

Reliability Evaluation Of Distribution System With Distributed Generation Using ETAP

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Abstract

Reliability is one of the vital area in electric power system which defines continuous supply of power and customer satisfaction. The distribution system have more than 80% of all customer interruptions occur (i.e power quality issues) due to component failures. That report indicates that, the expected reliability indices such as interruption frequency and interruption duration during the entire year. Many researches are finding to assess the reliability of the power system. Further, due to the wide growth of distributed generation in electrical power, investigating their impact on system reliability, it becomes an attractive area of research. In this paper, the reliability evaluations of distribution system using a minimal cut set method based on the FMEA technique is described and apply to the IEEE RBTS Bus-2. Development of reliability modeling using ETAP software is presented for determining the reliability indices. In addition to, improvement of reliability with introducing of distributed generation model is presented on the distribution system. Different reliability tests were done to find the optimum location to plant DG in distribution system. Reliability indices are load point indices and system indices which includes, System Average Interruption Frequency Indices (SAIFI), System Average Interruption Duration Indices (SAIDI), Customer Average Interruption Frequency Indices (CAIFI), Customer Average Interruption Duration Indices (CAIDI) etc. These indices are shows that, performances of reliability of the distributionsystem.

Keywords- Distribution system; Distributed Generation; Reliability Assessment; Reliability Indices

1. Introduction

The distribution network is run on low voltage and divided into sub transmission and radial/meshed network. Inside the distribution system, outages about 80 % because of both faults and failure of components i.e. Lifetime ended. With outages results, the distribution network want to man or woman contribution and that allows you to limit the numbers and period of purchaser failure. The number of interruptions and period of customer, failure rates can be dealt with as reliability indices at load points. Those indices have a tendency to approximately the system overall performance indices. In reality that, the conventional electricity with a constrained ability of DG and renewable sources is evolved energy and it'll transmit strength from one area to other purchasers' hundreds. This emerge can be in competitive structure, whilst environmental conditions and upkeep of lines can be changed along with the financial tests of energy guidelines. . The reliability modeling method by using connecting thru DG on the distribution network has presented in [1]. This isn't always definitely explored the reliability improvement and it offers with backup programs within the device, such as much less numbers and periods of interruptions. The IEEE RBTS-2 bus has five different feeders and can evaluate reliability with Monte Carlo simulation technology in ref [2]. It also covers radial networks with different operating conditions. The MCS method can be used to evaluate the reliability of the network, the random system being described in ref. [3]. In this discussion, describe the reliability of the network with various reliability parameters, taking into account customer data and load data.

The large-scale and small-scale network, the reliability assessment using analytical techniques, was the subject of ref. [4]. On the other hand, it determined the reliability of the network in association with the DG unit at different distances from the main power source, and if DG is located at the beginning for each section, it can be demonstrated that the improvement of the reliability of the network has less number and duration of interruptions. In addition, the conditional probability method is proposed based on Failure Mode and Impact Analysis (FMEA) to assess the reliability of the distribution system [5]. The author introduced the influence of DG and DSM techniques on distribution system with Dig SILENT software for evaluating indices. Also consider the different hourly load of the customers during the evaluation [6]. The author presented the quality placement of DG at the distribution network is used for you to maximize development in reliability in terms of the purchaser interruption variety and period are taken into consideration has been provided in [9]. An analytical method is used to evaluate reliability indices, such as SAIFI and SAIDI with the presence of DG

based on different energy sources and its operation characteristics[10].The impacts of DG on distribution system reliability are analyzed in two cases, namely the change in distance and the increase in the number of DG units [11]. The failure of the distribution system is strongly influenced by adverse weather conditions such as strong wind, lightning, icing, and so on[7]. Fig. 1 shows major causes of interruptions.

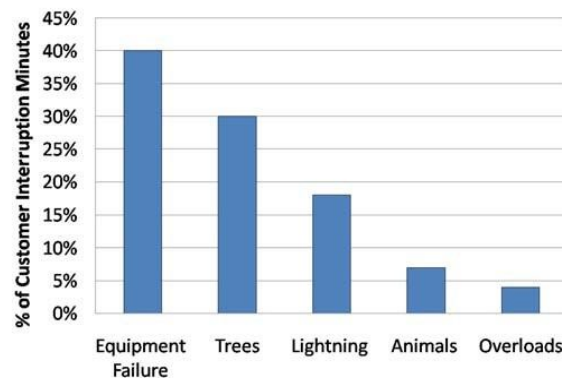


Fig. 1 Interruptions due to major causes

Distribution systems have more problems with customer reliability. The rest is determined by the generation and transmission systems. In this regards, this research work is being conducted to improve the reliability of distribution system by introducing Distributed Generation. The Modified Failure Mode Effective Analysis (FMEA) mathematical model has been developed for reliability evaluation of distribution network with Distributed Generation 100% reliability. The proposed technique is implemented on modified IEEE RBTS Bus 2. The paper is organized as follows: In section 2, distribution network reliability indices are discussed. Reliability Evaluation Methodology is presented in section 3. Case studies are presented in section 4. In section 5, results and discussion is presented. Section 6 presents the conclusion.

2. Distribution network reliability indices

Consider a radial distribution test network is shown in Fig. 2 and it include sections SE1, SE2, SEj together with laterals, breakers, and so forth[12],[13].

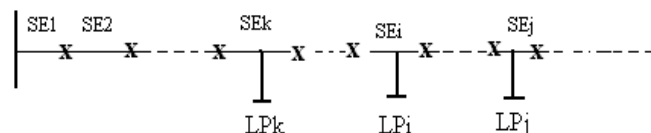


Fig. 2 The radial distribution network

Apply classical ideas to the distribution network; it offers the ones three essential reliability indices including average failure price (AFR) (λ_s) average outage time (r_s) and average annual outage time (AAOT) (Us) at load factor. The following eqns (1), (2) and (3) helps for calculating the reliability indices of the network. The system overall performance indices are calculated from eqns (4) to (8),

$$\lambda_s = \sum_{i=1}^N \lambda_i (f / yr) \quad (1)$$

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

$$r_s = \frac{U_s}{\lambda_s} (\text{hrs}) \quad (3)$$

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

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

Here, λ_i be the Load point FR and N_i is the number of customers to the LP i

$$CAIDI = \frac{\sum U_i N_i}{\sum \lambda_i N_i} (\text{hrs.} / \text{cust.yr}) \quad (6)$$

Where λ_i be the FR, U_i is the AOT e and N_i is the number of customer of load point i

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

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

Where, 8760 is the number of hours in a calendar year

3. Reliability Evaluation Methodology

For reliability modelling and analysis of RBTS Bus 2 with Distributed Generation is modeled by FMEA method. Apply FMEA method to test system of IEEE RBTS Bus 2 for calculating the average failure rate and average annual outage time from LP₁ to LP_n with the help of Eq. (9) to Eq. (10) as

$$\lambda'_s = \sum_{i=1}^{A-B} \lambda_i + \sum_{l=1}^{C-D} \lambda_l \quad (9)$$

Where,

λ'_s - Average failure rate at LPs within DG.

A-B, C-D means DG locations

$i = 1$ - Load point 1

The average annual outage time is calculated through the eqn (10)

$$U'_s = \sum_{i=1}^{A-B} \lambda_i r_i + \sum_{l=1}^{C-D} \lambda_l s \quad (10)$$

Where,

U'_s - Average annual outage time at LPs within DG.

r_i - Average repair time at LPs within DG location A-B, C-D.

S- Switching Time at LPs within DG location A-B and C-D.

3.1 Developed algorithm based on FMEA technique used to calculate reliability indices of the modified IEEE RBTS Bus 2 distribution network with DG

- Step 1: Consider each load point at the feeder in the distribution system;
- Step 2: Determine each failure mode of the components in the feeder;
- Step 3: Obtain the AFR and AAOT values of all load points;
- Step 4: Determine system performance indices to all the feeders;
- Step 5: Determine system performance indices to complete system;
- Step 6: Determine the AFR and AAOT of all the load points when the DG is connected;
- Step 7: Find system indices of SAIFI and SAIDI for all feeders in the distribution system
- Step 8: Develop the reliability modeling of all the feeders using ETAP; Find system performance indices;
- Step 9: Develop the reliability modeling of all the feeders with Distributed Generation using ETAP; Find system performance indices

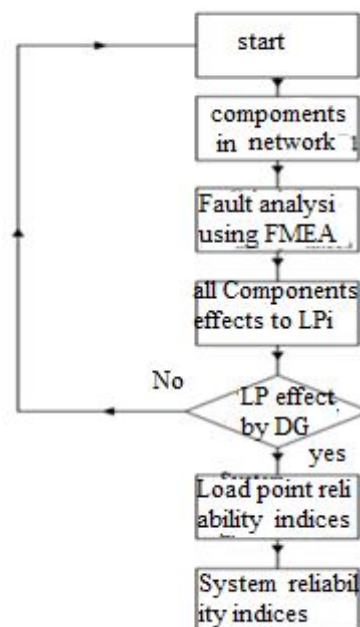


Fig. 3 Flow chart for evaluation of distribution system reliability indices

4. Case Studies

In this research work, three (3) case studies are performed as shown in Table 1. IEEE RBTS Bus2 has modified to conduct the case studies. The impact of DGs with 2 MW is placed on modified IEEE RBTS 2 bus of the distribution network individual feeders (see Fig.4). The reliability of the components and the data parameters of the customer, the total average load, the maximum load and the number of load points of IEEE RBTS-2 bus [8], [10]. The Electric Transient Analysis Program (ETAP) is an electrical power system tool which has complete integration of AC and DC systems [14]. In this case studies, second order faults that overlap, including their duration are ignored. In addition, open points are deleted. The following case studies are conducted,

- a. Case study-1: IEEE RBTS BUS2, with disconnects- with fuse- with alternative supply- with the repair of the transformer
- b. Case Study-2: Modeling of IEEE RBTS Bus2 Using ETAP Software.
- c. Case Study-3: IEEE RBTS BUS-2 Feeders with Distributed Generation Using ETAP Software

Table 1. Case studies structure

#	Description
Case 1	Reference case study
Case 2	Modeling of IEEE RBTS Bus2 Using ETAP
Case 3	IEEE RBTS BUS-2 Feeders with Distributed Generation i.e 2 MW Using ETAP

- a. *Case study-1: IEEE RBTS BUS2, with disconnects- with fuse- with alternative supply- with the repair of the transformer.*

In this case study, development of reliability modeling of IEEE RBTS BUS2, with disconnects- with fuse- with alternative supply- with the repair of the transformer using FMEA method is presented.

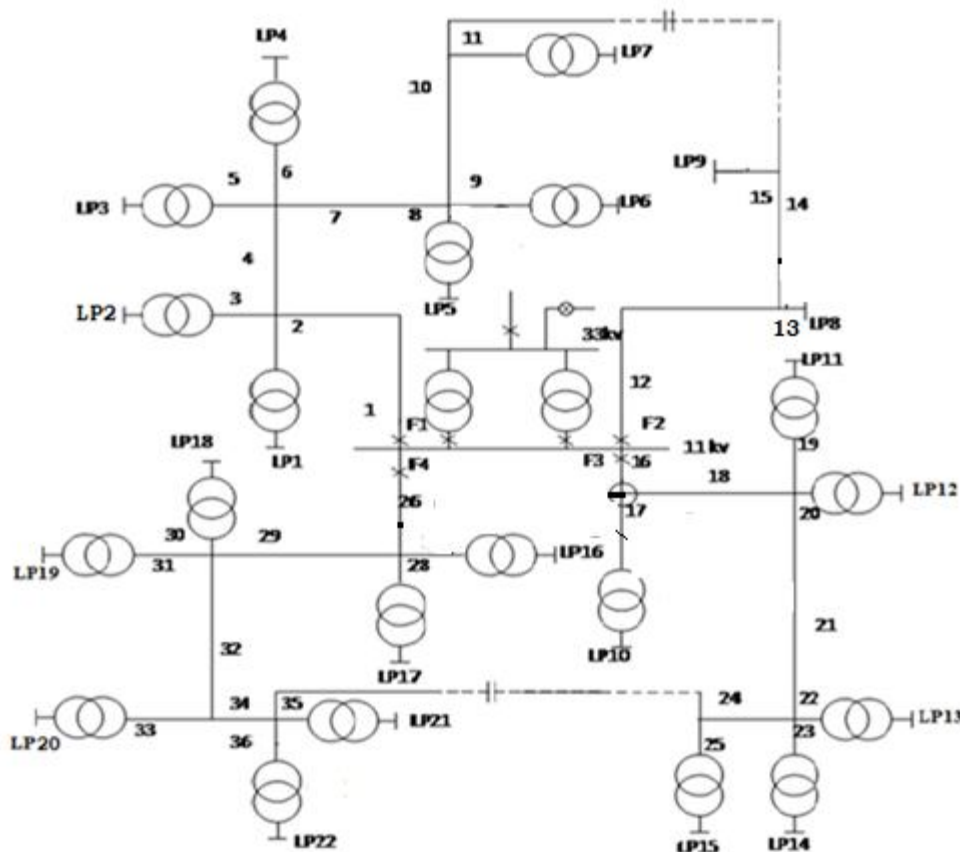


Fig.4 IEEE RBTS Bus -2 distribution system

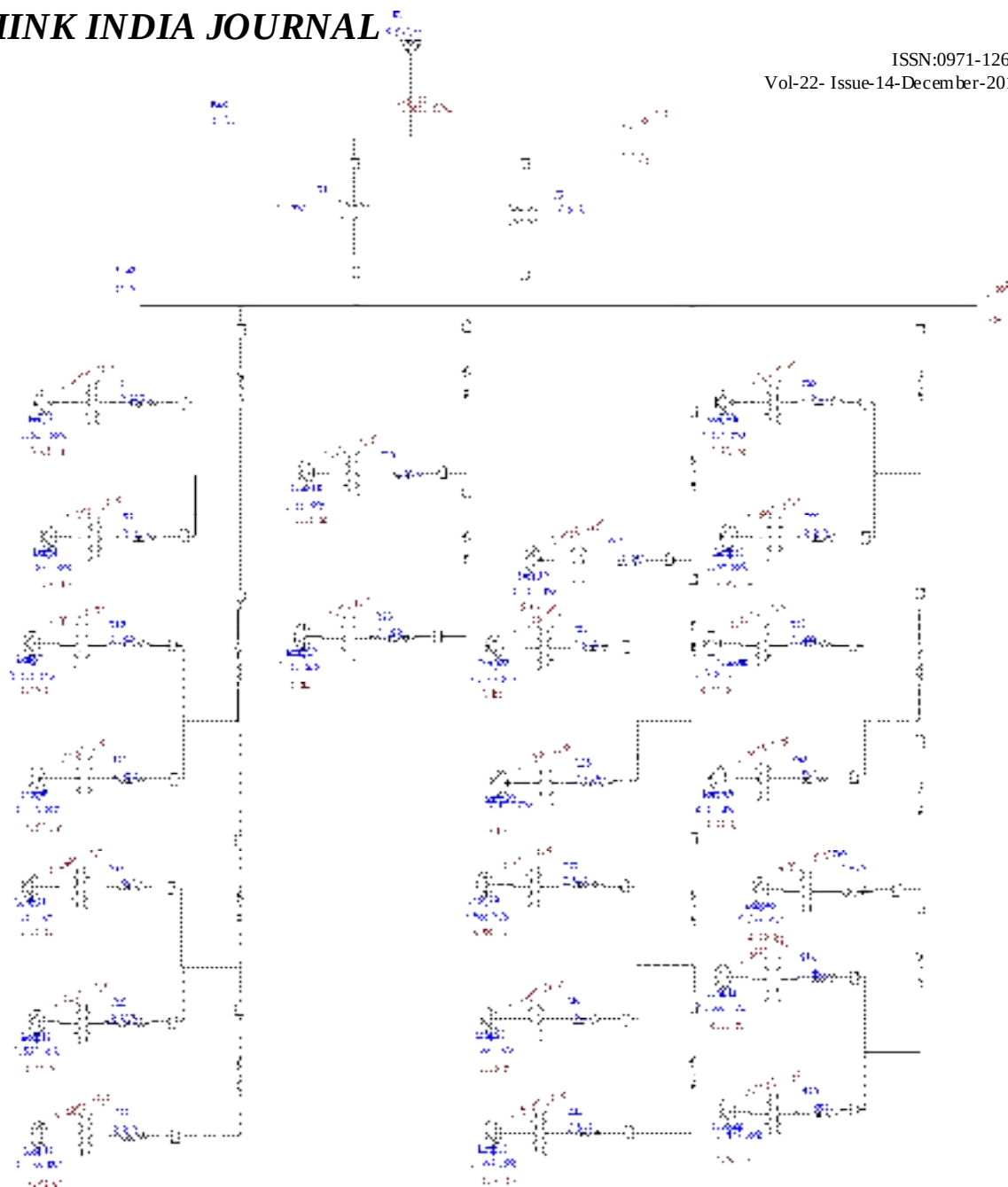


Fig. 5 IEEE RBTS Bus 2 modeled in ETAP

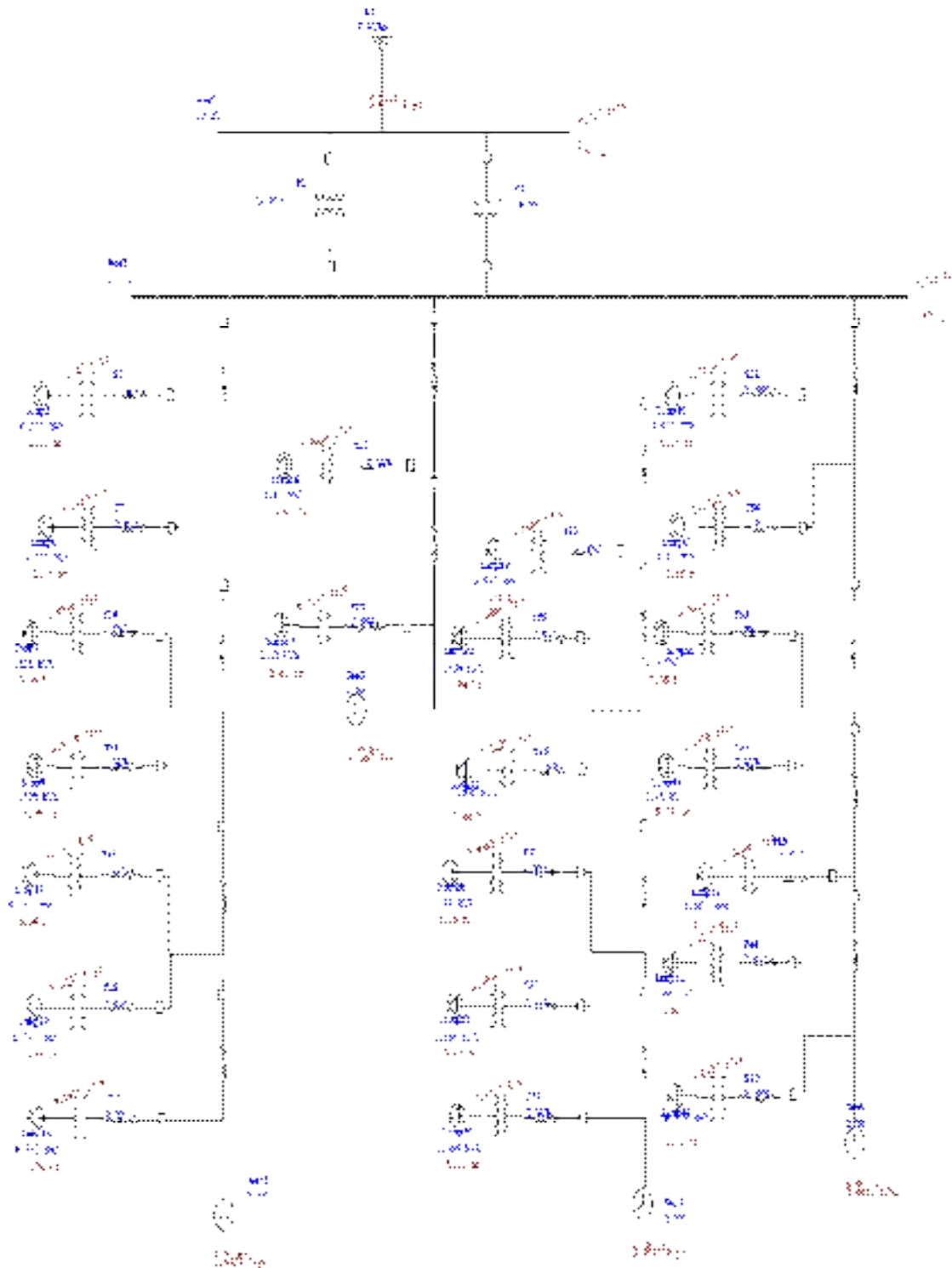


Fig.6 Improvement of reliability indices of IEEE RBTS BUS-2 with DG modeled in ETAP

Table 2. Results of system performance indices of IEEE RBTS BUS-2

S. N	FEEDER	SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/int.)	ASAI	ASUI
1	F1	0.248	3.62	14.5349	0.999587	0.000412
2	F2	0.140	0.523	3.7375	0.999402	0.000597
3	F3	0.250	3.62	14.4667	0.999586	0.000414
4	F4	0.247	3.61	14.38	0.999587	0.000412
5	System	1.4085	7.0424	5.000	0.9992	0.00080

Table 2. Shows that, the system performance of IEEE RBTS BUS2 including all the feeders. And also complete System indices are calculated using the FMEA technique.

b. CASE STUDY-2: Modeling of IEEE RBTS BUS2 using ETAP

In this case study, reliability analysis by means of ETAP helps to evaluate distribution system reliability with extremely efficient analytical algorithms, for this purpose IEEE RBTS bus 2 as shown in Fig. 5 was modeled and analyzed in ETAP. Fig.3 shows the flow chart that how results were calculated. The obtained results are tabulated in Table. 3.

Table 3: Results of performance indices of IEEE RBTS BUS2

S. No.	FEEDER	SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/int.)	ASAI	ASUI
1	F1	1.2973	6.5063	5.015	0.9993	0.00074
2	F2	1.3523	6.7900	5.021	0.9992	0.00078
3	F3	1.4870	7.4534	5.012	0.9991	0.00085
4	F4	1.3904	6.9679	5.012	0.9992	0.00080
5	System	1.4085	7.0424	5.000	0.9992	0.00080

Tab. 3, shows that, the performance indices of IEEE RBTS BUS2, F1, F2, F3, and F4 are calculated using ETAP software and obtained results are compared with FMEA technique. Both these results are same.

c. Case Study-3: IEEE RBTS BUS-2 Feeders with Distributed Generation Using ETAP

In this section, improvement of reliability IEEE RBTS BUS-2 feeders with distributed generation using ETAP software is presented. The capacity of DG is 2 MW and its working 100% reliable. The DG is connected to IEEE RBTS BUS2 and DG location is at several load points in feeder 1 and end load points at Feeder 2, Feeder 3 and Feeder 4. The reliability modeling of IEEE RBTS BUS-2 with DG is shown in Fig. 6. The obtained results are shown in Table. 4 and Table. 5.

Table. 4 System indices for IEEE RBTS Bus 2, Feeder 1

S.No	FEEDER	DG Location	SAIFI (int./ year)	SAIDI (hr/ year)	CAIDI (hrs/int.)	ASAI	ASUI
1	Feeder1	LP1	1.0625	5.3585	5.043	0.9994	0.00061
		LP2	1.0625	5.3585	5.043	0.9994	0.00061
		LP3	1.0616	5.3541	5.043	0.9994	0.00061
		LP4	1.0616	5.3541	5.043	0.9994	0.00061
		LP5	1.0504	5.2982	5.045	0.9994	0.00060
		LP6	1.0504	5.2982	5.045	0.9994	0.00060
		LP7	1.0427	5.2602	5.045	0.9994	0.00060

Table.4shows that, impact of DG at several different locations and system reliability indices have been seen, impact DG at seven different locations in Feeder 1 the reliability indices showed that optimum location for impact of DG was end load point.

Table. 5 System performance indices of IEEE RBTS BUS-2 with DG

S. N	FEEDER	DG Location	SAIFI (int./ year)	SAIDI (hr/ year)	CAIDI (hrs/int.)	ASAI	ASUI
1	F1	at LP7	1.0427	5.2602	5.045	0.9994	0.00060
2	F2	at LP9	1.0333	5.2218	5.054	0.9994	0.00060
3	F3	at LP15	1.0502	5.2998	5.2998	0.9994	0.00060
4	F4	at LP22	1.0262	5.1778	5.045	0.9994	0.00059
5	System	LP7, LP9, LP15& LP22	1.0384	5.2394	5.045	0.9994	0.00060

5. Results and Discussion

a.Comparison of Case Study-1 and Case Study-2

In this section, Case study-1, reliability indices of IEEE RBTS BUS 2 are calculated using the FMEA method and case study-2, reliability indices of IEEE RBTS BUS2 are calculated using ETAP software. Obtained case study-1 results are compared to case study-2 and these results tabulated in Table.6

Table.6 Results of system performance indices of IEEE RBTS BUS2 using FMEA method and ETAP

CASE STUDY-1							CASE STUDY-2				
S N	F	SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)	ASAI (hrs/ year)	ASUI (hrs/ year)	SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)	ASAI (hrs/ year)	ASUI (hrs/ year)
1	F1	1.2973	6.5063	5.015	0.9993	0.00074	1.2973	6.5063	5.015	0.9993	0.00074
2	F2	1.3523	6.7900	5.021	0.9992	0.00078	1.3523	6.7900	5.021	0.9992	0.00078
3	F3	1.4870	7.4534	5.012	0.9991	0.00085	1.4870	7.4534	5.012	0.9991	0.00085
4	F4	1.3904	6.9679	5.012	0.9992	0.00080	1.3904	6.9679	5.012	0.9992	0.00080
	Syste m	1.4085	7.0424	5.000	0.9992	0.00080	1.4085	7.0424	5.000	0.9992	0.00080

Table.6, shows that, results of case study-1 using FMEA method calculated the reliability indices of IEEE RBTS BUS 2 and in case study-2, modeling of IEEE RBTS BUS2 using ETAP software and results are presented. Both methods showing the results should be same.

b. Comparison of Case Study-1 and Case Study-3

In this section, case study-1 presented the reliability indices of IEEE RBTS BUS 2 without DG and case study-5, shows that reliability indices IEEE RBTS BUS2 feeders with distributed generation at several locations. Obtained case study-1 and case study-3 results are tabulated in Table 7.

Table. 7 System performance indices of IEEE RBTS BUS2 without and with DG at different locations

CASE STUDY-1								CASE STUDY-3				
S. N	F	SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/int .)	ASAI (hrs/ year)	ASUI (hrs/ year)	DG LOCA TION	SAIFI (hrs/ year)	SAIDI (hrs/ year)	CAIDI (hrs/int .)	ASAI	ASUI
1	F1	1.2973	6.5063	5.015	0.9993	0.00074	LP 7	1.0427	5.2602	5.045	0.9994	0.00060
2	F2	1.3523	6.7900	5.021	0.9992	0.00078	LP9	1.0333	5.2218	5.054	0.9994	0.00060
3	F3	1.4870	7.4534	5.012	0.9991	0.00085	LP15	1.0502	5.2998	5.2998	0.9994	0.00060
4	F4	1.3904	6.9679	5.012	0.9992	0.00080	LP22	1.0262	5.1778	5.045	0.9994	0.00059
5	Syste m	1.4085	7.0424	5.000	0.9992	0.00080	Syste m	1.0384	5.2394	5.045	0.9994	0.00060

Table. 7 shows that, improvement of system performance indices of IEEE RBTS BUS2 without and with DG at different load points. By connecting distributed generation at different locations, interruptions and

interruption duration are decreased. Results showed that, impact of DG only at end load point does not affect the or change reliability at near substation. Further, compare without DG on distribution, the reliability improved by including DG in the distribution system.

6. Conclusion

In this paper, reliability analysis of IEEE RBTS Bus 2 (33/11 kV) distribution system with and without distributed generation has been done. An analytical method for the evaluation of the reliability of distribution systems with generation of distribution has been described. Development of reliability modeling through ETAP software has been presented. And obtained results are compared with the FMEA method. The impact of a distributed generation unit near the final point of load showed an improvement in reliability compared to the absence of a DG in the distribution system. The case-3 conducted work has been proven that the Distributed Generation could enhance the reliability of IEEE RBTS Bus 2. Finally, it can be concluded that the proper injection of the DG into the distribution system increases the reliability of the distribution system.

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