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Distribution system reliability with considering variation in DG and load consumption

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Abstract

In recent years, network reliability is one of the major concerns in distribution system and network customers expect distribution companies to provide them high reliability and electrical power with better quality. Distributed Generations have proper effect on system reliability when they can control network in intentional islanding. In this paper with considering DG output and load consumptions in uncertainty mode, probability of supplying load points are estimated and then indexes of network load point's reliability is calculated more accurately. Normal distribution function is used to model load consumptions and DG output power and Monte Carlo simulation is applied to evaluate average annual outage time of load points. Numerical example is presented to demonstrate the efficiency of the proposed methodology.

Keywords: Distribution Generation, Distribution System, Load Indexes, Monte Carlo Simulation, Reliability.

Introduction

In recent years with ever increasing population, more load demand by customers and difficulties for construction of new power plants, transmission lines and substations (Hegazy *et al.,* 2003), power distribution system companies are going to use distributed generation sources. Since power industry is running by private sectors, giving service with better quality and higher reliability has become very important.

Since the rate of accessibility to distribution system (because of its radial structure) is much less than generation and transmission systems, evaluation and reliability improvement shall be considered in this part of power system (Allan & Billinton, 1993; Dasilva *et al.,* 2002; S.A.M. Javadian & M.Massaeli, 2011; Khalesi *et al*., 2011).

Many different methods have been discussed and proposed for modeling and reliability evaluation of distribution networks. But in general there are 2 methods for assessment of network reliability: analytical method and probability simulation method (Neto *et al.,* 2006). Monte Carlo method, one of the probability simulation methods, is in fact continuous simulation of a real act with accidental behavior in system and can be used for adequacy evaluation of the distribution system in presence of DG.

Duttagupta and Singh (2006) used Monte Carlo simulation for the review of network reliability indexes in the peak load. Hegazy *et al.* (2003) evaluated adequacy of distributed generation sources by using Monte Carlo method. Evaluation of the system adequacy involves assessment of real capacity of the system and the ability of this capacity in providing the network demand load.

Andrade *et al.* (2006) modeled the reliability in presence of distributed generation sources with accidental capacity. Reliability of distribution network depends on the rate and speed of consumer loads restoration and the speed of returning network into its natural configuration. DG can be effective in restoration operation by making intentional island which hasten restoration of network. Intentional islanding is a proper choice for enhancing the reliability of network for downstream loads which have no access to any other supporting sections.

The major lacuna One of the major weak points is not considering uncertainty in load consumption in network and modeling it as a constant load and uncertainty in power generation of distributed generation sources which are based on renewed energies; In this paper, by probability modeling of network load consumption and DG power generation, the probability of feeding network load points by DG in case of fault occurring is specified and by using this data, reliability indexes of load points can be calculated more truly. In this paper for load and DG modeling normal distribution function is used and for evaluating outage time of load points, simulation by Monte Carlo method is utilized. The proposed method has been applied on a sample network and its results have been presented.

Restoration network load points with DG

The most important property of DG for participating in load restoration is the ability to make island in network. The first characteristic which is necessary for making island is the ability of self-starting. It means that the generator can be driven without external voltage source. Moreover DG shall be able to control load voltage and frequency and to response the load changes as well. In addition DG unit shall have the ability to communicate, control and accepting commands from distribution operator. Necessary devices for protection, connection and synchronization of DG to network shall be considered (Carpaneto *et al.,* 2006).

Distributed generation can be effective in restoration operation in two ways. First, it itself causes additional fault (making unwanted island) and secondly during restoration operation, hastens the process by making an intentional island. Intentional islanding is a proper choice for enhancing reliability of downstream loads of network which have no access to any other supporting sections.

As it is shown in Fig.1 & 2, formed island on the feeder which distributed generation is placed on that is divided into two parts from load viewpoint: Upstream ($UPILP_i$) and downstream ($DNILP_j$).

Fig.1. Islanding in upstream of LPi

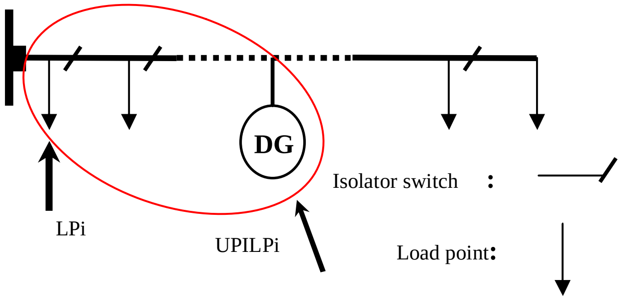
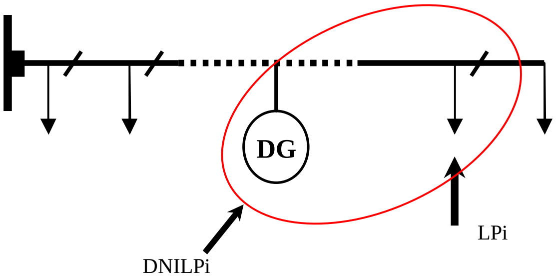


Fig.2. Islanding in downstream of LPi



Regarding mentioned points, the probability of feeding the considered load by DG is said to the probability of forming the smallest island that covers the considered load point. Therefore DG shall be able to provide the power for consuming loads specially the specific load point on that island. Since the smallest island is formed from viewpoint of specific load point, this consuming load is always at the end of island.

DG and load point modelling

In distributed generations, like any other studies in power systems, uncertainties are discussed like uncertainty in network load consumption and uncertainty in generated power of DG units which are based on renewed energies.

Hence, a powerful probability methodology is needed to manage lack of certainty in power generation (Celli *et al.,* 2003). Published information shows that uncertainty can be stated by normal distribution in an acceptable way (Billinton & Allan, 1996).

In this paper, in addition to load consumption, DG generated power is modeled by using normal distribution in seven spans in a way that DG generated power in network (μ) and variance of power generation of DG (σ) in considered network and the probability of DG power generation on network in various spans are different as indicated in Fig.3. Also for load consumption modeling, the same procedure is repeated.

Assessment of network load indexes

Among three basic reliability parameters which are average failure rate (λs), average outage time (rs) and average annual outage time (Us), and the latter is the most important one because it indicates customers' outage duration. When distributed generation has been allocated in network, average outage time for each load point (r_{LPi}) is estimated as follow:

$$r_{LPi} = (P_I)*(r_{DG}) + (1 – P_I)*(r_{NDG}) \qquad (1)$$

Where: r_{NDG} is average outage time from viewpoint of load point i (LPi) when distributed generation (DG) is not available

In the network, PI is load point (LPi) feeding probability via DG and r_{DG} is average outage time from view point of load point i (LPi) when DG is in network. λ_{LPi} is average failure rate from viewpoint of load point i.

Therefore average annual outage time from viewpoint of load point i can be estimated as "(2)":

$$U_{LPi} = \lambda_{LPi} * r_{LPi} \qquad (2)$$

When DG isn't in network or cannot feed load point i then P_I is considered zero and if DG was considered as substation which can feed all network load points, then P_I equals one. In other cases P_I shall be calculated based on section "V" of this paper.

In this paper it is supposed that DG can feed first load in upstream or downstream with probability of 100% and failure rate and outage time for all load points are evaluated considering minimal cutset method (Fotuhi & Ghahnavie, 2005).

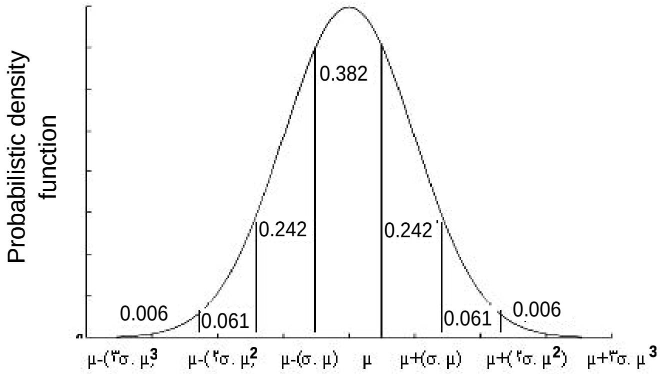
Proposed methodology

In this paper PI is simulated with MATLAB software and its algorithm is presented as bellow:

1. First, load point i is defined then island is constituted for supplying this load like section II.
2. By random process and with considering normal distribution function, power generation by DG source is defined (CAP_{DG}). The same method is applied for defining of each load point's power consumption (S_{LPi}) which is in island.
3. Considering "(3)", residual power generation of DG (RES_{LPi}) is defined for a specific load point.
$$RES_{LPi} = CAP_{DG} - (\sum S_{LPi}) \qquad (3)$$
4. After defining DG power generation in random process, probability of this power generation (P_{CAPDG}) is estimated with normal distribution function like Fig.3. This method is repeated for defining probability of each load point's power consumption which is in island.
5. Probability of residual power generation of DG in a specific load point (P_{RESLPi}) is calculated by "(4)":
$$P_{CAPDG} * P_{RESLPi} = \Pi P_{LPi} \qquad (4)$$

Where: P_{LPi} is probability of load point consumption, value between specific load point and DG. The symbol of (Π) indicates multiplying these values.

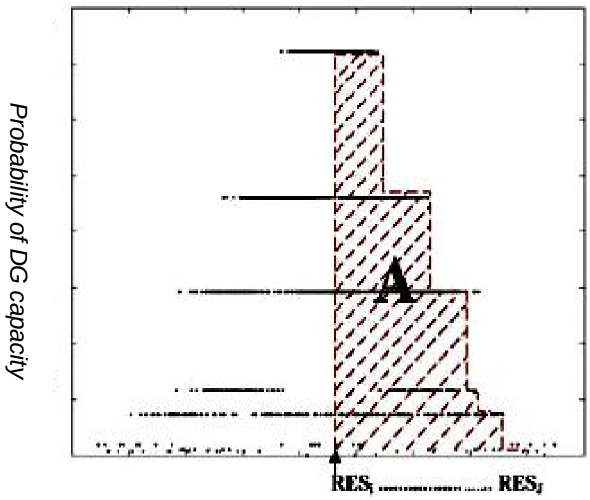
Fig.3. Modeling of power generation of DG and power consumption of load points with normal distribution function



6. Steps one to five are repeated with considering Monte Carlo simulation until appreciated convergence is achieved. Indeed repeated simulation of a real act with random process is applied in this methodology.
7. Probability of residual power generation of DG in a specific load point is drawn in Fig.4.

$$PI = A / (RES_J - RES_i) \qquad (5)$$

Fig.4. Probability of residual power generation of DG in a specific load point

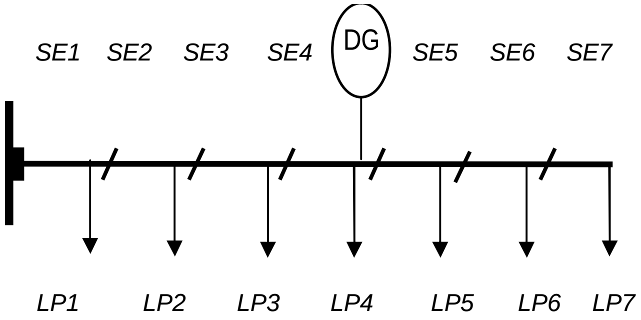


8. Based on fig.4, probability of supplying a specific load point is achieved by below equation:
   Where: PI is probability of a specific load point being supplied by DG; A is the value of area indicated with dash lines which is appreciated capacity of DG for supplying a specific load point between RES_J to RES_i. Indeed RES_i is load point consumption and RESJ is maximum residual capacity of DG.

It shall be noted that probability estimation is applied when DG can feed total consumption of a specific load point.

Case study

Fig.5. Test system



The proposed algorithm in section V was implemented with MATLAB programming language. In order to test the proposed method DG unit has been considered 2 MW. The proposed approach was tested on several distribution systems by use of prepared software with acceptable results. The test system is shown in Fig.5. This test system has seven sections and seven load points and DG is installed on fourth section. Average fault location time and isolator switch operation is half an hour. Test system data is indicated in Table 1.

Results of Monte Carlo simulations with 8000 times repetition with considering 0.04 for variance of power generation of DG is presented in Table 2. Results for load point numbers 2, 3, 6 and 7 have been indicated in Fig. 6, 7, 8 and 9 respectively.

Table 1. Test system data

Section Number	Length (Km)	Average Failure Rate	Repair Time (hour)	Load Point Consumption(kW)
SE1	1	0.065	5	500
SE2	2	0.13	5	200
SE3	3	0.195	5	400
SE4	1	0.065	5	1500
SE5	1	0.065	5	800
SE6	1	0.065	5	1200
SE7	1	0.065	5	100

Conclusion

Modeling method of DG output power and load points has great effect on average annual outage time index and on other indexes of distribution network load points. With probabilistic modeling of network power consumption and DG power generation, the probability of feeding load points by these sources, in the event of fault in network, is calculated and based on that indexes of network load points reliability is calculated more accurately. Achieving the accuracy of network condition, the probability of feeding a specific load point by DG sources can be increased which in turn results improvement in network reliability indexes.

Table 2. Results of Monte Carlo simulation

Load Point	Average annual outage time without DG(hour)	Probabilistic of feeding load point with DG(%)	Average annual outage time with DG(hour)
LP1	0.617	0	0.617
LP2	1.202	2	1.19
LP3	2.08	15	1.79
LP4	2.37	100	0.617
LP5	2.67	100	0.617
LP6	2.958	11	2.59
LP7	3.25	1.9	3.18

Fig.6. Probabilistic of residual capacity of DG for load point 2

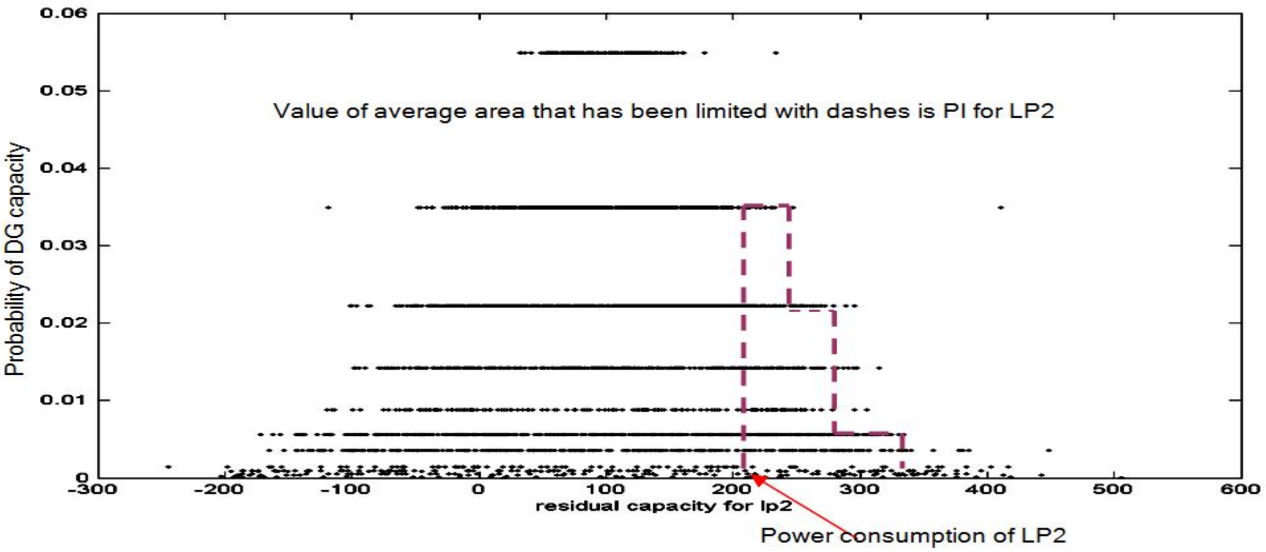


Fig.7. Probabilistic of residual capacity of DG for load point 3

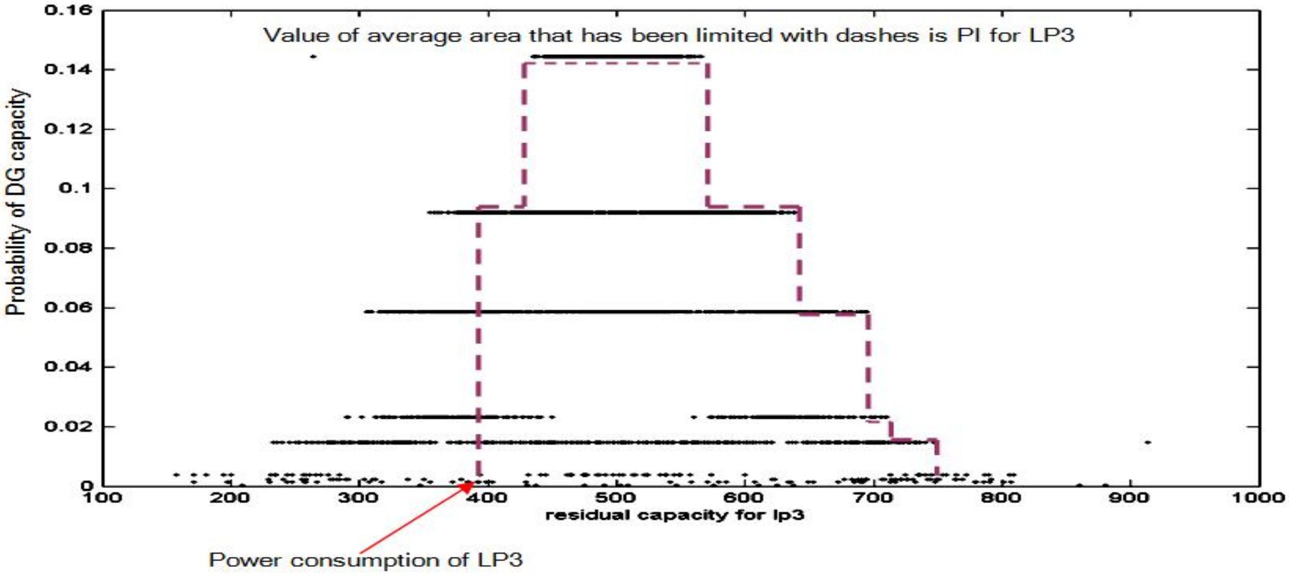


Fig.8. Probabilistic of residual capacity of DG for load point 6

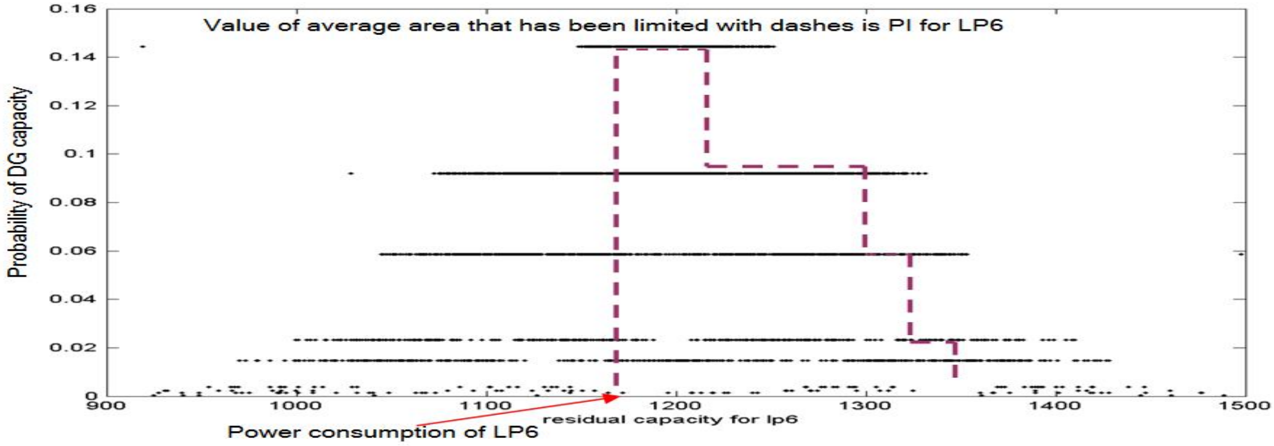
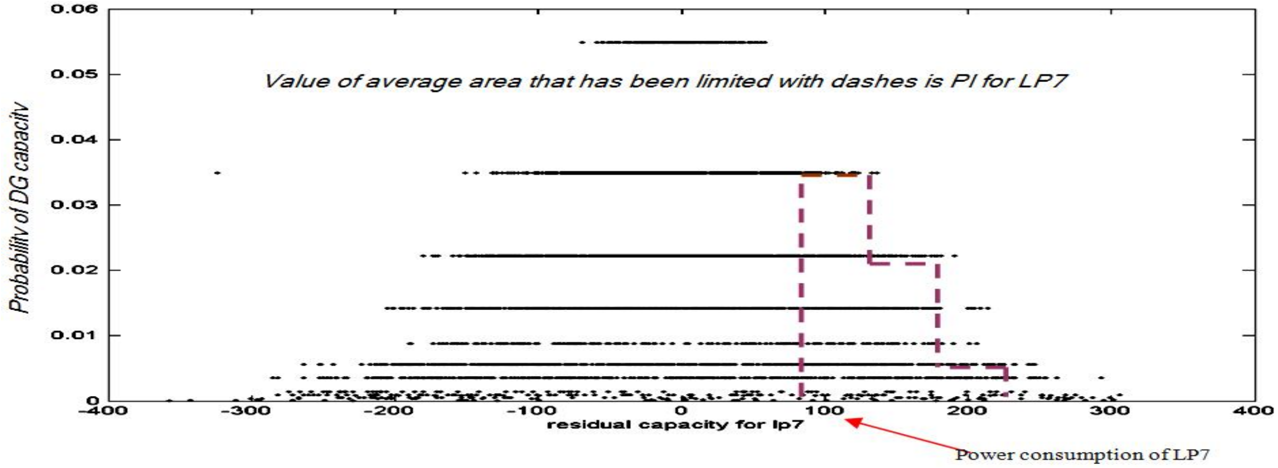


Fig.9. Probabilistic of residual capacity of DG for load point 7



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