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Optimal DG Location and Sizing in Semnan Power Distribution Networks in Iran

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ABSTRACT

Distributed Generation (DG) sources are becoming more prominent in distribution systems due to increased demand for the electrical energy. The locations and capacities of DG sources will have an impact on system losses of distribution network. In this paper, Genetic Algorithm (GA) for solving the problem of optimal location and sizing of DG on distributed systems is presented. The objective is to minimize network power loss and better voltage regulation with in frame-work of system operational and security constraints in the radial distribution systems. A detailed performance analysis is carried out on 65 buses Semnan distribution network to demonstrate the effectiveness of the proposed methodology.
KEYWORDS—Distributed generation, Genetic algorithm, Losses**,** Voltage profile.

I. INTRODUCTION

DG is defined as small, modular electricity generators which are located close to the end customer's load connection point. They can enable utilities to decrease investment costs in transmission and distribution system upgrades while still meeting increasing power demands and provide customers with improved quality and reliability of energy supplies without imposing undesirable effects on environment [3]. In general, DG can be intended as small sized power plants that are designed to be installed and operated within a local load center. Recently, several solutions have been suggested for complementing the passiveness of RDS by embedding electrical sources of small capacity to improve system reliability and voltage regulation [1], [2]. In distribution systems, DG can provide benefits for the consumers as well as for the utilities, especially in sites where there are deficiencies in the transmission system [10]. Some of the expected benefits of DG are [4], [6], [7]:

- Green house emissions reductions
- Energy efficiency
- Reduced transmission and distribution investments
- Minimization of the electric losses
- Network (voltage) support
- Quality of supply improvement
- New market opportunities and enhanced industrial competitiveness
- Reduction of the energy costs
- Locality, i.e. improved utilization of local resources

Table 1 has summarized a list of published works recently done on different techniques to choose proper location and capacity of installing DGs for distribution systems [9], [11]. Most of the techniques in the literature are aimed at optimize either location or capacity and to estimates the benefits resulting from that like voltage improvement, loss reduction, location marginal prices [8],[12], [14] .This paper proposes optimization of both location and capacity distributed generation sources by using GA.

II. PROPOSED METHODOLOGY

The objective of the present optimization problem is to minimize the network power loss and maximize the voltage regulation in a given radial distribution network.

Mathematically, the objective function is formulated as:

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Min.$f = (f_1 + kf_2)$ (1)

The minimum objective function of network loss is:

Min.f_1 = min { $P_{loss}(P_{d1}, P_{d2}, \dots, P_{dn_{DG}})$ } (2)

The objective function for improve the voltage profile is:

Min.$f_2 = \sum_{i=1}^{N_n}(V_i - V_{rated})^2$ (3)

Where:

V_i- Voltage magnitude of node i

V_{rated}-Desired steady state voltage magnitude (1 p.u.)

N_n- Total number of nodes in the given radial distribution system

P_{di}- Stands for the rating capacity of distributed generation fixing in the i bus

k- Weighting factor

Where P_{loss} is the system network loss in relation to dynamoelectric location and capacity.

Table 1: Different techniques for specifying location and capacity of DG and capacitor banks installation on distribution networks

No.	Author	Objective Function	Solution Technique	Load Model	DG Model	Published
1	S. Masoum, [2]	Loss minimizing	GA	uniform	---	2004
2	Grifin[3]	Loss minimizing	GA	Incremental	Constant power supply	2000
3	Teng e al. [4]	Minimizing loss and cost for the consumer	GA	Load averaged	Constant power supply	2002
4	Masoum [5]	Loss minimizing	PSO	uniform	-----	2009
5	Hassan[6]	Maximizing DG's gain Minimizing loss costs	GA	uniform	PV	2005
6	KIM[7]	Loss minimizing	GA-FUZZY	uniform	Constant power supply	2002
7	Golshan[8]	Minimizing costs of the power loss	TABO	uniform	Constant power supply	2008
8	Haghifam [9]	Minimizing investment costs	ACO	Time varied	Constant power supply	2008
9	Singh[10]	Cost minimizing	GA	Voltage dependent	Constant power supply	2009
10	Kumar[11]	Loss minimizing	Numerical method	Voltage and frequency dependent	Constant power supply	2008
11	Jabr[12]	Loss minimizing Maximizing DG's capacity	Numerical method	uniform	CHP	2009
12	Glokar[13]	Loss minimizing	GA	uniform	Constant power supply	2009
13	Hawary[14]	Loss minimizing	Honey bee	uniform	Constant power supply	2009
14	Haghifam[15]	Minimizing loss and cost	FUZZY-GA	Uncertainty and time varied	Constant power supply	2008
15	Moeini[16]	Cost minimizing	Extended GA	Uniform	Constant power supply	2010
16	Hung[17]	Loss minimizing	Numerical method	uniform	Variable power supply	2010

a. Voltage stability index:

Fig.1 shows a branch of radial system. In radial distribution system each receiving node is fed by only one sending node, [17]

From Fig.1

$$I_i = \frac{V_{mi} - V_{ni}}{R_{ni} + jX_{ni}} \quad (4)$$

$$P_{ni}(ni) - jQ_{ni}(ni) = V_{ni}^{*} I_{ni} \quad (5)$$

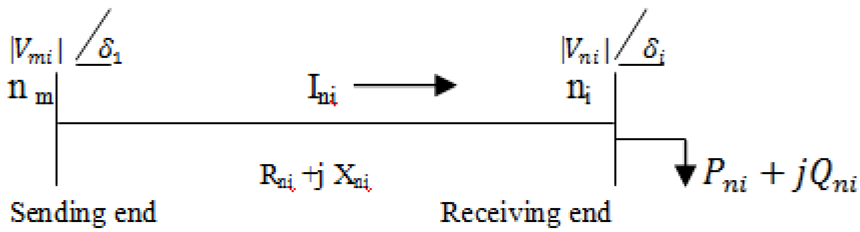

Fig. 1. Representative Branch of a radial distribution system

Equation (6) represents the voltage stability index. Using (4) and (5):

$$SI(n_2) = |V_{mi}|^4 - 4\left[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}\right]|V_{mi}|^2 - 4\left[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}\right]^2 \quad (6)$$

Objective function for improving voltage stability index is,

$$f_3 = \left(\frac{1}{(SI(ni))}\right) \; n_i = 2, 3, n_n \quad (7)$$

For stable operation of the radial distribution systems, $SI(n_i) > 0$ for i= 2 , 3...,n_n, so that; there exists a feasible solution. It is very important to identify weak buses for nodes with minimum voltage stability index that are prone to voltage instability. Investigating the voltage stability index behaviour demonstrate that the buses which experiencing large voltage drops are weak and within the context of remedial actions. So, it makes sense to act on controls that will improve the voltage magnitudes at weak buses.

b. *Constrains*:

When for each bus can be expressed as follows:

The equality constraints are the three nonlinear recursive power flow equations describing the system.

$$P_{gni} - P_{dni} = V_{ni} \sum_{j=1}^{N} V_{nj} Y_{nj} \cos\left(\delta_{ni} - \delta_{nj} - \theta_{nj}\right)$$
$$Q_{gni} - Q_{dni} = V_{ni} \sum_{j=1}^{N} V_{nj} Y_{nj} \sin\left(\delta_{ni} - \delta_{nj} - \theta_{nj}\right) \quad (8)$$

The inequality constraints are the system's voltage limits i.e., ±5% of the nominal voltage value.

$$V_{min} < V < V_{max} \quad (9)$$

As DG capacity is inherently limited by the energy resource at any given location it is necessary to constrain capacity between maximum and minimum levels**.**

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \quad (10)$$
$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max} \quad (11)$$

Final thermal limit of distribution lines of the network must not be exceeded.

$$|S_i| \le |S_i^{max}| \quad i=1\ldots N \quad (12)$$

Optimal sitting and sizing of distributed generation

The optimal sitting and sizing problem of distributed generation is formulated as a multi-objective constrained optimization problem. This paper using GA for solving the problem of optimal sitting and sizing DG .

III. SOLUTION METHODOLOGY

Generally, GAs start with an initial set of random solutions that lie in the feasible solution region, otherwise known as population. Each solution in the population, called a chromosome, represents a possible solution to the optimization problem[17], [6]. If the chromosome has N variables given by X1, X2, X3,. . . ,XN, it is written as an N element vector [X1, X2,X3, . . . , XN].

based on genetic algorithm can be done as the following steps:

1- Set the time counter and generates randomly n chromosomes.

2- Evaluate each chromosome in the initial population using the objective function. search for the best value of the objective function. Set the chromosome associated with as the global best.
3- time updating
4- create a new population by repeating the following steps until the new population is completed:
   - Select two parent chromosomes from a population according to their fitness
   - With a crossover probability, cross over the parents to form a new child.
   - With a mutation probability method mutates new child at each chromosome.
5- place new child in a new population
6- Use new generated population for a further run of algorithm.
7- if one of the stopping criteria is satisfied then stop, else go to step 2

Fig 2 shows the flow chart optimal sitting and sizing of distributed generation.

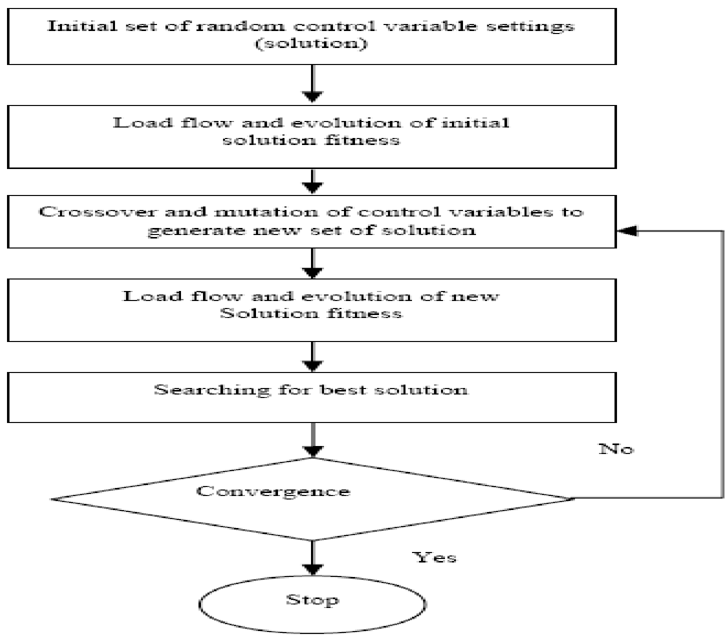

Fig.2. GA for optimal sitting and sizing of DG

IV. APPLICATION STUDY AND NUMERICAL RESULTS

In this section, the test results for Distribution system in [12] is presented and discussed. The studied distribution network is a radial system with the total load of 3.6 MW, 2.3 MVar, 65 bus and 64 branches as it has been shown in Fig. 3.The real power losses in the system is 70.1 (kW) while the reactive power losses in it is 54.2 (kVar) when calculated using the load flow method is based on that reported in [16].Gave the rating active power of distributed generation is 2 kW ;power factor is 1.The optimization is performed using GA software package was written for simulation of optimal sitting and sizing of DG in radial distribution systems. The parameters of GA and power system used for solving the problem presented in this paper are furnished in Table-1 and Table-2 respectively.

TABLE 1
GA PARAMATERS

Pop. size	Selection method	Cross over	Mutation	Algorithm Termination Condition
100	Normalized Geometric Selection	Simple Xover	Binary Mutation	Maximum Number of generation

The results optimal sitting and sizing problem of distributed generations are described in the Tables1. The DG size, real power loss and reactive power loss which are basic columns.

From the results presented in Table 3, they can observe that GA is effective for optimal sitting and sizing of DG.

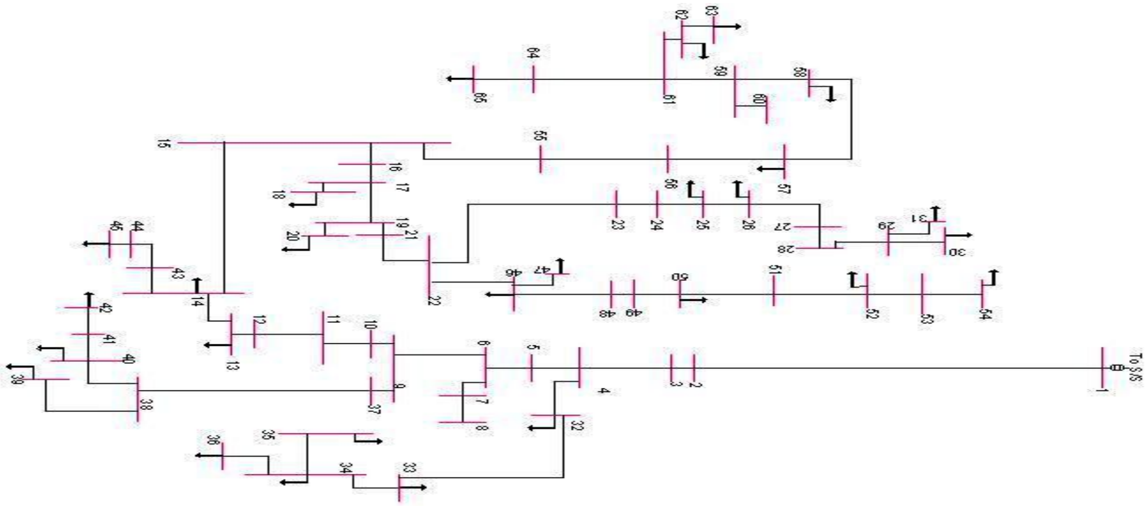

Fig.3.Single line diagram of a 65buses distribution system – daneshgah feeder.

Table 2
The base value before installing DG

	$P_{Loss(KW)}$	VDI	*SI*
Value	70.1	0.2123	**1.1379**

Table 3
The result of optimal DG

Method	Bus. No	DG Size (kW)	Ploss (p.u.)	SI	VDI
GA	52	0.592	0.0142	1.0432	0.0726
	15	1.081			
	26	0.876			

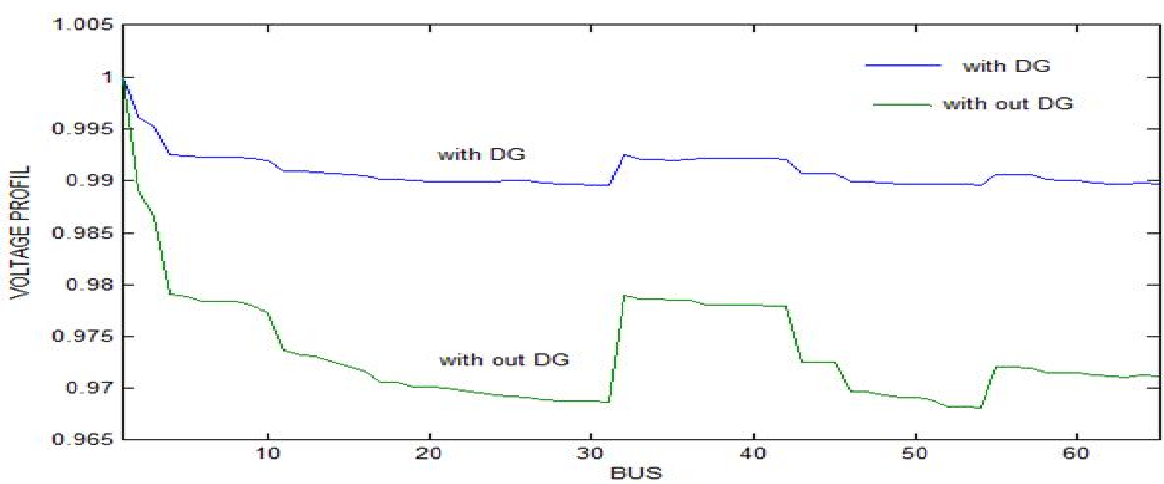

Fig.4. Voltage levels for the 65 bus radial distribution system

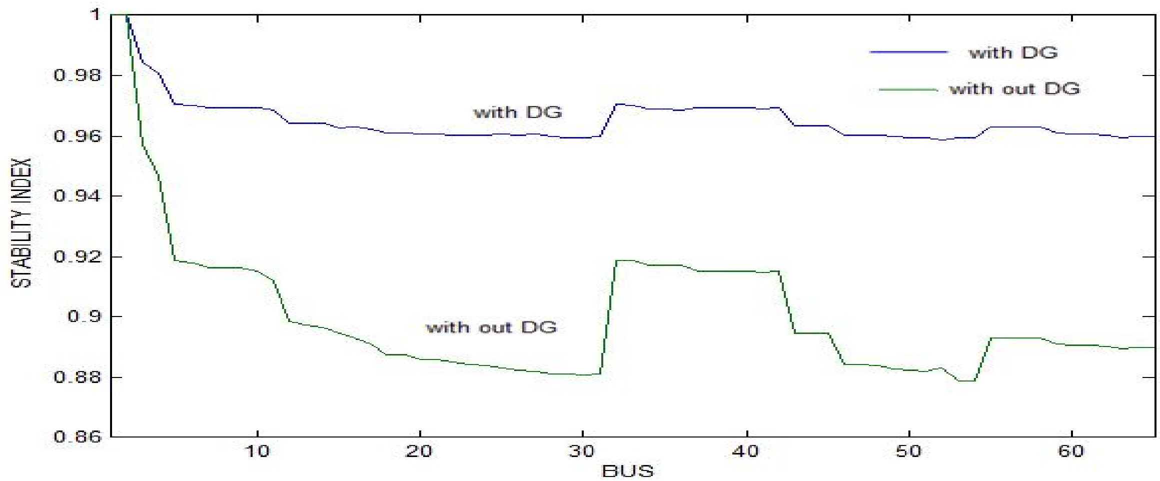

Fig.5. Voltage stability Index for the 65 bus radial distribution system

In Fig. 6, the results on the optimization function define in the total real power loss of 65 bus radial distribution system.

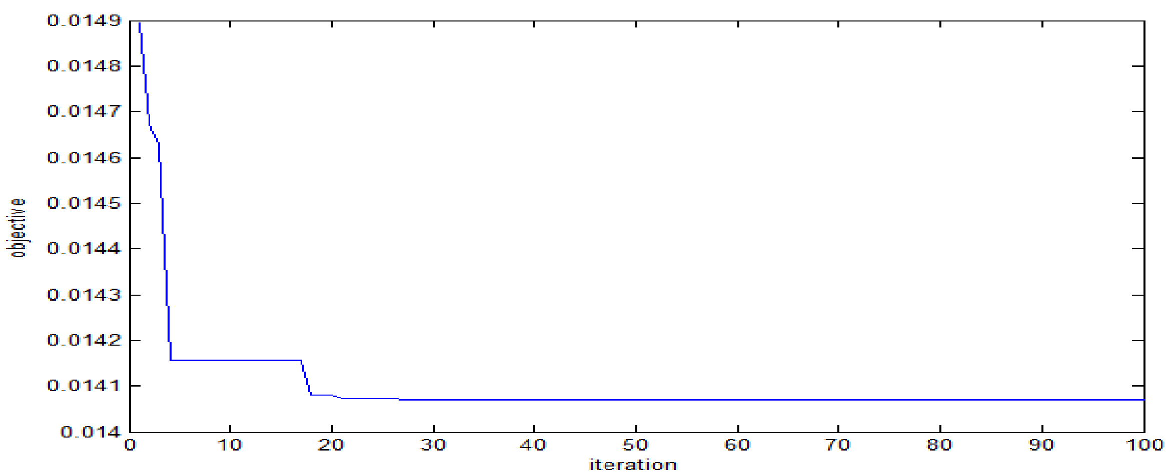

Fig. 6.Real power loss in the 65 bus radial distribution system.

From these results, we can confirm that the voltage level is improved and losses reduction.

V. CONCLUSION

Among the many benefits of DG are reduced line loss and improved system voltage profile, but depending on the sitting and sizing of DG units. In this paper GA is proposed for optimal sitting and sizing problem on distribution systems for reducing line loss and improved system voltage profile. Test results indicate that the GA algorithm is efficiently finding the optimal distributed generation sitting and sizing. In this paper GA is proposed for optimal sitting and sizing problem on distribution systems for reducing line loss and improved system voltage profile. Test results indicate that the GA algorithm is efficiently finding the optimal distributed generation sitting and sizing.

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