Analyzing the Effect of DG on Reliability of Distribution Systems

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***Abstract*— The growth of distributed generation technologies is becoming more and more advanced and with the progressive development of distribution automation technologies, the deployment of distributed generators in power system is gradually becoming broad and diverse. Distribution Reliability is one of the prominent areas in electric power industry due to its high interrelationship with customer satisfaction. The paper analyses the impact of Distributed Generation (DG) on Reliability of distribution system. The analysis is performed on a typical utility system from Calicut, Kerala. Reliability assessment is done for single DG and multiple DGs and results are compared with the base case.**

Keywords—distributed generation; reliability assessment; Failure rates; Distribution system reliability.

I. INTRODUCTION

All over the world, conventional power system is experiencing the issues regarding depletion of fossil fuel resources, high fuel costs, growing electrical demand and ecological pollution. These problems paved way towards generation of power locally at the point of consumption by using modular power techniques like photovoltaic cells, fuel cells, microturbines [1]-[2]. This scheme of power generation is termed as distributed generation (DG).

Reliability may be defined as the ability of a system to perform its function under given conditions for given period of time. The interruption in the distribution systems affects the customers directly, and hence it is given premier importance [3].

Normally, in a healthy distribution network every customer is energized. In the event of any fault power supply to the customers is interrupted, which is referred to as an outage. Some the factors that could disrupt these normal operating conditions are; the equipment life cycle and maintenance, natural causes like wind, lightning and trees [4]-[7]. With the increasing use of non-conventional energy resources for power generation, researches are being carried out to prove their feasibility as DGs in the system. Addition of DG units into the system reduces the interruptions due to previously mentioned causes and thereby improves the reliability of the system. In this paper the reliability impact of DG is analyzed using two cases viz varying the distance and increasing the number of DG units.

The paper is structured into five sections. Section I deals with the overview of research. Section II gives a brief description of distribution system reliability. Section III details about the problem formulation and steps for reliability evaluation. Sections IV and V discusses about the application methodology on a Practical system and Conclusions respectively.

II. DISTRIBUTION SYSTEM RELIABILITY

Distribution systems are highly influenced by climatic conditions, lightning etc. which may cause failure or outages.

They are normally of radial type, rather than looped design. Due to the radial nature many loads are affected by the failure of a single section. Hence reliability is of major concern in such systems.

Reliability in distribution system is assessed by means of certain predefined indexes. These indexes measure the performance of the system [8].

1) SAIFI (System Average Interruption Frequency Index):

$$\mathrm{SAIFI} = \frac{\sum U_j N_j}{\sum N_j} \text{ f / customer. yr}$$

2) SAIDI (System Average Interruption Duration Index):

$$\mathrm{SAIDI} = \frac{\sum U_j \lambda_j}{\sum N_j} \text{ hr / customer.yr}$$

3) CAIDI (Customer Average Interruption Duration Index):

$$\mathrm{CAIDI} = \frac{\sum U_j N_j}{\sum N_j \lambda_j} \text{ hr / customer interruption}$$

4) ASAI (Average Service Availability Index):

$$\mathrm{ASAI} = \frac{\sum N_j \times 8760 - \sum U_j \times N_j}{\sum N_j \times 8760} \text{ p.u.}$$

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5) ASUI (Average Service Unavailability Index):

$$ASUI = 1 - ASAI = \frac{\sum U_j N_j}{\sum N_j \times 8760} \text{ p.u.}$$

6) EENS (System Expected Energy Not Supplied):

$$EENS = \sum EENS_j \text{ MWhr / yr}$$

Where,

$EENS_j = P_j U_j$

P_j is the load of load point j

7) AENS (Average Energy Not Supplied):

$$AENS = \frac{\sum EENS_j}{\sum N_j} \text{ MWhr / customer . yr}$$

where,

N_j=number of consumers at load point j

λ_j = average failure rate at load point j

U_j = Unavailability

III. Problem Formulation

A part of Omassery feeder, a typical utility feeder is modeled as shown in Fig. 1. All the active and passive failure rates of components are considered here as per data from Omassery Electrical Section, Calicut, Kerala. The Section Data, Load Data, Transformer and Breaker Reliability Data and DG Reliability Data are given in Table I, Table II, Table III and Table IV respectively.

Average reliability indexes are evaluated as:

$$\lambda_T = \sum_j \lambda_j \quad (1)$$

$$U_T = \sum_j \lambda_j r_j \quad (2)$$

$$r_T = \frac{U_s}{\lambda_s} = \frac{\sum_j \lambda_j r_j}{\sum_j \lambda_j} \quad (3)$$

Where,

λ_T = average failure rate

r_T = average outage time

U_T = average annual outage time

1) Algorithm for reliability indexes evaluation

Following steps are used for calculating the reliability indexes.

a) Firstly the failed section and its location is identified.
b) Thereafter , the load points affected by the failed section and their respective failure duration is determined
c) Using equation (1) - (3) load indices are calculated and thereafter system indices are determined.

TABLE I. SECTION DATA

Feeder Type	Length (km)	Feeder Sections	Failure Rate (f/yr)	Repair Time(h)
1	1	L1 L6 L9	0.0325	5
2	1.5	L4 L7 L8	0.04225	5
3	2	L2 L3 L5 L10 L11	0.052	5

TABLE II. LOAD DATA

Load Points	Consumer category	Number of consumers
LP1	residential	350
LP2	residential	500
LP3	residential	250
LP4	Government and institutional	5
LP5	commercial	35
LP6	Office buildings	12

TABLE III. TRANSFORMER AND BREAKER RELIABILITY DATA

Type of Unit	Active Failure Rate (f/yr)	Passive Failure rate(f/yr)	Repair Time(h)
T1 (500 kVA)	0.0150	0.0150	Nil
T2-T8(250kVA)	0.0150	0.0150	200
CB1 CB2	0.0020	0.0015	4
CB3-CB13	0.0060	0.0040	4

TABLE IV. DG RELIABILITY DATA

Type of unit	Failure rate(f/yr)	Repair Time(h)	Switching Time(h)
DG(20MW)	0.02	50	2

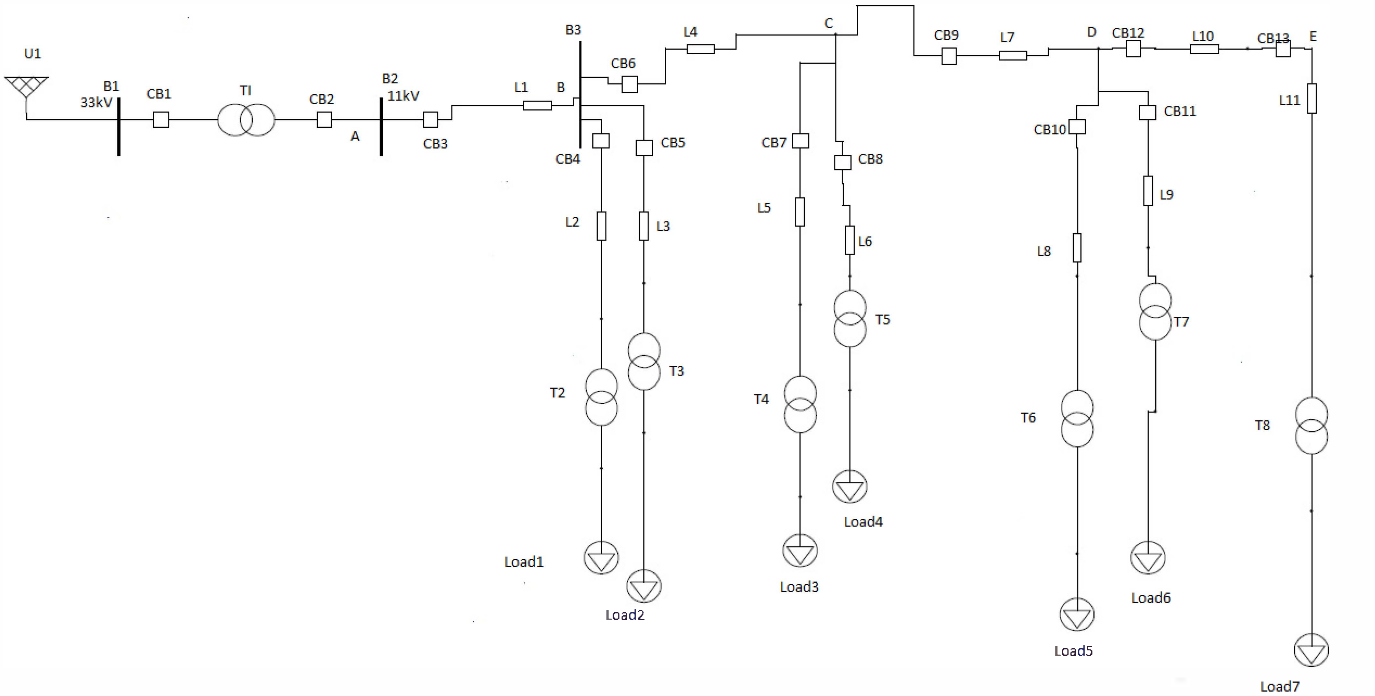

Fig. 1. A portion of Omassery Feeder

IV. Application Methodology

The reliability of the portion of the Omassery feeder is assessed using three cases viz base case without any DG, varying distance of DG from supply point and lastly by increasing the number of DG units.

Case 1: Base case analysis
In this case, the analysis is done without DG and indexes are computed.

Table V lists the reliability indexes for the base case analysis

TABLE V. RELIABILITY INDEXES FOR BASE CASE

Reliability Index	**Base Case**
SAIFI(f/customer.yr)	0.9225
SAIDI(h/customer.yr)	9.4586
CAIDI(h/customer interruption)	10.253
ASAI(pu)	0.9989
ASUI(pu)	0.00108
EENS(MWh/yr)	57.914
AENS(MWh/customer.year)	0.0632

Case 2: Reliability versus Distance
In this case DG is placed at varying distances from the supply point, starting from point E towards point A and the indexes are computed and compared with the base case.

Table VI and VII lists the comparison of system indexes for location of DG at varying distance from supply point with base case.

TABLE VI. COMPARISON OF SAIDI, SAIFI AND CAIDI FOR DG AT DIFFERENT DISTANCES

Reliability Index	**SAIFI f/cust.yr**	**SAIDI h/cust.yr**	**CAIDI h/cust.interruption**
Base Case	0.9225	9.4586	10.253
A	0.2635	9.1506	34.724
B	0.2354	9.0191	38.310
C	0.1909	8.3979	43.988
D	0.1665	8.0070	48.085
E	0.1601	7.7363	48.334

TABLE VII. COMPARISON OF ASAI, ASUI, EENS AND AENS FOR DG AT DIFFERENT DISTANCES

Reliability Index	**ASAI p.u**	**ASUI p.u**	**EENS Mwh/yr**	**AENS Mwh/cust.yr**
Base Case	0.9989	0.00108	57.914	0.0632
A	0.9990	0.00104	56.073	0.0611
B	0.9990	0.00103	55.287	0.0603
C	0.9990	0.00096	52.421	0.0572
D	0.9991	0.00091	49.376	0.0538
E	0.9991	0.00088	47.163	0.0514

The results indicate that penetration of DG in the system improves the reliability of the system and the best location for the DG in terms of reliability improvement is at point E.

Case 3: Reliability versus DG Penetration

In this case multiple (two units) DGs are placed all the above mentioned locations thereafter reliability indexes are computed and compared with the base case.

Table VIII and IX lists the comparison of system indexes for location of multiple DG penetration with base case

TABLE VIII. COMPARISON OF SAIDI, SAIFI AND CAIDI FOR MULTIPLE DG PENETRATION

Reliability Index	**SAIFI f/cust.yr**	**SAIDI h/cust.yr**	**CAIDI h/cust.interruption**
Base Case	0.9225	9.4586	10.253
A	0.2835	10.1506	35.802
B	0.2554	10.0191	39.226
C	0.2018	8.9398	44.311
D	0.1721	8.2861	48.147
E	0.1604	7.7526	48.337

TABLE IX. COMPARISON OF ASAI, ASUI, EENS AND AENS FOR MULTIPLE DG PENETRATION

Reliability Index	**ASAI p.u**	**ASUI p.u**	**EENS Mwh/yr**	**AENS Mwh/cust.yr**
Base Case	0.9989	0.00108	57.914	0.0632
A	0.9988	0.00116	62.049	0.0677
B	0.9989	0.00114	61.263	0.0668
C	0.9990	0.00102	56.871	0.0620
D	0.9991	0.00095	51.971	0.0567
E	0.9991	0.00089	47.903	0.0522

The results depict that introduction of multiple DGs will not show much improvement on reliability as placing more than one DG is equivalent to having DG in parallel to the same bus.

V. CONCLUSION

This paper presents the impact of DG in a Distribution system by considering a typical utility Feeder from Kerala and conducting the above mentioned case studies. The results obtained were compared with the base case analysis and it clearly indicates that the reliability is improved on introducing a DG into the system, placing the DG farther from the supply point. However, on placing multiple DGs into the system, it creates an adverse impact on reliability.

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