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Optimal Determination of Size and Site of DGs in Mesh System Using PSO

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Abstract

Nowadays, the penetration of Distributed Generation (DG) in power networks takes special place for them worldwide and is increasing in developed countries. In order to improve of voltage profile, stability, reduction of power losses and etc, it is necessary that this increasing of installation of DGs in Distribution system should be becomes systematically. This paper introduces an optimal placement method in order to sizing and sitting of distributed generation in IEEE 30 bus mesh test system. The algorithm for optimization is Particle Swarm Optimization (PSO). Proposed objective function is Multi Objective Function that considers active power losses of the system and the voltage profile. High performance of the proposed algorithm is proved by applying algorithm in 30 bus IEEE system using MATLAB software and in order to illustrate of feasibility of proposed method this optimization will achieved with Three DG units.

***Keywords**: Distributed Generation- DG Placement- Particle Swarm Optimization- Multi objective function-Optimization*

1. Introduction

The concern about rising environmental population and also concern about the fossil fuels problems and limitation, the distributed generation (DG) units has become more and more competitive against the conventional centralized system by successfully integrating new-generation technologies and power electronics and supported many customers from industrial, commercial, and residential sectors. DGs generally refer to distributed energy resources (DER) including photovoltaic, fuel cells, micro turbines, small wind turbines, etc [1].DG can be used in an isolated way, supplying the consumer's local demand, or in an integrated way, supplying energy to the remaining of the electric system [2].

The best choosing size and site of DGs in distribution system is a complex optimization problem and if this problem contain the multi objective function, this problem become much complex Now days, meta heuristics optimization methods are being successfully applied to combinatorial optimization problems in distribution systems [2,3].

In Ref [4] a method based on the analysis of power flow continuation and determination of most sensitive buses to voltage collapse is proposed. Yields efficiency in improvement of voltage profile and reduction of power losses were investigated. It also may permit an increase in power transfer capacity, maximum loading, and voltage stability margin. In Refs [5–7], the authors qualified 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 TS search method to find the optimal solution of their problem was explained in [8], but the TS is known to be time consuming algorithm also it is may be trapped in a local minimum.

In order to minimization of real power losses of power system in ref [9], a 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

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considered in this study in order to determine of optimally location and size of only one DG unit. Ref [10] suggested a heuristic method to select optimal location and to calculate DG size for minimum real power losses.

In ref [11], a deferent scenario were investigated for determine of optimum location of distributed generation in order to modify of voltage profile and minimize the investment risk.

A genetic algorithm (GA) based fuzzy multi-objective approach for determining the optimum values of fixed and switched shunt capacitors to improve the voltage profile and maximize the net savings is proposed in [12]

The placement of one DG unit with specific size in [13] was explained. In this paper multi objective function such as power line losses, modify of voltage profile, line loading capacity and short circuit level were considered. P-V curves in ref [14] 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.

Particle Swarm Optimization (PSO) is used in this paper in order to solution of optimization problem. Objective function of this paper is formed by combining on real power losses, voltage profile improving and of IEEE 30 buses mesh system.

Problem formulation contain of objective function and constrains is explain in 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 describe in section 4, Section 5 concludes the paper. The simulation test systems were simulated in MATLAB software.

2. Problem formulation

2.1. Objective Functions Formulation

As mentioned above, this paper introduces multi objective function optimization. The objective function procured from the gather of each DG impact by 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},V_{level}) [2].

Where

$$f(P_{loss}, V_{level}) = w_1 F_p + w_4 F_v \quad (1)$$

F_p relates to increase of active power loss index in percent of system due to installation of DG that 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.

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, closer the index to zero better is the network performance. The F_v can be defined as:

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

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

$$|w_1| + |w_4| = 1 \tag{6}$$

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

$$MOF = 0.7F_p + 0.3F_v \tag{7}$$

2.2. Constrains Formulation

The multi objective function (7) is minimized subjected to various operational constraints to satisfy the electrical requirements for distribution network. These constraints are the following.

1) 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.

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

2) Distribution Line Capacity Limits: Power flow through any distribution line must not exceed the thermal capacity of the line

$$S_{ij} < S_{ij}^{\max} \tag{9}$$

3) Voltage Limits: the voltage limits depend on the voltage regulation limits should be satisfied.

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{10}$$

This paper employs Particle Swarm Optimization technique to solve the above optimization problem and search for optimal or near optimal set of problem. Typical ranges of the optimized parameters are [0.1 100] MW for P_{DG} and [0.95-1.1] for voltage of buses.

3. Particle Swarm Optimization Algorithm

PSO was formulated by Edward and Kennedy in 1995 [15]. 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 [16]. In PSO, each individual is referred to as a particle and represents a candidate solution to the optimization problem [17].

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 next stage. The best situation of each particle will be determined by fitness function. If the fitness functions has 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 [18]. The particles update their velocities and positions based on the local and global best solutions. According to Eq. (9), The velocity of particle *i* is represented as $V_i = (v_{i1}, v_{i2} \ldots v_{iD})$. Acceleration is weighted 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 Eq. (10) [19].

$$v_{id} = w \times v_{id} + c_1 \times rand() \times (P_{id} - x_{id}) + c_2 \times rand() \times (P_{gd} - x_{id}) \tag{9}$$

$$x_{id} = x_{id} + cv_{id} \tag{10}$$

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.

$$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{iter_{max}} * iter \quad (11)$$

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 50, respectively. Dimension of the particles will vary for each condition.

4. Case Study and Placement Results

In this section, we illustrate that DG placement affects in active power loss, reactive power losses and voltage profile. The placement of Three DGs is considered. In order to prove of efficiency of the proposed placement algorithm, IEEE 30-bus mesh system that present in Fig (1) is considered and the system details are given inTable1.

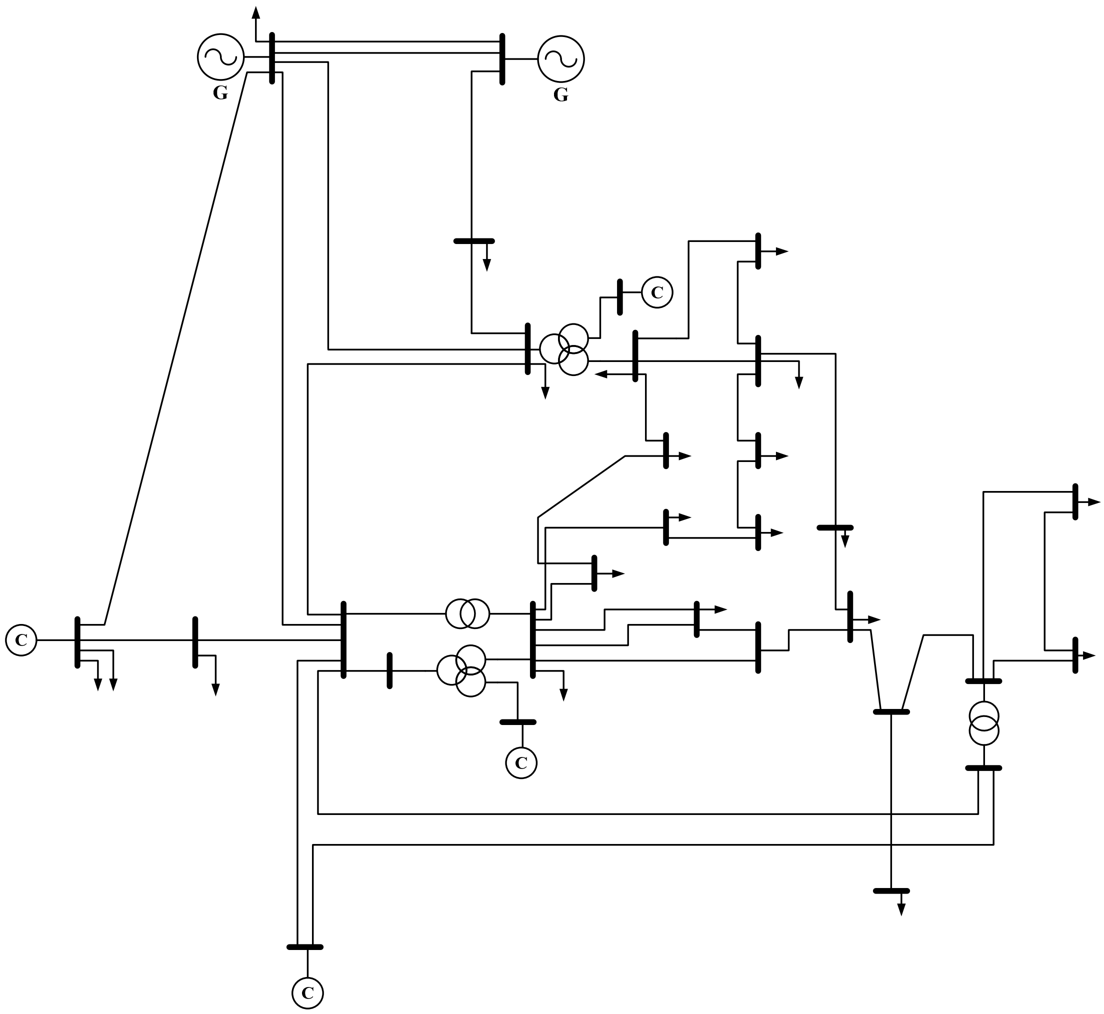

Figure 1. IEEE 30 bus mesh system

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

Sen. node	Rec. node	Resistance ohms	Reactance ohms	admittance ohms	Node number	PL	QL
1	2	0.0192	0.0575	0.0264	1	0	0
1	3	0.0452	0.1852	0.0204	2	21.7	12.7
2	4	0.057	0.1737	0.0184	3	2.4	1.2
3	4	0.0132	0.0379	0.0042	4	7.6	1.6
2	5	0.0472	0.1983	0.0209	5	94.2	19
2	6	0.0581	0.1763	0.0187	6	0	0
4	6	0.0119	0.0414	0.0045	7	22.8	10.9
5	7	0.046	0.116	0.0102	8	30	30
6	7	0.0267	0.082	0.0085	9	0	0
6	8	0.012	0.042	0.0045	10	5.8	2
6	9	0	0.208	0	11	0	0
6	10	0	0.556	0	12	11.2	7.5
9	11	0	0.208	0	13	0	0
9	10	0	0.11	0	14	6.2	1.6
4	12	0	0.256	0	15	8.2	2.5
12	13	0	0.14	0	16	3.5	1.8
12	14	0.1231	0.2559	0	17	9	5.8
12	15	0.0662	0.1304	0	18	3.2	0.9
12	16	0.0945	0.1987	0	19	9.5	3.4
14	15	0.221	0.1997	0	20	2.2	0.7
16	17	0.0824	0.1923	0	21	17.5	11.2
15	18	0.1073	0.2185	0	22	0	0
18	19	0.0639	0.1292	0	23	3.2	1.6
19	20	0.034	0.068	0	24	8.7	6.7
10	20	0.0936	0.209	0	25	0	0
10	17	0.0324	0.0845	0	26	3.5	2.3
10	21	0.0348	0.0749	0	27	0	0
10	22	0.0727	0.1499	0	28	0	0
21	22	0.0116	0.0236	0	29	2.4	0.9
15	23	0.1	0.202	0	30	10.6	1.9
22	24	0.115	0.179	0			
23	24	0.132	0.27	0			
24	25	0.1885	0.3292	0			
25	26	0.2544	0.38	0			
25	27	0.1093	0.2087	0			
28	27	0	0.396	0			
27	29	0.2198	0.4153	0			
27	30	0.3202	0.6027	0			
29	30	0.2399	0.4533	0			
8	28	0.0636	0.2	0.0214			
6	28	0.0169	0.0599	0.065			

In order to demonstrate variable number of DGs effect, we assume that three DG units which its size varying between 100 kW-100 MW will placement in mention network. The optimization results are given in Figure 2. This figure shows the value of Multi Objective Function (MOF) value in 50 iteration of PSO. From of these results this is obvious that the amount of MOF of three DGs placement is least at the 50^{th} iteration. The size and site location of three DGs are given in Table 2.

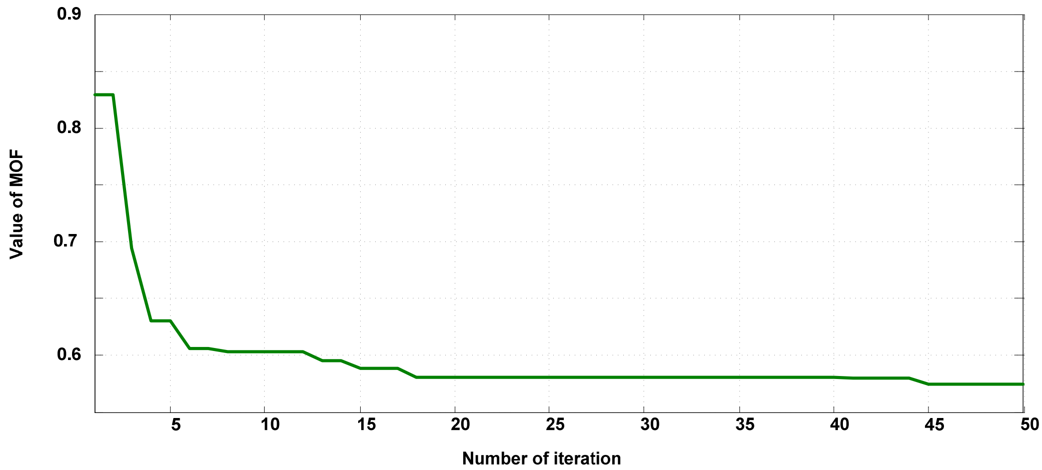

Figure 2. Value of multi objective function

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

Number of DG	DG Size			DG Site			Optimum MOF
Without DG		--			--		--
Three DGs	12.9178	9.3477	7.902	2	24	30	0.55

As can be seen from of Table 2, the multi objective function value of the network without DG has much value in comparison with after sitting three DG. Comparing of power loss in two cases that is obvious the DG placement can be has positive effect in power loss in whole mention network.

Figure (3) illustrate buses voltage in two cases. With attention to this Figure, the voltage profile with DG unit is better than without DG affect of DGs in voltage profile become well. Figure (4) shows the line loading of the system with and without DG units. It is clear that for most of the lines the loading decreased while for some lines it was kept the same or increased but still within line loading limits.

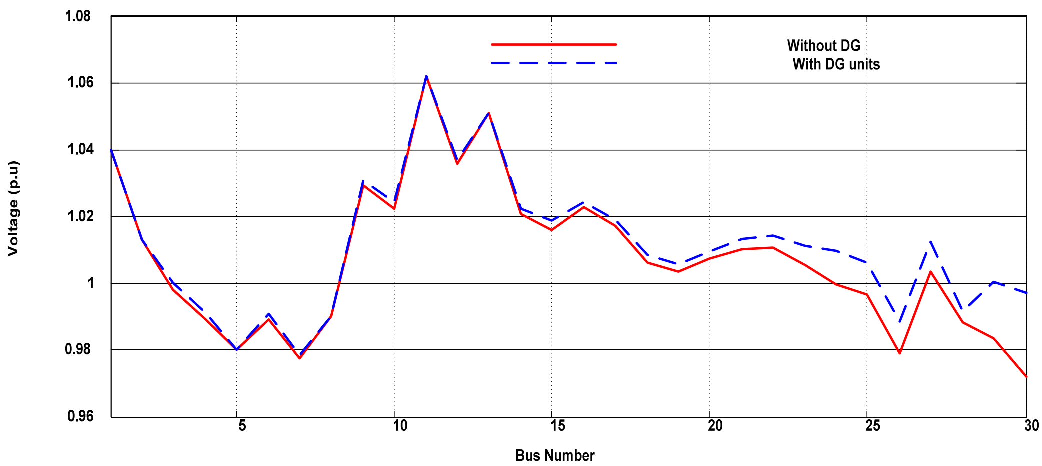

Figure 3. Voltage profile of study system with three DG units and without DG

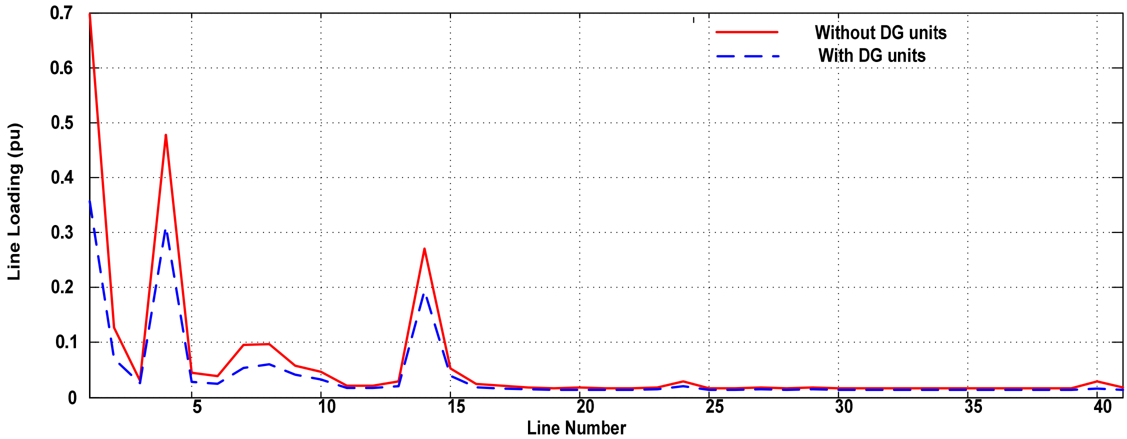

Figure 4. Line Loading with three DG units and without DG

5. Conclusion

In this paper, a different approach based on Particle Swarm Optimization in order to Multiobjective optimization analysis, including three DG units, for size-site planning of distributed generation in mesh system was 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 30-bus mesh system.

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

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