Reliability Indices of Distribution system by Fuzzy Method

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ABSTRACT—Reliability analysis is a very important factor in power system planning. Each of the components related to reliability of distributed power system related are taken separately. Four reliability indices in literature [1] are System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI) [4]. The reliability improvement is measured by these reliability indices that include SAIFI, SAIDI and CAIDI. This paper uses fuzzy value applied for every components related required for calculation of these reliability indices. The three methods of calculation of crisp value of normalized fuzzy values is carried out by defuzzification [9]. Here all components are continuous and taken fuzzy. Fuzzy values of four basic elementary variables (λ, r, u, n) are used for reliability indices are taken from standard fuzzy values. Fuzzy reliability indices values are calculated using standard methods to fuzzy [5] form given taken here.

Index Terms— SAIFI, SAIDI, CAIDI, failure rate, repair duration, fizzy value

INTRODUCTION

The reliability of a distribution system is usually measured in terms of several indices. They are divided into load point reliability and system point reliability indices [6].

Load point reliability indices are evaluated at each load point of the (distribution)

radial feeder system and are evaluated using failure rate(λ) outage time/repair duration (r) and the average annual outage time (U).

Although load point primary indices are fundamentally important, they do not always give a complete representation of the system behaviour and response. Hence Reliability related indices would be evaluated irrespective of size of customers. In order to reflect the severity or significance of a system outage, SAID, SAIF and CAIDI are considered necessary for their detailed analysis.

SYSTEM DESCRIPTION:

This paper discusses calculation of fuzzy value of reliability indices taken from Devanoor station ESC data [3] used for the required analysis.

26 feeder data was taken
8,389 interruption in the feeder /year
4, 28,698 interruption duration in minutes
40,174 customers
All data is taken for fuzzy calculation.
The paper analyses reliability of feeder of distribution system of this data is taken for the required analysis.
Here four fuzzy variables considered.

A: Feeder id used as primary key
B: Fuzzy Number of interruption in each feeder
C: Fuzzy Number of interruption of duration in the feeder
D: Fuzzy Number of customers connected in the feeder
E: Total duration of consumers interruption in year

Here fuzzy is applied for λ_I. Normalized fuzzy applied value of four different sections of feeder failure rate values λ_1, λ_2, λ_3 and λ_4 are given in table 1.
The failure rate at load point i is λ_I (f/yr).

$$\lambda_s = \sum_s \lambda_i \qquad (1)$$

Average Outage Duration at load point i is U_s
Here fuzzy is applied to $U_i = U_s$.
Normalised fuzzy applied value of four different values of U_1, U_2, U_3 and U_4 are obtained and given in table 2.

$$U_s = \sum_s \lambda_i * r_i \qquad (2)$$

Where r_i is the failure duration at load point i due to a failed element i.

Average outage duration at load point i, is r_i (hr)

$$r_i = U_s \div \lambda_s = \sum \lambda_i * r_i \div \sum_s \lambda_i \quad (3)$$

Fuzzy division is carried out using fuzzy division [10] Resulted fuzzy value is given in table 3.

An overview of commonly used system indices is as follows.

System Average Interruption Frequency Index SAIFI (f/customer .yr)
Ni is the number of customers at load point I
Normalised fuzzy applied value of four different values N_1, N_2, N_3 and N_4 are obtained and given in table 4.

$\sum$Ni can be calculated.

SAIFI is measured in units of interruptions per customer. It is usually measured over the course of a year. Fuzzy value of SAIFI is obtained using equation 4 to get table 7.

$$SAIFI = \sum \lambda i \times Ni \div \sum Ni \qquad (4)$$

System Average Interruption Duration Index, SAIDI (hr/Customer .yr)
SAIDI is measured in units of time, often minutes or hours.

SAIDI=∑Ui x Ni ÷ ∑Ni   (5)

Customer Average Interruption Duration Index

CAIDI (hr/customer interruption)

CAIDI ==∑Ui x Ni ÷ ∑λi x Ni   (6)

CAIDI gives an average outage duration that any given customer would experience. It can also be viewed as the average restoration time,

Table 1			
Normalised λ			
λ1	1.0083	1.4556	2.0028
λ2	0.9694	1.4306	1.9917
λ3	0.7833	1.3444	2.0167
λ4	1.6206	2.4528	3

Table 2			
Normalised ∑U			
U1	0.3805	0.6356	0.9855
U2	0.4135	0.6431	0.9688
U3	0.3092	0.9625	0.9625
U4	0.5941	1.0503	1.45

Table 3			
Normalised ∑r			
Small	0.25	0.3	0.35
Medium	0.4	0.45	0.5
Large	0.5	0.55	0.6

Table 4			
Normalised ∑ni			
n1	0.2	0.3	0.4
n2	0.3	0.4	0.4
n3	0.35	0.45	0.55
n4	0.95	1.15	1.25

Table5			
∑U x ni	0.125105	0.25452	0.434205
	0.14803	0.26127	0.41252
	0.102845	0.22698	0.415
	0.19249	0.41526	0.62

Table6			
∑ ni	0.311655	0.56002	0.861679
	0.34054	0.60002	0.826685
	0.246655	0.62248	0.950019
	0.49546	0.93251	1.25

Table 7	Method1	Method2	Method3
SAIFI 1	2.3167	2.20	2.09
SAIFI 2	1.702	1.65	1.60
SAIFI 3	1.512	1.48	1.45

Table 8	Method1	Method2	Method3
SAIDI 1	1.110	1.045	0.979
SAIDI 2	0.798	0.762	0.725
SAIDI 3	0.624	0.594	0.564

Table 9	Method1	Method2	Method3
CAIDI 1	0.665	0.612	0.560
CAIDI 2	0.135	0.566	0.522
CAIDI 3	0.187	0.629	0.541

RESULTS:

The sum of weighted normalized values for all criteria and from three defuzzification methods is used for SAIFI in the table7. Three methods of defuzzification methods are applied for SAIDI in table 8.

Three values of defuzzified values of CAIDI are given in table 9. Three cases are taken for each criteria.

CONCLUSION

According to IEEE standard 1366-1998 [2]

(i)   SAIFI value is 1.10 interruptions per Customer and year.

(ii)   SAIDI is usually measured over the course of a year, its value is 1.50 hours

(iii)   CAIDI is measured in units of time and over the course of a year.

Three methods of defuzzification [9] is Applied for all the three cases in respective tables.

APPENDIX

Defuzzification method of Triangular fuzzy number into crisp numbers

Method 1 (a, b, c) = (a+b+c) / 3.0
Method 2 (a, b, c) = (a+2b +c) / 4.0
Method 3 (a, b, c) = (a+4b+c) / 6.0

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