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Optimal DG Allocation Based On Two Novel Load Models By Group Search Optimization

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Abstract: *In this paper, two novel models have been used in optimal Distributed Generation (DG) placement in distribution system. To do this, the system load have been modeled based on types of costumer and parameter. Minimizing power loss and improving voltage bus have been considered in the proposed objective function. This objective function has been optimized by Group Search Optimization (GSO) algorithm. This algorithm one of particle swarm intelligence techniques which has been suggested to solve complex nonlinear problem. Case study has been performed on IEEE 34-bus radial distribution system.*

Keywords: Distributed generation, Group search optimization, Power loss minimization, Voltage Profile Improvement.

1. Introduction

In practical study, system load is consists of several types of load which impact on DG placement problem. It can been claimed that load modeling have been ignored in all studies of solar cell placement problem. While load model impacts on location and size of solar cell.

In this context, the prior works of Distributed Generation (DG) placement has been categorized in five groups; which are: evolutionary techniques, heuristic techniques, analytical approaches, swarm optimization algorithms and hybrid techniques.

In evolutionary techniques, the initial solution has been optimized in an iterative process which Genetic algorithm (GA) is one of the most common techniques for DG placement among these techniques that used in [1-4]. References [5-7] have proposed heuristic techniques to determine optimal location and size of DG. Analytical approaches are other group which in [8-10] have suggested to solve optimal DG allocation problem. Authors in [11-12] have been used swarm optimization algorithms to find optimal bus and capacity of DG units. Finally in [13-14], hybrid techniques have been proposed to solve the problem.

In this paper, a novel technique has been suggested to load model for optimal DG placement. This context consists of six sections. In section 2, the proposed objective function has been formulated. Section 3 expresses the proposed load modeling in two subsections; i.e. load modeling based on type of consumption and load modeling based on power constant power and constant impedance as well as constant current. Solving the problem by GSO algorithm has been presented in Section 4. Simulation results has been listed and illustrated in tables and figures of Section 5. This work has been concluded in Section 6.

2. Objective function

In this paper, a new objective function based on the parameters of objective function should be introduced. But there are two challenges, first challenge is that the parameters have different units; this problem does not happened in cost objective function, because all the parameters are in one form of expenditure. Second challenge is that the quantities have different scales too, in other words the parameters are extremely different so their effects on objective function and consequently on resulted optimal location and capacity are very different. Therefore a new objective function should be defined as follows:

$$OF = \frac{P_{loss,a}}{P_{loss,\mathrm{b}}} + \frac{VB_a}{VB_b} \qquad (1)$$

where, the indexes a and b are the values before and after allocation, respectively. VB is the voltage deviation.

With this technique, the parameters of objective function are normalized in an acceptable range and their effects on objective function would be directly of their variations not their real values. This objective function is a step forward than the cost objective function and it is more practical.

3. THE PROPOSED LOAD MODELING

The main challenge of this study was to investigate the effect of load modeling on the location and capacity of

the capacitor banks. Thus, two models are introduced as follows; i.e.

3.1 Load modeling based on type of consumption

Load is different in each distribution substation based on its type in terms of industrial, commercial, residential and agricultural loads, and the consumed power value for each load type is depending to the voltage magnitude of each substation based on Eqs. (2 3),

$$P_i = P_{0i} V_i^{\alpha} \tag{2}$$

$$Q_i = Q_{0i} V_i^{\beta} \tag{3}$$

where, α and β are coefficients of active and reactive powers variation, respectively. P_0 is power in *1pu* voltage. Q_0 are power in *1pu* voltage.

In this paper, the loads of networks have been classified in three types; i.e. industrial, commercial and residential loads while in the study, in addition to these levels, loads of agricultural, general and fixed-power are considered. The values of α and β for each load types have been listed in Table 1.

TABLE I: Load variation factors

Load type	Residential	Commercial	Industrial	Agricultural	General	Fixed-Power
α	0.92	1.51	0.18	0.92	0.92	0
β	4.04	3.4	6	4.04	4.04	0

The novel equations have been suggested to load model in a mixed case,

$$P_i = P_i^{res} V_i^{\alpha,res} + P_i^{ind} V_i^{\alpha,ind} + P_i^{com} V_i^{\alpha,com} + P_i^{agr} V_i^{\alpha,agr} + P_i^{gen} V_i^{\alpha,gen} \tag{4}$$

$$Q_i = Q_i^{res} V_i^{\alpha,res} + Q_i^{ind} V_i^{\alpha,ind} + Q_i^{com} V_i^{\alpha,com} + Q_i^{age} V_i^{\alpha,age} + Q_i^{gen} V_i^{\alpha,gen} \tag{5}$$

3.2 Load modeling based on power constant power and constant impedance as well as constant current

- Model of constant power

By assuming the presence of constant power loads on network, these loads are modeled by following equation:

$$P_i^{'} = P_i + P_{con} \tag{6}$$

$$Q_i^{'} = Q_i + Q_{con} \tag{7}$$

where, $P^{'}$ and P_{con} are active power after applying load model and constant active power of system, respectively. $Q^{'}$ and Q_{con} are reactive power after applying load model and constant reactive power of system, respectively.

- Model of constant current

Firstly, current is converted to impedance as,

$$Z_{pu} = \frac{V_{pu}}{I_{pu}} \tag{8}$$

By assuming $V_{pu}=1$ in at the beginning of load flow, the prior equation can be rewritten as following,

$$Z_{pu} = \frac{1}{I_{pu}} \tag{9}$$

From this equation, admittance is equal to current.

$$Y_{pu} = I_{pu} \tag{10}$$

- Model of impedance constant

The Eq.(9) is converted to as following for impedance constant model,

$$Y_{pu} = \frac{1}{Z_{pu}} \tag{11}$$

4. GROUP SEARCH OPTIMIZATION (GSO) ALGORITHM [15-16]

The population of the GSO algorithm is called a group and each individual in the population is called a member. In an *n*-dimensional search space, the *i*th member at the *k*th searching bout (iteration) has a current position $X_i^k \in R^n$, a head angle $\Phi_i^k = (\Phi_{i1}^k, \ldots, \Phi_{i(n-1)}^k) \in R^{n-1}$. The search direction of the *i*th member, which is a unit vector $\mathbf{D}_i^k(\Phi_i^k) = (d_{i1}^k, \ldots, d_{i(n-1)}^k) \in R^n$ that can be calculated from ϕ_i^k via a polar to Cartesian coordinate transformation.

$$d_{i_1}^k = \prod_{q=1}^{n-1} \cos\left(\phi_{i_q}^k\right) \tag{12}$$

$$d_{i_1}^k = \sin\left(\phi_{i_{(j-1)}}^k\right) \cdot \prod_{q=1} \cos\left(\phi_{i_q}^k\right) \quad (j = 2, \ldots, n-1) \tag{13}$$

$$d_{i_1}^k = \sin\left(\phi_{i_{(j-1)}}^k\right) \tag{14}$$

In GSO, a group consists of three types of members: producers and scroungers whose behaviors are based on the PS model; and dispersed members who perform random walk motions. For convenience of computation, we simplify the PS model by assuming that there is only one producer at each searching bout and the remaining members are scroungers and dispersed members. The simplest joining policy, which assumes all scroungers will join the resource found by the producer, is used. In optimization problems, unknown optima can be regarded as open patches randomly distributed in a search space. Group members therefore search for the patches by moving over the search space. It is also assumed that the producer and the scroungers do not differ in their relevant phenotypic characteristics. Therefore, they can switch between the two roles.

4,1 Producer

At the *k*th iteration, let the producer's position denoted by $X_p^k=(x^k_{p1},\ldots, x^k_{pn})$. It scans three points around it to find a better position. First, the producer scans a point in front of it:

$$X_F = X_P^k + r_1 l_{\max} D_p^k\left(\phi^k\right) \tag{15}$$

Second, it scans a point on its right-hand side:

$$X_F = X_P^k + r_1 l_{\max} D_p^k\left(\phi^k + r_2\,\theta_{\max}/2\right) \tag{16}$$

Third, it scans a point on its left-hand side:

$$X_F = X_P^k + r_1 l_{\max} D_p^k\left(\phi^k - r_2\,\theta_{\max}/2\right) \tag{17}$$

where, r_1 is a random number normally distributed with mean 0 and standard deviation 1, r_2 is a random number uniformly distributed in[0,1].The y_{max} is max-pursuit angle, and the l_{max} is max-pursuit distance:

$$l_{\max} = \|U - L\| = \sqrt{\sum_{j=1}^{n}\left(U_j - L_j\right)^2} \tag{18}$$

where, U_j and L_j are the upper bound and lower bound of the search range.

If the producer finds that the best position in the three points is better than its current position, it moves to the best position and change its head angle as Eq.(17),where $\alpha_{\max}$ is the max-turning angle. Otherwise, it stays at original position. If the producer fails to find a better point in a iterations, it scans front again as Eq.(20):

$$\phi^{k+1} = \phi^k + r_2\alpha_{\max} \tag{19}$$

$$\phi^{k+a} = \phi^k \tag{20}$$

4,2 Scrounger

In the computation, most of the members are chosen as scroungers. If the *i*th member is chosen as a scrounger at the *k*th iteration, it moves toward the producer with a random distance,

$$X_i^{k+1} = X_i^k + r_3.\left(X_p^k - X_i^k\right) \tag{13}$$

where, r_3 is a random sequence uniformly distribution in [0,1].

4,3 Ranger

The rest members in the group are rangers. If the *i*th member is chosen as a ranger at the *k*th iteration, it turns its head to a random angle as Eq.(17), and calculates the search direction using Eqs. (12-13), then moves to that direction with a random distance as the following:

$$l_i = a.r_1 l_{\max} \tag{21}$$

5. SIMULATION RESULTS

In this section, simulation has been performed on IEEE radial distribution 33-bus network (See Fig.1). Two scenarios have been introduced,

- Scenario I. By considering only residential load
- Scenario II. By considering industrial, commercial, residential, agricultural and general loads

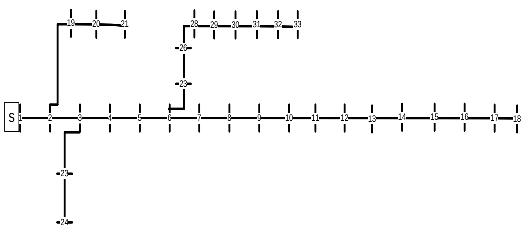

Fig.1: Single line diagram of IEEE radial distribution 33-bus network

Due to these scenarios, clearly, we know influence the location and capacity for DG at different loads. The goal of the introducing these scenarios is analyzing influence of the proposed models on location and size of DGs and system parameters and not to prove the superiority of any one of the scenarios. The capacitors are placed in three Cases in each scenario;

Case 1. With capacitor-with modeling

Case 2. With capacitor-without modeling

Case 3. Without capacitor- Without modeling

5,1 Placement of one source

In first placement, one source has been considered for system. Results of this allocation have been listed in Table 2.

TABLE II: Values of in the placement of one source

Scenario	Case	Power loss	VD	Total size	OF
I	1	449.7413	0.0488	250	1.7141
	2	361.6489	0.0430	250	1.6780
	3	521.4710	0.0573	-	2
II	1	447.5895	0.0485	250	1.9840
	2	364.6216	0.0432	250	1.4532
	3	433.4730	0.0510	-	2

By considering results of Table 2, second scenario presents better solutions respect to first scenario except power loss in case 1 while the installed capacity in four cases is equal. Optimal location and size of DG are visible in Table 3.

TABLE III: Optimal location and size of the placed one source

Scenario	Case	Optimal Location and size	
I	1	Location	18
		Size	250
	2	Location	18
		Size	250
II	1	Location	18
		Size	250
	2	Location	18
		Size	250

Based on Table 3, location and size of all units are similar and are 250 kVA and bus 18, respectively.

5,2 Placement of three sources

In second placement, three sources have been considered for system. Results of this allocation have been listed in Table 4.

TABLE IV: Values of in the placement of three sources

Scenario	Case	Power loss	VD	Total size	OF
I	1	367.2966	0.0432	675	1.4937
	2	274.1797	0.0361	700	1.3407
	3	521.4710	0.0573	-	2
II	1	368.1109	0.0432	675	1.6960
	2	303.0508	0.0383	650	1.2488
	3	433.4730	0.0510	-	2

Due to Table 4, values of first case in first scenario is better than prior scenario. The installed capacity of first cases in two scenarios are equal and in second cases are minor differences. Location and size of three sources have been listed in Table 5.

TABLE V: Optimal location and size of the placed three sources

Scenario	Case	Optimal Location and size			
I	1	Location	31	30	15
		Size	200	225	250
	2	Location	30	14	18
		Size	250	250	200
II	1	Location	31	29	17
		Size	200	250	225
	2	Location	8	13	16
		Size	225	175	250

By considering results of Table 5, it can claimed that all first sources in first cases of two scenarios have been installed in first 15 buses. Such an order cannot be seen in the second cases but we can say often placed in prior of bus 15. Source 250 *kVA* is the most widely used source.

5,3 Placement of five sources

In second placement, five sources have been considered for system. Results of this allocation have been listed in Table 6.

TABLE VI: Values of in the placement of five sources

Scenario	Case	Power loss	VD	Total size	OF
I	1	319.9753	0.0393	925	1.2995
	2	249.4280	0.0345	900	1.2525
	3	521.4710	0.0573	-	2
II	1	286.9768	0.0366	1200	1.3803
	2	245.3902	0.0347	1000	1.0768
	3	433.4730	0.0510	-	2

Based on Table 6, the capacity installed in the first scenario is low and the installed capacity of two cases of this scenario is close. Location and size of five placed sources have been listed in Table 7.

TABLE VII: Optimal location and size of the placed five sources

Scenario	Case	Optimal Location and size					
I	1	Location	28	33	31	14	16

		Size	200	150	225	125	225
	2	Location	8	9	10	18	29
		Size	50	175	250	200	225
II	1	Location	27	11	33	32	18
		Size	200	250	250	250	250
	2	Location	7	17	28	14	18
		Size	225	175	250	150	200

Based on results of Table 7, the most sources in first cases of two scenarios have been installed in first buses and the most sources in second cases of two scenarios allocated in terminal buses. Capacities 225 and 250 kVA are the most widely used sources.

5,4 Placement of seven sources

In second placement, seven sources have been considered for system. Results of this allocation have been listed in Table 8.

Based on Table 8, power loss of second case in first scenario is less than power loss before placement while its capacity is less than first case. Objective function of these two scenarios in seven sources are equal to its parameters in five sources approximately and increase the number of units have little impact on improving the network. Optimal location and size of the sources have been presented in Table 9.

TABLE VIII: Values of in the placement of seven sources

Scenario	Case	Power loss	VD	Total size	OF
I	1	275.1364	0.0341	1525	1.1035
	2	208.5163	0.0357	1275	1.1802
	3	521.4710	0.0573	-	2
II	1	264.6557	0.0327	1475	1.2512
	2	227.2003	0.0346	1225	1.0395
	3	433.4730	0.0510	-	2

Based on Table 9, bus 5 among first buses and bus 33 among terminal buses are the most probable location to install sources.

TABLE IX: Optimal location and size of the placed seven sources

Scenario	Case	Optimal Location and size							
I	1	Location	5	33	16	3	18	14	6
		Size	150	225	225	225	225	225	250
	2	Location	28	15	22	24	31	17	18
		Size	175	250	75	175	250	150	200
II	1	Location	8	13	23	15	17	33	31
		Size	125	250	175	250	250	200	225
	2	Location	18	32	31	23	17	9	5
		Size	200	250	100	200	225	125	125

5,5 Placement of nine sources

In second placement, nine sources have been considered for system. Results of this allocation have been listed in Table 10

Due to results of Table 10, actually increase the number of units or result in the destruction of the network parameters (first scenario) or little effect on improving them (the second scenario) no. Table 11 illustrates optimal location and capacity of nine sources.

TABLE X: Values of in the placement of nine sources

Scenario	Case	Power loss	VD	Total size	OF
I	1	253.4439	0.0345	1625	1.0881
	2	218.4036	0.0355	1425	1.1999
	3	521.4710	0.0573	-	2
II	1	236.7126	0.0337	1850	1.2074
	2	205.6026	0.0365	1325	1.0306
	3	433.4730	0.0510	-	2

TABLE XI: Optimal location and size of the placed nine sources

Scenario	Case	Optimal Location and size									
I	1	Location	30	13	6	31	18	3	11	10	17
		Size	200	175	150	175	125	225	200	225	150
	2	Location	27	26	13	18	23	24	28	11	32
		Size	125	50	225	250	175	50	175	125	250
II	1	Location	25	16	32	30	12	14	15	27	18
		Size	250	225	175	175	200	250	75	250	250
	2	Location	32	5	14	24	12	6	33	18	10
		Size	200	150	200	50	75	75	150	225	200

CONCLUSION

By considering many studies of DG placement, this paper made significant progress and tangible advantages over previous works. In this paper, a novel technique has been suggested to load model. For this, two load models have been suggested and a novel objective function formulated. Simulation has been performed by considering two scenarios; i.e. by considering only residential load and by considering industrial, commercial, residential, agricultural and general load. From simulation results, considering load model results in changes of location and size of DG and values of networks parameters. These changes are affected by the number of capacitors.

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