Loss Reduction and Reliability Improvement with Optimization of DGs Placement Using Genetic Algorithm - A Case Study on the Electrical Distribution Network of North Kerman Area

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Abstract

Increasing application of DG on distribution networks is the direct impact of development of technology and the energy disasters that the world is encountering, Recent developments in the electric power and problems arising from construction and maintenance of large power plants have raised a great deal of interest in distributed power generation (DG). Distributed generation units due to specifications, technology and location network connectivity can improve system and load point reliability indices. In this paper, the placement and sizing of Distributed Generators (DG) in distribution networks are determined using optimization. The objective is to improve the reliability indices. The placement and size of DGs are optimized using a Genetic Algorithm (GA). To demonstrate the validity of the proposed algorithm, computer simulations are carried out on actual power network of Kerman Province, Iran and the simulation results are presented and discussed.

Keywords: Component; Distributed Generation, Distribution System, Optimization, Reliability.

1. Introduction

Due to competition and restructuring in power systems and changes in management and ownership of electricity industry, the role of distributed generation units expected to be increasingly in the future. Also, factors such as environmental pollution, problems establishment of new transmission lines and technology development of DG unit increase the use of these resources. Although, use of DGs can lead the distribution network to lower loss, higher reliability, etc, it can also apply a high capital cost to the system. This demonstrates the importance of finding the optimal size and placement of DGs. In recent years, several studies have considered techniques for locating DG units on distribution systems. In all papers, improvement of system characteristics is the main objective of DG placement.

Almost all papers related to DGs have studied loss minimization and improve voltage profile (Wnag and Nehir, 2004 and Jabr and Pal, 2009) and a few papers have examined DGs for improving the reliability (Weixing Li, 2004 and Wang and Singh, 2008). This paper presents analysis of Genetic Algorithm (GA) based system power loss minimization approach Reliability Improvement and system energy loss minimization approach also the total loss of a practical distribution system is calculated with and without DG placement and an index, quantifying the total line loss reduction for optimal sizing and placement of DG in electrical power systems. The methods are presented to find optimal size and bus location for placing DG using power loss and energy loss minimization in a networked system based on bus admittance, generation information and load distribution of the system. The proposed methods are tested by simulations actual power network of Kerman Province, Iran of 5-DG.

2. Distribution system reliability Assessment

Reliability evaluation of distribution systems has received considerable attention and there are a number of publications dealing with modeling and evaluation techniques. However a continuing need to extend and develop the techniques still remains as new design and operation approaches are introduced into the system (Weixing Li, 2004). There are several available methods for evaluating the reliability of distribution systems. In this paper, the impact to all load points due to each component failure will be considered as well as the average failure rate of the component. Then, the interruption frequency and duration at each load point is calculated to eventually calculate the system reliability indices. The important point is that it should be noted that in each errors simulation, the effect of the network

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structure, switches, supply ability of loads from the main source of power or other resources, islanding of DGs in the simulation must be modeled properly. Note the simple illustrative distribution system as shown in (Figure1) for further explanation.

The feeder is operated as radial feeders but it can be supported by a DG through a normally open switch. For example following a fault occurrence on first section, with no DG on the feeder, service of all load points must be interrupted during repair process but with DG as shown in (Figure 1), some load points loads (due to DG capacity) can be restored via the DG. Existence of DGs can reduce the outage duration and consequently increase the system reliability.

This simple example shows that DG can have a positive impact on distribution system reliability in the case of local utility supply interruptions. Distribution

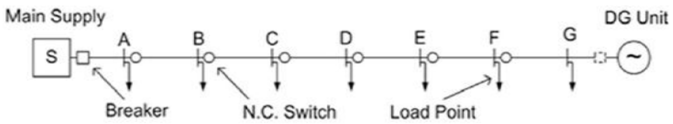

Figure 1: A Typical distribution system with one DG

automation system in a distribution system including DGs, load transfer to other feeders via switches operation can be performed in fault condition in order to keep customer supply (Hamid Falaghi and Mahmood-Reza Haghifam, 2005; Fangxing Li and Nura Sabir, 2004).

3. Problem Formulation

The objective of DGs placement in a radial feeder is to maximize the distribution network reliability under certain constraints. As a brief reminder, we will look at the standard reliability performance indices, such as system average interruption duration index (SAIDI), system average interruption frequency index (SAIFI) and energy not supply index (AENS) and the composite index obtained as a combination of all three. They are defined as follows:

$$SAIFI = \frac{\sum_i \lambda_i \times N_i}{\sum_i N_i}$$

Where Ni is the number of customers of load point i and λ_i is the failure rate.

$$SAIDI = \frac{\sum_i u_i \times N_i}{\sum_i N_i}$$

Where u_i is the outage time

$$AENS = \frac{\sum_i L_i \times u_i}{\sum_i N_i}$$

Where L_i is the average load connected to load point i.

The resistance and reactance of the line section between buses i and i+1 are denoted by $R_{i,i+1}$ and $X_{i,i+1}$ respectively. The power loss of the line section connecting buses i and i+1 may be computed as

$$P_{Loss}(i,i+1) = R_{i,i+1}\,\frac{P_i^2+Q_i^2}{|V_i|^2}$$

The total power loss of the feeder, P_T^{LOSS} may then be determined by summing up the losses of all line sections of the feeder, which is given as

$$LOSS = \sum_{i=0}^{n-1} P_{LOSS}(i,i+1)$$

For the purpose of optimization, we define a composite reliability indices and capacity of DG units through weighted aggregation of these indexes.

$$f_1 = w_{SAIFI}\frac{SAIFI}{SAIFI_T} + w_{SAIDI}\frac{SAIDI}{SAIDI_T} + w_{AENS}\frac{AENS}{AENS_T} + w_{LOSS}\frac{LOSS}{LOSS_T}$$

Where $w_x \geq 0$ are the weighting coefficients representing the relative importance of the objectives and the subscript T indicates the target value. These reliability indices are the most widely used indexes for measuring the distribution system reliability. The active and reactive losses are greatly depending on the proper location and size of the DGs. The indices are defined as

$$f_2 = \left(\frac{TP_{loss}^{withDG}}{TP_{loss}^{withoutDG}}\right)$$

$$f_3 = \left(\frac{TQ_{loss}^{withDG}}{TQ_{loss}^{withoutDG}}\right)$$

Where, TP_{loss}^{withDG} and TQ_{loss}^{withDG} are the real and reactive power losses of the distribution system with DG. $TP_{loss}^{withoutDG}$ And $TQ_{loss}^{withoutDG}$ are the real and reactive power losses of the system without DG.

4. Power Flow Analysis Method

The methods proposed for solving distribution power flow analysis can be classified into three categories: Direct methods, Backward-Forward sweep methods and Newton-Raphson (NR) methods. The Backward-Forward Sweep method is an iterative means to solving the load flow equations of radial distribution systems which has two steps. The Backward sweep, which updates currents using Kirchoff's Current Law (KCL), and the Forward sweep, which updates voltage using voltage drop calculations [5].

The Backward Sweep calculates the current injected into each branch as a function of the end node voltages. It performs a current summation while updating voltages. Bus voltages at the end nodes are initialized for the first iteration. Starting at the end buses, each branch is traversed toward the source bus updating the voltage and calculating the current injected into each bus. These calculated currents are stored and used in the subsequent

Forward Sweep calculations. The calculated source voltage is used for mismatch calculation as the termination criteria by comparing it to the specified source voltage. The Forward Sweep calculates node voltages as a function of the currents injected into each bus. The Forward Sweep is a voltage drop calculation with the constraint that the source voltage used is the specified nominal voltage at the beginning of each forward sweep. The voltage is calculated at each bus, beginning at the source bus and traversing out to the end buses using the currents calculated in previous the Backward Sweep [5].

5. Genetic Algorithm

Due to the discrete nature of allocation and sizing problem, it undergoes a number of local minima. To deal appropriately with this issue, using a reliable optimization method is required. The optimization methods are mainly divided into analytical and heuristic methods. The analytical methods show higher accuracy compared with the heuristic methods in the smooth functions. However, the objective function in the discrete problems is non-smooth which reduce the accuracy of the analytical method and lead them occasionally to be stuck in the local minima. For optimizing this type of functions, the heuristic algorithms play an acceptable role. They are based on the random values and if only one of these random values is located close to the global minimum, they can find acceptable solution (Ziari, et al., 2010).

In this paper Genetic Algorithm (GA) is used to achieve optimal response. GA simulates the biological processes that allows the consecutive generations in a population to adapt to their environment. Genetic Algorithm is unconstrained optimization methods, which model the evolutionary adaptation in nature. They work with a population of solutions and create new generations of solutions by appropriate genetic operators. The description and comments of algorithm implementation are presented as follows.

Step1: convert the problem variables to Codes used for GA operators

In this method any bus is encoded by three bits. The first bit indicates the presence or absence of DG units and next two bits represent the capacity of the unit is installed in bus. So length of each chromosome is equal to: 3 multiplied by number of buses. Capacity of distributed generation units 0.3, 0.6, 0.9, 1.2 MW is intended.

Step2: The initial population

To each of the chromosome genes are randomly assigned to zero or one. The initial population consists of 20 members.

Step3: Calculation of reliability indices and the objective function

In this step Constraints are examined and if the answer is not satisfactory, a large number as a penalty factor is added to the objective function.

Step4: The GA operators (Roulette Wheel Selection, Cross Over, Mutation)

To avoid trapped in local minimum during the program, amount of mutation probability is changed and amount of cross over probability has been selected 0.2.

Step5: Check convergence criterion

If Iter = Iter max or if the output does not change for a specific number of iterations, the program is terminated and the results are printed, else the programs goes to step 3.

6. Test Result

To study the proposed method, actual power network of Kosar feeder of Kerman Province, Iran is simulated in MATLAB. Figure 2 illustrates the single-line diagram of this network. The base values of the system are taken as 20kV and 20MVA. The system consists of 20 distribution transformers with various ratings. The details of the distribution transformers are given in table 1. The details of the distribution conductors are given in Table 2. The lengths of the feeder segments are given in Table 3. The total connected load on the system is 2550 KVA and the peak demand for the year is 2120 KVA at a PF of 0.8 lag. The connected loads on the transformers are listed in Table 4. The reliability index weights are chosen as follows: WSAIFI = 0.31, WSAIDI = 0.31, WAENS = 0.31 and WPDG = 0.07. The target values of the reliability indices are set as follows: SAIFIT = 10, SAIDIT = 100, AENST = 350 and PDGT = 1000. They are empirically justified and indicate the satisfactory level of reliability (Wang and Singh, 2008).

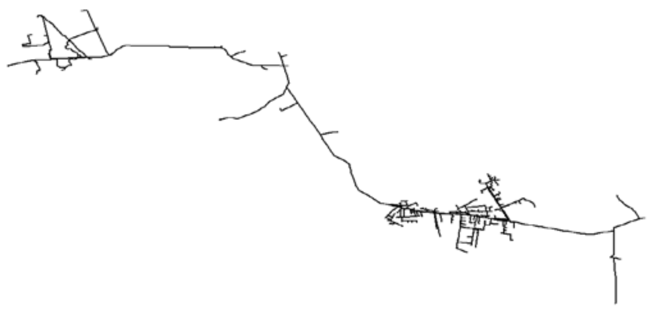

Figure 2: Single-line diagram of actual power network of Kosar feeder of Kerman Province in Cymedist

Table 1: Details of transformers in the system

Rating [KVA]	50	100	250
Number	5	9	6
No load losses [watts]	150	250	480
Impedance [%]	4.5	4.5	4.5

Table 2: Details of conductors in the system

Type	R [Ω/km]	X [Ω/km]	Cmax [A]	A [mm2]
Hyena	0.1576	0.2277	550	126
Dog	0.2712	0.2464	440	120
Mink	0.4545	0.2664	315	70

Table 3: Distribution System Line Data

from	To	Length (meters)
1	2	80
2	3	80
3	4	80
4	5	60
5	6	60
6	7	60
7	8	60
8	9	60
9	10	60
10	11	60
11	12	60
12	13	60
13	14	60
14	15	60
14	16	60
16	17	60
17	18	60
18	19	60
19	20	60

Table 4: Details of the connected loads

Transformer no	Load [Kva]
1	35
2	245
3	85
4	165
5	50
6	85
7	180
8	35
9	35
10	90
11	85
12	75
13	200
14	73
15	35
16	85
17	98
18	230
19	220
20	85

Fourth place after the implementation of algorithms for distributed generation units is proposed (The bus 11 and 18 and 19 and 25, respectively, with capacities of 600, 300,300, 900 kW) that network will reach the best reliability. Interconnection of DGs, the system reliability indices decrease. For a better understanding of how change in reliability indices, Indices changes in Table 5 and Figure 3-5 are shown.

Table5. Comparison of outputs before and after installation of DGS

	SAIFI	SAIDI	AENS
With DGs	2.654	6.78	33.97
Without DGs	8.7	92.16	513.62

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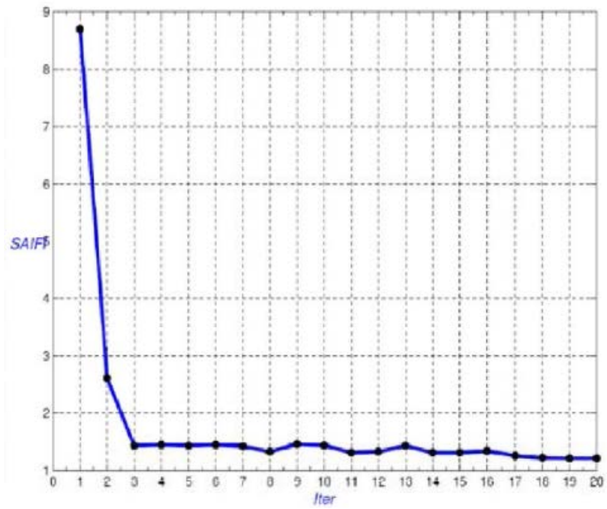

Figure3: Variation of SAIFI Index

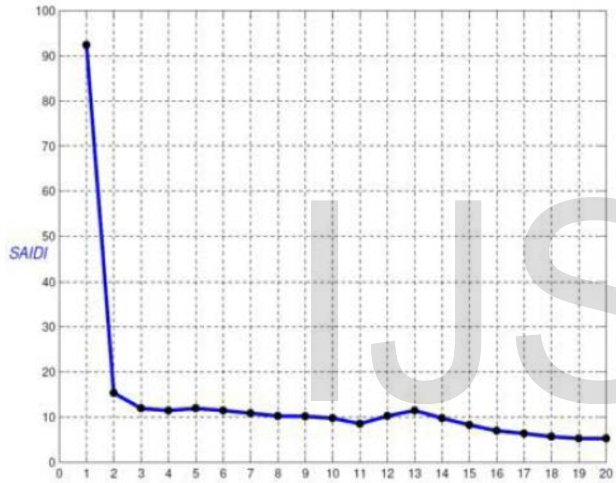

Figure4: Variation of SAIDI Index

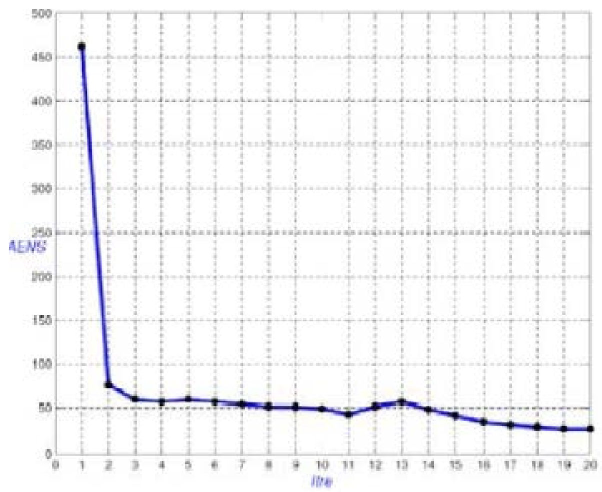

Figure 5: Variation of AENS Index

Initially, a load flow was run for the case study without installation of DG. Table 5 depicts the results of power flow for determination voltage before installation of DG. The detailed P.U voltages profile all the nodes of the system before and after DG placement with 5 DG units are shown in the Figure 6.

Table 6: Optimal place and capacity of DG

Location [#bus]	Capacity of DGs [Mw ; Mvar]
2	0.56 ; 0.35
4	0.68 ; 0.28
6	0.04 ; 0.3
14	0.25 ; 0.11
16	0.65 ; 0.38

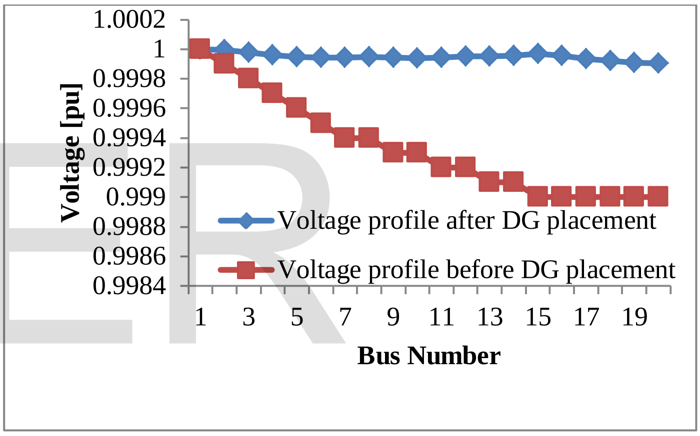

Figure 6: Voltage profile of 20 bus system before and after DG placement

7. Conclusion

In the present paper, a new population based Genetic Algorithm (GA) has been proposed to solve DG placement problem and quantifying the total line loss reduction in distribution system. Simulations are carried on actual power network of Kerman Province, Iran. This paper presents a problem formulation and solution for the placement and sizing of DGs optimally. The results are finally compared with the no DG condition and it show that reliability indices especially Energy Not Supply index (ENS) has improved considerably with optimal placement of distributed generation and beneficiary companies acquire more benefits.

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