islanded system. The situation between the PMT trip and DG starting to operate in an islanded system is assumed to be the time required for the switching components (ABSW or LBS) to work to connect DG to the load point and to separate areas that are included in the islanded system scenario from areas that are not.

Table 7. Summary of annual disturbance length of all load points when DG is installed

No.	Load Point	U_i (h/year)	L_i (KW)	N
1	Load-1	0,15	41,65	65
2	Load-2	0,15	41,65	47
3	Load-3	0,15	41,65	65
4	Load-4	2,46	41,65	141
5	Load-5	2,85	41,65	120
....	.....	.....	....	....
144	Load-143	15,00	20,825	65
145	Load-144	15,03	41,65	65
TOTAL				11764

From table 7 above, the average blackout duration index experienced by customers in a one-year period (SAIDI) can be determined as follows.

$$\mathrm{SAIDI} = \frac{\sum U_i N_i}{N_i}$$

$$\mathrm{SAIDI} = \frac{\sum((0{,}15x65) + (0{,}15x47) + .. + (15{,}03x65))}{11764}$$

$$\mathrm{SAIDI} = 7{,}567 hours/year$$

c. *Customer Average Interruption Durtion index*(CAIDI)

$$\mathrm{CAIDI} = \frac{\mathrm{SAIDI}}{\mathrm{SAIFI}} = \frac{7{,}567}{2{,}96228}$$

$$= 3{,}233 \text{ hours/interruptions}$$

d. *Energy Not Supplied* (ENS)

$$\mathrm{ENS} = \sum La(i).Ui$$

$$\text{ENS} = \sum 41{,}65x0{,}15 + 41{,}65x0{,}15 + \cdots + 20{,}825x15{,}00 + 41{,}65x15{,}03$$

$$\text{ENS} = 35115{,}78557 \text{ KWh/year}$$

$$\text{ENS} = 35{,}11578 \text{ MWh/year}$$

$$\text{AENS} \quad = \frac{35{,}11578}{11764} = 0{,}0029 \ \text{MWh/pelanggan}$$

5. Comparison of calculation results using the RIA method and simulation results when DG is not installed with real data calculations in the field

Table 8. Comparison of calculation results using the RIA method and ETAP simulation with real data in the field

Reliability Index	**RIA**	**ETAP**	**Field Data**
SAIFI	2,96228	2,9635	15
SAIDI	9,1185	9,0286	38,68
CAIDI	3,078	3,047	2,5788
ENS	42,1842	41,924	199,139
AENS	0,00358	0,0029	1,373

From table 8 it can be seen that the reliability index of the results of data calculations in the field has a difference compared to the reliability index of the results of calculations using the RIA method and the results of the ETAP simulation. Where the SAIFI value using the RIA method is 2.96228 disturbances/year, the ETAP simulation is 2.9635 disturbances/year, while field data calculations are 15 disturbances/year. The SAIDI value using the RIA method was 9.1185 hours/year, in the ETAP simulation it was 9.0286 hours/year, while field data calculations were 38.68 hours/year. The CAIDI value using the RIA method was 3.078 hours/disturbance, in the ETAP simulation it was 3.047 hours/disturbance, while field data calculations were 2.5788 hours/disturbance. The ENS value using the RIA method is 42.1842 MWh/year, in the ETAP simulation it is 41.924 MWh/year, while the field data calculation is 199.139 MWh/year. The AENS value using the RIA method is 0.00358 MWh/customer, the simulation on ETAP is 41.924 MWh/customer, while the calculation of field data is 1.373 MWh/customer

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6. Comparison of calculations when DG is not installed and installed.

Table 9. Comparison of calculation results when DG is not installed and installed

Reliability Index	**DG is not installed**	**DG installed**
SAIFI	2,96228	2,96228
SAIDI	9,1185	7,567
CAIDI	3,078	2,5546
ENS	42,1842	35,11578
AENS	0,00358	0,0029

Table 9 above shows the simulation results of the reliability index when DG is not installed and installed. Where the value of SAIFI when DG is not installed is 18.1156 interruptions/year, while when DG is installed it is 18.1156 disturbances/year, SAIDI value when DG is not installed is 58.5678 hours/year, when DG is installed is 47.404 hours/year ,. The CAIDI value when DG is not installed is 3.233 hours/interruption, when DG is installed it is 2.616 hours/interruption. The ENS value when DG is not installed is 301.5035 MWh/year, when DG is installed it is 247.975 MWh/year. The AENS value when DG is not installed is 2.0793 MWh/customer, when DG is installed it is 1.710 MWh/year. From table 14 it can be concluded that the presence of DG installed can increase the reliability of the MRA05 feeder. It can be seen by the smaller value of the SAIDI, CAIDI, ENS and AENS reliability indexes. Meanwhile, the value of SAIFI does not change when the DG is not installed and installed, this is because the feeder only has one PMT, so wherever there is a disturbance in the feeder, the PMT will trip. Thus, the calculation results are in accordance with the existing theory.

CONCLUSION

Based on the results of calculations and analyzes that were carried out when DG conditions were not installed using the Reliability Index Assessment (RIA) method, the magnitude of the reliability index on the MRA05 feeder was a SAIFI of 2.96228 disturbances/year, SAIDI of 9.1185 hours/year, CAIDI of 3.078 hours/customer, ENS of 42.1842 MWh/year, AENS of 0.00358 MWh/customer. In the DG condition installed using the RIA method, the magnitude of the reliability index on the MRA05 feeder is SAIFI of 2.9635 disturbances/year, SAIDI of 7.567 hours/year,

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