Global Scientific JOURNALS

GSJ: Volume 7, Issue 11, November 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

RELIABILITY ANALYSIS OF LOCAL DISTRIBUTION SYSTEM USING DISPERSED DISTRIBUTED GENERATION

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KeyWords

DG, Dispersed, EENS, ECOST, Reliability, SAIDI, SAIFI,

ABSTRACT

Traditional electrical power system is becoming complex because of the growing use of DG. The development and usage of DG has increased over the period of time. Power system reliability is a key feature when dealing with electric power system as it ensures to deliver as per consumer requirements and suffering to minimum losses. It enables the system to come back to its steady state condition after experiencing disturbance within minimum possible time. In this research, a local distribution system with dispersed generation will be analyzed using reliability parameters. When a single DG is injected, the reliability is increased. The optimum location to inject DG in the distribution system is also found by carrying out reliability test. The analysis will be carried out by selecting a modified roy billinton test system. Electric transient analysis program will be used for modeling the distribution feeder.

I Introduction

Electrical power system are real time systems as the power is produced, conducted and spread the moment the switch is turned on. The power generated by electrical power plants should fulfill the required electricity demand. The generation, transmission and distribution section of a traditional power plant are shown in Fig1. The capacity of power system mainly relies on the size and kind of power plant used. The range of capacity of a power plant ranges from MW to GW. The thermal and stability limit should be set such that the distribution system operates close to them [1].

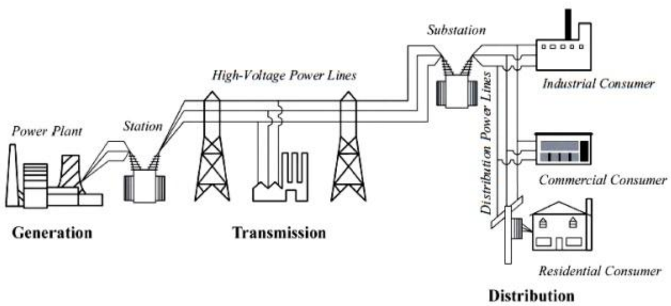

Fig1. Structure of a Power System

In modern ages, the main problems faced by distribution companies is the use of distribution generation in a network. The planning and evaluation of distributed generators (DGs) for residential, commercial and industrial loads must be done beforehand [2].Redesigning of network in distributed generation (DG) with an objective to solve power and voltage problem is presented in [3].In conventional power system, power is transferred to consumer through transmission lines resulting in technical difficulties. If distributed generators are installed close to the load centers the voltage profile can be improved hence eliminating transmission losses.

Distributed Generation & Reliability

The places where central generation is not practical and there are flaws in the transmission system the distributed generators can provide benefit for consumers. DG are also known as Distributed Energy Resources (DER). The benefits of DG when connected in an electric system are: [4]

- The cost of transmission is reduced when DG is allocated closer to load.
- The time required for construction of smaller plants is reduced
- Adequacy to the sector competition policy.

Energy can be obtained from two types of sources namely Renewable and non-renewable source. The advantages that can be attained by injecting DG into power system have been discussed by policy makes and power generation companies [5]. The characteristic of DG effects the benefits that can be obtained from it.

This relies on using type of DG such as wind, photovoltaic system, loads used, renewable sources and generating system [6]. This research will review the technical, commercial and environmental benefits of using DGs which are reducing line-losses and improved reliability. The rising energy demand and oil prices has compelled researchers to focus on use of renewable energy sources[7]. Commonly used renewable energy sources used for DGs are discussed in this chapter.

By connecting DG, the profile of voltage has a prominent effect. Certain areas have low voltage profiles, this can be improved by using DGs. The effect on voltage and power have been discussed in different papers.

[8] Analyses a local distribution system and the result of power quality on it by using renewable energy sources. The research paper discusses the use of power electronics with distributed generation. It discusses the effect of changes in environment due to the distortions. The performance and efficiency of the results are tested by changing levels of renewable sources in reference to the control action being set.

The effect of DG in power network is examined in [9]. Different issues encountered in installation of DG such as losses in power, voltage profile and harmonics are also analyzed. In order to alter voltage from its allowed range a DG can be installed by changing the settings of voltage regulator. Voltage regulation technique is also proposed. Voltage control mode is preferred when inserting DG based on simulation result [10].

The impact of voltage control in distribution system using renewable generation are discussed in [11]. The voltage alleviation can be achieved if the control equipment is based on smart grids concept specifically at the demand side.

A current correction approach is presented in [12]. A detail of asymmetrical power flow is present in this paper. The approach is quite flexible as a number of phase and conductors can be considered. A number of technical and operational challenges are related to DG when more than one DG is inserted although DG is able to achieve the increased demand of energy [13]. Power quality and voltage fluctuations can be analyzed through fast Fourier and discrete Fourier transform. A number of techniques are analyzed and their merits and de merits are also mentioned [14].

[15] A multi objective model that suggests optimal position and dimension of distributed generation that can decrease loss by means of genetic algorithm is presented. Multiple generation that can support reliability indices is presented using analytical schemes. Load is considered and uncertainty is not involved in the load values. Impact of dispersed distributed generation through optimization approach is analyzed [16].

II Research Methodology

In this research work, a modified Roy Billinton Test System(RBTS) developed for a local distribution system is modeled[17]. This modified RBTS consists of five load buses, two buses used as generator buses , circuit breakers, nine transmission lines, feeders/ conductors, and eleven generation components. The total capacity installed is 240MW and maximum load is 185MW. Fig 2 shows an RBTS developed for distribution system. It is developed by Saskatchewan University for educational purpose.

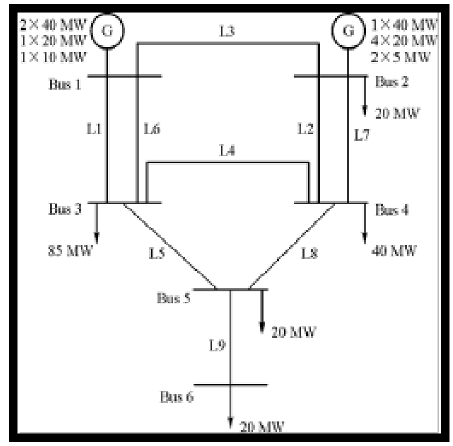

Fig 2. RBTS for a distribution system

The assumptions and limitations considered are as mentioned below:

1. The switching devices used are functioning effectively whenever they are required.
2. To separate fault the switching devices can be operated.
3. Power can be provided to load points by restoring power supply.
4. The failures are statistically independent.
5. Single contingency considered as first order faults
6. Size of DG is unchanged
7. Modified RBTS is used to analyze the reliability

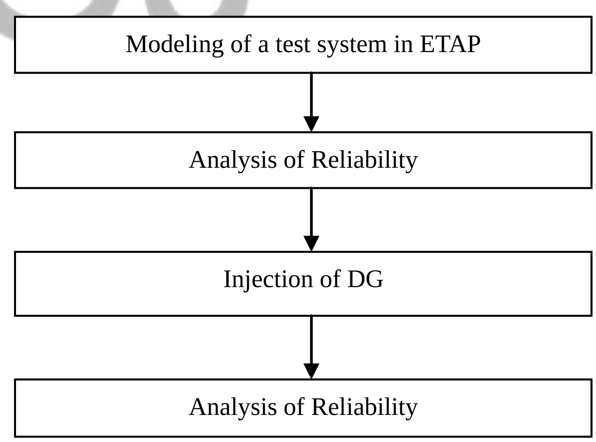

Fig 3. Block diagram methodology used

The Distribution system is modeled by using ETAP and tests for different indices are performed by assigning values as mentioned in Table 1, 2, 3, 4 and 5.Table 1 shows the distance of line from feeder in km. Table 2 show the data that is used for different loads such as industrial, residential and commercial. Table 3, and 4 show the data for different reliability parameters such as rate of failure, switching time, repair time, the distance of load points from feeder for different components and wind turbine.

Table 1: Feeder Section in Kms

S. No	Unit Capacity(MW)	Rate of Failure (f/Yr)	Time of Repair (hr)	Time of switching (hr)
1.	5	0.020	50	1

Table 2: Details of each components

Component used	Failure Rate(f/Yr)	Time of repair (hr)	Time of switching(hr)
Reliability data for T/F			
33.0/11.0 kv	0.0150	15.0	01
11.0kv/220.0 v	0.0150	10.0	01
Reliability data for Breakers			
33.0 kv	0.0020	04	01
11.0 kv	0.0060	04	01
Reliability data for Busbars			
33.0 kv	0.0010	02	01
11.0 kv	0.0010	02	01
Reliability data for Feeders			
11.0 kv	0.6500	5.0	01

Table 3: Data For Load Points

Customer's nature	Load in MVA	Total Customers
Residential		
Res.1	0.5350	210.0
Res.2	0.5350	200.0
Res.3	0.5350	200.0
Res.4	0.5350	210.0
Res.5	0.5350	210.0
Res.6	0.5350	200.0
Res.7	0.4500	200.0
Res.8	0.4500	200.0
Res.9	0.4500	200.0
Government & Institutions(GI)		
GI 1	0.566	01
GI 2	0.566	01
GI 3	0.566	01
GI 4	0.566	01
GI 5	0.566	01
GI 6	0.566	01
Commercial load		
Comm1	0.4540	10.0
Comm2	0.4540	10.0
Comm3	0.4540	10.0
Comm4	0.4540	10.0
Comm5	0.4540	10.0
Industrial load		
Ind.1	1.130	01
Ind.2	1.130	01
Total	12.486	1888

Table 4: Reliability Data for Wind turbine

S.No	Length measured in Km	Feeders
1.	0.800	C36,C34,C28,C33,C23,C26,C21,C22,C17,C19,C16,C11,C8
2.	0.750	C35,C30,C27.C25,C20,C7,C13,C5,C12,C10,C2, ,C3,C1
3.	0.600	C32,C31,C29,C24.C18,C15,C14,C9,C6,C4

III Mathematical Modeling

IEEE has defined the reliability indices in its standard number P1366, Guide for Electric Distribution Reliability Indices. These reliability indices are commonly accepted. IEEE-P1366 has defined and listed different terms that can be used to define reliability. The document contains indices which can beneficial today and in future as well [18].

The indices are divided into the following two categories:

i) Reliability indices(load based)

ii) Reliability indices(system based)

i)Reliability indices(load based)

The load points are selected and the indices are then calculated shows some basic concepts that can be used to find the reliability of a power system. When reliability is to be discussed for load points it is important to discuss indices such as rate of failure (γ), duration of outage(r) and the time that the outage occurred (U) which have also been discussed above.

Expected Energy Not Supplied Index (MWhr/year):

$$EENSi= Pi1:Ui1 \ldots\ldots\ldots\ldots(1)$$

Where:

Pi1= Average load at point i1.

Ui1= Average outage interval at point i1.

Expected Interruption Cost Index at Load Point, ECOSTn (K$/yr)

$$ECOSTn= P_{i1}\sum_{j\in Nf} f\,(\gamma_{e.g.}\partial_{I,g})\ldots\ldots\ldots\ldots(2)$$

Represents:

GSJ: Volume 7, Issue 11, November 2019
ISSN 2320-9186

Pi1=Average load at point i.
∑=Total or sum.
$\gamma_{e.g}$ = Failure rate average.
Nf= Collective faults that interrupts load at n.
f(∂I,g)=damage factor for customer.

ii)Reliability indices(system based)

System Average Interruption Frequency Index (SAIFI)

The frequency interruption index is calculated by finding the average times customer faces an outage per annum. Since it is a ratio so it has no dimensions.
The formula is given below

$$SAIFI = N_i/N_T \ldots\ldots\ldots(3)$$

Represents:
∑=Total or sum.
N_i =Aggregate of customer interrupted.
N_T= Aggregate of customers benefitted.

System Average Interruption Duration Index (SAIDI)

It is used to Measure continuous interruptions faced by a system.It is measured as the total time period of interruption that a customer experiences. This index can be calculated on daily basis but generally it is calculated on monthly, annual or for a specific time.
The value of SAIDI can be calculated by using the formula given below:

$$SAIDI = \frac{\sum(\partial_i * N_i)}{N_T} \ldots\ldots\ldots(4)$$

Represents:
SAIDI = System average interruption duration index.
∑=Sum or Total.
Ni =Customers interrupted altogether.
NT = Customers served altogether.
∂_i=Time required for restoring in minutes.

IV Simulation Results and Analysis

Analysis of a local distribution system with and without DG is done using ETAP software.
Case 01: Reliability Analysis considering without DG
Case 02: Reliability Analysis considering DG at point A
The different cases of DG injection are discussed with their figure and analysis in the following subsection.

Case 01: Reliability Analysis considering without DG

The value of outage duration is increased as the span of load points increases from feeder so it is observed that the feeders that are close to the load experience lesser duration of outages. System becomes vulnerable to outages because of this reason. Figure 2 shows a distribution system without DG and its results are presented in Table 5.

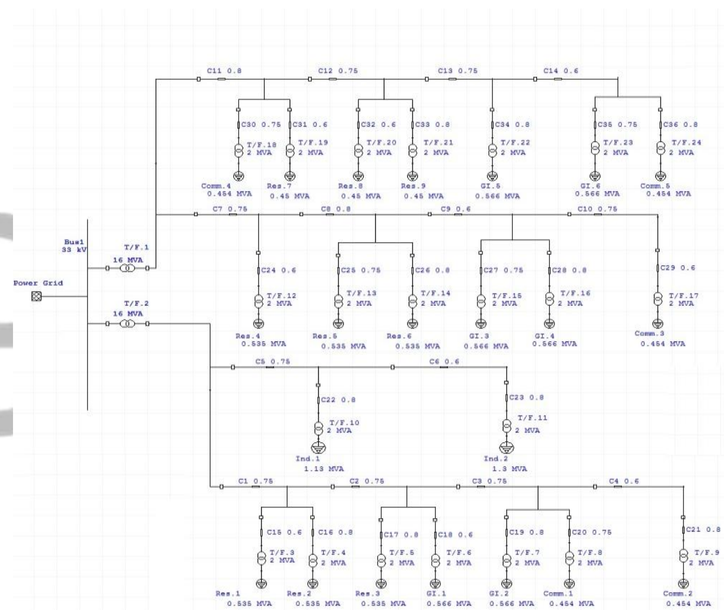

Fig 4: Reliability Analysis considering without DG

Table 5: Result of analysis considering without DG

Considering without DG		
S.No	System Indices	Results
1.	SAIFI	1.9782 f/customer.yr
2.	SAIDI	8.1258 hr/ customer .yr
3.	EENS	119.945 MW hr/ yr
4.	ECOST	477,095.70 $/yr

Case 02: Reliability Analysis considering DG at point A

Dispersed generation is inserted in distribution system at a point A as shown in figure 3. The reliability indices such as interruption frequency is improved and duration of interruption is decreased which can be seen in Table 6.

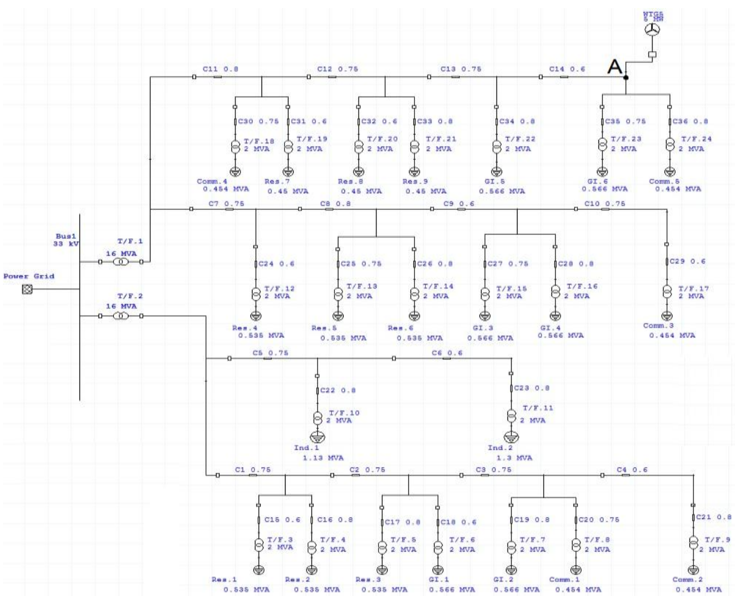

Fig 5: Reliability Analysis considering DG at point A

Table 6: Result of analysis considering DG at point A

Considering DG at Point A		
S.No	System Indices	Results
1.	SAIFI	1.4112 f/customer.yr
2.	SAIDI	8.1258 hr/ customer .yr
3.	EENS	96.624 MW hr/ yr
4.	ECOST	399,571.50 $/yr

Table 7 shows a comparison of reliability indices of local distribution system without DG and when DG is injected at different points.

Table 7: Comparison of Analysis considering DG and without DG

S. No	System Indices	Without DG	DG at Point A
1.	SAIFI (f/customer.yr)	1.9782	1.4112
2.	SAIDI (hr/ customer .yr)	8.1258	6.4852
3.	EENS (MW hr/ yr)	119.945	96.624
4.	ECOST ($/yr)	477,095.70	399,571.50

It can be seen that when dispersed generation is injected at point A, the system experiences minimum interruption. It is also seen that the energy not supplied is also minimum when DG is at point A. However the cost also decreases when the DG is injected at point A.

V. Conclusion

The assessment of reliability has proved to be a key feature to be considered when designing distribution system such that it functions in an economical approach and with decreased interruption to consumer or load. Reliability analysis of a local distribution system has been implemented with and without injecting DG. If the span of the load point were increased from the feeder, the reliability indices indicate that the interruption frequency and interval were increased. When DG was injected closer to load station, positive impacts on reliability were observed.

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