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Distributed Generation Impact on Distribution System Reliability

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Abstract**: *Reliability is the most important factor of distribution system and this system should be operated economically with low customer loads interruption. This is because that the distribution system gives supply to customers from transmission system. There are some power quality issues due to the failures of components in distribution system. Researchers are going on to assess the reliability of the power system. In the power system, reliability evaluation is an important aspect in complete electric distribution system planning and operation. Due to the extreme scale of problem, it is not possible to conduct reliability on complete power system, it is performed independently. Hence, In this paper, the reliability of distribution system is evaluated by using an analytical method is described and is applied to the IEEE RBTS BUS-6. Development of reliability model of distribution system using Electrical Transient Analyzer Program (ETAP) software is developed. And the Distributed Generation is introduced for the improvement of reliability. Reliability indices are such as System Average Interruption Frequency Indices (SAIFI), System Average Interruption Duration Indices (SAIDI), Customer Average Interruption Frequency Indices (CAIFI), Customer Average Interruption Duration Indices (CAIDI), Energy Not Supplied (ENS), Average Service Availability Indices (ASAI), etc. The performance of reliability of the system is shown by these indices.***

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

I. INTRODUCTION

The distribution system network which divided into the radial and meshed networks and this system is running in low voltage. The life span of components are come to end because of outages are up to 80 percent in the distribution system because of system faults and failures of the equipments. Because of these outages inside of the distribution system there is a need of human contribution which resulting in limiting in the no. of customers and duration failure time. The interruption rates and duration index, customer period, rate of failure can be changed by reliability indices near load points. The system's overall performance indices are approximated with the help of reliability indices. In these days the electricity which is conventional which has the ability of distribution generation and also renewable resources are involved in energy generation and it will transmit energy from one area to different customers. And the reliability modeling is improved by aiding distribution generation to the distribution system is explained in this paper [1]. This will not always improves the reliability of the distribution system sometimes it gives backup programming in the system. The IEEE RBTS bus-6 has four feeders for the main section which can be evaluated by Monto Carlo simulation technology in reference [2]. An analytical technique is used to assess reliability the network with the impact of DG has been research in [3]. Furthermore, for acquiring to numbers and length of interruptions and gadget indices through considered the issue failure costs, load level, DG vicinity and DG generation parameters. The reliability of the network is calculated in line with frequency and length approach and showed in [4]. In this case, improvement in reliability does not affect the system overall performance. The MCS method can be used to evaluate the reliability of the network, the random system being described in ref. [5]. 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. [6]. 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 [7]. 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 [8]. 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 [12]. 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 [11]. 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].

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The failure of the distribution system is strongly influenced by adverse weather conditions such as strong wind, lighting, icing, and so on [9]. 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 6. 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 are presented. Section 6 presents the conclusion.

II. 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 [13],[14].

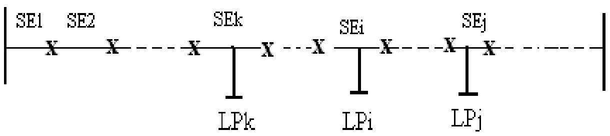

Fig. 2 The radial distribution network

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

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

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

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

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

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

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

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

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

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

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

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

III. RELIABILITY MODELLING OF DG

For reliability modelling and analysis of RBTS Bus 6 with Distributed Generation is model 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 LP_i to LP*n* with the help of Eq. (9) to Eq. (10) as [16]-[17].

$$\lambda_s' = \sum_{i=1}^{n} \lambda_i + \sum_{l=1}^{n} \lambda_l \quad (9)$$

Where,

λ_s'- Average failure rate at LPs within DG.

i =1- Load point 1

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

$$U_s' = \sum_{i=1}^{n} \lambda_i r_i + \sum_{l=1}^{n} \lambda_l s \quad (10)$$

Where,

U_s'- Average annual outage time at LPs within DG.

r_i - Average repair time at LPs within DG location

S- Switching Time at LPs within DG location

3.1 Developed algorithm based on FMEA technique used to calculate reliability indices of the modified IEEE RBTS Bus 6 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 average failure rate and average annual outage time 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 average failure rate and average annual outage time 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

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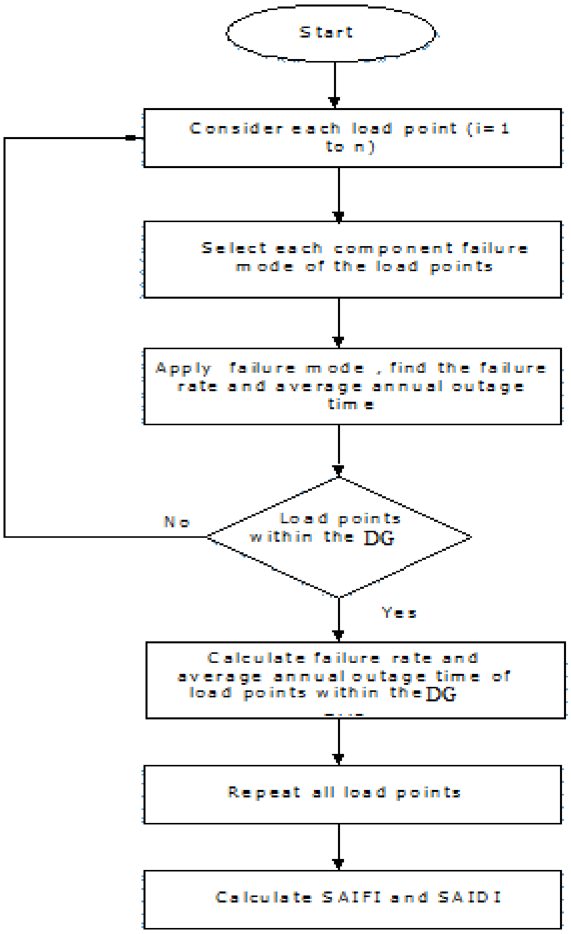

Fig. 3 Flow chart for evaluation of distribution system reliability indices

IV. CASE STUDIES

. In this research work, four (4) case studies are performed as shown in Table 1. IEEE RBTS Bus-6 has modified to conduct the case studies. The impact of DGs with 2 MW is placed on modified IEEE RBTS-6 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-6 bus [5], [16]. The Electrical Transient Analyzer Program (ETAP) is an electrical power system tool which has complete integration of AC and DC systems [15]. 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,

Table- I: Case studies structure

#	Description
Case 1	Evaluation of Reliability Indices Of IEEE RBTS Bus-6 Feeder Wise Using FEMA method
Case 2	Reliability Modeling of IEEE RBTS Bus6 Feeder Wise Using ETAP Software
Case 3	Evaluation of Reliability Indices of IEEE RBTS Bus-6 Feeder Wise With Distribution Generation Using FEMA Method
Case 4	Reliability Modeling of IEEE RBTS Bus-6 Feeder Wise With Distribution Generation Using ETAP Software

CASE STUDY- 1: Evaluation of reliability indices of IEEE RBTS Bus-6 feeder 4 using FEMA method

The single line diagram of IEEE RBTS Bus-6 (33/11 KV) main feeder is as shown Fig 4. This diagram consists of four sub feeders and all combined has 23 load points, and connected with 30 lines, 23 transformers and disconnect switches. In this case study, development of reliability modeling of IEEE RBTS BUS 6, with disconnects- with fuse- with alternative supply- with the repair of the transformer using FMEA method is presented.

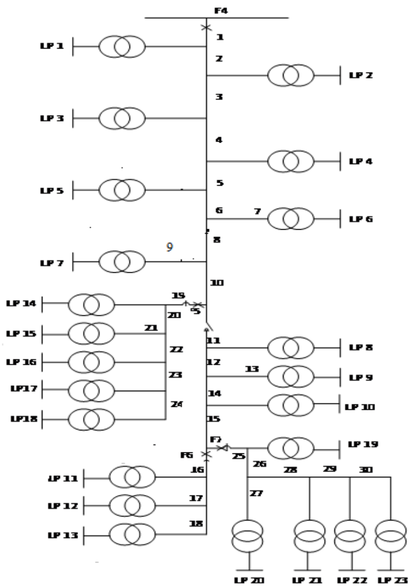

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Fig.4 IEEE RBTS Bus -6 feeder 4 distribution system

Table-II: System performance indices of IEEE RBTS Bus6 feeder wise using FEMA method

S.NO	IEEE RBTS BUS 6	PERFORMANCE INDICES		
		SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/int.)
1	F1	1.195	7.211	6.040
2	F2	1.347	8.305	6.162
3	F3	1.231	7.797	6.329
4	F4	1.300	8.592	6.60

The reliability indices of the distribution system of IEEE RBTS BUS-6 feeder wise calculated using FMEA method and the values of SAIFI, SAIDI and CAIDI are shown in the Table.II.

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CASE STUDY-2: Reliability modeling of IEEE RBTS Bus 6 using ETAP software

Development of reliability modeling the of IEEE RBTS BUS-6 feeder 1, 2,3& 4 are using ETAP software as shown in Fig.5.

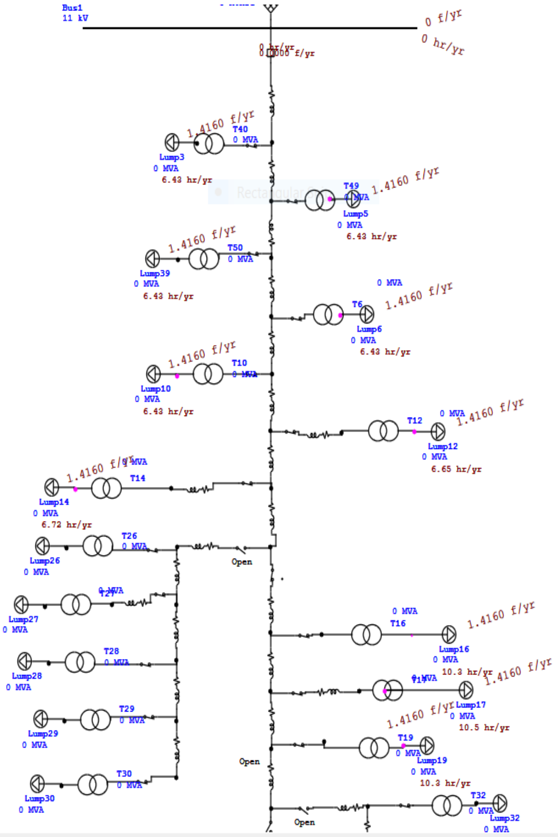

Fig 5. Improvement of reliability indices of IEEE RBTS BUS-6 feeder wise modeled in ETAP

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 6 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-III: The performance indices obtained from ETAP software

S.NO	IEEE RBTS BUS 6	PERFOMANCE INDICES USING ETAP SOFTWARE		
		SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	1.193	7.211	6.040
2	F2	1.347	8.305	6.162
3	F3	1.231	7.797	6.329
4	F4	1.300	8.592	6.6059

Table. III, 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.

Case Study-3: Evaluation of reliability indices of IEEE RBTS Bus 6 feeder wise with Distributed Generation using FEMA method.

In this case study, the reliability indices of IEEE RBTS BUS-6 main feeder with distribution generation are evaluated using failure modes effective analysis (FMEA). The single line diagram of IEEE RBTS Bus-6 with Distribution Generation is shown in Fig.6. The circuit is operated by using switches, fuses, transformers, customer loads points, disconnect switches and distribution generation is added to improve the reliability of the distribution system. The obtained results are shown in Table. 4.

Table-IV System performance indices of IEEE RBTS BUS-6 with DG

S.NO	IEEE RBTS BUS 6	DG location	PERFORMANCE INDICES WITH DG'S USING FEMA METHOD		
			SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	LP_{10}	1.218	5.634	4.624
2	F2	LP_{12}	1.43	6.528	4.565
3	F3	LP_{18}	1.39	5.867	4.219
4	F4	LP_{23}	1.529	6.002	3.925

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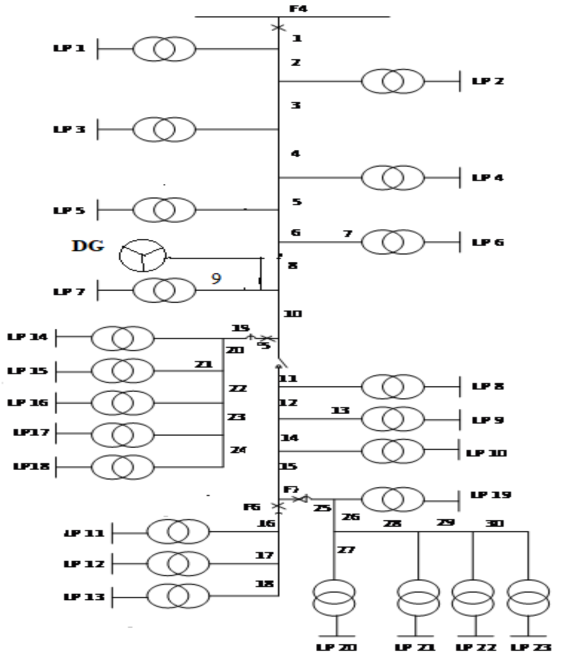

Fig 6. Single line diagram of IEEE RBTS BUS-6 with DG

Table.IV shows that, impact of DG at specific location and system reliability indices have been observed. These reliability indices are showed that optimum location for impact of DG in the feeder wise.

Case Study-4: Reliability modeling of IEEE RBTS bus-6 feeder wise distributed generation using ETAP software

The distribution system reliability can be improved by introducing distribution generation connected to the IEEE RBTS BUS-6 main system. The capacity of DG is 2 MW and its reliability is mean time to failure rate is 550 hours, and mean time to repair time is 75 hours, switching time is 1 hour. In this the modeling is done using ETAP software.

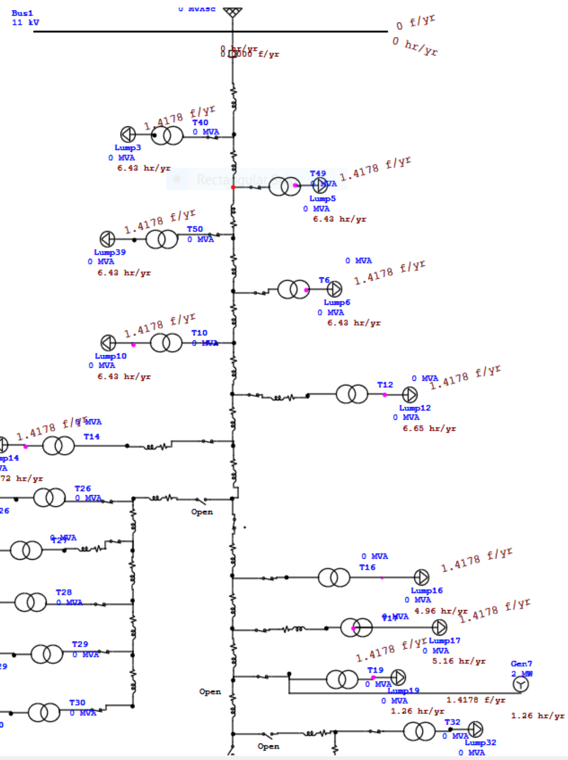

Fig 7. Improvement of reliability indices of IEEE RBTS BUS-6 with DG modeled in ETAP

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The performance indices of IEEE RBTS BUS-6 FEEDER WISE WITH DG'S using ETAP software

S.NO	IEEE RBTS BUS 6	DG LOCATION	PERFOMANCE INDICES USING ETAP SOFTWARE WITH DG'S		
			SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	LP_{10}	1.218	5.6342	4.6241
2	F2	LP_{12}	1.34	6.5288	4.5655
3	F3	LP_{18}	1.29	5.8675	4.219
4	F4	LP_{23}	1.329	6.002	3.925

Table V shows that, impact of DG at several different locations and system reliability indices have been seen, impact DG at seven different locations in IEEE RBTS BUS6 the reliability indices showed that optimum location for impact of DG was end F1 and F3.This distribution generation is placed at different location and reliability is calculated.

V. 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 6 are calculated using the FMEA method and case study-2, reliability indices of IEEE RBTS BUS6 are calculated using ETAP software. Obtained case study-1 results are compared to case study-2 and these results tabulated in Table6.

Table-VI Results of system performance indices of IEEE RBTS BUS6 using FMEA method and ETAP Software

CASE STUDY-1					CASE STUDY-2				
S.NO	IEEE RBTS BUS6	PERFORMANCE INDICES USING FEMA METHOD WITHOUT DG			S.NO	IEEE RBTS BUS 6	PERFORMANCE INDICES USING ETAP SOFTWARE WITHOUT DG		
		SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)			SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	1.193	7.211	6.040	1	F1	1.193	7.211	6.040
2	F2	1.347	8.305	6.162	2	F2	1.347	8.305	6.162
3	F3	1.231	7.791	6.329	3	F3	1.231	7.791	6.329
4	F4	1.300	8.592	6.605	4	F4	1.300	8.592	6.605

Table.VI, shows that, results of case study-1 using FMEA method calculated the reliability indices of IEEE RBTS BUS-6 and in case study-2, modeling of IEEE RBTS BUS-6 using ETAP software and results are presented. By using both the methods, obtained results are same.

b. Comparison of Case Study-3 and Case Study-4

In case study-3, the reliability of IEEE RBTS BUS-6 with DG's are calculated using failure mode effecting analysis and the results are compared with evaluation of reliability indices of RBTS BUS-6 with DG's using ETAP software results. Both the obtained results are shown in the Table.7. And the results obtained by using the above process are same

Table-VII Comparison of case study-3 and case study-4

CASE STUDY-3					CASE STUDY-4				
S.NO	IEEE RBTS BUS 6	PERFORMANCE INDICES USING FEMA METHOD WITH DG			S.NO	IEEE RBTS BUS 6	PERFORMANCE INDICES USING ETAP WITH DG		
		SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)			SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	1.218	5.634	4.6241	1	F1	1.218	5.634	4.6241
2	F2	1.430	6.528	4.565	2	F2	1.430	6.528	4.565
3	F3	1.390	5.867	4.219	3	F3	1.390	5.867	4.219
4	F4	1.529	6.002	3.925	4	F4	1.529	6.002	3.925

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Table.VII shows that, results of system case study-3 performance indices of IEEE RBTS BUS-6 with DG's distributed system using FMEA method and results of system case study-4 performance indices of IEEE RBTS BUS-6 with DG's using ETAP software. Using both the methods, obtained results are same.

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

In this section case study-1 is the reliability indices of IEEE RBTS Bus-6 without DG is calculated is using the FEMA method and then the case study-3 is the reliability indices of IEEE RBTS Bus-6 with DG's using FEMA method. The results that obtained are compared as shown in the Table. And this shows that the system reliability is improved when distribution generation is added.

Table-VIII Comparison of case study-1 and case study-3

CASE STUDY-1					CASE STUDY-3				
S.NO	IEEE RBTS BUS6	PERFORMANCE INDICES USING FEMA METHOD WITHOUT DG			S.NO	IEEE RBTS BUS6	PERFORMANCE INDICES USING FEMA METHOD WITH DG		
		SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)			SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	1.193	7.211	6.404	1	F1	1.218	5.634	4.624
2	F2	1.347	8.305	6.162	2	F2	1.430	6.528	4.565
3	F3	1.231	7.791	6.329	3	F3	1.390	5.867	4.219
4	F4	1.300	8.592	6.605	4	F4	1.529	6.002	3.925

Table.VIII shows that reliability indices of IEEE RBTS Bus-6 with and without distribution generation and DG's are located at different places. By the connected distributed generation at the various locations ASAI and ASUI have same values. The impact of DG in the feeders wise various location because the DG location is ending of this feeder. % SAIDI improved means that, interruption duration is the decreasing at the load points.

a. Comparison of Case Study-2 and Case Study-4

In this section, the case study-2, the reliability modeling of IEEE RBTS Bus-6 without DG'S using ETAP software is calculated, and case study-4 the modeling of IEEE RBTS Bus-6 with DG's using ETAP software is calculated and the obtained results are compared with each other and the comparison of case study-2 and case study-4 is shown in the Table IX And it is observed that the reliability of system is improved when DG is added to the system.

Table IX Comparison of case study-2 and case study-4

CASE STUDY-2					CASE STUDY-4				
S.NO	IEEE RBTS BUS 6	PERFORMANCE INDICES USING ETAP SOFTWARE WITHOUT DG			S.NO	IEEE RBTS BUS 6	PERFORMANCE INDICES USING ETAP SOFTWARE WITH DG		
		SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)			SAIFI (int./ year)	SAIDI (hrs/ year)	CAIDI (hrs/ int.)
1	F1	1.193	7.211	6.404	1	F1	1.218	5.634	4.6241
2	F2	1.347	8.305	6.162	2	F2	1.430	6.528	4.565
3	F3	1.231	7.791	6.329	3	F3	1.390	5.867	4.219
4	F4	1.300	8.592	6.605	4	F4	1.529	6.002	3.925

VI. CONCLUSION

In this paper, reliability analysis of IEEE RBTS Bus 6 (33/11 kV) feeder wise 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-4 conducted work has been proven that the Distributed Generation could enhance the reliability of IEEE RBTS Bus 6. Finally, it can be concluded that the proper injection of the DG into the distribution system can increases the reliability of the distribution system.

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