Evaluation and Improvement of Distribution System Reliability Indices using ETAP Software

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Abstract: ***Reliability assessment is the most important factor in designing and planning of distribution system that should operate in an economical manner with minimal interruption of customer loads. This is due to the fact that the distribution system provides the final link between a utility transmission system and its customers. It is observed that more than 80% of all customer interruptions occur (i.e., power quality issues) due to component failures in the distribution system. That report quantifies the expected reliability indices such as interruption frequency and interruption duration during the entire year. Many research findings are out there 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 evaluation of distribution system using a minimal cut set method based on the FMEA technique is described and applied to the IEEE RBTS Bus-2 and Indian practical distribution system (33/11 kV). Development of ETAP software is presented for calculating reliability indices. Further, improvement of reliability with introducing of Distributed Generation is presented. 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), Energy Not Supplied (ENS), Average Energy Not Supplied (AENS), etc. These indices are shows the reliability performance of the system.***

Keywords: Distributed Generation; IEEE RBTS BUS 2; Indian practical Parigi distribution system (33/11 kV); Reliability indices of Distribution System.

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1. Introduction

The distribution device is a hyperlink related among to the transmission line and load point. The energy failure occurs came about due to the supply system failure and cargo point customers failures. In beyond years distribution device turned into supplied less and terrible strength to the patron's call for the environment and society maximum impact due to the generated energy. The electricity system has a purpose of supplying the electricity without any interruption, satisfactory energy, customers fulfil, users demand and customers proper price. The unavailability of the purchaser delivers within the distribution of system failure. The updated, new generation, improvement, financial growth inside the electricity system many countries are targeted at the distribution device reliability. The transmission and distribution structures are the generated strength is supplied to the reliable strength to customers call for pride and with none running price. The many cases deliver failure, bad energy best, and client interruption passed off because of the distribution system are imparting the unreliable energy to customers; then purchaser was given much less satisfactory electricity.

Energy outage is impacting at the monetary and software of the customers. The unreliable energy supply without delay effects on the energy nice, environments, economic and customers. The distribution reliable strength development many authors were investigated and plenty of one of a kind technic using many software programs, loss of equipment, manipulate and hold the reliable power and energy high-quality. In view of the above problems, distributed generation is introduced in the distribution system.

The distribution reliability indices of the electric power distribution device reliability strength carried out by using the distribution device strength and distribution automation system it's supplied the device-extensive status and health tracking [1]. This implement using the (R-APDRP) restructured extended power improvement and reforms program and (IPDS) incorporated energy improvement scheme by means of the usage of this distribution system networks utility of electrical non-compulsory issues have been the reduced. This implements the managed exceptional and reliable of the delivery. The drawbacks of previous work based totally on that used software for calculating reliability indices. The interruption amassed from the log e-book of the feeder Indian Electrical application and modelled the CYMDIST software program. Using this software program discussed the effects analyzed.

Based on the climate circumstance of the substation modelled the reliability, the reliability of substation parameters operating weather situations [2]. In this the low voltage, the feeder becomes converted to the excessive voltage feeder and it turned into reliability overall performance became evaluated. In this FMEA technique was used to assess the load factor and system overall performance reliability indices.

The distribution system reliability impacts the clients [3]. Each consumer scattering case becomes analyzed for determined reliability indices using the device with distribution generators and the system without distribution generator and the outcomes had been compared. The outcomes confirmed that point changed into laid low with the optimum region of distribution generator hooked up various client scattering and recuperation. In this, reliability assessment taken into consideration time calculated each load point with distribution generator and circle of relatives positioned. The fault befell in a segment of the feeder the circuit breaker changed into mechanically opened. Improve the system reliability in electrical distribution networks approached the most useful allocation of distribution generator, genetic set of the rule's optimization approach. The interruption fee supply electricity to the customers that considered distinctive consuming devices.

The fundamentals of the electric distribution system for training purposes, educate the energy system reliability indices assessment [4]. This was applied a sensible system of fundamental elements of the device, reliability checking out device is nearly carried out to the substation system modelled and evaluated the reliability indices, the effects discussed and analyzed.

The modern electricity system improves the reliability energy with the aid of adding the distribution generator at load it's far minimized some of the interruptions inside the distribution device network [5]. The distribution generator is the opportunity supply of distributed system network and load factor, the interruption time of system distribution generator supply to loads. The distribution issue of system fuses, disconnectors, and distribution generators brought to the device to enhance the reliability of electricity. Performance measure reliability, keep cash accurately and purchaser election. The electrical enterprise evolved to degree device and reliability overall performance of the system. This is mentioned distribution system reliability indices observe and analysis.

Reliability indices of electrical distribution network system assessment dependability evaluation of appropriation foundation based unwavering quality measurements on being registered in accordance with the field information accumulated for an investigation period [6]. Both account and quantitative unwavering quality portrayals of dispersion infrastructural expenses ought to be utilized so as to proffer sound operational methods of reasoning went for protecting productive, secure, solid and amazing power conveyance to purchasers.We along these lines emphasize the significant centrality of a dependable dispersion system tied down on sound arranging theory and usage procedure just as the appropriation of present-day dissemination computerization framework.

Electricity Act 2003 / Electricity (Amendment) Act, 2014, Government of India, Ministry of Law and justice accompanying Demonstration of Parliament got the consent of the President on the 26th May 2003 and is thus distributed for general data [7]. A Demonstration to solidify the laws identifying with age, transmission, appropriation, exchanging and utilization of power and for the most part for taking estimates helpful for advancement of power industry, advancing challenge in that, securing enthusiasm of purchasers and supply of power to all regions, legitimization of power duty, guaranteeing straightforward arrangements with respect to endowments, advancement of effective and ecologically generous strategies, constitution of Focal Power Specialist, Administrative Commissions and foundation of Redrafting Council what's more, for issues associated therewith or coincidental.

Predicting distribution system performance So as to guarantee that the changing utility condition does not unfavourably influence the unwavering quality of electric power provided to clients, a few state administrative offices have begun to endorse unwavering quality measures least dependability levels to be kept up by electric power dispersion organizations [8]. The gauges depend on unwavering quality files registered from authentic blackout information. The unwavering quality files shift from year to year on the grounds that of the factual variety in the number of client intrusion, what's more, the length of such intrusions. To be successful, the unwavering quality models embraced must distinguish feeders that reliably perform inadequately, while being obtuse toward those that infrequently have poor dependability. In this utilizes a term-based Monte Carlo recreation to investigate the anticipated effect of different unwavering quality benchmarks on a huge down to earth dissemination framework. The affectability of various guidelines to contrasts in framework size and segment disappointment rate is likewise investigated.

Modeling and Analysis of Distribution Reliability Indices Evaluation of client power supply unwavering quality is a significant piece of conveyance framework activity and arranging [9]. Monte Carlo reenactments can be utilized to locate the factual conveyance of the unwavering quality files, alongside their mean and standard deviation. The standard deviation of the unwavering quality records furnishes circulation engineers with data on the normal scope of the yearly qualities. Be that as it may, the Monte Carlo recreation more often than not is a tedious calculation. Further, a productive Monte Carlo recreation technique for appropriation framework unwavering quality evaluation is introduced. Examination of blackout information from a handy dispersion framework is performed to decide the disappointment and fix models proper for use in the Monte Carlo recreation. The affectability of the unwavering quality lists to the decision of model is displayed. At long last, the effect of insurance systems on the factual dissemination of Framework Normal Intrusion Recurrence Record (SAIFI) for a down to earth conveyance feeder is introduced.

System Reliability Concept Framework approach to demonstrating and examination has been increasing much significance in the course of recent decades [10]. Frameworks Society of India has likewise been started long back and the creator is additionally an individual from the general public. The creator has done his exploration work in the region of framework unwavering quality applications to control framework systems. He has the chance to broaden the work to different fields of utilizations like Mechanical Designing, Software engineering, Transportations issues, and so on. In mechanical building issues, the maximal-stream insignificant cut hypothesis has been utilized which depends on the cut sets of systems. Cut sets are widely utilized in creating hypotheses of electrical circuit examination at first. Cut sets are likewise valuable in framework examination of the likelihood of disappointment. Further, real points of interest of the cutest approach are that they legitimately speak to the disappointment methods of the frameworks. In this way, not just frameworks can be dissected utilizing cut set, and criticality examination can likewise be managed.

Assessment of Reliability in the power distribution system it is a calculation accessible to assess the circulation arrange dependability in the downtown region as per the present activity conditions [11]. New sensible records are displayed to compute the circulation arrange dependability and an appraisal result is given remove a portion of Beijing downtown zone for instance. A quick and compelling strategy to pass judgment on the feeders' extra limits and to improve the administration reclamation is given, which prompts discover the frail focuses in the dispersion arrange and gives the advisers for the improvement of the power supply security and unwavering quality.

The impact of distributed energy resources on the reliability of smart distribution system the incorporation of Disseminated Vitality Assets (DER) in power frameworks can give the chance to supply power to clients all the more proficiently and viably [12]. The DER incorporates Disseminated Age (DG) and Request Side Administration (DSM). In a keen framework consolidating computerized control and appropriated vitality frameworks, a successful DSM can ease the pinnacle burden and move some portion of the interest to off-crest hours. The point of this exploration is to evaluate the effect of the DG and the DSM on the dependability of a brilliant appropriation framework by breaking down various Contextual investigations. Roy Billinton test framework RBTS Bus2 is utilized to approve contextual analyses which are executed as a piece of this paper. For progressively down to earth contemplations a change of the RBTS Bus2 model is created to survey the framework unwavering quality.

The appropriation framework is inclined to disappointments and unsettling influences due to component disappointments [13]. Disseminated age (DG) goes about as a reinforcement source to guarantee the unwavering quality of electric power supplies. In this research, the authors proposed an investigative technique, which is a restrictive likelihood approach. This method used to and the unwavering quality lists of RBTS Transport with various DGs. The estimation of DG situating as a reinforcement generator is measured as far as its commitment to the unwavering quality improvement in a circulation organize. The unwavering quality improvement is watched dependent on dependability lists that incorporate SAIFI, SAIDI, CAIDI, and ENS. Furthermore, the estimation of DG installed at different areas on the feeder from the substation, just as the effects of introducing, accumulated DGs and numerous DGs are presented.

In this paper, we determine the reliability indices of distribution systems with distributed generation using FMEA method and ETAP software. This paper can be summarized in the following way: section 2 discusses the reliability indices. Section 3 describes the IEEE RBTS Bus 2 model and Indian PARIGI Distribution system research system model that is used in case studies in this research. Section 4 summarizes the results of the different case studies that all conduct in this paper. Section 5 presents the conclusion.

2. Reliability indices

The system reliability indices evaluation is classed into 3 types they're; sections, lateral distribution and load points. The distribution system community consists of the extraordinary components, deliver, busbars, circuit breakers, transformers, switches, disconnectors, reclosers and fuses; all components are required to connect system [14].

2.1 Reliability Indices of Distribution System

2.1.1 Load Point Indices

Annual foundation or normally determine the load point indices. The calculating indices took any particular year values or random values, and features of the failure of the component quote repair time, switching time and restoration time in the 12 months. The load point indices are three parts load factor average failure rate (λ_s), common annual outage time (U_s)and common outage time (r_s).

A. Average failure rate (λ_s)

The average failure rate is calculated by means of the all phase failure price of distribution system feeders.

$Average$ failure rate (λ_s) = Total sum of section failure rate

Average failure rate (λ_s) = $\sum_i \lambda i$ (failure/year) (2.1)

B. Average annual outage time (u_s)

The common failure charge is calculated through the all segment failure rate and repair of time of distribution system feeders.

Average annual outage time (U_s)

= Section failure rate * Repair of time

Average annual outage time (U_s)

$= \sum_i \lambda_i * r_i$ (hours / year) (2.2)

C. Average outage time (r_s)

The average outage time is calculated through the ratio of the Average annual outage time (U_s) and Average failure rate (λ_s) of distribution system feeders.

$$\text{Average outage time } (r_s) = \frac{\text{Average annual outage time } (U_s)}{\text{Average failure rate } (\lambda_s)}$$

Average outage time (r_s) = $\frac{U_S}{\lambda_S} = \frac{\sum_i \lambda_i * r_i}{\sum_i \lambda_i}$ (hours/ interruption) (2.3)

2.1.2 System Reliability Indices

The customer factor of distribution system indices affected by the overall system supply, overall performance, responses, and behaviour. The distribution system primary reliability indices are the following:

D. System average interruption frequency index (SAIFI)

The index constitutes the common value of interruption frequency within the distribution system that consequences customers inside the 12 months. In a location modified in the enclosed the variety of purchasers and interruption revel in. SAIFI is the average fee of interruption frequency inside the system that affects clients all through the yr. The equation is shown system common interruption frequency index.

$$\text{SAIFI} = \frac{Total \text{ number of customers interrptions}}{Total \text{ number of customers served}}$$

$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i}$ (interruptions/customer year) (2.4)

E. System average interruption duration index (SAIDI)

The index represents the device average interruption of consumer period in a year. SAIDI is the common fee of outage length inside the system that affects customers at some stage in the year. The equation for the system average interruption duration index is

$$SAIDI = \frac{\text{Total sum of customer interrptions durations}}{\text{Total number of customer served}}$$

$$SAIDI = \frac{\sum U_i N_i}{N_T} \quad \text{(hours/ customers year)} \qquad (2.5)$$

where N_i is the number of customers and U_i is the annual outage time for location i, and N_T is the total number of customers served.

F. Customer average interruption duration index (CAIDI)

The index represents the system customer common interruption duration in a year. CAIDI is the ratio of the SAIDI and SAIFI. CAIDI is the average price of outage length time in the system that affects customers in step with interruption. The equation is shown the patron common interruption duration index.

$$CAIDI = \frac{\text{Sum of customer interruptions durations}}{Total \text{ number of customer interruptions}}$$

$$CAIDI = \frac{\sum U_i N_i}{\sum \lambda_i N_i} \text{(hrs/customer interruption)} \qquad (2.6)$$

G. Average service availability index (ASAI)

The index represents the common service availability index. The Average Service Availability Index (ASAI) is a reliability index commonly used by electric power utilities. ASAI is calculated as

$$\text{ASAI} = \frac{\text{Customer hours of avaliable service}}{\text{Customer hours demanded}}$$

$$ASAI = \frac{\sum N_i * 8760 - \sum U_i N_i}{\sum N_i * 8760} \text{(hr/customer yr)} \qquad (2.7)$$

where N_i is the number of customers and U_i is the annual outage time (in hours) for location i.

H. Average service unavailability index (ASUI)

The index represents the average service unavailability index. To calculate the ASUI, the equation below provides the unavailability index.

$$ASUI = \text{1-ASAI} = \frac{\text{Customer hours of unavailable service}}{\text{Customer hours demanded}}$$

$$ASUI = \frac{\sum U_i N i}{\sum N_i * 8760} \quad \text{(hours/customer year)} \qquad (2.8)$$

I. Energy is not supplied index (ENS)

The index constitutes the energy isn't provided with the aid of the system, the calculation of ENS is proven equation energy no longer supplied.
ENS = Total energy not supplied by the system

$$ENS = \sum L_{a(i)} U_i \qquad \text{(KWH/ year)} \qquad (2.9)$$

J. Average energy not supplied (AENS)

The index represents the average strength now not furnished by means of the system, the calculation of AENS is proven equation average energy not supplied.

$$AENS = \frac{Total \text{ energy not supplied}}{\text{Total number of customers served}}$$

$$AENS = \frac{\sum L_{a(i)} U_i}{\sum N_i} \text{(KWH/ customer year)} \qquad (2.10)$$

3. Case Studies

In all the case studies consider IEEE RBTS BUS2 and PARGI distribution system with disconnects- with fuse- with alternative supply- with the repair of the transformer. The following case studies have been conducted.

- Case study-1: IEEE RBTS BUS2, with disconnects- with fuse- with alternative supply- with the repair of the transformer.
- Case Study-2: Modeling of IEEE RBTS Bus2 Using ETAP Software.
- Case Study-3: Reliability Indices of PARGI Distribution System, with disconnects- with fuse- with alternative supply- with the repair of the transformer.
- Case Study-4: Modeling of PARGI Distribution System Using ETAP Software.
- Case Study-5: IEEE RBTS BUS-2 Feeders with Distributed Generation Using ETAP Software
- Case Study-6: PARGI Distribution System with Distributed Generation Using ETAP Software

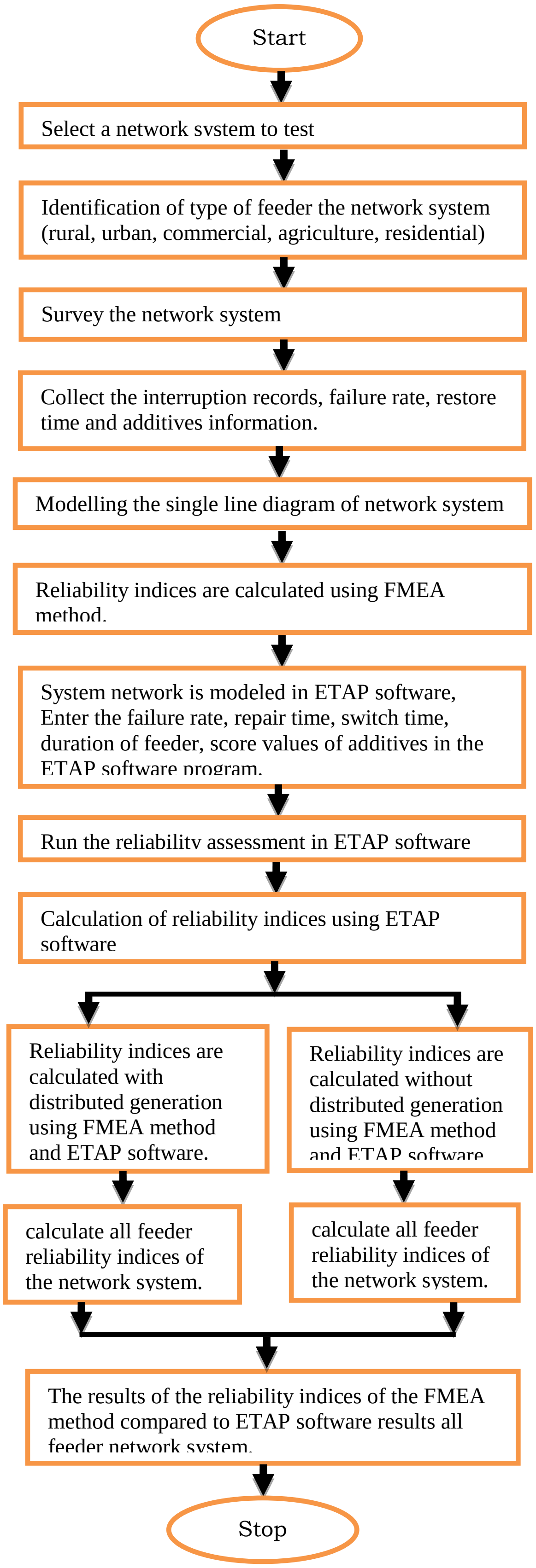

Figure 1: Flow chart for Evaluation of reliability indices of IEEE RBTS BUS2 and PARGI distribution system without and with distributed Generator.

3.1 Development of algorithm for calculating IEEE RBTS BUS2 and PARGI DISTRIBUTION SYSTEM Reliabilty indices

Step1: Select the community system to a check.
Step2: Identification of feeders, urban feeder, commercial feeder, Rural feeder, agriculture feeder, industrial feeder and residential feeder from the network system.
Step3: Survey of the network system.
Step4: Collect the interruption records, failure rate, restore time and additives information.
Step5: Model the single line diagram of the network system.
Step6: Reliability indices are calculated using the FMEA method.
Step7: System network is modeled in ETAP software, Enter the failure rate, repair time, switch time, duration of feeder, score values of additives in the ETAP software program.
Step8: Run the reliability assessment in the ETAP software.
Step9: Calculation of reliability indices the usage of the ETAP software program.
Step10: Reliability indices are calculated with distributed generation using FMEA method and ETAP software.
Step11: Calculate all feeder reliability indices of the network system.
Step12: The results of the reliability indices of the FMEA method compared to ETAP software results all feeder network system.

3.2 Case study-1 IEEE RBTS BUS2,with disconnects-with fuse-with alternative supply-with the repair of the transformer

Results obtained are tabulated in Tables 3 and 4.

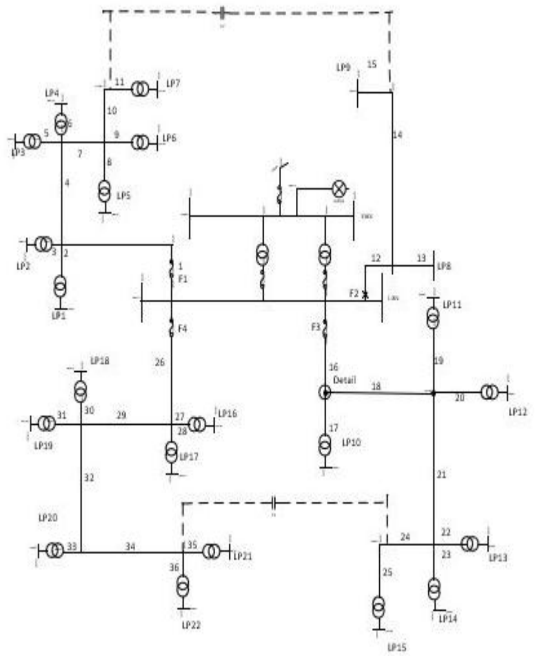

Figure 2: Single line diagram of RBTS BUS2 system.

Table 1: Results of load point indices RBTS BUS-2 FEEDER-4

S. No.	LOAD POINT	λ_{Lpi}	U_{LPi}	r_{Lpi}
1	1	0.240	3.58	14.90
2	2	0.253	3.64	14.40
3	3	0.253	3.64	14.40
4	4	0.240	3.58	14.90
5	5	0.253	3.64	14.40
6	6	0.250	3.63	14.51
7	7	0.253	3.60	14.24
8	8	0.140	0.542	3.890
9	9	0.140	0.503	3.604
10	10	0.243	3.58	14.73
11	11	0.253	3.64	14.40
12	12	0.256	3.66	14.29
13	13	0.253	3.59	14.19
14	14	0.256	3.61	14.08
15	15	0.243	3.58	14.73
16	16	0.253	3.64	14.40
17	17	0.243	3.59	14.78
18	18	0.243	3.58	14.73
19	19	0.256	3.65	14.24
20	20	0.256	3.65	14.24
21	21	0.253	3.59	14.19
22	22	0.256	3.61	14.08

Table 2: Results of system performance indices of IEEE RBTS BUS2

S.N0.	**FEEDER NAME**	**SAIFI** (interruption/ year)	**SAIDI** (hours/ year)	**CAIDI** (hours/interruption)	**ASAI** (hours/ year)	**ASUI** (hours/ year)	**ENS** (KWH/ year)	**AEN** (KWH/ year)
1	F1	0.248	3.62	14.5349	0.999 587	0.000 412	1.31 94	0.20 23
2	F2	0.140	0.52 3	3.7375	0.999 402	0.000 597	1.12 49	0.56 24
3	F3	0.250	3.62	14.4667	0.999 586	0.000 414	11.2 12	0.01 77
4	F4	0.247	3.61	14.38	0.999 587	0.000 412	12.2 37	0.09 16

Table 2 shows that, the system performance of IEEE RBTS BUS2, F1, F2, F3 and F4. Indices are calculated using the FMEA technique.

3.3 Case Study-2 : Modelling of IEEE RBTS BUS2 USING ETAP software

Development of reliability modeling of IEEE RBTS BUS2, feeder1, feeder2, feeder3 and feeder4 are developed using ETAP software as shown in Fig. 3. The obtained results are tabulated in Table3.

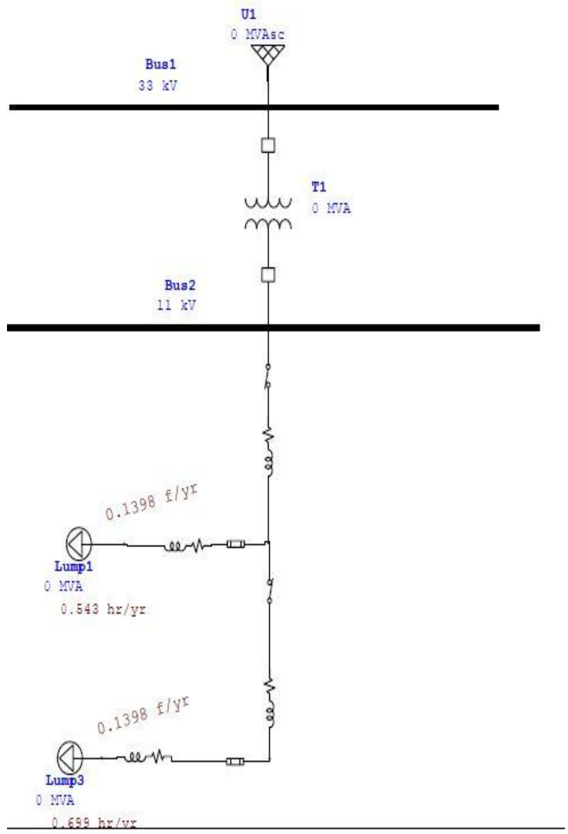

Figure 3: IEEE RBTS BUS-2 FEEDER-2 modeled in ETAP software

Table 3: Results of performance indices of IEEE RBTS BUS2

S.N	FEEDER NAME	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)	ENS (KWH/yr)	AEN (KWH/yr)
1	F1	0.248	3.62	14.5349	0.999587	0.000412	1.194	0.2023
2	F2	0.140	0.523	3.7375	0.999402	0.000597	1.1249	0.5624
3	F3	0.250	3.62	14.4667	0.999586	0.000414	11.212	0.0177
4	F4	0.247	3.61	14.38	0.999587	0.000412	12.237	0.0916

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

3.4 Case Study-3: Reliability indices of PARGI distribution system

Consider PARGI distribution system (33/11KV) with disconnects- with fuse- with alternative supply- consider the repair of the transformer. The practical PARGI distribution sub-station length of the 11 kV feeder sections and 0.4 kV distribution component data are shown in Table 23. Calculated the reliability indices of the PARGI distribution system in the PARGI distribution system, 33/11KV it has the 154 no. of distribution transformer, 154no. of loads, 154 no. of fuses. PARGI distribution system has six feeders. The PARGI distribution system reliability indices calculated using the FMEA method. The obtained results are tabulated in table 4.

Table 4: Results of Reliability indices the PARGI distribution system including F1, F2, F3, F4, F5, and F6.

S.N	FEEDER NAME	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)	ENS (KWH/yr)	AEN (KWH/ yr)
1	F1, INDUSTERIAL	0.1791	3.4288	19.141	0.9996	0.00039	18.8584	0.0060695
2	F2, AGRICULTURAL	0.4640	3.9947	8.609	0.9995	0.046	243.6767	0.0915347
3	F3, COMMERCIAL	0.5370	4.1905	7.803	0.9995	0.048	184.382	0.15718841
4	F4, RURAL	0.7408	4.4696	6.034	0.9995	0.00051	214.5408	0.17789453
5	F5, URBAN	0.6005	4.1735	6.950	0.9995	0.048	371.4415	0.13033035
6	F6, RESINDENTIAL	0.5053	4.1319	8.177	0.9995	0.00047	210.7269	0.18166112

3.5 Case study-4: Modelling of PARGI distribution system using ETAP software

Development of reliability modeling of PARGI distribution system with disconnects, with fuses, with alternative supply and repair of the transformer using ETAP software. The obtained results are tabulated in Table 5.

Table 5: Results of PARGI distribution system Performance indices using ETAP

S.N	FEEDER NAME	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)	ENS (KWH/yr)	AEN (KWH/yr)
1	F1, INDUSTERIAL	0.1791	3.4288	19.141	0.9996	0.00039	18.8584	0.0060695

2	F2, AGRICULTURAL	0.4640	3.9947	8.609	0.9995	0.0046	243.6767	0.0915347
3	F3, COMMERCIAL	0.5370	4.1905	7.803	0.9995	0.0048	184.382	0.15718841
4	F4, RURAL	0.7408	4.4696	6.034	0.9995	0.00051	214.5408	0.17789453
5	F5, URBAN	0.6005	4.1735	6.950	0.9995	0.0048	371.4415	0.13033035
6	F6, RESINDETIAL	0.5053	4.1319	8.177	0.9995	0.00047	210.7269	0.18166112

The PARGI distribution system F1, F2, F3, F4, F5, and F6 are calculated using ETAP software. The obtained results are compared with the FMEA method and the results are the same.

3.6 Case Study-5: IEEE RBTS BUS-2 Feeders with Distributed Generation Using ETAP Software

Improvement of reliability IEEE RBTS BUS-2 feeders with distributed generation using ETAP software is presented. The capacity of DG is 1MW and its working 100% reliable. The DG is connected to IEEE RBTS BUS2 and DG location at A, B, C, and D. The system is shown in Fig 4. The obtained results are tabulated in Tables 6, 7, 8 and 9.

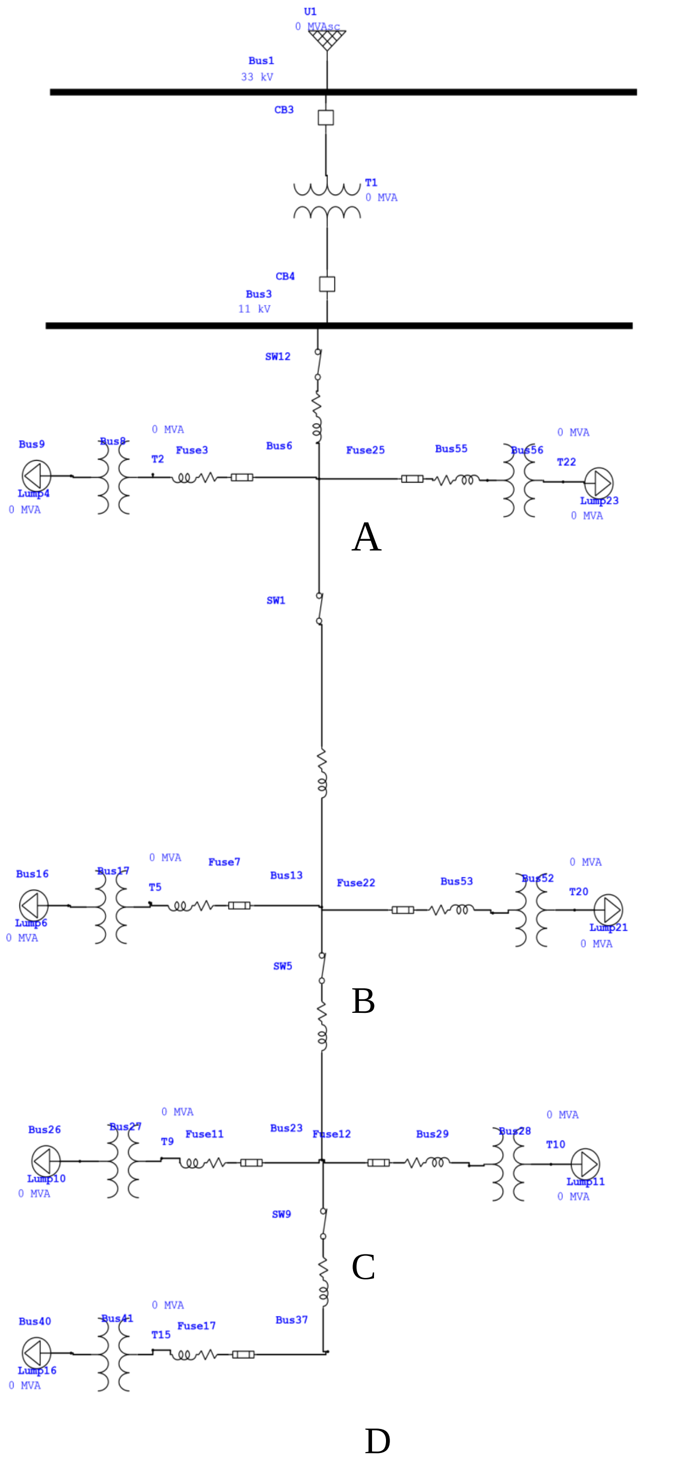

Figure 4: Improvement of reliability indices of IEEE RBTS BUS-2 FEEDER-1 with DG at location A, B, C and D modeled in ETAP software

Table 6: Improvement of reliability indices of IEEE RETS BUS 2 feeder1 with DG

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)
1	A	0.75	0.2396	3.6553	15.253	0.9996	0.000042
2	B	1.5	0.2396	3.5859	14.964	0.9996	0.000041
3	C	2.25	0.2396	3.5796	14.937	0.9996	0.000041
4	D	2.85	0.2396	3.5766	14.925	0.9996	0.000041

Table 7: Improvement of reliability indices of IEEE RETS BUS 2 feeder2 with DG

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/year)	SAIDI (hours/year)	CAIDI (hours/interruption)	ASAI (hours/year)	ASUI (hours/year)
1	A	0.75	0.1398	0.6208	4.442	0.9999	0.000007
2	B	1.35	0.1398	0.5233	3.744	0.9999	0.000006

Table 8 Improvement of reliability indices of IEEE RETS BUS 2 feeder3 with DG

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)
1	A	0.75	0.2499	3.7636	15.059	0.9996	0.000043
2	B	1.55	0.2499	3.6325	14.535	0.9996	0.000041
3	C	2.15	0.2499	3.6257	14.507	0.9996	0.000041
4	D	2.9	0.2499	3.6223	14.498	0.9996	0.000041

Table 9: Improvement of reliability indices of IEEE RETS BUS 2 feeder4 with DG

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)
1	A	0.8	0.2470	3.6130	15.179	0.9996	0.000043
2	B	1.55	0.2470	3.4752	14.622	0.9996	0.000041
3	C	2.3	0.2470	3.4714	14.607	0.9996	0.000041
4	D	2.9	0.2470	3.4680	14.593	0.9996	0.000041

3.7 Case Study-6: PARGI Distribution System with Distributed Generation Using ETAP Software

Improvement of reliability PARGI distribution system feeders such as industrial, agricultural, commercial, rural, urban, residential feeders with distributed generation using ETAP software is presented. The capacity of DG is 1MW and its working 100% reliable. The DG is connected to PARGI distribution system with DG at location A, B, C, D, E and F the system shown in Fig 5. The obtained results are tabulated in Tables 10, 11, 12, 13, 14 and 15.

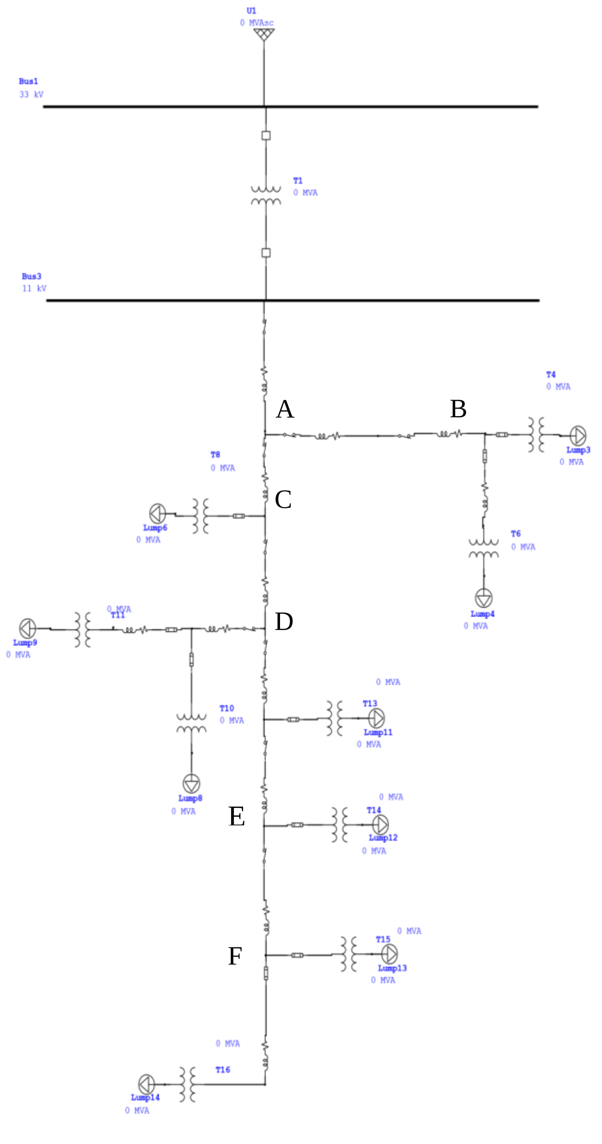

Figure 5: Improvement of reliability indices of PARGI distribution industrial feeder with DG at location A,B,C,D,E and Fmodeled in ETAP software

Table 10: Improvement of reliability indices of PARGI distribution system industrial feeder with DG at location A,B,C,D,E and F.

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)
1	A	0.3	0.1791	3.4288	19.141	0.9996	0.00039
2	B	0.9	0.1791	3.3848	18.896	0.9996	0.00039
3	C	0.4	0.1791	3.3696	18.811	0.9996	0.00038
4	D	0.5	0.1791	3.3528	18.717	0.9996	0.00038
5	E	0.95	0.1791	3.3323	18.603	0.9996	0.00038
6	F	1.55	0.1791	3.3117	18.488	0.9996	0.00038

Table 11: Improvement of reliability indices of PARGI distribution system Agricultural with DG at location A,B,C,D,E and F.

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/year)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours / yr)
1	A	0.4	0.4640	3.9947	8.609	0.9996	0.00046
2	B	0.6	0.4640	3.8949	8.394	0.9996	0.00044
3	C	0.9	0.4640	3.8486	8.294	0.9996	0.00044
4	D	1.2	0.4640	3.7874	8.162	0.9996	0.00043
5	E	1.4	0.4640	3.7524	8.087	0.9996	0.00043
6	F	1.9	0.4640	3.7401	8.060	0.9996	0.00043

Table 12: Improvement of reliability indices of PARGI distribution system Commercial feeder with DG at A,B,C,D,E and G.

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/year)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours / yr)
1	A	0.3	0.5370	4.1905	7.803	0.9995	0.00048
2	B	0.8	0.5370	4.1158	7.664	0.9995	0.00048
3	C	1.3	0.5370	3.9421	7.340	0.9996	0.00045

4	D	1.9	0.5370	3.9268	7.312	0.9996	0.000045
5	E	2.8	0.5370	3.8361	7.143	0.9996	0.000044
6	F	3.3	0.5370	3.8035	7.082	0.9996	0.000043
7	G	3.7	0.5370	3.7844	7.047	0.9996	0.000043

Table 13: Improvement of reliability indices of PARGI distribution system rural feeder with DG at location A,B,C,D,E,F,G and H.

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)
1	A	0.5	0.7408	4.4696	6.034	0.9995	0.00051
2	B	0.9	0.7408	4.3556	5.880	0.9995	0.00050
3	C	1.3	0.7408	4.2853	5.785	0.9995	0.00049
4	D	1.8	0.7408	4.2285	5.708	0.9995	0.00048
5	E	2.4	0.7408	4.1743	5.635	0.9995	0.00048
6	F	2.9	0.7408	4.1253	5.569	0.9995	0.00047
7	G	3.3	0.7408	4.1010	5.536	0.9995	0.00047
8	H	4.1	0.7408	4.0851	5.514	0.9995	0.00047

Table 14: Improvement of reliability indices of PARGI distribution system urban feeder with DG at location A,B,C,D,E,F,G and H.

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/ yr)
1	A	0.6	0.6005	4.173	6.950	0.9995	0.00048
2	B	0.9	0.6005	4.12667	6.872	0.9995	0.00047
3	C	1.2	0.6005	4.0641	6.768	0.9995	0.00046
4	D	1.6	0.6005	4.0093	6.677	0.9995	0.00046
5	E	2.1	0.6005	3.9559	6.588	0.9995	0.00045
6	F	2.3	0.6005	3.9016	6.498	0.9995	0.00045
7	G	2.5	0.6005	3.8867	6.473	0.9996	0.00044
8	H	2.75	0.6005	3.8732	6.450	0.9996	0.00044

Table 15: Improvement of reliability indices of PARGI distribution system Residential type feeder with DG at location A,B,C,D,E,F,G,H,I and J.

S.N	DG LOCATION	DISTANCE	SAIFI (interruption/yr)	SAIDI (hours/yr)	CAIDI (hours/interruption)	ASAI (hours/yr)	ASUI (hours/yr)
1	A	0.5	0.5053	4.1319	8.177	0.9995	0.00047
2	B	0.8	0.5053	4.1178	8.149	0.9995	0.00047
3	C	0.9	0.5053	4.0220	7.959	0.9995	0.00046
4	D	1.2	0.5053	3.9431	7.803	0.9995	0.00045
5	E	1.6	0.5053	3.8982	7.714	0.9996	0.00045
6	F	2.1	0.5053	3.8498	7.618	0.9996	0.00044
7	G	2.4	0.5053	3.7981	7.516	0.9996	0.00043
8	H	3.3	0.5053	3.7769	7.474	0.9996	0.00043
9	I	3.2	0.5053	3.7476	7.416	0.9996	0.00043
10	J	4.1	0.5053	3.7275	7.376	0.9996	0.00043

4. Results of different case studies

4.1 Comparison of Case Study-1 and Case Study-2

Table 16 shows the results of system performance indices in Case study-1: IEEE RBTS BUS2 using FMEA method and ETAP software. The obtained results the same for both methods.

Table 16: Results of system performance indices of IEEE RBTS BUS2 using FMEA method and ETAP software

CASE STUDY-1									CASE STUDY-2						
S.N	**FEEDER NAME**	**SAIFI** (interruption / year)	**SAIDI** (hours / yr)	**CAIDI** (hours / interruption)	**ASAI** (hours/ yr)	**ASUI** (hours/ yr)	**ENS** (KWH/ yr)	**AEN** (KWH / yr)	**SAIFI** (interruption/ yr)	**SAIDI** (hours/ yr)	**CAIDI** (hours/ interruption)	**ASAI** (hours/ yr)	**ASUI** (hours/ yr)	**ENS** (KWH / yr)	**AEN** (KWH/ yr)
1	F1	0.248	3.62	14.5349	0.999587	0.000412	1.3194	0.2023	0.248	3.62	14.5349	0.999587	0.000412	1.3194	0.2023
2	F2	0.140	0.523	3.7375	0.999402	0.000597	1.1249	0.5624	0.140	0.523	3.7375	0.999402	0.000597	1.1249	0.5624

4.2 Comparison of Case Study-1 and Case Study-5

Table 17 shows the improvement of system performance indices of IEEE RBTS BUS2 without and with DG at different locations.

Table 17: Improvement of system performance indices of IEEE RBTS BUS2 without and with DG at different locations

CASE STUDY-1 IEEE RBTS BUS2 without DG using FMEA method							CASE STUDY-5 IEEE RBTS BUS2 with DG using ETAP software							
S.N	**FEEDER NAME**	**SAIFI** (interruption/ year)	**SAIDI** (hours/ year)	**CAIDI** (hours/interruption)	**ASAI** (hours/ year)	**ASUI** (hours/ year)	**DG LOCATION**	**DISTANCE** (KM)	**SAIFI** (interruption / yr)	**SAIDI** (hours/ year)	**CAIDI** (hours/interruption)	**ASAI** (hours/ yr)	**ASUI** (hours/ yr)
1	F1	0.248	3.62	14.5349	0.999587	0.000412	D	2.85	0.23296	3.5766	14.925	0.9996	0.00041
2	F2	0.140	0.523	3.7375	0.999402	0.000597	B	1.35	0.1398	0.5233	3.744	0.9999	0.00006
3	F3	0.250	3.62	14.4667	0.999586	0.000414	D	2.9	0.2499	3.6223	14.498	0.9996	0.00041
4	F4	0.247	3.61	14.38	0.999587	0.000412	D	2.9	0.2470	3.4680	14.593	0.9996	0.00041

By connecting distributed generation at different locations, ASAI and ASUI have same values. In case study-5, SAIFI value of F1 is 0.015% increased, SAIDI value of F1 is 4.34% increased. SAIDI value of F4 is 14.2% increased and SAIFI is constant. It is observed that, In F2 and F4, SAIFI and SAIDI are constant when conducting case study-1 and case study-5. The impact of DG in F1 and F4 with location D, because the DG location is the end of the feeder. % SAIDI improved means that, interruption duration is decreased at the load points.

4.3 Comparison of Case Study-3 And Case Study-6

Table 18 shows the improvement of system performance indices of PARGI distribution system without and with DG at different locations. In case study-6, PARGI distribution system with DG have SAIDI of the industrial feeder at 11.71 %, the agricultural feeder is 25.46%, the commercial feeder is 40.61% the rural feeder is 38.45 %, the urban feeder is 34.1%, the residential feeder is 40.44% are improved as DG location changed, i.e., near to end of load points. % SAIDI improved means that, interruption duration at the load points is decreased. Once interruption duration is decreased, then the reliability can be improved at the customer load points. This improvement of reliability indices can be compared without DG of PARGI distribution system.

Table 18: Improvement of system performance indices of PARGI distribution system without and with DG at different locations

CASE STUDY-3 of PARGI distribution system without and with DG						CASE STUDY-6 of PARGI distribution system without and with DG							
FEEDER NAME	**SAIFI (interruption/ year)**	**SAIDI (hours/ year)**	**CAIDI (hours/interruption)**	**ASAI (hours / year)**	**ASUI (hours/ year)**	**DG LOCATION**	**DISTANCE (KM)**	**SAIFI (interruption / year)**	**SAIDI (hours / year)**	**CAIDI (hours /interruption)**	**ASAI (hours/ year)**	**ASUI (hours/ year)**
Industerial	0.1791	3.4288	19.141	0.9996	0.00039	F	1.55	0.1791	3.3117	18.488	0.9996	0.00038
Agricultral	0.4640	3.9947	8.609	0.9995	0.0046	F	1.9	0.4640	3.7401	8.060	0.99996	0.00043
Commercial	0.5370	4.1905	7.803	0.9995	0.0048	G	3.7	0.5370	3.7844	7.047	0.99996	0.00043
Rural	0.7408	4.4696	6.034	0.9995	0.00051	H	4.1	0.7408	4.0851	5.514	0.9995	0.00047
Urban	0.6005	4.1735	6.950	0.9995	0.0048	I	3.7	0.6005	3.8325	6.382	0.9996	0.00044
Residential	0.5053	4.1319	8.177	0.9995	0.00047	J	4.1	0.5053	3.7275	7.376	0.9996	0.00043

5. Conclusion

In this paper, IEEE RBTS Bus 2 and Indian practical PARGI distribution system (33/11 kV) reliability indices are evaluated. An analytical method for reliability evaluation of a distribution system with distribution generation has been presented. Development of reliability modeling through ETAP software is used to compare with the FMEA method. The study of the case-5 and case-6 of the research work proved that the Distributed Generation could enhance the reliability of IEEE RBTS Bus2 and Indian practical PARIGI distribution system. The impact of Distributed generation on distribution systems can decrease the interruption duration time greatly, and the distribution systems reliability was improved to a large extent.

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APPENDIX

Table 19: PARGI distribution substation system reliability data

COMPONENT	RATING OF COMPONENT	AVERAGE FAILURE RATE (f/yr)	AVERAGE REPAIR TIME (hr)
TRANSFORMER	33/11KV 11/0.415 KV	0.015 0.0150	0 200
CIRCUIT BREAKER	33 11	0.0015 0.004	4 4
BUS BAR	33 11	0.001 0.001	2 2
LINES	33 11	0.0460 0.0650	2 2

Table 20: PARGI distribution substation system customer data

S. N	NAME OF THE FEEDER	TYPE OF FEEDER	NUMBER OF DT'S	AVERAGE LOAD	PEAK LOAD	NUMBER OF CUSTOMERS	SECTION NUMBERS	LENGTH OF FEEDER
1	URBAN	Industrial	9	0.0066	0.0055	3107	1-9	3.2
2	AGRICULTURAL	Agriculture	29	0.061	0.12	2650	10-38	12.5
3	COMMERCIAL	Commercial	28	0.044	0.072	1173	39-66	14.2
4	GADISINAPIR	Rural	31	0.048	0.128	1206	67-97	18.5
5	URBAN	Urban	31	0.089	0.118	2850	98-128	14.85
6	NASKAL	Residential	26	0.51	0.078	1160	129-154	13.65

Table 21: PARGI distribution substation system components data

S. N	Feeder Name	Length in KM	Feeder Section Number
1	F1, INDUSTRIAL	0.1 0.2 0.25 0.3 0.35 0.4 0.6	5,6,9 3,8 12 1,4,7 10 2 11
2	F2, AGRICULTURAL	0.1 0.2 0.3 0.4 0.5	31,33,35 14,15,17,18,20,23,26,27,28,32,36,37,38,40, 42,43,44,46,51,52,54,57,58,59,60 16,19,21,22,24,25,29,30,34,39,45,48,49,53 13,47,50,56,61 41,55
3	F3, COMMERCIAL	0.1 0.2 0.3 0.4 0.5 0.6	74,75,86 63,68,69,70,71,76,79,85,100,103 62,65,66,72,77,78,80,87,89,92,93,95,96,99, 101,104,105 67,73,82,83,84,88,102,106 64,90,91,94,97,98 81

4	F4, RURAL	0.2	117,119,125,127,128,135,137,138, 144,145,150,151,156,158,162,163
		0.3	109,111,113,116,118,122,124,130, 131,134,136,139,143,148,152,155,157, 159, 161,
		0.4	108,110,112,114,115,120,121,123,126, 132,142,147,149,153,154
		0.5	107,129,133,140,146,160
		0.6	141
5	F5, URBAN	0.05	210,212
		0.1	165,215
		0.2	166,168,169,174,175,177,178,180,182183, 187,188,189, 190,191,197,202,203,208,209, 211
		0.25	167
		0.3	170,171,172,176,184,185,186,199,201,204, 206,207
		0.4	164,173,181,193,194,195,196,198,200,213, 214
		0.5	179,192,205
		0.6	216
6	F6, RESIDENTIAL	0.05	220
		0.1	247
		0.2	225,230,232,237,238,239,242,245,246,255, 258
		0.3	219,222,226,228,234,243,244,250,251,252,253,256,257
		0.4	218,221,223,224,227,233,236,241,248,259
		0.5	217,229,235,240,249
		0.6	254