Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 4, Issue 12, December -2017

Reliability Modelling and Analysis of Distribution System Considering Weather Effects on Substation and HVDS Concept on Feeder

[1]E.VidyaSagar, [2]T.Kavitha, [3]S.Deepti, [4]A.Purna Chandar

[1]Associate Professor, University College of Engineering, Osmania University, Hyderabad.
[2] Electrical engineering, M.E, Hyderabad.
[3]Associate Professor, Bhoj Reddy Engineering College for Women, Saidabad, Hyderabad.
[4] Assistant Professor, ACE College of Engineering, Hyderabad.

Abstract- *A radial distribution system consists of 33/11 kV substation, 11 kV circuit breaker, 11 kV feeder, 11 /0.4 kV distribution transformer, 0.4 kV distributor, service wires and load points. The reliability of distribution system has significant effect on the reliability of overall power system network. The reliability of 33/11 kV substation depends on the reliability of its components like power transformers, circuit breakers , bus bars and also operating weather conditions. The reliability of radial feeder depends on reliability of its components like distribution transformer, fuses, disconnectors, operating conditions of distributor like its length and voltage levels. In this paper the reliability of substation is calculated assuming either all the faults occur in normal weather or in adverse weather. Thelow voltage radial feeder is converted into high voltage feeder and their reliability performance is evaluated. Further, the reliability of the complete distribution system is evaluated for all the above said conditions.*

Keywords – *Substation, Radial Feeder, Reliability, Weather Modelling, Reliability Indices.*

I. INTRODUCTION

The basic function of distribution system is to supply the reliable and qualitative power to the consumer load requirements at an acceptable cost. The reliability of distribution system place an important role in the reliability of power system. The reliability performance of distribution system depends on average failure rate, average repair time, average switching time and operating conditions like voltage levels and weather conditions. The existing distribution systems are having some limitations like low reliability, more losses, not a self-monitoring system, few customers choice, low voltage profile especially at the tail end customer nodes. To overcome these limitations it is necessary to modernise the existing distribution systems using the modern technologies such as automation, smart grid technology and high voltage distribution system concepts. In a given period of operating time, weather conditions may change randomly, it may be in single weather or multi weather conditions. The weather conditions can be modelled as (i) single weather (ii) two weather and (iii) three weather models. In this paper, the impact of single weather and two weather models on reliability of distribution system is investigated.

II. RELIABILITY ANALYSIS

This section describes the reliability analysis of 11 kV radial feeder and substation.

A. 11 kV Feeder:

Failure Modes and Effect Analysis (FMEA) technique is used to evaluate load point and system performance reliability indices of 11 kV feeder network. It consists of distribution transformers, fuses, disconnectors, sectional lines, different load points. The load point indices of load point ‘i’ are: average failure rate λ_i (f/yr), average outage time r_i(hr) and average annual outage time U_i (hr/yr). The system basic reliability indices such as SAIDI, ASUI and ENS are defined [3]&[4].

B. Substation:

In this paper approximation method is used to evaluate load point indices of substation. In the process of reliability evaluation overlapping failures, first order active failures and active & stuck breaker failures of substation for normal and adverse weather conditions.

i. Single weather condition:

Reliability evaluation of substation in single weather model for evaluating the failure rate, outage duration and annual outage time or unavailability of load points [4].

ii. Two weather condition:

Reliability evaluation of substation in two weather model, the effect of weather on the reliability indices associated with overlapping outages [4].

C. Adoption of HVDS

In low voltage distribution system (LVDS) networks the lengths of 11 kV feeder is less as compared to 0.4 kV distributors as shown in Figure 10. Where as in high voltage distribution system (HVDS) networks the lengths of 11 kV feeder is more as compared to 0.4 kV distributors as shown in Figure 1. Adoption of HVDS by converting existing LVDS to HVDS as shown in the Figure.2 reduces the technical losses and improves the voltage profile appreciably [2]. Prior to the introduction of HVDS, 3-phase 11 kV lines were being run upto large sized 3-phase transformers 11 kV/433 V from which lengthy 3-phase LT lines were run. An agricultural sector becomes very difficult as voltage profiles are poor, losses are high and outages in supply are also high. HVDS enables running of 11 kV lines right upto a cluster of 3 to 5 consumers, employing small sized distribution transformers (15 or 25 kVA) and extending supply to these with LT less lines (or almost nil).

III. CASE STUDY

In this paper a 33/11 kV distribution substation, 11 kV radial feeders and 0.4 kV distributor is considered for the case study. The impact of weather modeling on reliability of substation and impact of high voltage on reliability of 11 kV feeder is investigated.

A. 11 KV RADIAL FEEDER RELIABILITY

The 11 kV radial feeder with 38 agricultural load points, 7 no.of distribution transformers, 7 no.of fuses and 9 no.of disconnectors considered and shown in Figure 1[2].

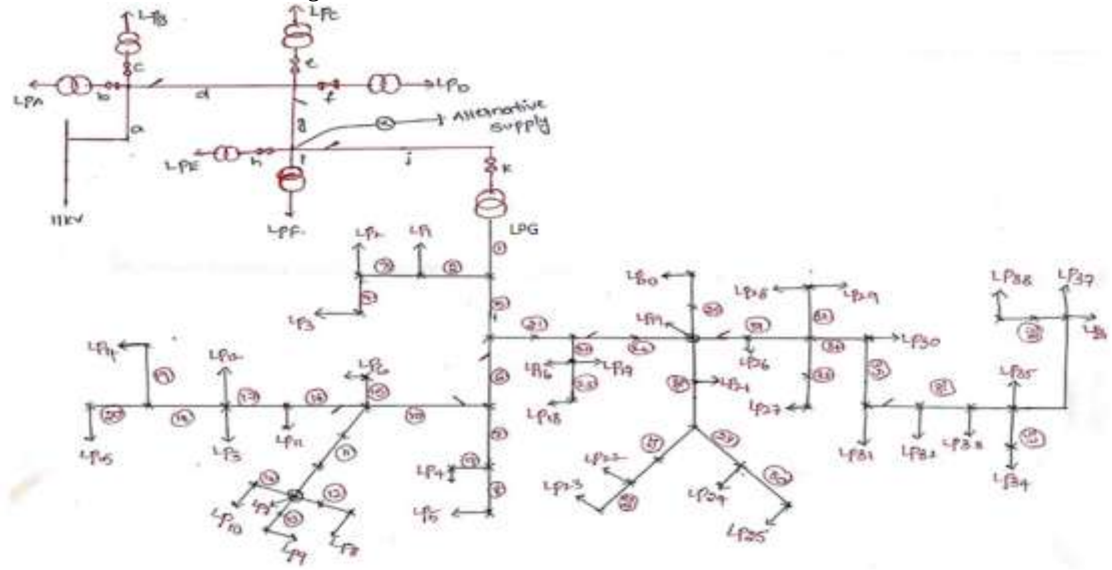

Figure.1. Low Voltage Distribution System

The Low Voltage Distribution System (LVDS) shown in Figure 1 is converted into High Voltage Distribution System (HVDS) and shown in Figure 2. HVDS network consists of seven 100 kVA distribution transformers, 11 No.of load points, 11 No.of 15 kVA small distribution transformers, 16 No. of fuses and 9 No.ofdisconnectors .

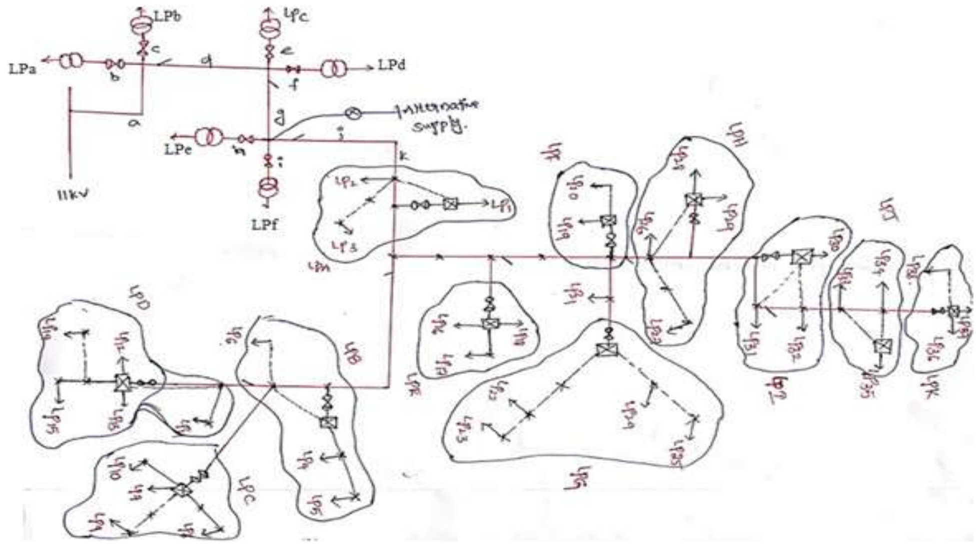

Figure 2. High Voltage Distribution System

Length of the 11 kV feeder sections and 0.4 kV distributor sections shown in Table 1.

Table 1. 11 kV Feeder and 0.4 kV Distributor Section Lengths

Component	Lambda (f/yr/km)	r (hr)	Length (kM)	Section numbers
Feeder	0.065	5	0.6	b, f, j
	0.065	5	0.75	a, g, d, i
	0.065	5	0.8	c, e, h, k
Distributor	0.065	2.5	0.06	All distributor sections
DTR (100 kVA)	0.015	200		
DTR (15 kVA)	0.015	150		

B. Substation Reliability:

Figure.3. shows the typical substation includes the following equipments: 33 kV and 11kV buses, 33 kV and 11 kV circuit breakers, power transformers.

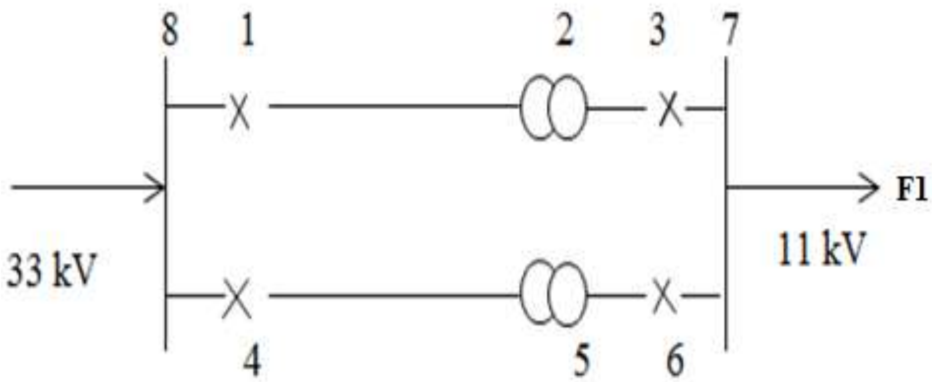

Figure3. Dual Transformer Feeder System

The reliability data of 33/11 kV circuit breaker, power transformer and bus bar is given in Table 2.

Table 2. Components Data of 33/11 kV Substation

Component	Rating of component	Average Failure rate (f/yr)	Average Repair time (hr)	Component	Rating of component	Average Failure rate (f/yr)	Average Repair time (hr)
Transformers	33/11 kV	0.015	200	Bus bars	33	0.001	2
Circuit Breakers	33	0.0015	4		11	0.001	2
	11	0.004	4	Lines	33	0.0460	5
					11	0.0650	2.5

It is assumed that the expected duration of normal weather (N) and adverse weather (S) are 724 hours and 4 hours respectively [5].

IV. RESULTS

A. Reliability indices of Low Voltage Distribution System (LVDS)

The load point indices of 11 kV feeder and 0.4 kV distributor are evaluated as shown in Table 3 and Table 4 respectively. The evaluation of load point indices of distributor have same failure value (λ= 0.43425) for all load points. From these results the system performance indices are evaluated as shown in Table 5.

Table 3. Load Point Indices of Feeder

Load point	(λ)(f/yr)	r(hr)	U (hr/yr)	Load point	(λ)(f/yr)	r(hr)	U (hr/yr)
a	0.23925	14.94357	3.57525	d	0.23925	14.94357	3.57525
b	0.2523	14.43112	3.64025	E	0.25225	14.43112	3.64025
c	0.25225	14.43112	3.64025	f	0.249	14.55422	3.624
g	0.43425	8.803454	3.8229				

Table 4. Load Point Indices of Distributor

Load point	r(hr)	U (hr/yr)	Load point	r(hr)	U (hr/yr)
1	8.803454	3.8229	20	8.803454	3.8229
2	8.803454	3.8229	21	8.803454	3.8229
3	8.803454	3.8229	22	8.951641	3.88725
4	8.870812	3.85215	23	8.951641	3.88725
5	8.870812	3.85215	24	8.951641	3.88725
6	9.005527	3.91065	25	8.951641	3.88725
7	9.005527	3.91065	26	9.072884	3.9399
8	9.005527	3.91065	27	9.072884	3.9399
9	9.00527	3.91065	28	9.072884	3.9399
10	9.00527	3.91065	29	9.072884	3.9399
11	9.113299	3.95745	30	9.072884	3.9399
12	9.113299	3.95745	31	9.072884	3.9399
13	9.113299	3.95745	32	9.180656	3.9867
14	9.113299	3.95745	33	9.180656	3.9867
15	9.113299	3.95745	34	9.180656	3.9867
16	8.803454	3.8229	35	9.180656	3.9867
17	8.803454	3.8229	36	9.180656	3.9867
18	8.803454	3.8229	37	9.180656	3.9867
19	8.803454	3.8229	38	9.180656	3.9867

Table5.System Performance Indices

Index	Value	Unit
SAIDI	0.43425	hrs/customer year
ASUI	0.999554	----
ENS	94.79404	kWh/year

B. Reliability indices of High Voltage Distribution System (HVDS)

The load point indices of 11 kV feeder and 0.4 kV distributor are evaluated as shown in Table6 and Table7 respectively. From these results the system performance indices are evaluated as shown in Table 8.

Table6. Load Point Indices of 11 kV Feeder in HVDS

Load point	(λ)(f/yr)	r(hr)	U (hr/yr)
a	0.40045	9.330628	3.73645
b	0.41345	9.194461	3.80145
c	0.41345	9.194461	3.80145
d	0.40045	9.330628	3.73645
e	0.41345	9.194461	3.80145
f	0.4102	9.227694	3.7852

Table 7. Load Point Indices of Distributor in HVDC

Load point	(λ)(f/yr)	r(hr)	U (hr/yr)
A	0.41995	7.903917	3.31925
B	0.41995	8.163948	3.42845
C	0.418	8.190371	3.423575
D	0.4219	8.211721	3.464525
E	0.41605	7.954573	3.3095
F	0.41605	8.179546	3.4031
G	0.41995	8.126801	3.41285
H	0.41995	8.498274	3.56885
I	0.41995	8.498274	3.56885
J	0.41995	8.869746	3.72485
k	0.41605	8.929456	3.7151

Table 8. System Performance Indices

Index	Value	Unit
SAIDI	0.419159	hrs/customer year
ASUI	0.999602	----
ENS	82.41094	kWh/year

C. Reliability indices of two weather model

The relative magnitudes of λ and λ' are calculated with using equationswith which is considering λ_{avg} = λ value from Table 2, N = 724 hours, S = 4 hours for different F values such as 0%, 50%, 70% and 100% Shown in Table 9.

Table 9. Relative Magnitudes of λ and λ' For Different F Values

λ (f/yr) of normal weather				λ′(f/yr) of adverse weather			
F (%)	Components			F (%)	Components		
	1 & 4	2 & 5	3 & 6		1 & 4	2 & 5	3 & 6
0	0.00201105	0.01508287	0.0060331	0	0	0	0
50	0.00100552	0.00754143	0.0030165	50	0.182	1.365	0.546
70	0.00603	0.004522	0.001809	70	0.2548	1.911	1.911
100	0	0	0	100	0.364	2.73	1.092

The calculated λ and λ' values are used to evaluate the overlapping forced outages [4]. Table 10 shows the model calculation of failure F=0% with using λ and λ' values from the Table 9.

Table 10. Reliability Indices for System F=0%

Components	λ_k (f/yr)	λ_l(f/yr)	λ_m(f/yr)	λ_n(f/yr)	λpp(f/yr)
1 and 4	3.6732×10^{-9}	0	0	0	3.6732×10^{-9}
1 and 5	6.5428×10^{-8}	0	0	0	6.5428×10^{-8}
1 and 6	1.1019×10^{-8}	0	0	0	1.1019×10^{-8}
2 and 4	6.5428×10^{-8}	0	0	0	6.5428×10^{-8}
2 and 5	7.7481×10^{-7}	0	0	0	7.7481×10^{-7}
2 and 6	1.9628×10^{-7}	0	0	0	1.9628×10^{-7}
3 and 4	1.1019×10^{-8}	0	0	0	1.1019×10^{-8}
3 and 5	1.9628×10^{-7}	0	0	0	1.9628×10^{-7}
3 and 6	3.3058×10^{-8}	0	0	0	3.3058×10^{-8}
					1.357×10^{-6}

Similarly the total reliability indices of the system for different failures per year as shown in Table 11.

Table 11. Reliability Indices of 33/11 kV Substation Proportion of Failures (F) Occurring in Adverse Weather

F	λpp(f/yr)	r_{pp}(hr)	Upp(hrs/yr)
0%	1.357×10^{-6}	5.586957	7.5815×10^{-6}
100%	3.79×10^{-5}	5.173005	0.000196

Active failure and stuck breaker events are also involve in two weather modelling. The Table 11 values are added to the total failure rates for example take F=0%.as shown in Table12.

Table.12 Over Lapping Failure with Active Failure and Stuck Breaker of F = 0%

Failure event	Lambda (λ) (f/yr)	r(hr)	U (hrs/yr)
Over lapping	1.357×10^{-6}	5.586957	7.5815×10^{-6}
Total failure 33kV bus	0.001	2.000	0.002
Total failure 11kV bus	0.001	2.000	0.002
First order failure 3	0.004	4.000	0.016
First order failure 6	0.004	4.000	0.016
2A+3S	0.00075	1.000	0.00075
5A+6S	0.00075	1.000	0.00075
TOTAL	0.011501	3.259516	0.0375075

Similarly the reliability indices of remaining cases are also calculated considering Active failure of components and stuck breaker condition.

Table.13. Reliability Indices of Substation (33/11 kV) Including Active Failure and Stuck Breaker

F	λ_{pp}	r_{pp}	U_{pp}
0%	0.011501	3.259516	0.0375075
100%	0.283037851	1.092419	0.309196

D. Reliability indices of Low Voltage Distribution System (LVDS) in two weather model

The load point indices and system performance indices of low voltage distribution system (LVDS) including substation, feeder and distributor in two weather model for different failures are evaluated as shown in Table 14. Table 14 shows the model calculations of load point indices for failure F =0% with using λ and λ′ value. This total reliability value of two weather model for F = 0% such as λ and U values are 0.011501 and 0.0375075 is added to the load point indices of LVDS network.The evaluation of load point indices of distributor have same failure value (λ= 0.44576) for all load points.

Table 14. Load Point Indices of LVDS Network in Two Weather Model (F=0%)

Load point	r(hr)	U (hr/yr)	Load point	r(hr)	U (hr/yr)
1	8.803454	3.860416	20	8.803454	3.860416
2	8.803454	3.860416	21	8.803454	3.860416
3	8.803454	3.860416	22	8.951641	3.924766
4	8.870812	3.889666	23	8.951641	3.924766
5	8.870812	3.889666	24	8.951641	3.924766
6	9.005527	3.948166	25	8.951641	3.924766
7	9.005527	3.948166	26	9.072884	3.977416
8	9.005527	3.948166	27	9.072884	3.977416
9	9.00527	3.948166	28	9.072884	3.977416
10	9.00527	3.948166	29	9.072884	3.977416
11	9.113299	3.994966	30	9.072884	3.977416
12	9.113299	3.994966	31	9.072884	3.977416
13	9.113299	3.994966	32	9.180656	4.024216
14	9.113299	3.994966	33	9.180656	4.024216
15	9.113299	3.994966	34	9.180656	4.024216
16	8.803454	3.860416	35	9.180656	4.024216
17	8.803454	3.860416	36	9.180656	4.024216
18	8.803454	3.860416	37	9.180656	4.024216
19	8.803454	3.860416	38	9.180656	4.024216

Table15.System Performance Indices

Index	Value	Unit
SAIDI	0.44576	hrs/customer year
ASUI	0.000451	----
ENS	95.70522	kWh/year

System performance indices for different failures such as SAIDI and ENS of LVDS network in two weather modelare compared as shown in Table 16.

Table16.System Performance Indices

Index	F =0%	F=100%	Units
SAIDI	0.44576	0.717288	hrs/customer year
ASUI	0.000451	0.000482	----
ENS	95.70522	102.3038	kWh/year

E. Reliability indices of High Voltage Distribution System (HVDS) in two weather model

The load point indices and system performance indices of high voltage distribution system (HVDS) including substation, feeder and distributor in two weather model for different failures are evaluated as shown in Table 17. Table17 shows the model calculations of load point indices for failure F =0% with using λ and λ′ value. This total reliability value of two weather model for F = 0% such as λ and U values are 0.011501 and 0.0375075 is added to the load point indices of HVDS network.

Table17. Load Point Indices of HVDS Network in Two Weather Model (F=0%)

Load point	(λ)(f/yr)	U (hr/yr)
A	0.43146	3.356766
B	0.43146	3.465966
C	0.42951	3.461091
D	0.43341	3.502041
E	0.42756	3.347016
F	0.42756	3.440616
G	0.43146	3.450366
H	0.43146	3.606366
I	0.43146	3.606366
J	0.43146	3.762366
K	0.42756	3.752616

Table18.System Performance Indices

Index	Value	Unit
SAIDI	0.430669	hrs/customer year
ASUI	0.000402	----
ENS	83.30142	kWh/year

Table19.System Performance Indices

Index	F =0%	F=100%	Units
SAIDI	0.430669	0.702197	hrs/customer year
ASUI	0.000402	0.000433	----
ENS	83.30142	89.75002	kWh/year

Table20. Comparison of System Performance Indices of LV and HV in Two Weather Model

Index	F = 0%		F = 100%		Units
	LV	HV	LV	HV	
SAIDI	0.44576	0.430669	0.717288	0.702197	hrs/customer year
ENS	95.70522	83.30142	102.3038	89.75002	kWh/year

CONCLUSION

The distribution system reliability is evaluated for different proportion of failures occurring in adverse weather of two weather model with the conversion of low voltage distribution system into high voltage distribution system. Reliability improvement is indicated by improvement in System performance indices such as SAIDI and ENS.Fromthe results SAIDI and ENS values are improved in HVDS compared to LVDS in two weather model.

REFERENCES

[1] TuranGonen, ‘Electrical Power Distribution System Engineering’, 2nd Edition, 2010, TataMcGrach Hill.
[2] M V S Birinchi, ‘Modernisation on Power Distribution (Focus on APDRP)’, First Edition, March 2005, National Power Training Institute (NPTI), India.
[3] R. Billinton and R. N. Allan, Reliability Evaluation of Engineering Systems: Concepts and Techniques. Springer, 1992.
[4] Roy Billinton, Ronald N. Allan, “Reliability Evaluation of Power Systems”, 2nd Edition, Springer (India) Private Limited, 2006.
[5] R. N. Allan and R. Billinton, ”A Reliability Test System For Educational Purposes- Basic Distribution System Data and Results”, IEEE Trans. On Power Systems, Vol.6.No.2, May 1991.

