JAREE-Journal on Advance Research in Electrical Engineering
Volume3, Number 2, October 2019

Integrating the PV-Diesel Hybrid System for Reliability Improvement in Distribution System

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***Abstract*— In Myanmar, as the main power generation is hydro power generation. the utility cannot supply sufficient power to customers during the dry season. Besides interruptions occur frequently due to aging system and lack of prospered protection. Therefore, reliability is an urgent issue in Myanmar. As a result of unbalance between generation and load, the distribution system is getting poor voltage profile, instability and high power losses in high load condition. According to network characteristics, the failure of a component always leads to consequence interruption in a radial distribution system. Therefore, it is a must consideration to mitigate these challenges to enhance the system reliability. There are many techniques to solve the reliability problems such as reclosers, switching devices (manual and automated switches), system reconfiguration, feeder re-conducting and integration of distributed generation (DG). In this paper, system reliability assessment is evaluated in detail with the integration of the distributed generation such as PV-Diesel Hybrid System. The location of DG is chosen according to the expected energy not supply (EENS) and the voltage drop in proposed system. Next, the optimal sizing of DG is chosen depends on the penetration level of generator. Reliability indices can be evaluated depending on the failure rate(λ), repair time(r) and annual outage time(U) in Electrical Transient and Analysis Program (ETAP) software. The case study of this thesis is carried out in 33/11 kV network which is connected Kyatminton Substation, Kyaukse, Middle Myanmar.**

Keywords*— *distribution system, reliability, reliability indices, EENS, distributed generation,

I. INTRODUCTION

Electrical distribution systems are essential part of the electrical power system. In distribution network, flow of power is unidirectional and consumer at the far end getting low voltage as compare to consumer close to substation. There are two basic types of distribution system: meshed and radial systems [6]. A mesh system has multiple sources of supply operating in parallel. Therefore, Evaluation methods for meshed distribution systems are conceptually the same as those used for composite systems. A radial system is arranged like a tree where each customer has one source of supply. Therefore, the techniques for a radial distribution system are based on failure-mode analysis including considerations of all realistic failure and restoration processes [7].

The reliability concepts of distribution system differ from generation and transmission systems. Generation and transmission reliability mainly emphasizes capacity and loss of load probability, configuration whereas the distribution reliability looks like the engineering design, planning and operations. It is important to note that the distribution system is a vital link between the bulk power system and its customers. In many cases, these links are radial in nature that makes them vulnerable to customer interruptions due to a single outage event. A radial distribution circuit generally uses main feeders and lateral distributors to supply customer energy requirements. The distribution system occurs the failures that have 90% of all customer interruption according to the reported in literature [8].

In this paper, distribution system reliability is mainly analyzed in Kyaukse Feeder line in Kyatminton (Kyaukse) Substation, Kyaukse in Mandalay Division as case study because the Kyaukse area is situated in Mandalay region (dry zone area) and then it has more interruption than others feeder line according to the collected data. The source of power supply to Kyaukse Substation is fed from Belin Station which is obtain the main supply from Yeywa and Shweli hydro power station. When it has been coming in dry season, the system always has to be Load-Shed when the Yeywa dam has insufficient water to drive the water turbine.Therefore, system reliability is required to improve in Kyaukse area.

There are many techniques to solve the reliability problems such as reclosers, switching devices (manual and automated switches), system reconfiguration, feeder re-conducting and integration of distributed generation (DG) [9]. Distributed generation (DG) is one of the solutions to improve the system reliability. DG is often used as backup power to enhance reliability or as a means of deferring investment in transmission and distribution network, avoiding network charges, reducing line losses, deferring construction of large generation facilities, displacing expensive grid-power supply, providing environmental benefits [11], [14].

II. BACKGROUND THEORY OF RELIABILITY

Reliability is the probability of success or the probability that the system will perform its intended function under specified design limits [1]. Power system reliability assessment can be divided into the two basic aspects of system adequacy and system security. Adequacy is associated with static conditions which do not include system dynamic and transient disturbances. Security is associated with the response of the system to whatever perturbations it is subject to [2].

Distribution system of this paper based on analytical evaluation involves assessment of suitable adequacy indices at the actual consumer load points.

$$\lambda_S = \sum_{i=1}^{N} \lambda_i \ \text{interruption/year} \qquad (1)$$

$$U_S = \sum_{i=1}^{N} \lambda_i r_i \ \text{hr/yr} \qquad (2)$$

$$r_S = \frac{U_S}{r_S} \ \text{hr} \qquad (3)$$

The basic load point indices are the load point failure rate (λ), the average outage time (r) and average annual unavailability or outage (U). These three basic reliability parameters can be calculated to assess the reliability as the above equations (1), (2) and (3) [3].

There are many outage types in distribution system. Among them these outage types such as permanent outages, temporary outages, transient outages, scheduled maintenance outages and utility outage are always happening in distribution system. According to the collecting data of distribution system, Kyaukse feeder is more interrupt than other feeders. Therefore, Kyaukse feeder need to improve the reliability for their customers. Furthermore, Fig. 1 shows the flow chart for calculation of reliability indices.

The basic indices are fundamentally important but they do not give the complete system behavior and response. Therefore, in this paper, the following reliability indices such as system average interruption frequency index (SAFI) in (4), system average interruption duration index (SAIDI) in (5), customer average interruption duration index (CAIDI) in (6), expected energy not supplied index (EENS) in (9), expected interruption cost index (ECOST) in (12), average energy not supplied index (AENS) in (13) and interrupted energy assessment rate index (IEAR) in (14) are calculated to get the complete assessment of distribution system. These equations are expressed as the following [4].

$$SAIFI = \frac{\text{total number of customer interruptions}}{\text{total number of customer served}}$$

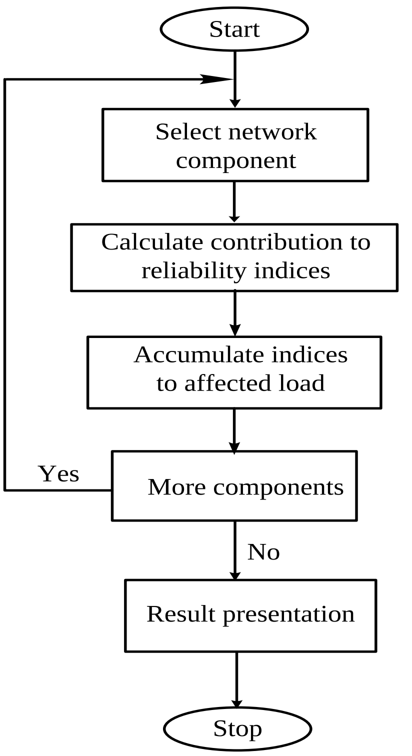

Fig. 1. Flow chart for calculation of reliability indices

$$= \frac{\sum \lambda_i N_i}{\sum N_i} \text{ failure/customer/year} \quad (4)$$

$$SAIDI = \frac{\text{sum of customer interruption duration}}{\text{total number of customer served}}$$

$$= \frac{\sum U_i N_i}{\sum N_i} \text{ hr/customer/year} \quad (5)$$

$$CAIDI = \frac{\text{sum of customer interruption duration}}{\text{total number of customer interruptions}}$$

$$= \frac{\sum U_i N_i}{\sum \lambda_i N_i} \text{ hr/customer interruption/year} \quad (6)$$

$$ASAI = \frac{\text{customer hours of available service}}{\text{customer hours demanded}}$$

$$= \frac{\sum N_i * 8760 - \sum U_i N_i}{\sum N_i * 8760} \quad (7)$$

$$ASUI = 1 - ASAI \quad (8)$$

$$EENS_i = P_i * U_i \text{ MWh/year} \quad (9)$$

$$EENS = \sum_i^N EENS_i \text{ MWh/year} \quad (10)$$

$$ECOST_i = P_i \sum_i^N f(r_i)\lambda_i \text{ \$/year} \quad (11)$$

$$ECOST = \sum_i^N ECOST_i \text{ MWh/year} \quad (12)$$

$$AENS = \frac{\text{total energy not supplied by the system}}{\text{total number of customer served}}$$

$$= \frac{\sum EENS_i}{\sum N_i} \quad (13)$$

$$IEAR = \frac{ECOST_i}{EENS_i} \quad (14)$$

Where P_i is average load demand and U_i is outage time at load point i, ASAI is average service availability index, ECOST is expected interruption cost index, IEAR is interrupted energy assessment rate index and ASUI in (8) is average service unavailability index [5].

III. Using the Template

This paper presents 33/11 kV Kyaukse Feeder line of Kyatminton substation as case study and the ETAP software was used to analyze the reliability assessment of test system. This paper also analyzed the reliability improvement by integrating the distributed energy resource (DER) to the distribution network of 33/11 kV Kyaukse Feeder of Kyaukse (Kyatminton) Substation. Fig.2 shows the one-line diagram of the test system from Kyaukse Feeder. The customer types of test system are presented in Table I.

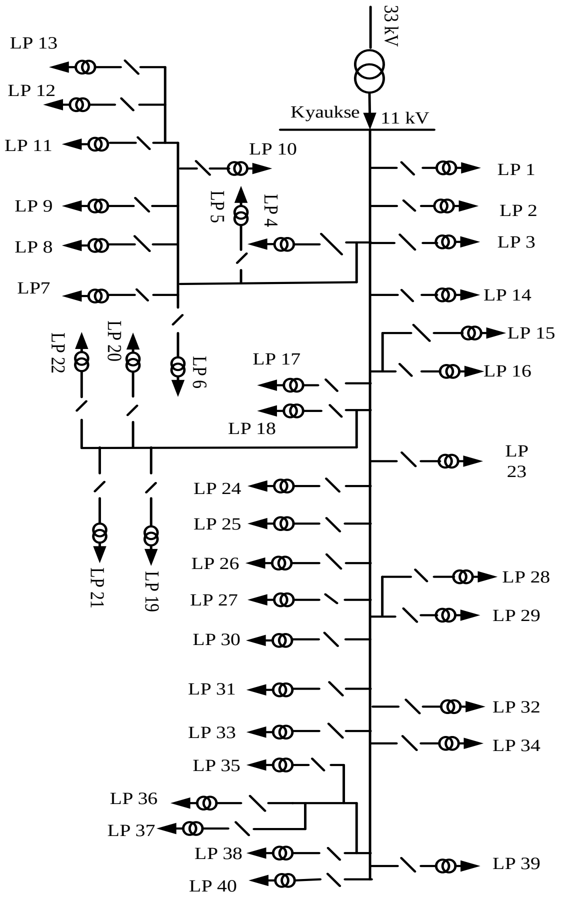

Fig. 2. One line diagram of test system

TABLE I. INPUT DATA FOR RELIABILITY ASSESSMENT OF TEST SYSTEM

Load Point	Customer Type	Average Load per Load Point(kW)	No. of Customer
29	G & I	22.1	1
14,18,33,34,36,38	Residential	22.1	317
3,9,12,13,17,24,	Commercial	22.1	6
11,20,25,26,32,37,39,40	Residential	32.3	828
15,30	Commercial	32.3	2
10,6,27,35	Residential	41.65	567
7,8	Commercial	41.65	2
19,21,28,31,	Residential	51.85	734
1	G&I	62.05	1
22	G&I	72.25	1
5	Commercial	121	1
2	G&I	132	220
16	Residential	142	366
4	Residential	192	369
23	Residential	262	183
Total			**3598**

There are forty load points and its length has 8.5 miles and its lateral points have 0.5 miles. Its total load is 2 MW, total customer of kyaukse feeder is 3598. The basic indices such as average interruption rate (f/yr), average outage duration (hr) and annual outage duration (hr) are important to run the reliability assessment of test system. Fig. 3 shows the reliability assessment of test system before integrating DG in ETAP software.

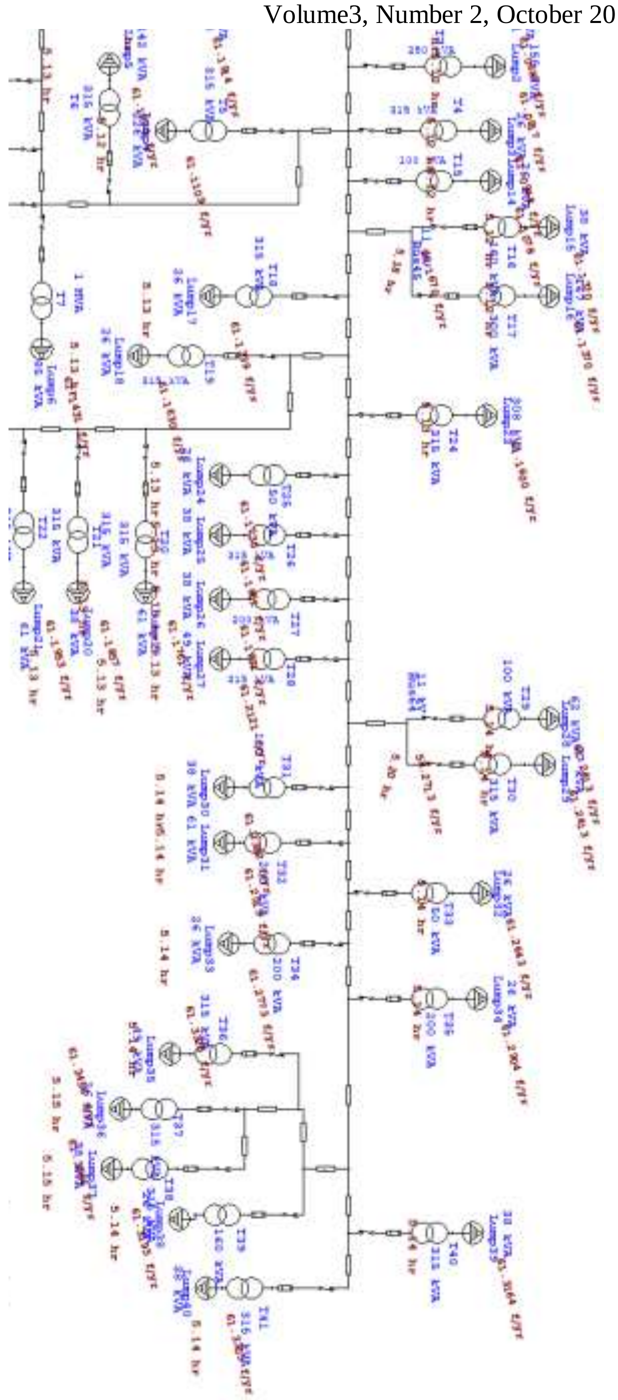

Fig. 3. Reliability Assessment of Test System before Integrating DG by using ETAP Software

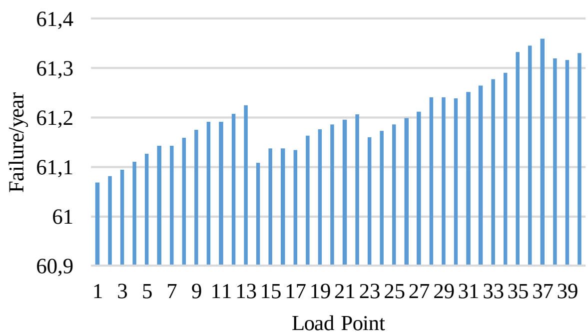

Fig. 4. Different Failures Rate of Each Load Points

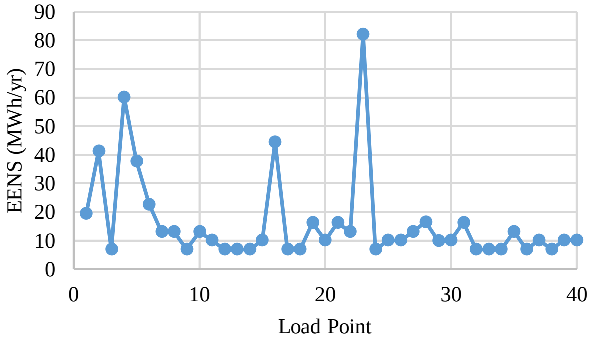

Fig. 5. Expected Energy Not Supply (EENS) of Forty Load Points in Test System

Fig.4 shows the different failures rate of each load points of test system. Moreover, the expected energy not supply (EENS) of each load point can been seen in Fig. 5 According to reliability assessment of test system by using ETAP Software, Average service Availability Index (ASAI) is 0.9642 pu, Expected Energy Not Supplied (EENS) is 643.359 MWh / year and Average Energy Not Supplied (AENS) is 0.1859 MWh/ customer/yr.

IV. Integrating the PV-Diesel Hybrid System

When the reliability assesses the proposed system in the load shed and no load shed condition, the expected energy not supply is 643.36 MW hr/year and system availability has 96%. Therefore, the system need to be improve the reliability, decrease the energy not supply and increase the system availability. There are many ways to increase the system reliability: Reconfiguration, Capacitors Installation, Demand Side Management, Distribution Transformer Load Management and integrating the distributed generation 12]. In this paper, integrating PV-Diesel Hybrid System distributed generation is considered for reliability improvement of test system. Firstly, if the Hybrid system integrates as the distributed generation in the test system, the system is required to optimal location and size of distributed generation for reliability improvement [13].

In this paper, the method is considered for determining the placement for distributed generation (DG) in distribution system based on the system energy not supply and load flow analysis by using Newton Raphson Method. The proposed methodology aims to optimize the better location to reduce the power losses and improves the voltage profile and to optimize the distribution system in ETAP software.

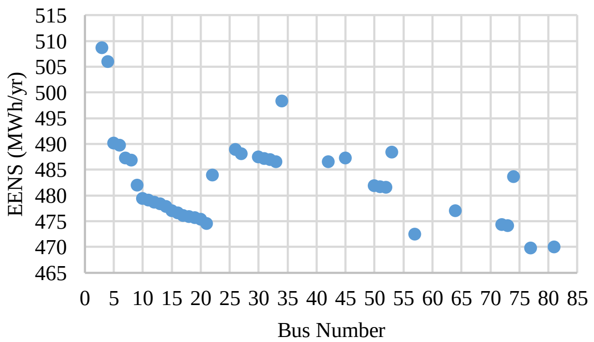

Fig. 6. Choosing the location of Distributed Generation based on EENS

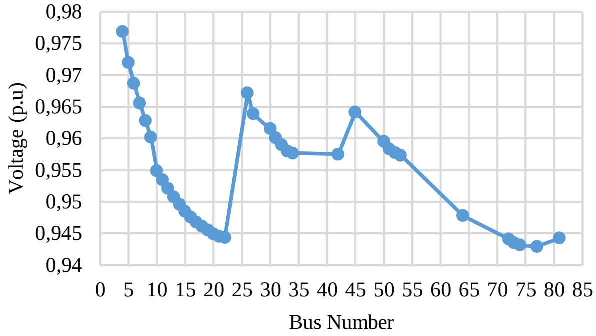

Fig. 7. Choosing the Location of PV-Diesel Hybrid System based on the Voltage Drop

In choosing the location of distributed generation in proposed system, it can be considered in two conditions such as system expected energy not supply (EENS) in each bus when the system run in reliability assessment and real power losses in each bus when the system run in load flow analysis. It's mention the choosing of DG location above two methods (EENS assessment and load flow analysis) and these results are shown in Fig. 6 and Fig. 7. According to the analysis, Bus 77 is optimal location to integrate the distributed generation in the distribution system.

For choosing the penetration level of distributed generation, the amount of DG must be put into relation to an area, e.g. local distribution system or nation-wide power network. The high penetration of DG is defined as DG penetration is obtained when DG is implemented to cover a 50% of load increment.

The penetration level (PL) can be defined as the following equation.

$$PL = \frac{P_{DGi}}{P_{load} + P_{DGi}} \times 100\% \qquad (15)$$

where, P_{DGi} stand for the total active power of all DG units installed in a given area and P_{Load} is the total active power of the load in the same area. In this paper, the penetration level of distributed generation is considered as 20%, 50%,70% of maximum load.

In according with the load flow analysis of proposed system, 20% DG the penetration level is a point to integrate the optimal sizing in the distribution system. It' level can be reduced the power losses, increase the voltage profile and improve the system reliability. This result is shown in Fig. 8. According to the analysis of optimal sizing for distributed generation, 300 kW PV and 200 kVA are connected as the hybrid system for reliability improvement.

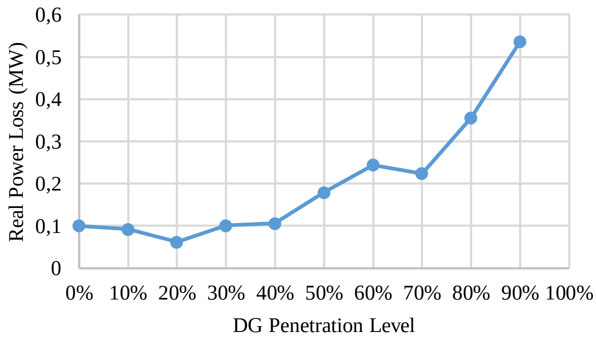

Fig. 8. Choosing the size of Distributed Generation based on Load Flow Analysis

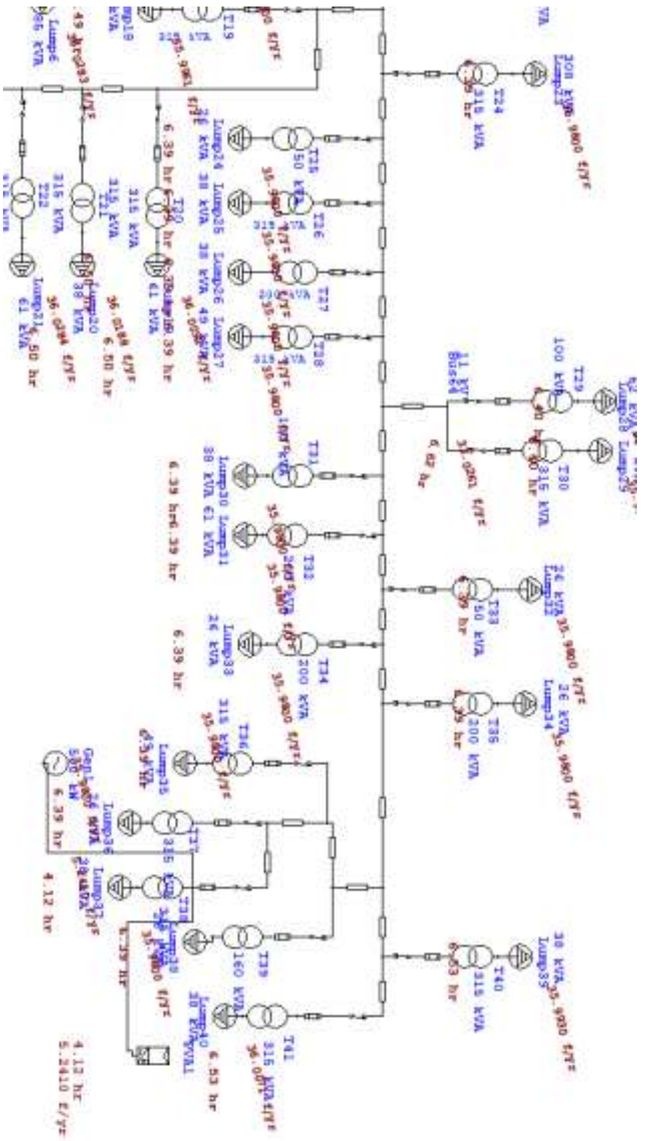

Fig. 9. Reliability Assessment After Integrating PV-Diesel Hybrid System at Bus 77 in ETAP Software

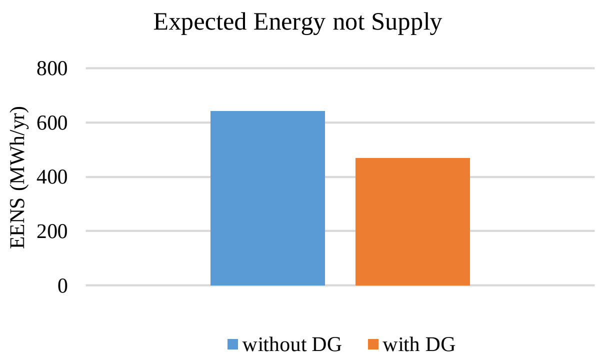

Fig. 10. Comparison of Expected Energy Not Supply in Two Conditions

In this hybrid system, PV DG is usually operating as the grid connected type and diesel generator can only operate when the system has interruption occurs due to the various effects of faults. When the PV-Diesel hybrid system is integrated as the distributed generation at bus 77 with 20% of maximum load in test system as shown in Fig. 9, the system reliability is improved 27% based on the energy not supply (EENS). Moreover, comparison of expected energy not supply (EENS) and comparison of System Available Index (ASAI) in two conditions are respectively shown in Fig.10 and Fig. 11. Finally, the summary of reliability indices in two condition is shown in Table II.

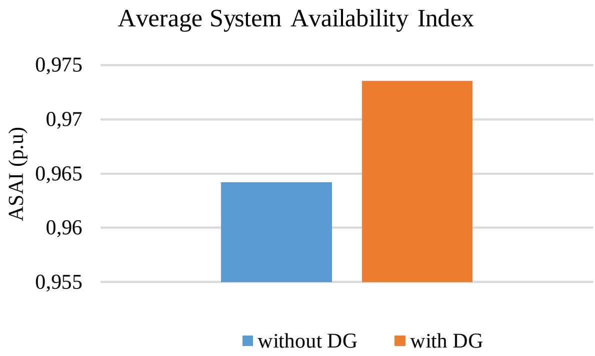

Fig. 11. Comparison of System Availability Index in Two Conditions

TABLE II. RESULTS OF RELIABILITY ANALYSIS IN TWO CONDITIONS

Summary of Reliability Indices in Two Condition		
Indices	***Without DG***	***With PV-Diesel Hybrid***
SAIFI	61.1951 failures / customer.yr	35.9855 failures / customer.yr
SAIDI	314 hr / customer.yr	231.7 hr / customer.yr
CAIDI	5.131 hr / customer interruption	6.4 hr / customer interruption
ASAI	0.9642 pu	0.9735 pu
ASUI	0.03585 pu	0.02645 pu
EENS	643.36 MW hr / yr	470 MW hr / yr
ECOST	2,421,614.0 $/year	1,885,166.0 $/year
AENS	0.1859 MW hr / customer.yr	0.1358 MW hr / customer.yr
IEAR	3.764 $/kWh	4 $/kWh

V. CONCLUSION

This paper investigates the effectiveness of improving the reliability of power distribution network with PV-Diesel Hybrid System of distributed generation (DG). ETAP software was used to determine the reliability analysis of test system. Comparison of reliability indices in normal case and PV-Diesel hybrid system of DG are respectively showed with result tables. According to the simulating results, the failure rate is decreased from 61.1951 to 35.9855 failure/customer.yr and expected energy not supply is decreased from 643.36 MW hr/yr to 470 MW hr/yr by integrating DG in test system. An important study is the behavior of distributed energy sources which allows employing the size and variable in time energy sources while providing a continuous supply.

ACKNOWLEDGMENT

The author would like to express her deepest appreciation to Yangon Technological University (YTU) for its support and then also thanks to Kyaukse Substation's incharge for helping to get data. Especially, the author wish to express her sincere thanks to her teachers for ideas, sharing knowledge and their valuable times whenever the author want to discuss about her research.

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