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A method for placement of distributed generation (DG) units using particle swarm optimization

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Nowadays, the penetration of distributed generation (DG) in power networks takes special place worldwide and is increasing in developed countries. In order to improve voltage profile, stability, reduction of power losses etc, it is necessary that, this increasing of installation of DGs in distribution system should be done systematically. This paper introduces an optimal placement method in order to sizing and sitting of DG in IEEE 33 bus test system. The algorithm for optimization is particle swarm optimization (PSO). The proposed objective function is the multi objective function (MOF) that considers active and reactive power losses of the system and the voltage profile in nominal load of system. High performance of the proposed algorithm is proved by applying algorithm in 33 bus IEEE system using MATLAB software and in order to illustrate the feasibility of the proposed method optimization in three cases: one DG unit, Two DG units, and Three DG units- will achieved.

Key words: Distributed generation (DG), placement, particle swarm optimization, multi objective function (MOF), optimization.

INTRODUCTION

The anguish about rising environmental population and also the concern about the fossil fuels problems and limitations led to the installation of Distributed Generation (DG) which increases annually. In order to improve voltage profile, stability, reduction of power losses and etc, it is necessary that this increasing of installation of DGs in Distribution system should be systematically (Hedayati et al., 2008). The best choosing size and site of DGs in a distribution system is a complex optimization problem and if this problem contain the Multi Objective Function (MOF), this problem become much complex. Nowadays, meta heuristics optimization methods are being successfully applied to combinatorial optimization problems in distribution systems (Carmen and Djalma, 2006; Thong et al., 2007).

Gandomkar et al. (2005) determined the optimum location of the DG in the distribution network. The work was directed towards studying several factors related to the network and the DG itself such as the overall system efficiency, the system reliability, the voltage profile, the load variation, network losses, and the DG loss adjustment factors.

A Tabu search (TS) search method to find the optimal solution of their problem was explained by Katsigiannis and Georgilakis (2008), but the TS is known to be time consuming algorithm also it is may be trapped in a local minimum. In order to minimize the real power losses of power system in Lalitha et al. (2010), a Particle Swarm Optimization (PSO) algorithm was developed to specify the optimum size and location of a single DG unit. The problem was converted to an optimization program and the real power loss of the system was the only aspect considered in this study in order to determine optimally the location and size of only one DG unit.

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El-Khattam et al. (2005), a deferent scenario was investigated to determine the optimum location of DG in order to modify the voltage profile and minimize the investment risk. The placement of one DG unit with specific size was explained by Ochoa et al. (2006). In this paper, MOF such as power line losses, modification of voltage profile, line loading capacity, and short circuit level were considered. P-V curves in Singh and Goswami (2010) have been used for analyzing voltage stability in electric power system to determine the optimum size and location of multiple DG units to minimize the system losses under limits of the voltage at each node of the system.

A genetic algorithm (GA) based fuzzy multi-objective approach for determining the optimum values of fixed and switched shunt capacitors was used to improve the voltage profile and maximize the net savings is proposed in Das (2008).

Particle Swarm Optimization (PSO) is used in this paper in order to find solution to optimization problems (Hashemi et al., 2011), optimal size and site of DG in 33-bus radial system of IEEE test system (Kashem et al., 2000). The aim of this paper is to proffer solution to sitting and sizing problem for optimization of MOF. Objective function of this paper is formed by combining on real power losses, reactive power reduction, voltage profile improving, and short circuit level improving of the mention system.

Problem formulation containing the objective function and constrains is explained in the next section. Section 3 presents the PSO algorithm in order to solve the optimization problem. The test system used to verify the effectiveness of the proposed technique is describe in Section 4 which explores the effectiveness of the proposed technique applied on simulation test system, Section 5 concludes the paper. The simulation test systems were simulated in MATLAB software.

PROBLEM FORMULATION

Objective functions formulation

As mentioned above, this paper introduces MOF optimization. The objective function was procured from the gather of each DG impact by the weighting factor assigned to that impact. This weighting factor is chosen by the planner to reflect the relative importance of each parameter in the decision making of sitting and sizing the DG. The DG location and its corresponding size in the distribution feeders can be optimally determined using the following objective function:

Max f (P_{loss},Q_{loss}, I_{SC},V_{level}).

Where:

$$f(P_{loss},Q_{loss},Isc,V_{level}) = w_1F_p + w_2F_q + w_3F_i + w_4F_v \quad (1)$$

F_p relates to increase of active power loss index in percent of system due to installation of DG which is given by:

$$F_p = \frac{P_{Loss}^{withoutDG} - P_{loss}^{withDG}}{P_{Loss}^{withoutDGl}} \quad (2)$$

Where, P_{Loss}^{withDG} is the real power loss in study system after installation of DG and $P_{Loss}^{withoutDG}$ is active power losses before installation.

F_q is a factor in order to determine the effect of DG in reactive power losses in mentioned system that given by:

$$F_q = \frac{Q_{Loss}^{withoutDG} - Q_{loss}^{withDG}}{Q_{Loss}^{withoutDGl}} \quad (3)$$

Where, Q_{Loss}^{withDG} and $Q_{Loss}^{withoutDG}$ are total reactive power losses in study system with installation DGs and without DGs respectively.

One of the avails of optimizes location and size of the DG is the improvement in voltage profile. This index penalizes the size-location pair which gives higher voltage deviations from the nominal value (Vnom). In this way, the closer the index to zero, the better is the network performance. The F_v can be defined as:

$$F_v = \max_{i=2}^{n}\left(\frac{|V_{nom}| - |V_i|}{|V_{nom}|}\right) \quad (4)$$

At last, in order to improve the short circuit level of system, F_I given in Equation 5, is gathered with the objective function:

$$F_I = \frac{I_{sc}^{withoutDG} - I_{sc}^{withDG}}{I_{sc}^{withoutDGl}} \quad (5)$$

The sum of the absolute values of the weights assigned to all impacts should add up to one as shown in the following equation:

$$|w_1| + |w_2| + |w_3| + |w_4| = 1 \quad (6)$$

The MOF in this paper in order to achieve the performance calculation of distribution systems for DG size and location is given by:

$$MOF = 0.4F_p + 0.2F_q + 0.15F_I + 0.25F_v \quad (7)$$

Constrains formulation

The MOF Equation 7 minimized is subjected to various operational constraints to satisfy the electrical requirements for distribution network. These constraints are the following.

Power-conservation limits

The algebraic sum of all incoming and outgoing power including line losses over the whole distribution network and power generated from DG unit should be equal to zero.

$$P_{Gen} + P_{DG} - \sum_{i=1}^{n} P_D - P_{total}^{Loss} = 0 \quad (8)$$

Distribution line capacity limits

Power flow through any distribution line must not exceed the thermal capacity of the line:

$$S_{ij} < S_{ij}^{\max} \quad (9)$$

Voltage limits

The voltage limits depend on the voltage regulation limits should be satisfied:

$$V_i^{\min} \le V_i \le V_i^{\max} \quad (10)$$

This paper employs PSO technique to solve the above optimization problem and search for the optimal or near optimal set of problem. Typical ranges of the optimized parameters are (0.01 to 100) KW for P_{DG} and (0.95-1.05) for voltage of buses.

PARTICLE SWARM OPTIMIZATION ALGORITHM

PSO was formulated by Edward and Kennedy in 1995 (Randy et al., 2004). The thought process behind the algorithm was inspired by the social behavior of animals, such as bird flocking or fish schooling. PSO is one of the most recent developments in the category of combinatorial met heuristic optimizations (Gaing, 2003). In PSO, each individual is referred to as a particle and represents a candidate solution to the optimization problem (Yoshida et al., 2000).

In first, a population of random solutions ''particles'' in a D-dimension space are composed. Each particle is a solution. The *i*th particle is represented by $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$. Situation of each particle will be change in the next stage. The best situation of each particle will be determined by fitness function. If the fitness functions has a minimum value so far it is called best situation and save in $Pbest_i$. The global version of the PSO keeps track of the overall best value (gbest), and its location, obtained thus far by any particle in the population (Mandal et al., 2008). The particles update their velocities and positions based on the local and global best solutions. According to Equation 11, the velocity of particle *i* is represented as $V_i = (v_{i1}, v_{i2}, \ldots v_{iD})$. Acceleration is weighed by a random term, with separate random numbers being generated for acceleration toward pbest and gbest. The position of the *i*th particle is then updated according to Equation 12 (Binghui et al., 2007):

$$v_{id} = w \times v_{id} + c_1 \times rand() \times (P_{id} - x_{id}) + c_2 \times rand() \times (P_{gd} - x_{id}) \quad (11)$$

$$x_{id} = x_{id} + cv_{id} \quad (12)$$

Where, P_{id} and P_{gd} are pbest and gbest, c_1 and c_2 are constant values, ω will be determined by this equation:

ω_{max} and ω_{min} are the maximum and minimum value of ω respectively. At first ω start with large value that in the end of problem the value of the ω will be minimum.

In this optimization problem, the number of particles and the number of iterations are selected 30 and 40, respectively. Dimension of the particles will vary for each condition.

$$\omega = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{iter_{\max}} * iter \quad (13)$$

CASE STUDY AND PLACEMENT RESULTS

In this section, we illustrate that, DG placement affects the active power loss, reactive power losses and voltage profile. The placement of only a single DG, two DGs and three DGs are considered. In order to prove the efficiency of the proposed placement algorithm, IEEE 33-bus test system without tie lines that was presented in Kashem et al. (2000) as shown in Figure 1 is considered and the system details are given in Table 1.

In order to demonstrate variable number of DGs effect, we assume that, one-two and three DG unit which its size varying between 25 to 10 MW will be place in the mention network. The optimization results are given in Figure 2. This figure shows the value of MOF value in 40 iteration of PSO. From these results, it was obvious that the amount of MOF of the three DGs placement is least at the 40th iteration. The size and site location of one, two and three DGs are given in Table 2.

As can be seen from Table 2, the active power loss of the network without DG has maximum value and with three DG sitting have minimum amount and with comparing of power loss in four cases that is obvious that, the DG placement can has positive effect in power loss in the whole mention network.

Figure 3 illustrates buses voltage in four cases. With attention to this figure, the voltage profile with DG unit is better than without DG and the increasing number of DG unit's affect the DGs in voltage profile become well.

In the next study, we assume that, three DG units in order to optimal placement are considered. The result of this study is represented by power system. The results of line power loss were presented in Table 2 and in this case this power loss becomes less than other cases and in Figure 4 the voltage profile is showed. The voltage profile in this case is better than the previous cases.

Conclusion

In this paper, a different approach based on PSO in order to multi objective optimization analysis, including one, two and three DG units, for size and site planning of DG in distribution system were presented. In solving this problem, at first problem was written in the form of the optimization problem which its objective function was defined and written in time domain and then the problem has been solved using PSO. The proposed optimization algorithm was applied to the 33-bus test system with tie lines.

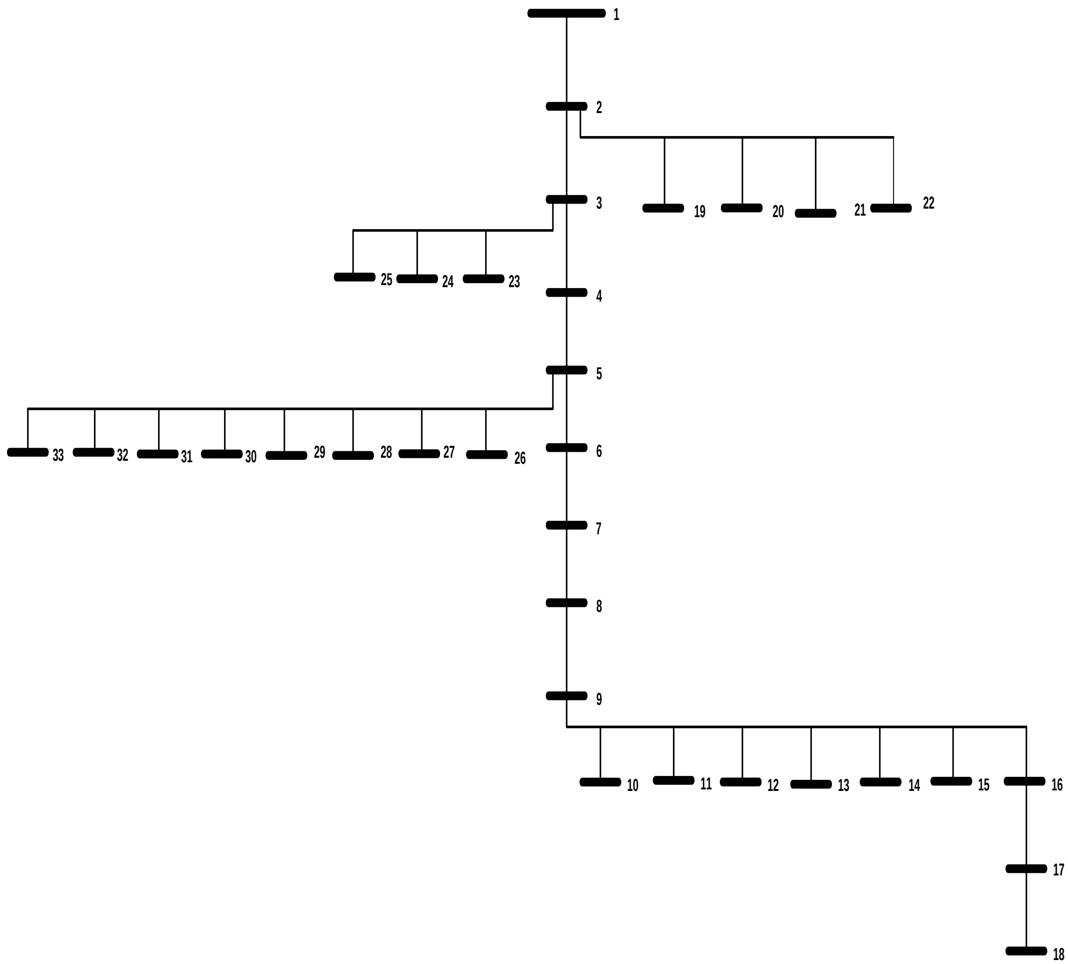

Figure 1. IEEE 33 bus study system with tie lines.

Table 1. Lines, active and reactive power details in study system.

Branch nom	Sen. node	Rec. node	Active power of rec. node KW	Reactive power of rec. node KVAr	Resistance ohms	Reactance ohms
1	1	2	100	60	0.0922	0.0470
2	2	3	90	40	0.4930	0.251 1
3	3	4	120	80	0.3660	0.1 864
4	4	5	60	30	0.3811	0.1941
5	5	6	60	20	0.8190	0.7070
6	6	7	200	100	0.1872	0.6188
7	7	8	200	100	1.7114	1.2351
8	8	9	60	20	1.0300	0.7400
9	9	10	60	20	1.0440	0.7400
10	10	11	45	30	0.1966	0.0650
11	11	12	60	35	0.3744	0.1238
12	12	13	60	35	1.4680	1.1550
13	13	14	120	80	0.5416	0.7129
14	14	15	60	10	0.5910	0.5260
15	15	16	60	20	0.7463	0.5450

Table 1. Contd.

16	16	17	60	20	1.2890	1.7210
17	17	18	90	40	0.7320	0.5740
18	2	19	90	40	0.1640	0.1565
19	19	20	90	40	1.5042	1.3554
20	20	21	90	40	0.4095	0.4784
21	21	22	90	40	0.7089	0.9373
22	3	23	90	50	0.4512	0.3083
23	23	24	420	200	0.8980	0.7091
24	24	25	420	200	0.8960	0.7011
25	5	26	60	25	0.2030	0.1034
26	26	27	60	25	0.2842	0.1447
27	27	28	60	20	1.0590	0.9337
28	28	29	120	70	0.8042	0.7006
29	29	30	200	600	0.5075	0.2585
30	30	31	150	70	0.9744	0.9630
31	31	32	210	100	0.3105	0.3619
32	32	33	60	40	0.3410	0.5302

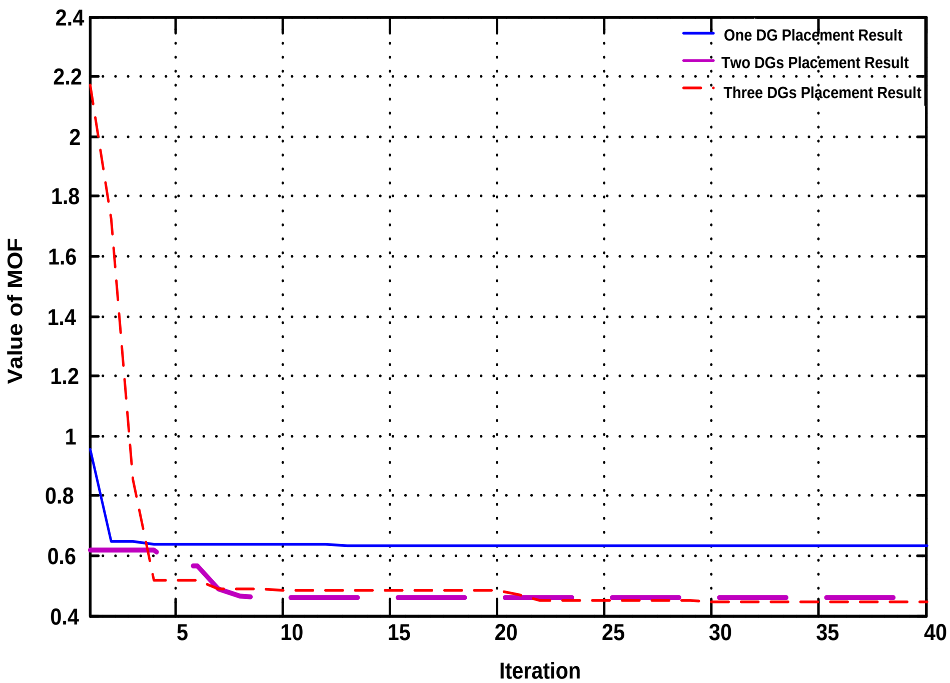

Figure 2. Value of MOF for one, two and three DGs.

Table 2. Optimum results of PSO for location and size of DGs.

Number of DG	DG size			DG site			Network loss
Without DG	-			-			0.8920
One DG	1136.6			11			0.6340
Two DGs	1143.2		1044.2	24		11	0.4583
Three DGs	1700.1	668.7	506.0	3	8	15	0.4436

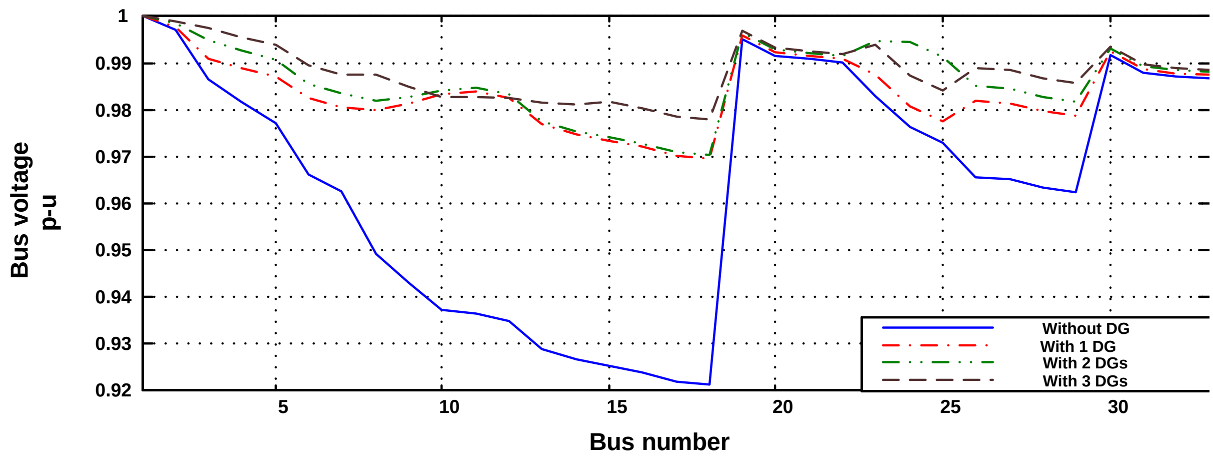

Figure 3. Voltage profile of study system with three DG units, two DG units, single DG unit, and without DG.

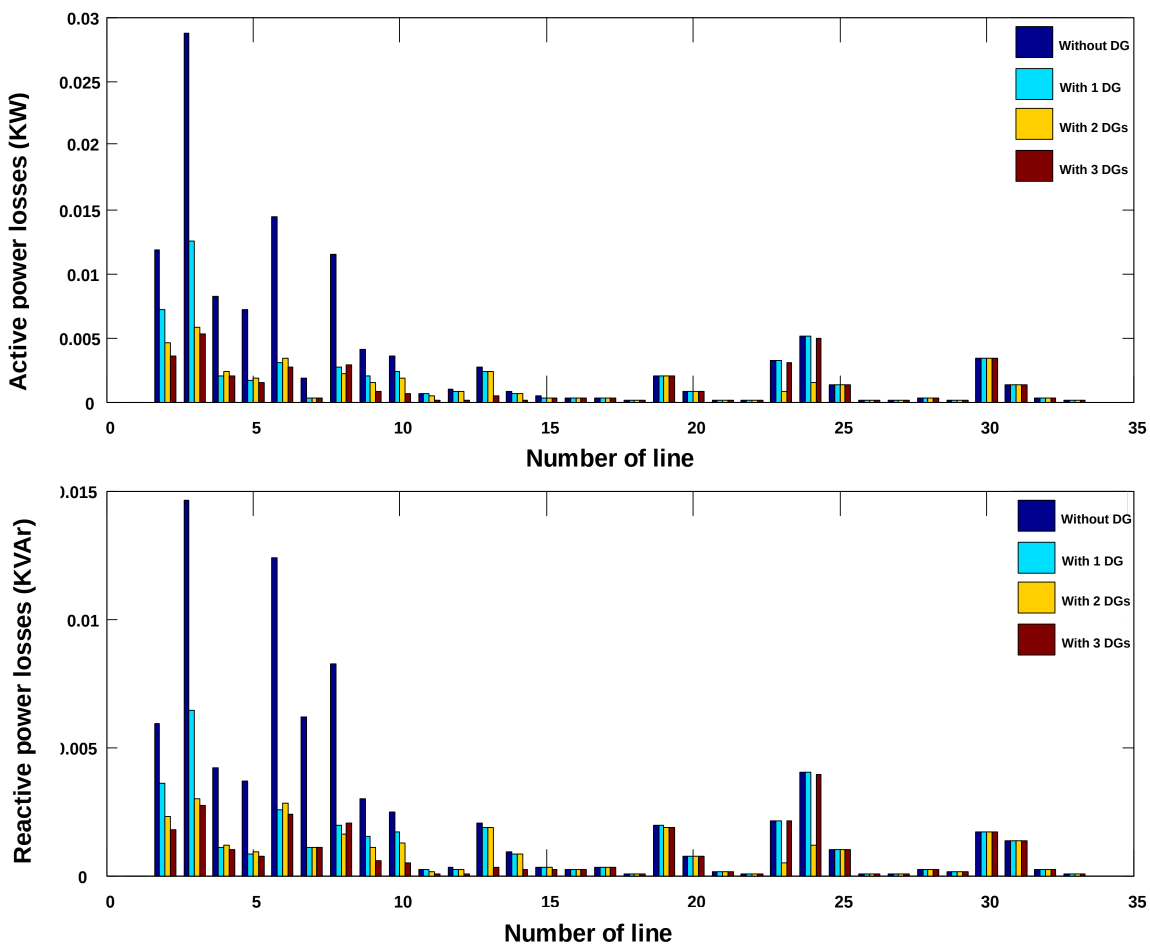

Figure 4. Active and reactive of lines with three DG units, two DG units, single DG unit and without DG.

The results clarified the efficiency of this algorithm for the improvement of voltage profile and reduction of power losses in study system.

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