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DG Placement with Considering Reliability Improvement and Power Loss Reduction with GA Method

Mohammad Mohammadi and M. Akbari Nasab
Department of Engineering, Aligoudarz Branch, Islamic Azad University, Aligoudarz, Iran

Abstract: Distributed generators are beneficial in reducing the losses effectively compared to other methods of loss reduction. DGs can be implemented for improvement of reliability of system; too In this study optimal DG unit placement using GA is discussed. The optimal size of the DG unit is calculated analytically using approximate reasoning suitable nodes are determined for DG unit placement. Reliability and power loss reduction indices of distribution system nodes are modeled. GA containing a set of rules is used to determine the DG unit placement. DG units are placed with the highest suitability index. Simulation results show the advantage of optimal DG unit placement. Compared to other power loss and reliability improvement techniques, placement it is giving very good reduction not only in power loss but also it is improving reliability improvement.

Key words: Distributed generation, distribution system, genetic algorithm, power loss reduction, reliability

INTRODUCTION

There are many methods of loss reduction techniques used like feeder reconfiguration, capacitor placement, high voltage distribution system, conductor grading, and DG unit placement. All these methods are involved with passive element except DG unit placement. Both DG units and capacitors reduce power loss and improve voltage regulation. But with DG s loss reduction almost double that of Capacitors (Takahashi *et al*., 2006). Utilities are continuously planning the expansion of their existing electrical networks in order to face the load growth and to properly supply their consumers. Distribution system provides a final link between the high voltage transmission system and the consumer. Electricity networks are in the era of major transition from stable passive distribution networks with unidirectional electricity transportation to active distribution networks with bidirectional electricity transportation. Distribution networks without any DG units are passive since the electrical power is supplied by the national grid system to the customers embedded in the distribution networks. It becomes active when DG units are added to the distribution system leading to bidirectional power flows in the networks (Zareipour *et al*., 2004). In an active distribution network the amount of energy lost in transmitting electricity is less as compared to the passive distribution network, because the electricity is generated very near the load centre, perhaps even in the same building. Active Distribution Network has several advantages like reduced line losses, voltage profile improvement, reduced emission of pollutants, increased overall efficiency, improved power quality and relieved T&D congestion. Hence, utilities and distribution companies need tools for proper planning and operation of Active Distribution Networks. The most important benefits are reduction of line losses and voltage stability improvement. They are crucially important to determine the size and location of DG unit to be placed. Studies indicate that poor selection of location and size would lead to higher losses than the losses without DG (Kim, 2001a, b). In (EI-hattam and Salma, 2004), an analytical approach has been presented to identify appropriate location to place single DG in radial as well as loop systems to minimize losses. But, in this approach, optimal sizing is not considered. Loss Sensitivity Factor method (LSF) (Caisheng and Hashem-Nehrir, 2004) is based on the principle of linearization of the original nonlinear equation (loss equation) around the initial operating point, which helps to reduce the amount of solution space. The LSF method has widely used to solve the capacitor allocation problem. Optimal placement of DG units is determined exclusively for the various distributed load profiles to minimize the total losses. They have iteratively increased the size of DG unit at all buses and then calculated the losses; based on loss calculation they ranked the nodes. Top ranked nodes are selected for DG unit placement. The Genetic Algorithm (G.A) based method to determine size and location of DG unit is used in (Eduardo *et al*., 2000). They have addressed the problem in terms of cost, considering cost function may lead to deviation of exact size of the DG unit at suitable location. It always gives near optimal solution, but they are computationally demanding and slow in convergence.

Corresponding Author: Mohammad Mohammadi, Department of Engineering, Aligoudarz Branch, Islamic Azad University, Aligoudarz, Iran

In this study, a new objective function to calculate optimal location and optimum size value for DG is proposed. The DG is considered to be located in the primary distribution system and the objective of the DG placement is to improve the voltage profile and short circuit level at each bus of system. The cost and other associated benefits have not been considered while solving the location and sizing problem.

In this study a multi objective function consist of reliability and power loss function is considered and in follow solved with GA. This study proposes a Genetic Algorithm for optimal placement of Distributed Generation (DG) in a primary distribution system to minimize the total real power loss. The GA provides a population-based search procedure in which individuals called particles change their positions with time. The GA can obtain maximum loss reductions for each of three types of optimally placed multi-DGs. Moreover, reliability improvement and power loss reduction are obtained.

MODELING

Power loss reduction: DG sources are normally placed close to load centers and are added mostly at the distribution level. They are relatively small in size (relative to the power capacity of the system in which they are placed) and modular in structure (Goldberg, 1989; Eduardo *et al*., 2000; Baran and Wu, 1989; Rau and Wan, 1994). A common strategy for sizing and placement of DG is either to minimize system power loss or system energy loss of the power systems. The voltage at each bus is in the acceptable range and the line flows are within the limits. These limits are important so that integration of DG into the system does not increase the cost for voltage control or replacement of existing lines. The formulation to determining the optimal size and location of DG in a system is as follows:

Loss Reduction Factor Index per node is defined as the ratio of percentage reduction in loss from base case when a DG having size DGS KW is installed at bus i, to the DG size at that bus. Power Loss Reduction Index (PLRI) is expressed as:

$$PLRI = (Ploss_{Base} - Ploss_{DGi}) / Ploss_{Base} \quad (1)$$

where,
After the iterative solution of bus voltages, line flows and line losses can be calculated. The complex powers Sij from bus i to j and Sji from bus j to i are:

$$\begin{aligned} S_{ij} &= V_i I_{ij}^* \\ S_{ji} &= V_j I_{ji}^* \end{aligned} \quad (2)$$

The power loss in line i-j is the algebraic sum of the power flows determined from the above equations.

$$Ploss = \sum_{i=1}^{N\_bus} \sum_{j=i}^{N\_bus} \mathrm{Re}\left\{S_{ji} + S_{ij}\right\} \quad (3)$$

Reliability improvement: In order to guaranty the reliability of system, the study calculates the power not supplied after the three phases short-circuit. In Vietnam, the more detail rate values for calculating the reliability are not yet available. So we just consider the time after fault clearing assuming that all DG are in ready state. The momentary interruption due to DG ready state is neglected. Reliability Improvement Index (RII) is illustrated as:

$$RII = \{(AENS_T - AENS_i) / AENS_T\} \quad (4)$$

where,
ENS_T : The total average energy not supplied when the fault happened in sequence in all the sections in the case of without DG.
ENS_i : The total average energy not supplied when the fault happened in sequence in all the sections with the i-combination of DG.
which

$$AENS = \frac{\sum L_a(i) u_i}{\sum N_i} \quad (5)$$

which
N_i : Number of customer at ith load point
U_i : Interruption duration at ith load point
L_a(i): Average load at ith load point

Enethic Algorithm (GA): GA is a search method based on the natural selection and genetics. GA is computationally simple yet powerful and it is not limited by assumptions about the search space. The most important goal of optimization should be improvement. Although GA cannot guarantee that the solution will converge to the optimum, it tries to find the optimum, that is, it works for the improvement. The GA is basically an evolutionary algorithm, analogous to a part of the physical world. GA is a stochastic optimization technique introduced by (Goldberg, 1989) and further discussed by (Zareipour *et al*., 2004). Binary and floating-point representations are used to implement GA, for the sake of comparison. In the binary implementation, each element of a string (or chromosome) vector was coded using the same number of bits and each occupied its own fixed position. The minimization process in the binary representation used is characterized by the following:

The implemented GA starts by randomly generating an initial population of possible solutions. For each solution a value of power generation units is chosen

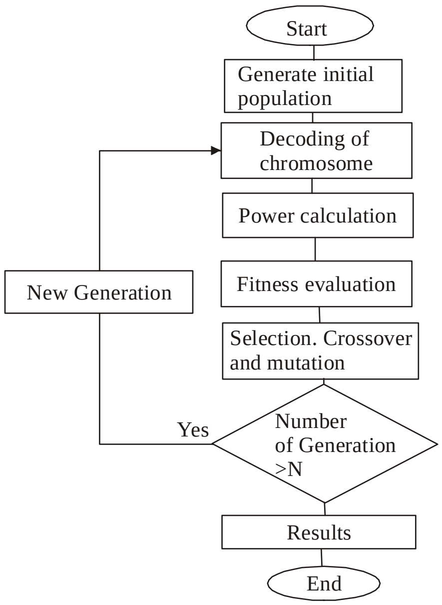

Fig. 1: Flowchart of the Genetic Algorithm

between 0 and a maximum limit, fixed by the planner on the ground of economical and technical justifications; then, a different size of MG and DG units are randomly chosen until the total amount of power installed reaches the MG and DG penetration level assigned. At this point, the objective function is evaluated verifying all the technical constraints. In Fig. 1 the block diagram of optimization problem has been shown.

Parameters used for the GA with binary representation include:

- Population size 30
- String length 10 bits
- Reproduction rate 40% for the first preferred string; 30% for the second preferred string; 20% for
- The third preferred string, 10% for the random string.
- Crossover rate from exp (0.10) to exp (0.86)
- Mutation rate from exp (0.500) to exp (0.005)
- Maximum number of 1500 generations

In the proposed application the goal is to obtain the position of individual devices on the feeder, where these devices may be placed on a limited number of branches or buses (Rau and Wan, 1994). The locations where protective devices may be placed could be coded using discrete number between 1 and M, where M is the number of possible branches in the system where protective devices may be placed. Similarly, possible DGs may be coded using discrete numbers ranging from 1 to P for location and C_{min} and C_{max} for capacity, that R is the number of possible buses where DGs may be placed and C_{min} to C_{max}, that C_{min} and C_{max} are minimum and maximum possible capacity of DGs. So, a single solution can be defined as a specific allocation of individual DGs and protective devices on the feeder, i.e., the k^{th} solution in the population is an (2N)-dimensional row vector of discrete numbers:

$$X_k = \begin{Bmatrix} [x\ y\ z] \,|\, x_i \in \{1,\dots,P\}, i = 1,\dots,N, \\ y_i \in \{C_{\min},\dots,C_{\max}\} \\ z_j \in \{1,\dots,R\},\ j = 1,\dots,M \end{Bmatrix}$$

where,

X Location list of each chromosomes,

P	Number of buses
N	Number of DGs
M	Number of lines
C_{min}	Minimum Capacity of DGs
C_{max}	Maximum Capacity of DGs

With constraint

$$m \le M_{\max}$$
$$n \le N_{\max}$$
$$P_{\min} \le P_{DG}(i) \le P_{\max}$$
$$Q_{\min} \le Q_{DG}(i) \le Q_{\max}$$
$$\sum_{i=1}^{m} P_{DG}(i) \le P_{DG,total}$$

where,

m	Number of DGs
M_{max}	Maximum number of DGs
n	Number of MGs
N_{max}	Maximum number of MGs
P_{DG}	Active power of DGs
Q_{DG}	Reactive power of DGs
P_{min}, P_{max}	Constraint of active power of DGs
Q_{min}, Q_{max}	Constraint of reactive power of DGs
$P_{DG, total}$	Maximum capacity of DGs for Network

The first part of constraint is related to DGs that is formed of number, possible location, active and reactive power for each source. The second part is related to permissible voltage of each load point in islanding mode, and the last part is the number and possible location of MGs, so:

$$P_{DG-i,\min} \le P_{DG-i} \le P_{DG-i,\max}$$
$$Q_{DG-i,\min} \le Q_{DG-i} \le Q_{DG-i,\max}$$
$$V_{i-\min} \le V_i \le V_{i-\max}$$

where,

Q_{DG-I}	Reactive power of *ith* DG
V_i	Voltage at *ith* load point
$P_{DG-I,min}$, $P_{DG-I,max}$	Constraint of active power of *ith* DG
$Q_{DG-i,min}$, $Q_{DG-i,max}$	Constraint of reactive power of *ith* DG
V_{min}, V_{max}	Constraint of load point voltage

In this study DGs have capability of voltage control and they are modeled as PV bus in power flow study. The Newton-Raphson method is applied in each island, and if one of the constraints about DGs or load point voltage has been broken the island will be shut down. For each combination of switches and DGs, reliability areas are determined. Then, considering the islanding capability of the network, reliability index is calculated after the fault simulation on each line. In order to calculate the loss and voltage profile, a complete power flow is applied. Finally, for each chromosome, the amount of objective function is calculated.

SIMULATION AND RESULTS

The proposed methodology is tested on test systems to show that it can be implemented in distribution systems of various configuration and size. The test system is a 12 bus system with the total load of 761.04 KW and 776.50 KVAR and base voltage 11KV. A single line diagram of the test system is shown in Fig. 2.

A computer program has been written in MATLAB 7.6 to calculate the optimum location and sizes of DG at various buses using GA and reparative load flow method to identify the best location and size of DG. A complex Newton based load flow program is used to solve the load flow problem. The multiobjective function optimally minimized is shown in Fig. 3.

By using the method described here, the best location in 12 bus system is in the order 3, 6, 7 and 11 and corresponding optimal sizes are 447.41 KW, 460.85 KW, 487.11 KW and 523.27 KW for reducing power loss and improvement reliability .The corresponding optimal size of DGs Table 1.

Results show that installing DG on system improve reliability indices and decrease power loss in system. Table 2 gives the total power loss in system before and after installing DG in optimal place with optimum result value. Also another index i.e. reliability index, show that average energy not supplied in system reduces when DGs are implemented in system at optimal locations.

By using the method described here, the best location in 12 bus system is in the order 3, 6, 7 and 11 and corresponding power loss are 210.5, 220.6, 240.3 and 250.2 KW, also corresponding average energy not supplied are 45.67, 58.34, 69.10 and 74.30 kwh/yr.

Table1: Optimal DG unit sizes for 12-bus radial distribution system

Test system	Optimal locations	Optimum DG size in KW
12 Bus	3	447.41
	6	460.85
	7	487.11
	11	523.27

Table2: Results of power loss and average energy not supplied

Power loss		AENS	
Without DG	With DG	Without DG	With DG
280.8 KW	210.5	75.7 kwh/yr	45.67
	220.6		58.34
	240.3		69.10
	250.2		74.30

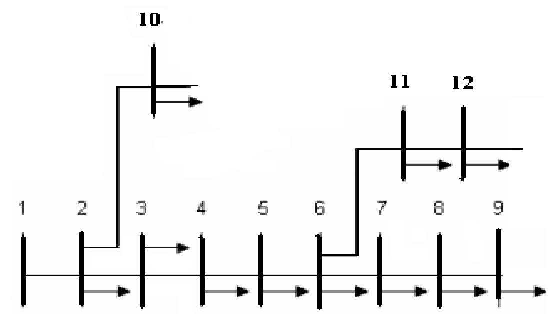

Fig. 2: Test distribution system

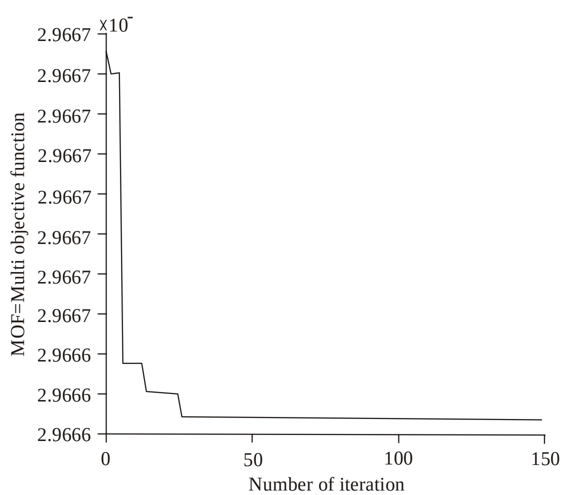

Fig. 3: Multiobjective function optimally minimized value versus iteration number

Figure 4 gives voltage profile of each bus in 12 bus radial system. The result shows the voltage level before and after installing DG. Before DG installation, voltage level from bus number 6-12 is lower than 0.92 p.u. After DG installation, the voltage levels of these buses are improved with minimum of 0.96 p.u. for bus number 8. Further more if multiple DGs are installed, voltage level will be higher than the previous levels.

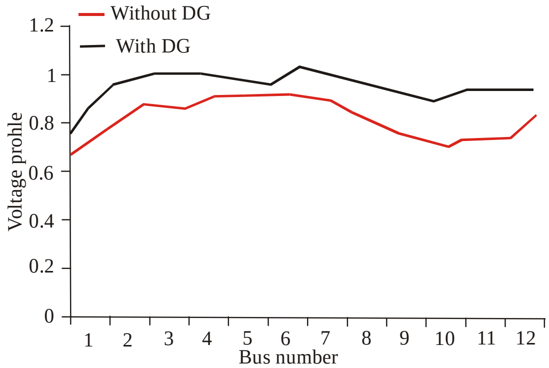

Fig. 4: Voltage profile before and after DG installation at each bus of system

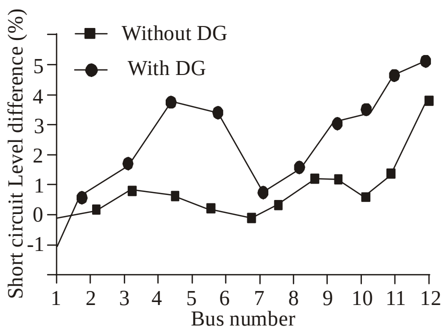

Fig. 5: The short circuit level difference of the system at each bus

As a result of the placement of DG units in the system, the short circuit level at most of the system buses was increased. Figure 5 shows the difference between the short circuit level at each bus of the system with and without DG as a percent of the value of short circuit level before placement of DG units in the system. As shown in figure, the maximum increase is very low where a maximum difference of 3.92% occurred at bus 4.

CONCLUSION

The DG placement in distribution must meet some objective functions in order to enhance the quality of network. The proposed objectives of the study are met to Iran condition. These objective functions must be reflex not only the benefit of utility but also the private owner. In this study special type of DG as photovoltaic arrays (P.V), is introduced and that makes the solution more suitable. Beside, the expanding of objective and constraints are available in this study, so the paper's program is very convenient for users. In this study an objective function with aim to reduce real power loss in all feeders of system and increase reliability of system, is considered and analyzed with GA. in this investigation the effect of presence of DGs on voltage profile and short circuit level of each buses of test system are considered and analyzed.

REFERENCES

Baran, M.E. and F.F. Wu, 1989. Network reconfiguration in distribution systems for loss reduction. IEEE Trans. Power Delivery, 4(2): 1401-1407.

Caisheng, W. and M. Hashem-Nehrir, 2004. Analytical approaches for optimal placement of distributed generation sources in power systems. IEEE Trans. Power Sys., 19(4): 27-34.

Eduardo, G.C., A.E. Luiz, R.H. Soares, W.A. Graham and J.R. Mc-Donald, 2000. Planning for distributed generation within distribution networks in restructuted electricity markets. IEEE Power Engine. Rev., 19: 52-54.

EI-hattam, W. and M.M.A. Salma, 2004. Distributed generation technologies, definitions and benefits. Electric Power Sys. Res., 71: 119-1283.

Goldberg, D.E., 1989. Genetic Algorithms in Search, Optimization & Machine Learning. Addison Wesley.

Kim, T.E., 2001a. A method for determinig the introduction limit of distributed generation system in distribution system. IEEE Trans. Power Delivery, 4(2): 100-117.

Kim, T.E., 2001b. Voltage regulation coordination of distributed generation system in distribution system. IEEE Trans. Power Delivery, 6(3): 100-117.

Rau, N.S. and Y.H. Wan, 1994. Optimal location of resources in distributed planning. IEEE Trans. Power Sys., 9: 2014-2020.

Takahashi, C., R.S. Rodney and M.N. Oriane, 2006. Electric distribution network multi objective design using a problem-specific genetic algorithm. IEEE Trans. Power Delivery, 21(2): 157-164.

Zareipour, H., K. Bhattacharya and C.A. Canizares, 2004. distributed generation: current status and challenges. IEEE Proce. NAPS., 21(2): 157-164.