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Evaluation and Analysis of Customer Specific Distribution Reliability Indices

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Abstract
Reliability of electrical distribution network is significant in ensuring quality service for customers. Reliability indices based on load and sustained interruptions are used to evaluate the reliability of distribution network. In this paper, taking the data from a chosen area of electrical distribution network in A.P, the reliability indices are computed
Keywords: Distribution system, reliability indices, sustained interruption indices, matlab.

1. INTRODUCTION

Reliability of a unit (or product) is the probability that the unit performs its intended function adequately for a given period of time under the stated operating conditions or environment. The objective of a particular system or mission will determine its reliability requirements. Maintainability can be defined as the probability that failed equipment is restored to operable condition in a specified time when the maintenance is performed under stated conditions. It characterizes the adaptability of the equipment to the detection and elimination of failures as well as their prevention. To measure system performance, the electric utility industry has developed several performance measures of reliability. These reliability indices include measures of outage duration, frequency outages, system availability, and response of time. Customer satisfaction can be improved through providing better quality power in terms of voltage and frequency fluctuations and reliability by reducing outages.

1.1 Reliability of Power Supply and Consumer Satisfaction

Reliability to a consumer means that power is made available to him is fault free and the outage or interruptions are tolerable and do not disturb his normal life. System reliability is not the same as power quality. System reliability pertains to sustained interruptions and momentary interruptions. Power quality involves voltage fluctuations, abnormal waveforms, and harmonic distortions .An interruption of greater than five minutes is generally considered a reliability issue, and interruptions of less than five minutes are a power quality concern.

The indices are calculated for 33KV feeder connected to a 220KV substation of power utility and the single line diagram is shown in annexure C.

2. COMPUTATION

2.1 Calculation of Indices for a System with No Major Event Days

The equations (1-4) are shown in annexure A and they are used to calculate the annual indices and assuming that there were no major event days in this data set. The total number of customers affected (CN) for this system can be no more than 12642. However, it is likely that not all of the 12642 customers on this feeder experienced an interruption during the year. 12400 will be arbitrarily assumed for CN (total Number of Customers who have Experienced a Sustained Interruption during the Reporting Period). The data given in table1 is used for computing the reliability indices.

Table 1: The data of year 2011 from 33KV feeder which serves total customers 12642 with a total load 12MW.

S .No	Date	Time	Time on	Duration	Duration min	Load current	Number o customers	Load KVA	Interruption type
1	01/01/2011	11:40:00	16:30:00	04:50:00	290	122	770	4026	S
2	11/01/2011	09:20:00	18:28:00	09:08:00	548	104	668	3432	S
3	18/01/2011	22:10:00	22:13:00	00:03:00	3	243	1540	8019	M
4	24/01/2011	08:01:00	08:04:00	00:03:00	3	125	1155	4125	M
5	26/01/2011	21:12:00	21:30:00	00:18:00	18	156	990	5148	S
6	10/02/2011	11:52:00	13:07:00	01:15:00	75	113	715	3729	S
7	21/04/2011	13:09:00	13:15:00	00:06:00	6	139	1320	4587	S
8	25/04/2011	15:12:00	18:37:00	03:25:00	205	140	880	4620	S
9	06/05/2011	15:23:00	18:59:00	03:36:00	216	156	890	5148	S
10	11/05/2011	03:57:00	04:30:00	00:33:00	33	125	578	4125	S
11	11/05/2011	21:45:00	22:25:00	00:40:00	40	190	1815	6270	S
12	13/05/2011	16:55:00	17:00:00	00:05:00	5	156	980	5148	M
13	14/05/2011	11:40:00	11:44:00	00:04:00	4	174	825	5742	M
14	15/05/2011	11:50:00	17:45:00	05:55:00	355	165	1040	5445	S
15	01/06/2011	15:45:00	17:58:00	02:13:00	133	160	970	5280	S
16	04/06/2011	06:37:00	17:09:00	10:32:00	632	105	694	3465	S
17	08/06/2011	21:58:00	22:09:00	00:11:00	11	175	1100	5775	S
18	12/06/2011	10:46:00	12:46:00	02:00:00	120	140	860	4620	S
19	22/06/2011	22:37:00	22:40:00	00:03:00	3	155	1485	5115	M
20	15/07/2011	10:02:00	12:06:00	02:04:00	124	138	668	4554	S
21	13/08/2011	10:25:00	17:15:00	06:50:00	410	156	1485	5148	S
22	25/08/2011	10:22:00	00:00:00	13:38:00	818	155	994	5115	S
23	26/08/2011	00:00:00	09:43:00	09:43:00	583	190	1210	6270	S
24	30/08/2011	16:45:00	18:05:00	01:20:00	80	138	1320	4554	S
25	31/08/2011	15:35:00	15:40:00	00:05:00	5	140	660	4620	M
26	06/09/2011	06:25:00	06:28:00	00:03:00	3	122	1155	4026	M
27	19/09/2011	21:48:00	21:57:00	00:09:00	9	191	907	6303	S
28	22/09/2011	12:59:00	13:05:00	00:06:00	6	165	1568	5445	S
29	19/10/2011	09:05:00	10:50:00	01:45:00	105	139	890	4587	S
30	18/10/2011	17:05:00	17:17:00	00:12:00	12	174	1650	5742	S
31	29/10/2011	15:41:00	15:44:00	00:03:00	3	150	742	4950	M
32	12/11/2011	08:05:00	10:05:00	02:00:00	120	135	1320	4455	S
33	18/11/2011	14:15:00	17:15:00	03:00:00	180	175	1100	5775	S
34	10/12/2011	07:15:00	09:00:00	01:45:00	105	139	528	4587	S

S – Sustained Interruption
M – Momentary Interruption

Table 2: One month of daily SAIDI and ln (SAIDI/day) data For December 2010.

S .No	Date	SAIDI/day min	In (SAIDI/day)
1	01/12/2010	0	0
2	02/12/2010	0	0
3	03/12/2010	0	0
4	04/12/2010	0	0
5	05/12/2010	0	0
6	06/12/2010	0	0
7	07/12/2010	0	0
8	08/12/2010	0	0
9	09/12/2010	0	0
10	10/12/2010	0	0
11	11/12/2010	6.910	1.933
12	12/12/2010	0	0
13	13/12/2010	0	0
14	14/12/2010	0	0
15	15/12/2010	0	0
16	16/12/2010	0	0
17	17/12/2010	0	0
18	18/12/2010	0	0
19	19/12/2010	0	0
20	20/12/2010	0	0
21	21/12/2010	10.851	2.384
22	22/12/2010	0	0
23	23/12/2010	0	0
24	24/12/2010	0	0
25	25/12/2010	0	0
26	26/12/2010	0	0
27	27/12/2010	0	0
28	28/12/2010	0	0
29	29/12/2010	0	0
30	30/12/2010	0	0
31	31/12/2010	30.434	3.416

Table 2: One month of daily SAIDI data for January 2011.

S .No	Date	SAIDI/day min
1	01/01/2011	17.663
2	02/01/2011	0
3	03/01/2011	0
4	04/01/2011	0
5	05/01/2011	0
6	06/01/2011	0
7	07/01/2011	0
8	08/01/2011	0
9	09/01/2011	0
10	10/01/2011	0
11	11/01/2011	28.956
12	12/01/2011	0
13	13/01/2011	0
14	14/01/2011	0
15	15/01/2011	0
16	16/01/2011	0
17	17/01/2011	0
18	18/01/2011	0.365
19	19/01/2011	0
20	20/01/2011	0
21	21/01/2011	0
22	22/01/2011	0
23	23/01/2011	0
24	24/01/2011	0.274
25	25/01/2011	0
26	26/01/2011	1.410
27	27/01/2011	0
28	28/01/2011	0
29	29/01/2011	0
30	30/01/2011	0
31	31/01/2011	0

3. RESULTS

3.1 Major Event Day Threshold value

Mean = 2.5777
Standard deviation = 0.6207
T_{MED} = 62.1458
The SAIDI/day exceeds the threshold value (T_{MED} = 62.1458), indicating that the distribution system experienced stresses beyond that normally expected on that day. Therefore such day is classified as a major event day. The SAIDI/day for all days was less than T_{MED}, indicating that normal stresses were experienced on those days.
The results obtained are in close proximity to the results obtained for U.S.A system. The comparison provided in Table to show this agreement.
The graphical representation of results is shown in annexure B.

Index	Available Indices for U.S.A system	Computed Indices for Present System
SAIFI	4	2.1302
SAIDI	98 to 423	398.9579
CAIDI	55 to 197	187.2865
ASAI	0.9898 to 0.9999	0.9992

4. CONCLUSION

One view of distribution system performance can be garnered through the use of reliability indices. To adequately measure performance, both duration and frequency of customer interruptions must be examined at various system levels. The most commonly used indices are SAIFI, SAIDI, CAIDI and ASAI. All of these indices provide information about average system performance. Many utilities also calculate indices on a feeder basis to provide more detailed information for decision making.

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3. IEEE Guide for Electric Power Distribution Reliability Indices.
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ANNEXURE A

RELIABILITY INDICES

Basic factors

These basic factors specify the data needed to calculate the indices.
i = Interruption event
ri = Restoration Time for each Interruption Event
CI = Customers Interrupted
CMI = Customer Minutes Interrupted
T = Total
Ni = Number of Interrupted Customers for each Sustained
Interruption event during the Reporting Period
NT = Total Number of Customers Served for the Areas
Li = Connected KVA Load Interrupted for each Interruption
Event
LT = Total connected KVA Load Served
CN = Total Number of Customers who have Experienced a
Sustained Interruption during the Reporting Period
TMED = Major event day identification threshold value
α = Mean value
β = Standard deviation

SUSTAINED INTERRUPTION INDICES

System Average Interruption Frequency Index (SAIFI)

The system average interruption frequency index indicates how often the average customer experiences a sustained interruption over a predefined period of time. Mathematically, this is given by

$$SAIFI = \frac{\sum \text{Total number of Customers Interrupted}}{\text{Total number of Customers Served}}$$

To calculate the index, use Equation below

$$SAIFI = \frac{\sum N_i}{N_T} = \frac{CI}{N_T} \quad \ldots\ldots\ldots (1)$$

System Average Interruption Duration Index (SAIDI)

This index indicates the total duration of interruption for the average customer during a predefined period of time. It is commonly measured in customer minutes or customer hours of interruption. Mathematically, this is given by

$$SAIDI = \frac{\sum \text{Customer Interrupted Duration}}{\text{Total number of Customers Served}}$$

To calculate the index, use Equation

$$SAIDI = \frac{\sum r_i N_i}{N_T} = \frac{CMI}{N_T} \quad \ldots\ldots\ldots (2)$$

Customer Average Interruption Duration Index (CAIDI)

CAIDI represents the average time required to restore service. Mathematically, this is given by

$$CAIDI = \frac{\sum \text{Customer Interrupted Duration}}{\text{Total number of Customers Interrupted}}$$

To calculate the index, use Equation

$$CAIDI = \frac{\sum r_i N_i}{\sum N_i} = \frac{SAIDI}{SAIFI} \quad \ldots\ldots\ldots (3)$$

Average Service Availability Index (ASAI)

The average service availability index represents the fraction of time (often in percentage) that a customer has received power during the defined reporting period. Mathematically, this is given by

$$ASAI = \frac{\text{Customer Hours Service Availability}}{\text{Customer Hours Sevice Demands}}$$

To calculate the index, use Equation

$$ASAI = \frac{N_T \cdot (\text{Number of hours/yr}) - \sum r_i N_i}{N_T \cdot (\text{Number of hours/yr})} \ldots. \quad (4)$$

ANNEXURE B

The comparison of graphs for SAIFI, SAIDI, CAIDI and ASAI during the years 2010 and 2011 are shown in the given below figures.

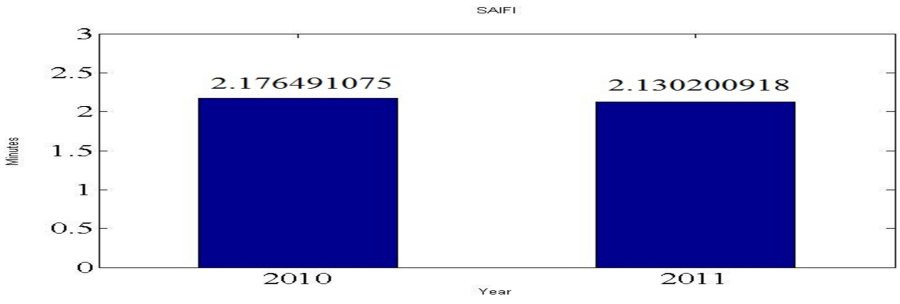


Figure (1)

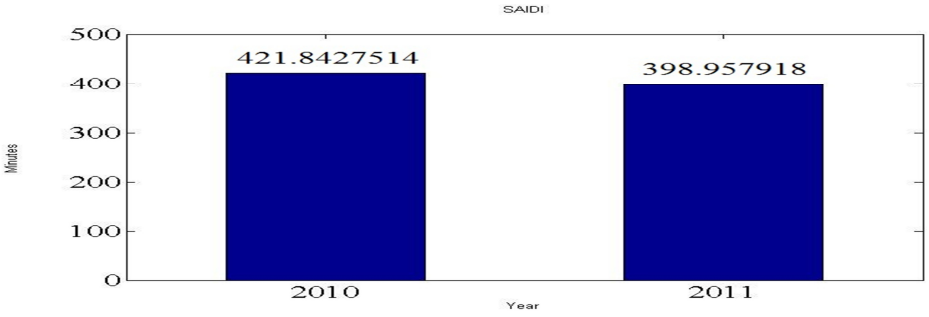


Figure (2)

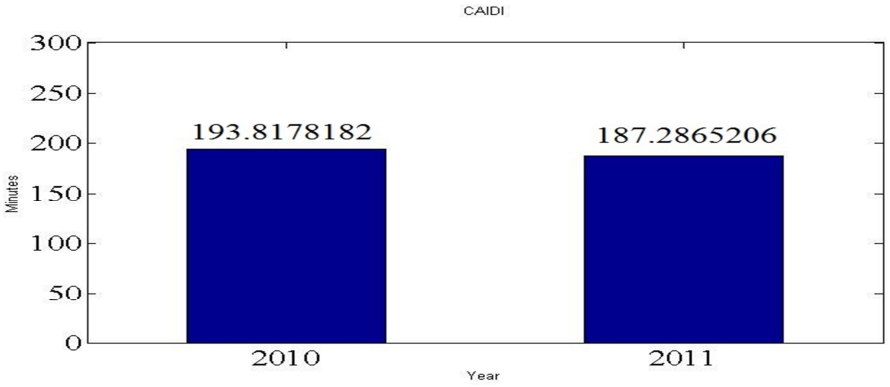


Figure (3)

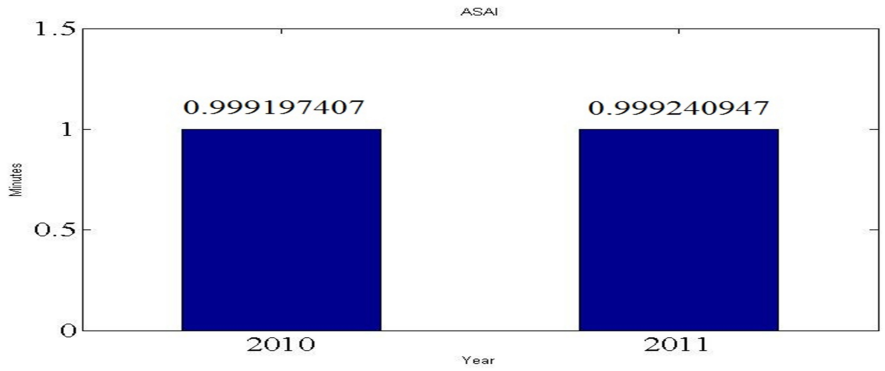
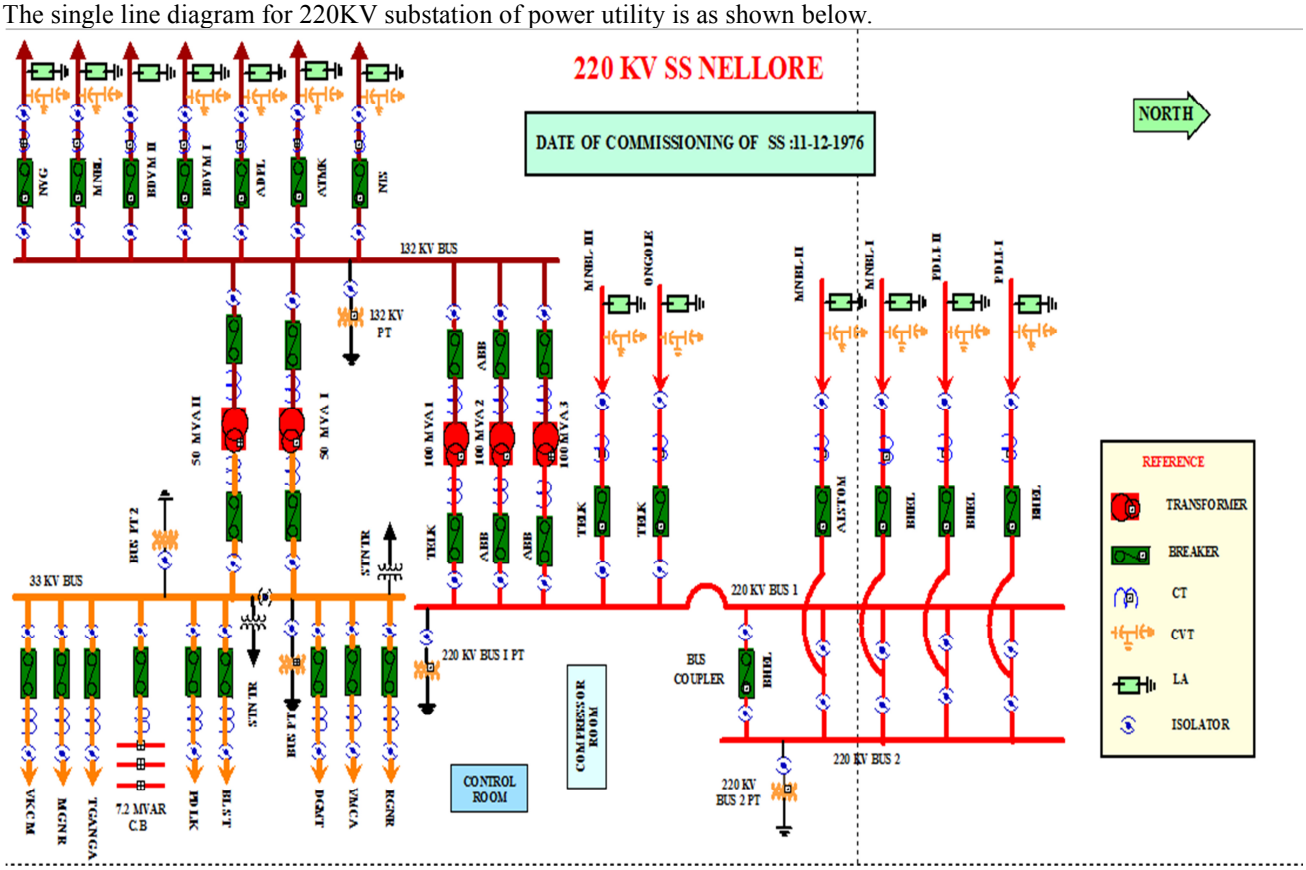


Figure (4)

ANNEXURE C

The single line diagram for 220KV substation of power utility is as shown below.



BIO-GRAPHICAL INFORMATION

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