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Evaluation of Distribution System Reliability in the presence of multiple DGs

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ABSTRACT

The distribution system is prone to failures and disturbances due to component failures. Distributed generation (DG) acts as a backup sources to ensure the reliability of electric power supplies. In this paper, proposed an analytical method which is a conditional probability approach. This method used to find the reliability indices of RBTS Bus-2 with multiple DGs. The value of DG locating as a backup generator is quantified in terms of its contribution to the reliability improvement in a distribution network. The reliability improvement is observed based on reliability indices that include SAIFI, SAIDI, CAIDI and ENS. In addition, the value of DG installed at various locations on the feeder from the substation, as well as the impacts of installing, aggregated DGs and multiple DGs are presented. Therefore, distributed generation is expected to play a key role in the industrial, commercial and residential, sectors of the distribution system.

1. Introduction

Distributed generation is the part of the electric power system, which is a power flow from the bulk power source to the consumers' facilities. The distribution network is divided into sub transmission and radial / meshed segments. In the distribution system, outages about 80% are occurred due to either faults or components failure i.e. lifetime ended. With an outages effects, the distribution network need to individual contribution to outages effects, in order to minimize the numbers and duration of the customer failure. The numbers and duration of customer failure rate can be treated as reliability indices at load points. These indices tend to about the overall system performance indices. In fact, that, electrical industry is developed power by the conventional with limited capacity of DG and renewable sources and it can be transmit power from one place to other

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consumers' loads. This become may be in competitive structure, when the environmental conditions and maintenance of lines can be changed including the financial assessments of electricity regulations.

In view of above scenario, the customer load points need to alternative supply from other source. In this case, suitable distributed generation (DG) has provided supply to customer load points. Basically, the DG technologies are divided in to two types ; firstly, renewable energy source and second is continuous fuel source. The distribution system reliability indices measured in terms of SAIFI, SAIDI, CAIDI and ENS, the IEEE standard for reliability indices [1][2] and definitions related to them, were presented. The reliability modeling technique by connecting through DG on the distribution network has presented [3]. This is not totally explored the reliability improvement and it deals with backup applications in the system including the less numbers and durations of interruptions. In [4], the author performed a survey of the distribution system reliability indices practices in the US. The results indicated that SAIDI, SAIFI, CAIDI and ASAI where the used indices. The paper also discussed outage interruptions and their roles in reliability calculation. The calculation reliability indices can be calculated by using commercial software. The reliability of distribution network with WTG can determine by sequential simulation technique has been addressed in [5]. This analysis showed included time varying wind speed, random failure of WTG and cost worth of repair in distribution network. This is not useful for the reliability improvement such as terms of indices. In [6], the DG modeling techniques is applied to a radial distribution network using commercial software tools that indicate improvement in the distribution system reliability indices. The author performed reliability of the system with effect of intrinsic attributes of DG, its failure, and load demand changed in season wise is depends on frequency and duration method [7]. The paper also presented many factors were considered for the reliability indices calculation in the proposed technique. The reliability of network can have calculated in according to frequency and duration technique has showed in [8]. In this case, improvement in reliability does not affect system performance. In [9], an analytical and probabilistic approach is used to determine the reliability of distribution network by considering the momentary interruptions. Furthermore, this paper deals with cost evaluation technique that unifies sustained and momentary interruption costs. In [10], the authors performed the impact of DG on Iranian distribution network reliability. In this case, an analysis of distribution system reliability indices has been changed to location of DG. In [11], the author presented the impact of DG on reliability, losses and voltage profile of the system. The paper also contained that reliability indices could be improved by properly allocating DG into the distribution system. Properly coordinated distributed generation which is positive impact on the system.

The author presented the reliability modeling according from aging components in the systems and including the history of components and its failure in the systems has been presented in [12]. The paper showed a MCS method could be used to model of history of working, failure of system and stochastic point process. In [13], the author showed the intentional islanding impacts of DG for the reliability improvement in the distribution network. The paper also contained basic results of continuing studies for a range of sensitivity analysis and alternate configurations. The author of [15], studied a validation method for the reliability model. The paper also presented model given component reliability data so that the predicted values of reliability indices compare with the historical data. The reliability of network by using the analytical method and MC simulation has been results addressed in [16]. In analytical method, network reliability parameters are used in mathematically modeling; it is often simplified, and evaluates indices. This paper, proposes an analytical method is used to calculate reliability indices such as SAIFI, SAIDI, CAIDI and ENS in radial distribution network with DG. The conditional probability method based on failure mode and effect analysis (FMEA) is proposed to evaluate reliability of the distribution system. The proposed method is applied to IEEE RBTS BUS-2 with DG. The test system can be performed in three cases. Firstly, distribution system without DG secondly, distribution system with multiple DGs sizes, thirdly, distribution system with aggregated DGs versus multiple DGs.

2. Distribution system reliability indices

Now in this section, discusses reliability evaluation technique is applied to the distribution system.

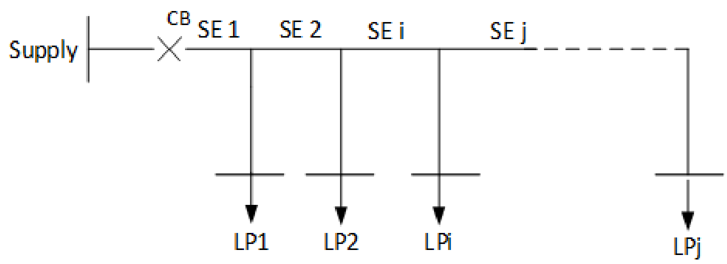

Fig. 1 – Distribution network

In general, the distribution network reliability such as load point reliability and system reliability are determined using the minimal cut set technique [17] The three basic reliability parameters are average failure rate (λ_s), average outage time (r_s), and average annual outage (U_s), is given by

$$\lambda_s = \sum_{i=1}^{N} \lambda_i f/yr \tag{1}$$

$$U_s = \sum_{i=1}^{N} \lambda_i r_i hrs/yr \tag{2}$$

$$r_s = \frac{U_s}{\lambda_s} hrshrs \tag{3}$$

Where, λ_i is the failure rate of components i and r_i is the repair time of component i. System Average Interruption Frequency Index (SAIFI) :

$$\text{SAIFI} = \frac{\sum \lambda_i N_i}{\sum N_i} \text{(int./yr.cust)} \tag{4}$$

Where, λ_i be the failure rate, N_i be the number of customers at load point i. [17], [14]
System Average Interruption Duration Index (SAIDI) :

$$\text{SAIDI} = \frac{\sum U_i N_i}{\sum N_i} \text{ (hrs./yr.cust)} \tag{5}$$

Where, U_i is the annual outage time and N_i is the number of customers at load point i.
Customer Average Interruption Duration Index (CAIDI) :

$$CAIDI = SAIDI/SIFI \tag{6}$$

Energy not supplied (ENS) :

$$ENS = \sum La(i)U_i$$

Where, $La(i)$ is the average load connected to load point i.

3. DG modeling and evaluation technique

Now consider a simple radial system with protection fuses on the laterals, as shown in Fig. 2.

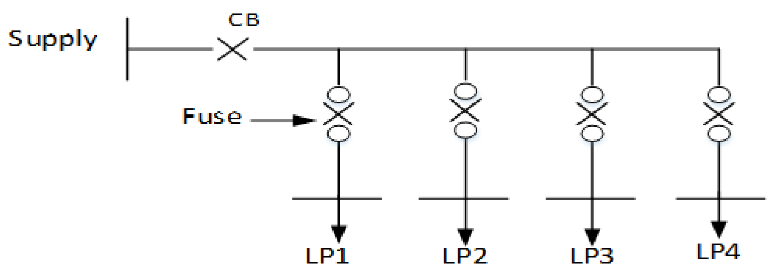

Fig. 2 – A simple radial system with no disconnects on the main line

In this section, no disconnects on the main line and if any sections or components on the main distribution line fails; it results to show power interruptions to in all the distributor laterals. Due to interruptions, numbers of customers has supplying losses from the substation. This instant, installing a DG on the main distribution feeder and this will not improve the system reliability because a failed section on the main lines cannot be isolated when the distribution feeder has without disconnecting the line. Therefore, the failed section is isolated from using disconnects switches and these adding to the main distribution line. Once disconnects has been presented in the feeder, which function causes the isolated to the failed sections in the rest of the loads on the feeder [16] loads are supplied by both the substation and DG. Fig.3 shows the same circuit, adding disconnects in the main line. The failed section has isolated and the rest of the loads can be supplied with both the substation and DG when the disconnecting is adding to the distribution feeder.

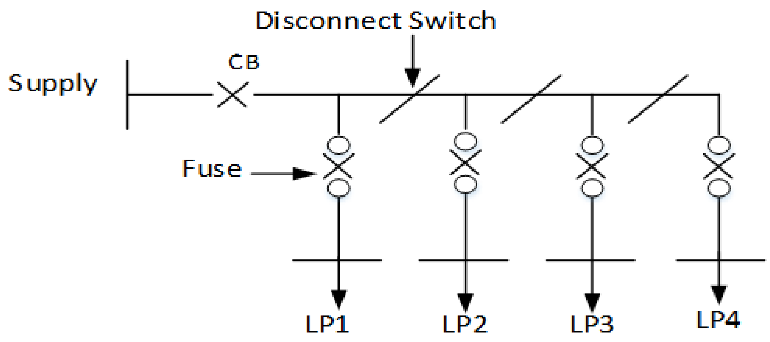

Fig. 3 – A Simple radial system with disconnects on the main line

The modelling concept used in the distribution system with DG as shown in Fig.4

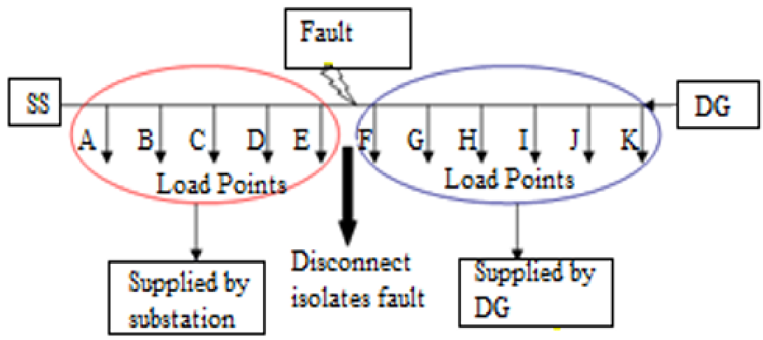

Fig. 4 – Distribution system supplied with DG

In this case, if the main section F of distribution feeder is failing, then the remaining sections A – E, is protected from the fault using disconnects and this will have a continuous power supply from the substation. There is no supply to sections F-K from the substation. At this instant, introduces DG is installed in section F ; then DG will serve a supply to load F and further downstream loads in an islanded mode. After supplying the downstream loads, the DG still has reaming DG power. This supply is to upstream loads in the distribution network. In case of adding a distributed generation near to the substation, that will have no effect on the reliability of the system since the DG will act as an additional source of the system. However, the power interruptions are occurred in the main substation, and then the DGs can be used to supply the system. The repair time of the main sections has changed where the DG connected with distribution feeder. Therefore, repair time calculated using the conditional probability approaches form as

$$\begin{aligned}\text{Outage time} &= (\text{outagetime}/\text{transfer}) * P(\text{of transfer}) \\ &\quad + (\text{Outage Time}/\text{no transfer}) * P(\text{of no transfer})\end{aligned} \tag{7}$$

However, the DGs failure rate is 10%, hence the outage time for the load point is

$$\begin{aligned}\text{Outage time} &= [\text{DG available}](\text{outage time} * \text{availability of DG}) \\ &\quad + [\text{DG fail}](\text{outage time} * \text{no transfer})\end{aligned} \tag{8}$$

Hence, if any section A-E fails, the DG will supply power to x% loads on load point E. Therefore, the repair time will be reduced from 5 hr to r (decreased).

4. Case study

The following assumptions are considered for this analysis : The failure rate for sections in the main distribution line and distributed laterals is 0.0650 f/ km-yr. Disconnects, transformers and fuses are 100% available; however, the DG's failure rate is 10%. The total isolation and switching time is 0.5hrs. The repair time for each section is 5 hours while that for each distributor lateral is 2 hours. DGs are to be installed in our circuit is used as backup generators. In this section, the proposed technique is applied to IEEE RBTS- BUS-2, which is a four feeders and number of loads 22[16]. In this case study, the numbers of loads with respect to feeders are treated as under a single feeder.

Three case studies are discussed. Firstly, the distribution feeder without disconnecting and with disconnect from the system no DG is quantified, as discussed in subsection 1. Secondly, system reliability indices resulting in multiple distributed DG units (3MW, 5MW and 7MW) located in several locations such as A, B and C across the distribution system and comparison of DGs as discussed in subsection 2. In the subsection 2, the DG location A at 5th load into RBTS BUS-2, it is near to the substation and DG location B at 10th load with RBTS-BUS 2 and DG location C at 22nd load, it is the end of the feeder. Thirdly, system reliability indices resulting from installing an aggregated DG unit (3 MW) and multiple three DG units (1 MW x3) are located at the same locations and also compared of these DGs. This Concept discussed in subsection 3.

4.1. Reliability analysis without DG

In this subsection, we observed the reliability indices of distribution feeder without disconnecting and disconnecting in the distribution feeder. The reliability indices such as SAIFI, SAIDI, CAIDI and ENS are shown in Table 1. SAIFI is improved from 2.2024 f/yr to 1.074 f/yr, which represents 51% improvements in SAIFI. SAIDI is improves from 6.9842 hr/yr to 2.7972, which indicates that 59% improvement in SAIDI. And also CAIDI is improves from 3.1711 hr to 2.6044 hr, which represents a 17% improvement in CADI. Finally, ENS is improved from 86.922 to 36.394. % improvements of all reliability indices indicate that, with disconnecting switches are adding in to the feeder.

4.2. Reliability analysis with multiple DGs

In this section, Distributed Generations are 3 MW, 5 MW and 7 MW are installed at various distances from the substation. It can be observed that results in Table 2, when the multiple DGs (3 MW, 5MW and 7 MW) are located place A, B and C in RBTS BUS-2. The DG Capacity is 3 MW, which is located A, B and C into the RBTS BUS-2, reliability improvement of SAIDI are 15%, 12% and 14%. This is because of DG is connected near to the substation. The DG capacity is 5 MW, which is located A, B and C in RBTS Bus-2, the reliability improvements of SAIDI is 24%, 21%, and 35%. In this case, the DG capacity is increased by 2 MW. The DG capacity is 7 MW, which is located A, B and C into RBTS BUS-2, the reliability improvement of SAIDI are 35%, 32%, and 42%. Similarly, it can be observed that CAIDI and ENS calculated when the 3 MW, 5MW and 7MW are installing at different locations A, B and C. These results are shown in from Table.3 to Table 5.

It is observed that, 7 MW DG is given the higher reliability improvement than a 3 MW and a 5 MW. Because of repair time of DG is small. Therefore, the reliability improvement in terms of SAIDI is dependent on number of customers, location of DG in the feeder and DG capacity. In this connection, CAIDI depend on number of customers and ENS depends on the load on the feeder. In all the subsection, SAIFI gave constant. SAIFI is dependent on failure rate, but not the repair time.

4.3. Reliability analysis with aggregated DG and multiple DGs

The DGs considered in this case study includes 3 MW DG and 1 MW DG *3 in the same locations. Similar improvement is observed in Table 7, 8, 9 and 10 which gives reliability indices SAIDI, CAIDI and ENS of aggregated DG and multiple DGs. The reliability indices SAIDI of aggregated 3 MW DG and multiple DG (1 MW *3) in location A is increased from 2.792 f/yr to 2.786 f/yr, which represents the reliability improving corresponding to multiple DGs, we notice that, placing of DG is near the substation, improvement is small. And also the remaining indices CAIDI and ENS are improved if multiple DG as compared to an aggregated DG at location B and C. The reason being if one DG is fails the other DG is still serve remaining load points. The best reliability improvement is observed when the DG is placed at the end of the line.

5. Results and Discussion

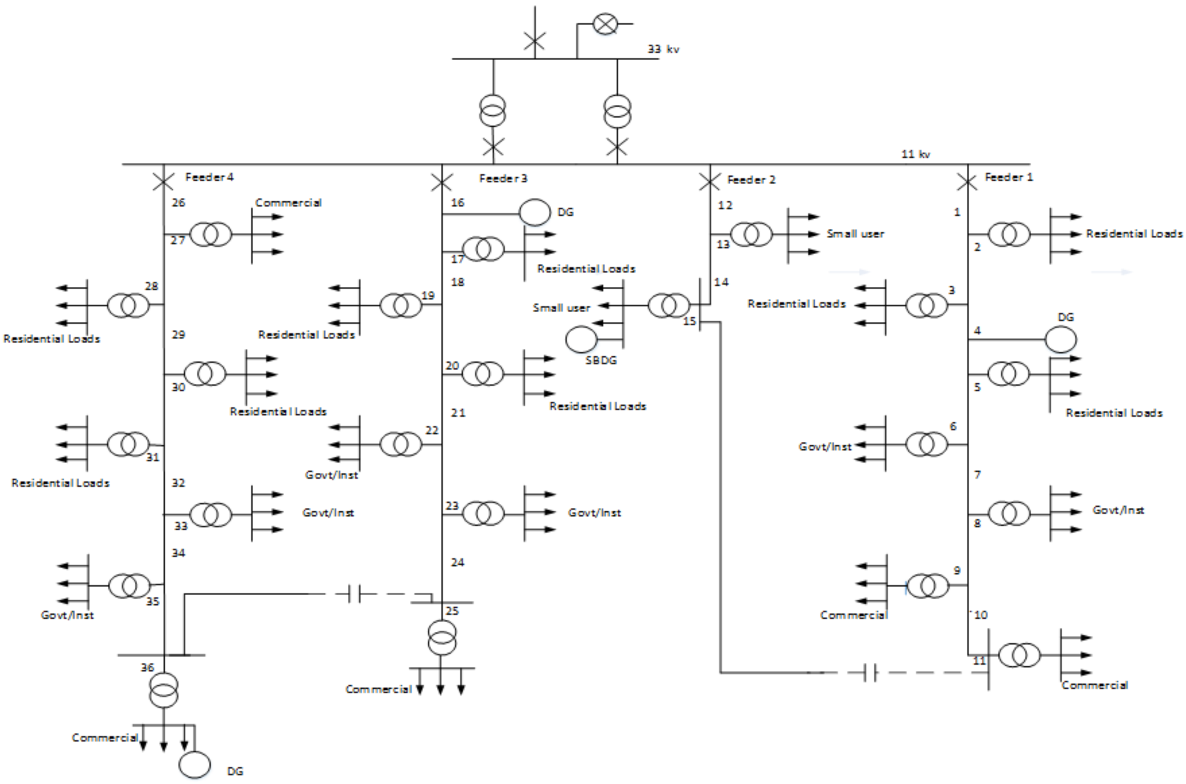

Fig. 5 – Distribution System for RBTS Bus 2

Table 1 – Reliability indices without DGs

INDICES	Without Disconnect	With Disconnect	Improvement
SAIFI(f/yr)	2.2024	1.074	51%
SAIDI(hr/yr)	6.9842	2.7972	59%
CAIDI(hr)	3.1711	2.6044	17%
ENS	86.922	36.394	58%

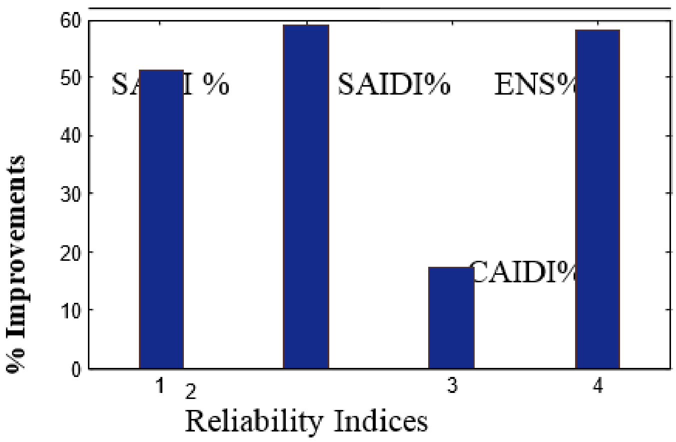

Fig. 6 – 6 % Improvements of reliability indices without DGs

Fig. 6 indicates that, % improvements of reliability indices in the absence of DGs in the RBTS Bus-2. With disconnects in to the feeder. % improvements of reliability indices SAIFI, SAIDI, CAIDI and ENS are increased as compared to without disconnect. With the effect of disconnect into the distribution feeder, sections repair time decreased.

Table 2 – Results of SAIDI (hr/cus. Yr)

DG Location	DG Sizes		
	3 MW	5 MW	7 MW
A	2.7928	2.79047	2.698
B	2.438	2.2085	1.9
C	2.3967	1.8029	1.6

Table 3 – % improvements of SAIDI

DG Location	DG Sizes		
	3 MW	5 MW	7 MW
A	15%	24%	35%
B	12%	21%	32%,
C	14%	35%	42%

Table 4 – Results of CAIDI (hr/cus.int)

DG Location	DG Sizes		
	3 MW	5 MW	7 MW
A	2.6	2.593	2.51
B	2.271	2.056	1.8135
C	2.232	1.6786	1.562

Table 5 – Results of ENS (MWh/yr)

DG Location	DG Sizes		
	3 MW	5 MW	7 MW
A	35.412	34.064	34.003
B	33.958	30.081	29.304
C	29.598	24.750	21.502

Table 6 – % improvement of reliability indices

DG Size (end of line)	SAIDI Improvement	CAIDI Improvement	ENS Improvement
3MW	14%	14.2%	18%
5MW	35%	35.5%	31%
7 MW	42%	40%	40.9%

Table 7 – Aggregated DG and multiple DGs

Indices	DG	DG Sizes	
	Location	3 MW	1*3MW
SAIDI (hr/cus.yr)	A	2.792	2.786
	B	2.438	2.213
	C	2.396	2.370

Table 8 – Aggregated DG and multiple DGs

Indices	DG	DG Sizes	
	Location	3 MW	1*3MW
CAIDI (hr/cus.int)	A	2.600	2.534
	B	2.271	2.060
	C	2.232	2.213

Table 9 – Aggregated DG and multiple DGs

Indices	DG	DG Sizes	
	Location	3 MW	1*3MW
ENS (MWh/y)	A	35.412	33.957
	B	33.958	32.429
	C	29.598	28.015

Table 10 – % Improvement of reliability indices

DG Size (end of line)	SAIDI Improvement	CAIDI Improvement	ENS Improvement
3 MW	14%	14.2%	18%
1 MW*3	15%	15%	23%

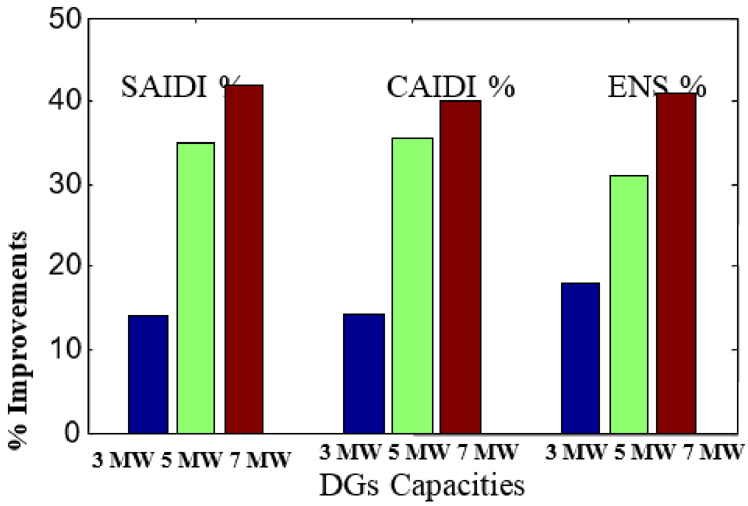

Fig. 7 – % Improvements of reliability indices with DGs (3MW & 1*3 MW)

The result of this section is as shown in Fig.8. It can be seen clearly that the % improvement of reliability indices is slightly increased as compared to Fig.7.The reason is DGs repair time is increased. Therefore, it can be used as back up source while one DG is failing in the system, other DGs served of the loads into the distribution system.

6. Conclusion

In this research work, evaluation of reliability indices of radial distribution system with and without distributed generation has been done. It is observed that, reliability analysis has been carried out to several DGs on IEEE RBTS BUS-2. In this work, a methodology for determining the load points indices and performance indices is described. Impact of without disconneced switches on the distribution system line contain DG won't not show the improvement in reliability indices. The system has disconnected switch to give reliability improvement in the system. The DG is inserted at the last section at load point, the system has improvement in reliability. Using aggregated DGs, the reliability indices are changed depending on DG location, loads have customer type and load sizes on the system. The test system has improvement in reliability with DG placed to the end of line. Comparison in between multiple DGs and aggregated DGs have in in equal size at the same location, the multiple DGs won't not give the higher reliability against to the aggregated DGs. However, the reliability indices are improved from multiple DGs. In this connection, the loads have served by the remaining DGs, where the aggregated DG is failure. Finally, this work has been contribution on the reliability enhancing to the distribution system with multiple DGs. This contribution is used in the planning of distribution system by placing DG units along the sections from the main supply towards enhancing the distribution system reliability indices.

Acknowledgements

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