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Estimation of Reliability indices of Radial Distribution System with DG

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Abstract-This paper presents a general assessment of reliability indices of radial distribution system with and without DG. A typical case study with an example of radial distribution system is also presents. The reliability improvement is measured by different reliability indices that includes SAIFI, SAIDI, CAIDI, ASAI, ASUI, ENS.
The main objective of this paper is to represent the effect of DG on system and customer side reliability indices and conclude on the benefits of DG and technologies that are involves in DG. At the end an example is presented with all indices and comparison between results when DG is connected when not connected.

Keywords— reliability, radial distribution system, distributed generation.

INTRODUCTION

With the advancement of technology and population and electricity requirement, the electrical utility industry is moving towards the deregulation, competitive environment where utility must have all data and information about system to ensure that all the expectations of customers are meet and each dollar is spent wisely for reliability improvement.
Due to increment in sensitive loads, the requirement of customers for more reliable power also increases. Customers are demanding good quality of power with enough reliability. Some customers therefore may be ready to pay for higher reliability and others are not. In this case responsibility of utility is to provide higher reliability and quality with very small or no increment in customer cost because of present market scenario.
To improve reliability, DG is a new technology and penetration of DG in distribution system is increasing continuously. Another technology is reconfiguration of radial distribution system. One of the measure to improve the system reliability after fault is to reduce the reclosing time of switches as explained in reference [1-5].

Distributed generator

Distributed generation includes the application of small size generators, mostly of the range of 15KW to 10MW. These small size generators may be at utility side or customer side i.e. these small size plants are scattered throughout the power system. Most of the DG energy source use the renewable technologies like solar power, wind power, biomass power etc. which are pollution free.
DG includes voltage profile improvement, reduction in losses, improves restoration duration, increase the system and utility reliability. All these benefits can be claimed only by proper sitting and sizing of DG. Several methods have been investigated for proper allocation of DG in distribution system.

RELIABILITY AND ITS INDICES

In simple words we can say if any system is providing continuity in service then that system is said to be reliable. Reliability can be calculated on both customer side and utility side. Reliability analysis is generally done in distribution system because most of fault occurs in distribution system only. The IEEE defines the generally accepted reliability indices in its standard number P-1366 "Guide for electrical distribution reliability indices". IEEE P-1366 includes several definitions related to reliability like- momentary interruption, sustained interruption [6].

Momentary interruption
Single operation of an interrupting device that results in a voltage zero. For example- two circuit breaker operation equals 2 momentary interruption.

Sustained interruption:
Any interruption not classified as a momentary interruption. Interruption longer than 5 minutes.

Distribution system reliability indices

The most common distribution indices include the System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), System Average Interruption Frequency Index (SAIFI), Momentary Average Interruption Frequency Index (MAIFI), Customer Average Interruption Frequency Index (CAIDI) Customers Interrupted per Interruption Index (CIII), and the Average Service Availability Index (ASAI). We will review each of these indices with an example of how to use them [7].

- *System Average Interruption Duration Index (SAIDI)*

  The most often used system performance measurement for a sustained interruption is SAIDI. This index measures the total duration of an interruption for the average customer during a given time period.

  $SAIDI = \Sigma(U_i * N_i) / N_t$

  Where

  U_i = annual restoration duration, minutes
  N_i = number of customers interrupted
  N_t = total number of customers served

- *System average interruption frequency index (SAIFI)*

  The SAIFI is the average number of time that a customer experiences an outage during the year. The SAIFI is found by divided the total number of customers interrupted by the total number of customers served.

  $SAIFI = \Sigma(\lambda_i * N_i) / N_t$

  Where

  λ_i = failure frequency (per year)
  N_i = number of customers interrupted
  N_t = total number of customers served

- *Customer average interruption duration index(CAIDI)*

  Once an outage occurs, the average time to restore service is found from the CAIDI. CAIDI can be calculated by dividing SAIDI with SAIFI.

  $$CAIDI = \frac{SAIDI}{SAIFI}$$

- *Average Service Availability Index (ASAI)*

  This index represents the availability of supply.

  $$ASAI = 1 - \frac{SAIDI}{8760}$$

- *Average Service Unavailability Index (ASUI)*

  This index represents the unavailability of supply.

  ASUI = 1- ASAI

DESCRIPTION OF THE RADIAL DISTRIBUTION SYSTEM

The radial distribution system as shown in figure is used in this paper for analysis purpose. This system contains four load points with total load capacity of 4025 KW and total customers connected with system is 2025 customers [8].
Initially all the reliability parameters are calculates for the base case. Then a fuse is connected with load point C3and again all parameters are calculated.
Now in 3rd case a DG of capacity 1500 KW is connected at the end of the feeder and again all the reliability parameters are calculated.
At the end comparison between all the three cases is done to analyze the effect of DG on radial distribution system.

TABLE I. LOADING AND CUSTOMER DATA OF SYSTEM

Load point	*Load capacity*	*No. of customers*
C1	1800	900
C2	1100	550
C3	825	450
C4	300	125

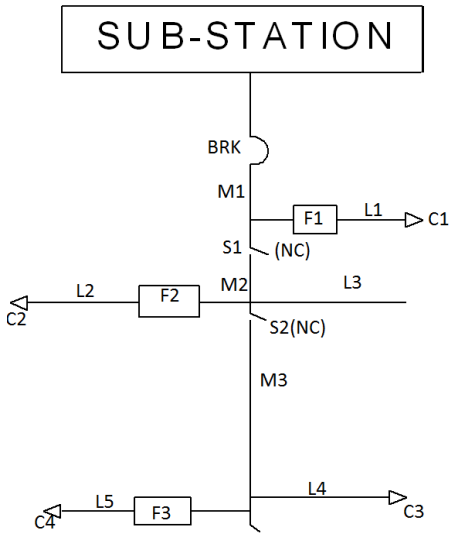

Fig 1 RADIAL DISTRIBUTION SYSTEM FOR ANALYSIS PURPOSE

TABLE II. RELIABILITY AND SYSTEM DATA

Component	*Failure rate*	*MTTR*
M1	0.10	4
M2	0.25	4
M3	0.30	4
L1	0.20	3
L2	0.40	3
L3	0.10	1
L4	0.10	2
L5	0.25	2

RESULT ANALYSIS

Here all the three cases are considered and reliability indices are calculated for each case. A complete analysis is done by simple hand calculation but this can also be implemented using MATLAB.

CASE I

TABLE III. LOAD POINT INDICES FOR BASE CASE

Load point	*λ failure/yr*	*r Hrs*	*U Hrs/yr*
C1	*1.05*	*1.31*	*1.375*
C2	*1.25*	*2.32*	*2.90*
C3	*0.85*	*3.4*	*2.90*
C4	*1.1*	*3.10*	*3.40*

CASE II:

TABLE IV. LOAD POINT INDICES FOR CASE II

Load point	*λ failure/yr*	*r Hrs*	*U Hrs/yr*
C1	1.05	1.31	1.375
C2	1.25	2.32	2.90
C3	0.85	1.911	1.625
C4	1.1	1.93	2.125

CASE III:

TABLE V. LOAD POINT INDICES FOR CASE III

Load point	*λ failure/yr*	*r Hrs*	*U Hrs/yr*
C1	0.95	1.205	1.145
C2	1.15	2.47	2.85
C3	0.75	1.9	1.425
C4	1.1	1.93	2.125

TABLE VI. RELIABILITY INDICES FOR ALL 3 CASES

Parameters	*Case 1*	*Case 2*	*Case 3*
SAIFI (INTERRUPTION/CUSTOMER)	1.06	1.06	0.685
SAIDI (HRS/CUSTOMER INTERRUPTION)	2.253	1.89	1.730
CAIDI (HRS/ CUSTOMER)	2.12	1.78	2.52
ASAI	0.999878	0.999878	0.999921
ASUI	0.000121	0.000121	0.000078

CONCLUSION

From the results we obtained, we can say that reliability improves in a good manner for system. As system reliability indices SAIFI and SAIDI gets improves but customer side parameter CAIDI reduces. Availability of service also increases and therefore unavailability reduces. We can see from the above table that for the base case SAIFI and SAIDI are1.06 interruptions/ customer and 2.253 hrs/customer int. but after putting a DG source and a fuse in distribution system, both parameters gets improved.

So we can conclude that with the application of DG at proper place and of proper size, system reliability improves and restoration time of the system reduces.

In this system if we put a DG of more capacity reliability of system will improves more but cost of DG will much higher than service availability.

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