ORIGINAL RESEARCH

Optimal location and capacity of multi-distributed generation for loss reduction and voltage profile improvement using imperialist competitive algorithm

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Abstract

This paper proposes an Imperialist Competitive Algorithm (ICA) for optimal multiple distributed generations (DGs) placement and sizing in a distribution system. The objective is to minimize the total real power losses and improve the voltage profile within real and reactive power generation and voltage limits. Three types of DG are considered and the ICA is used to find the better sizes and locations of DGs for maximum real power losses reduction and voltage improvement for given number of DG units in each type. Both integer and continuous variables are considered in ICA, integer variable for locations and continues variable for sizes. The total real power losses and voltage profile evaluation are based on a power flow method for radial distribution system with the representation of DGs. The proposed method has been demonstrated on 33 bus radial distribution system. The efficiency of the ICA in reducing the total power losses and improving voltage is validated by comparing the obtained results with Particle Swarm Optimization (PSO) algorithm.

Key words

Imperialist competitive algorithm, Distributed generation, Optimal distributed Generation placement, Loss reduction, Particle swarm optimization

1 Introduction

Power distribution from power station to final customers is accomplished via transmission, subtransmission, and distribution network. In radial distribution systems, all customers are fed at only one point that is the substation. Because of high R/X ratios in distribution lines, there are voltage drops and high power losses in distribution networks. Recently, by embedding DGs, the distribution networks operation including voltage, losses and network reliability are improved.

DGs are small generator that connected directly to the distribution networks and supply customers. DGs are not part of the central power system [1].

Conventional power plants in the power system only generate energy, but DGs also participate in the voltage and frequency control. Depending on the load demand, the DGs can reduce the system losses and improve voltage profile in cases where they supply local customer. The sitting and sizing of DGs in distribution system have an important impact on the operations and control of power system. Non optimal placement and sizing of DGs can increase system losses, voltage flicker and costs. So, optimal placement and sizing of DGs can be very useful for the system operation.

An analytical methods to optimal placement and sizing of DGs in radial distribution system are presented in ref [2].the objective is to minimize the real power loss. In ref [3] genetic algorithm is used to find optimal placement and sizing of single and multiple DGs to minimize the distribution systems real power losses. Optimal placement of DGs in order to minimize the electrical network losses using a tabu search metaheuristic is proposed [4]. In ref [5] and [6] GA and PSO algorithm is used to improve the voltage profile in distribution network, respectively. A novel approach based on dynamic programming is used in ref [7] to find the optimal locations of DGs to minimize power losses enhance reliability and improve voltage profile of the distribution network. Time varying load is considered in this optimization. A new methodology using fuzzy and artificial bee colony (ABC) algorithm is presented in ref [8]. The objective is to minimize the real power losses and improve the voltage profile. Some technical and economic impacts of DGs using some heuristic methods have been studied in ref [9–11].

In this paper an Imperialist Competitive Algorithm (ICA) is proposed for optimal multiple distributed generations (DGs) placement and sizing in a distribution system. The heuristic methods has probably no application to more than one DG but ICA is fully practiced and robust to determine optimal placement and sizing of multi-distributed generations (DGs) in the distribution systems Because both integer and continuous variables is considered in ICA. A Direct approach for distribution system load flow solutions is applied for the load flow problem solving [12].

The rest of this paper is set out as follows. In Section 2, DG types are explained. Section 3 and 4 describes the problem formulation and constrains. In Section 5, Particle Swarm Optimization (PSO) is explained. The ICA algorithm is represented in Section 6. In Section 7, an ICA computation procedure in order to optimal placement of DG is described. Numerical results are illustrated in Section 8. Finally, the conclusion is given in Section 9.

2 Case study

There are several types of DGs. From the energy source view point, DGs can be divided into two parts, renewable energy like photovoltaic, small hydro power turbines and wind turbines technologies and non-renewable energy like gas turbines, diesel engines, and micro-turbine technologies. In this paper three DG types are considered including photovoltaic, synchronous condenser and wind turbine.

A. Case 1

Photovoltaic systems convert solar energy into electrical energy. Photovoltaic systems only supply real power. The ICA will search for optimal real power size and location of DG unit. When a DG of size PDG is placed at bus j:

$$P_j = P_{DG,j} - P_{D,j} \tag{1}$$

Where, $P_{DG,j}$ is real generation power of DG and $P_{D,j}$ is real demand power in bus j. P_j is net real power injection in bus j.

B. Case 2

Synchronous condenser systems only supply reactive power. This type of DG can improve the voltage profile by providing reactive power. The synchronous machine is considered as synchronous condenser when running without a mechanical load and it can either supply or absorb reactive power. When a DG of size Q_{DG} is placed at bus j:

$$Q_j = Q_{DG,j} - Q_{D,j} \tag{2}$$

Where, $Q_{DG,J}$ is reactive generation power of DG and $Q_{D,j}$ is reactive demand power in bus j. Q_j is net reactive power injection in bus j.

C. Case 3

The wind turbine converts wind kinetic energy into electrical energy. The wind turbine is connected to an induction or synchronous generator. If wind turbine is connected to an induction generator, Wind generator supply real power and in turn absorbs reactive power. When a wind generator of size P_{DG} is placed at bus j the absorbing reactive power can be given as [13]:

$$Q_{DG,j} = -(0.05 + 0.04 P_{DG,j}^2) \tag{3}$$

3 Problem formulation

Optimal placement and sizing of DGs is formulated as a nonlinear optimization problem subject to nonlinear inequality and equality constraints. In these sections objective functions is proposed. The real power losses minimization and voltage profile improvement is considered in a given radial distribution network. The goal is to converge these tow objective functions into one, using the weighting coefficient. The objective function is formulated as:

$$f = \alpha f_1 + \beta f_2 \tag{4}$$

α and β are weighting coefficient for real losses and voltage profile respectively.

A. Power loss

The power losses in the distribution system depend on the line resistance and currents and are usually called thermal losses. In a distribution system with n number of branches, the total real power losses can be calculated as [14]:

$$f_1 = P_{loss} = \sum_{j=1}^{n} |I_j|^2 R_j \tag{5}$$

Where, I_j and R_J are the magnitude of current and the resistance of the branch j, respectively.

B. Voltage profile

One of the advantages of suitable location and size of the DGs is the improvement in voltage profile. This is due to reduced real power flow from the slack bus to the network. Because of reduced real power flow from the upper level of the network, the losses are reduced and the bus voltage can be higher than its normal operating limits. In a distribution system with m number of buses, the objective function to improve voltage profile is:

$$f_2 = VP = \sum_{j=1}^{m} |V_{level} - V_j| \tag{6}$$

Where, V_{level} is voltage level and V_J is the measurement voltage at bus j.

These two objective function*s* can satisfy the designer requirements using the weighting coefficient. When distributed generation is connected to the distribution network, ICA uses the different Combination of these functions for optimal sizing and placement of DG.

4 Constraints

Another important part of the optimization problem is the constraints. In this paper, three types of constraints are considered, Power balance, real and reactive power generation and bus voltage limits.

4.1 Power balance

Power balance equations corresponding to both the real and the reactive powers must be satisfied. This constraint can be written as:

$$\sum_{j=1}^{m} P_{DG,j} = \sum_{j=1}^{m} P_{D,j} + P_{loss} \tag{7}$$

$$\sum_{j=1}^{m} Q_{DG,j} = \sum_{j=1}^{m} Q_{D,j} + Q_{loss} \tag{8}$$

Where, $P_{D,j}$, $Q_{D,j}$, $P_{DG,j}$ and $Q_{DG,j}$ are the real and reactive power demand and generation corresponding to the bus j, respectively. P_{loss} and Q_{loss} are the total real and reactive power losses in the system. m is the total number of buses.

4.2 Real and reactive power generation limits

Real and reactive power generation limits specify upper and lower limits for the real and reactive power outputs. These constraints are as follows:

$$\left|P_{DG,\min}\right| \leqslant \left|P_{DG,j}\right| \leqslant \left|P_{DG,\max}\right| \tag{9}$$

$$\left|Q_{DG,\min}\right| \leqslant \left|Q_{DG,j}\right| \leqslant \left|Q_{DG,\max}\right| \tag{10}$$

Where, $P_{DG,min}$, $Q_{DG,min}$, $Q_{DG,max}$ and $P_{DG,max}$ denotes upper and lower active and reactive power generation limits of DGs at bus j.

4.3 Bus voltage limits

The bus voltage magnitudes must be kept within acceptable operating limits throughout the optimization process. This can be mathematically described as:

$$\left|V_{j,\min}\right| \leq \left|V_{j}\right| \leq \left|V_{j,\max}\right| \tag{11}$$

Where, $V_{j,min}$ and $V_{j,max}$ denote upper and lower limits of voltage at bus j.

5 Particle swarm optimization

Particle Swarm Optimization (PSO) algorithm is a population based stochastic optimization technique developed in 1995 by Kennedy and Eberhart, inspired by the social behavior of birds flocking and fish schooling [15]. In this algorithm optimal solution to a mathematical optimization problem is imitated of birds behave during the food pursue, the escape from hunters and the search for mates. In recently years, the PSO algorithm has been used in wide variety of problems ranging from classical mathematical programming problems to highly specialize engineering and scientific optimization problems [21-23].

Conventional PSO algorithm works by having a population (called a swarm) of candidate solution (called particles). These particles are moved around in the search-space according to a few slick formulae. The movements of the particles are followed by their own best known position in the search-space as well as the whole swarm's best known position. After discovering the improved positions, these will then come to guide the movements of the swarm. The process is repeated and by doing so it is hoped, but not guaranteed, that a satisfactory solution will eventually be detected [15, 16]; subsequently, the swarm is adjusted according to the following two equations:

$$v_i^{t+1} = w.v_i^t + c_1 r_1 (p_i^t - x_i^t) + c_2 r_2 (g_i^t - x_i^t) \tag{12}$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \qquad i = 1, 2, ..., n \tag{13}$$

Where, n is the number of particles, w is the weighted inertia, $C_1$and C_2 are the positive constants, r_1 and r_2 are two random numbers distributed within the range [0, 1], t is the iteration number, P_i is the best position of the ith particle and g_i is the best particle among the group members. The particle updates its velocity according to its previous velocity and the distances to its current position from both its own best historical position and the best positions of the neighbors in every iteration step, and then it flies towards a new position given by [12, 13].

The pseudo code of PSO Algorithm is presented below:

Step 1: Input the basic data and maximum number of iteration (I_{max}).

Step 2: Initialize particles in the population.

Step 3: Calculate fitness value of the each particle.

Step 4: Compare and update fitness value with p_i, g_i.

Step 5: If the $I=I_{max}$, go to step 7. Otherwise, go to the next step.

Step 6: Update velocity and position by Equations [12, 13].

Step 7: Print the global best solution

6 Imperialist competitive algorithm

Imperialism is the policy of developing the potency and rule of a government beyond its own boundaries. A country may endeavor to dominate others by direct rule or by less obvious means such as a control of markets for goods or raw materials which is often called *neocolonialism* [17]. Imperialist Competitive Algorithm (ICA) [18] is a new evolutionary algorithm which uses imperialism and imperialistic comparative process as a source of inspiration. The pseudo code of Imperialist Competitive Algorithm is presented below:

1 Initialize the empires by selecting random points on the function.

2 Colonies movement into their relevant imperialist (Assimilation).

3 Random changing of the position of some colonies (Revolution).

4 If there is a colony in an empire which has lower cost than the imperialist, replace the positions of that colony and the imperialist.

5 Unify similar empires.

6 Calculate the total cost of whole empires.

7 Set the weakest colony (colonies) from the weakest empires and give it (them) to one of the empires (Imperialistic competition).

8 Discard weak empires.

9 If stop conditions is reached, stop, if not go to 2.

ICA, like other evolutionary algorithms, commences with an initial population. In this algorithm each member of the population is known as *country*. Some of the foremost countries in the population are selected as *imperialist states* and all the remained countries are be selected as the *colonies* of these imperialists; after that initial colonies of population will be partitioned among the assigned imperialists based on their power which is inversely proportional to their cost.

Afterwards, these colonies start moving into their relevant imperialist country. This movement is an easy model of *assimilation* policy that was survey by some imperialist states [19]. Figure 1 shows the colony movement into the imperialist.

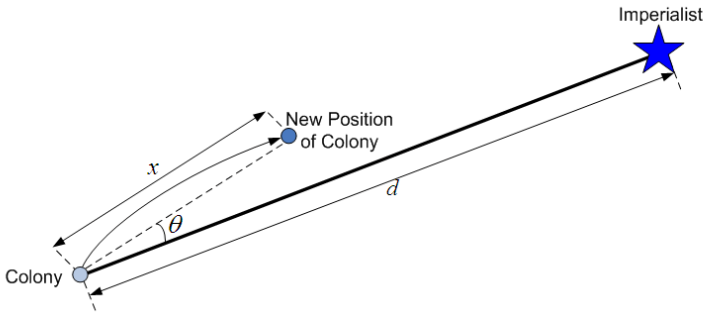

Figure 1. Motion of colonies toward their relevant imperialist.

θ and x are random numbers with equal distribution and d is the distance between colony and the imperialist.

$$x \approx \grave{U}(0, \beta_1 \times d) \tag{14}$$

$$\theta \approx U(-\gamma, \gamma) \tag{15}$$

Where β_1 is a positive number less than 2, d is the region between the imperialist and its colony and γ is the derivation from original direction;Figure 2 shows that if this movement makes to find a colony with better situation (lower cost) rather than it's imperialist, the position of the colony and imperialist will be changed together.

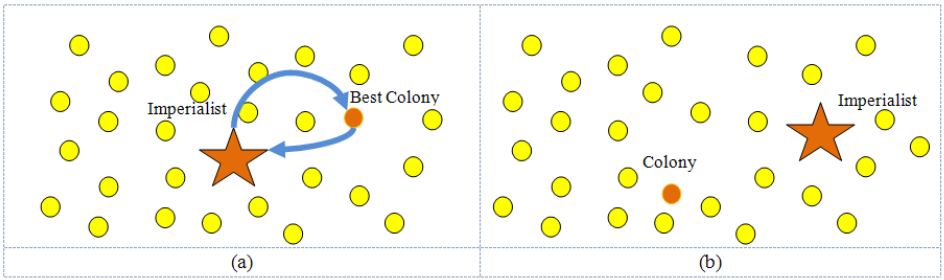

Figure 2. (a) Imperialist and colony position change, (b) Total empire after applying changes

The whole power of an empire belongs to the power of the imperialist country and colonies one which is illustrated as below:

$$P_t = P_{im} + emean\ \{power(colonies)\}, \tag{16}$$

Where P_{im} is the imperialist power and e is a positive number less than 1. In this situation, weak empires which cannot compete, develop their power and even if cannot hold diminution of its power will be collapsed.

Imperialistic competition and the motion of colonies into their relevant imperialist will anticipant form a new world with one empire that all countries from the colonies to the imperialist are the identity in both position and power. In this set, the imperialist comprises an array of variables which is an optimal eliminating the problem.

7 ICA procedure

In order to determine the best locations and sizes of the DGs, the ICA-based approach has been suggested. The major steps of the proposed algorithm are:

Step 1. Input data and maximum number of iteration (I_{max}).

Step 2. Generate initial countries. Countries consist of two parts, the first is the optimal location of DG and the second is the optimal sizing. Results for first parts are integers and for second parts are continuous variables.

Step 3. Create the primary empires and set the iteration counter I=0.

Step 4. Apply the assimilation policy. If one of the colonies reaches to a better position, change the position of colony and imperialist.

Step 5. Select one colony from weakest empire. The more powerful empires have the more chance to get colony.

Step 6. Stop if only one empire exists or $I=I_{max}$, otherwise I=I+1 and go to 4.

8 Numerical results

The distribution test system is the 33 bus system [20]. The 33 bus radial distribution system has a total load of 3.715 MW, 2.3MVAR and base voltage is 12.66kv. The total active and reactive power losses are 202.4 kW and 135.1 kVAR, respectively. The single line diagram of the 33 bus test system is shown in Figure 3. This paper uses ICA for solving the problems of optimal sitting and sizing of DGs. For ICA parameters, countries size=100, imperialists size=10, number of Iteration=100, revolution rate=0.2, and assimilation coefficient=2. In the PSO algorithm, population size=80, the positive constants are C_1 =2 and C_2=2, the weighted inertia is w=0.9 [22]. The bus voltage is limited to 0.9 and 1 per unit; real power generation and reactive power generation are limited to 0.05 and 5MVAR. In order to magnify the role of each objective, related weighting coefficient (α, β) can change. The obtained result with ICA is compared with PSO algorithm. Tables 1–3 present optimal DGs locations and sizes of each method in 33 bus radial distribution system for different value of λ. Where

$$\lambda = \frac{\alpha}{\beta} \tag{18}$$

After DG installation, the voltage profile is improved and an active power loss is also reduced.Comparison of active power losses reduction for three types of DGs (DG number=3) for different value of λ is shown in Figure 4. Comparison of

voltage profile for three types of DGs is also shown in Figure 5. Loss reduction and improvement in voltage profile show the acceptable efficiency of proposed algorithm compared with PSO algorithm.

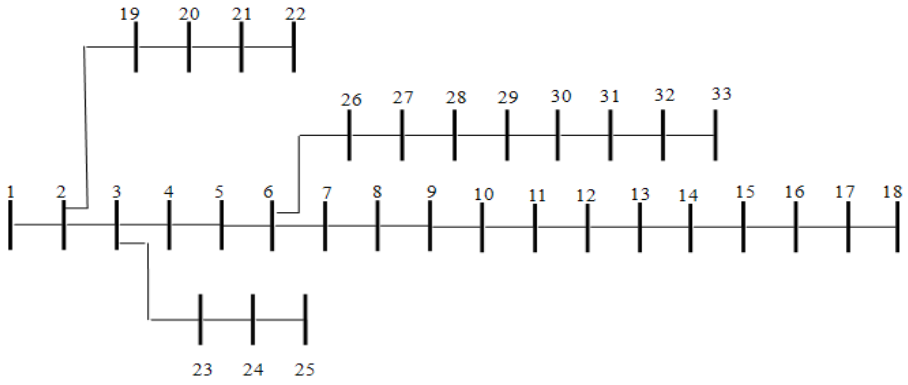

Figure 3. 33 Bus Radial Distribution System

Table 1. Optimal DG placement with DG supplying real power (Type 1)

λ	Algorithm	Bus number	DG size (MW)	Bus number	DG size (MW)	Bus number	DG size (MW)	VP (P. u.)	Ploss (KW)	Qloss (KVAR)	%Active Loss reduction	%Reactive Loss reduction
10	ICA	6	3.65512					0.48746	119.300	86.1134	41.0568	36.2595
	PSO	6	3.65812					0.48660	119.386	86.1721	41.0144	36.2160
	ICA	13	1.22392	29	1.6958			0.23791	103.910	73.2142	48.6609	45.8073
	PSO	26	2.66381	14	0.8654			0.24445	107.151	75.1979	47.0593	44.3390
	ICA	14	0.8675	31	0.9176	6	1.7710	0.14593	94.6719	66.4752	53.2253	50.7955
	PSO	6	2.25901	15	0.686151	32	0.77463	0.15404	96.9388	68.0200	52.1053	49.6520
20	ICA	6	3.16265					0.64105	108.352	78.4924	46.4663	41.9004
	PSO	6	3.16261					0.64106	108.351	78.4920	46.4666	41.9008
	ICA	13	1.09833	30	1.3747			0.41234	91.4493	63.2860	54.8175	53.1561
	PSO	30	1.18000	10	1.5828			0.34313	97.3983	67.6788	51.8783	49.9046
	ICA	13	1.03373	24	1.2106	30	1.2630	0.34468	77.2368	53.6350	61.8395	60.2997
	PSO	10	0.99595	24	1.5853	7	1.1184	0.56921	88.5512	65.3293	56.2493	51.6437
50	ICA	6	2.80955					0.75353	104.417	75.5439	48.4104	44.0829
	PSO	6	2.79146					0.75933	104.305	75.4507	48.4655	44.1519
	ICA	30	1.18677	12	1.0868			0.55533	86.6040	59.3124	57.2114	56.0973
	PSO	30	1.32084	13	0.9338			0.52843	87.2017	60.1208	56.9161	55.499
	ICA	30	1.15552	14	0.8471	24	1.1470	0.48983	72.1473	50.2742	64.3540	62.7873
	PSO	15	0.89341	30	1.1578	24	1.3822	0.42051	75.3909	52.9267	62.7515	60.8240

Table 2. Optimal DG placement with DG supplying reactive power (Type 2)

λ	Algorithm	Bus number	DG size (MVAR)	Bus number	DG size (MVAR)	Bus number	DGsize (MVAR)	VP (P. u.)	Ploss (KW)	Qloss (KVAR)	%Active Loss reduction	%Reactive Loss reduction
10	ICA	30	1.6443					1.2101	148.603	100.828	26.5792	25.3673
	PSO	30	1.6560					1.2069	148.923	101.076	26.4211	25.1843
	ICA	14	0.7009	30	1.3569			0.9806	145.812	98.7243	27.9581	26.9250
	PSO	7	1.6148	33	0.7840			1.0209	147.840	104.976	26.9561	22.2972
	ICA	14	0.5230	30	1.1020	7	0.7726	0.9316	142.734	98.0214	29.4788	27.4452
	PSO	26	0.7869	17	0.4931	30	1.0444	0.9704	144.296	98.1545	28.7071	27.3467
20	ICA	30	1.4504					1.2628	144.655	97.6799	28.5300	27.6980
	PSO	30	1.4489					1.2633	144.634	97.6622	28.5404	27.7111
	ICA	14	0.5452	30	1.2249			1.0820	138.232	92.9685	31.7032	31.1853
	PSO	17	0.4812	30	1.2653			1.0789	140.863	95.8569	30.4035	29.0474
	ICA	30	0.9674	7	0.7864	14	0.3906	1.0211	136.27	92.8649	32.6729	31.2620
	PSO	17	0.3208	30	1.4605	23	0.5607	1.0669	139.605	94.5179	31.0249	30.0385
50	ICA	30	1.3322					1.2956	143.51	96.6427	29.0958	28.4657
	PSO	30	1.3305					1.2961	143.500	96.6324	29.1007	28.4734
	ICA	11	0.5673	30	1.0973			1.1492	135.877	90.9136	32.8670	32.7063
	PSO	7	0.9427	30	0.9799			1.1517	136.877	92.0492	32.3729	31.8658
	ICA	24	0.5672	14	0.4248	30	1.0952	1.1306	132.339	88.7496	34.6151	34.3081
	PSO	30	0.6134	14	0.3430	26	1.0812	1.1148	136.654	91.7806	32.4830	32.0646

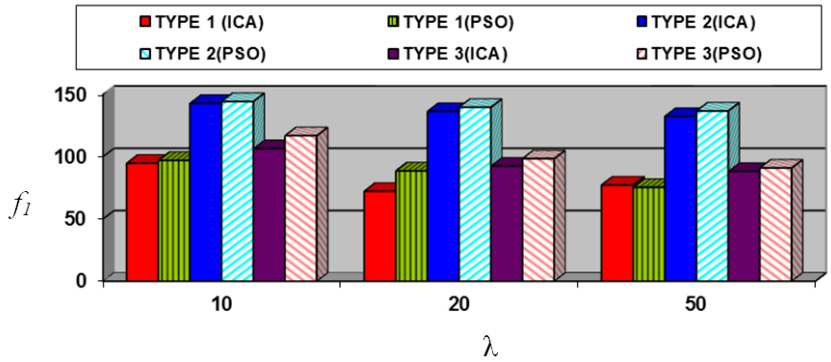

Figure 4. Comparison of active power losses for tree types of DGs (DG number=3)

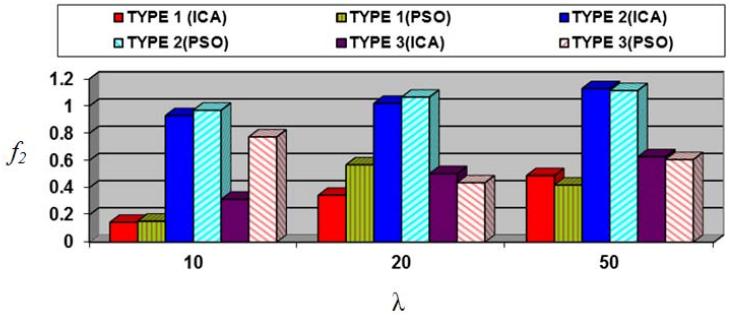

Figure 5. Comparison of voltage profile for tree types of DGs (DG number=3)

Table 3. Optimal DG placement with DG supplying real power and absorbing reactive power (Type 3)

λ	Algorithm	Bus number	DG size (MW) (MVAR)	Bus number	DG size (MW) (MVAR)	Bus number	DG size (MW) (MVAR)	VP (P. u.)	Ploss (KW)	Qloss (KVAR)	%Active Loss reduction	%Reactive Loss reduction
10	ICA	6	3.0273 -0.4166					0.7741	129.421	91.6387	36.0584	32.1696
	PSO	6	3.0269 -0.4165					0.7742	129.410	91.6316	36.0620	32.1749
	ICA	29	1.4925 -0.1391	13	1.2403 -0.1115			0.3934	118.623	82.5158	41.3914	38.9224
	PSO	13	1.2849 -0.1160	29	1.4827 -0.1379			0.3741	120.651	83.9096	40.3894	37.8906
	ICA	30	1.3128 -0.1189	13	1.1985 -0.1074	24	1.264703 -0.11397	0.3158	106.41	73.1401	47.4231	45.8622
	PSO	16	0.8353 -0.0779	6	1.7425 -0.1714	33	0.840023 -0.07822	0.7740	116.76	82.6740	42.3088	38.8052
20	ICA	6	2.6396 -0.3287					0.8795	121.563	86.1766	39.9388	36.2127
	PSO	6	2.6377 -0.3283					0.8800	121.53	86.1580	39.9516	36.2264
	ICA	30	1.2355 -0.1111	13	1.0472 -0.0938			0.5737	105.16	72.1437	48.0389	46.5997
	PSO	13	1.1440 -0.1023	30	1.1985 -0.1074			0.5365	107.461	73.7135	46.9063	45.4377
	ICA	13	0.9891 -0.0891	30	1.1420 -0.1021	24	1.153643 -0.10323	0.5045	92.3195	63.4759	54.3875	53.0155
	PSO	12	1.3207 -0.1197	30	1.0026 -0.0902	24	1.250963 -0.11259	0.4367	98.3813	66.8776	51.3926	50.4976
50	ICA	6	2.3936 -0.2792					0.9485	119.159	84.3661	41.1267	37.5527
	PSO	6	2.3961 -0.2796					0.9478	119.173	84.3779	41.1197	37.5440
	ICA	12	1.03744 -0.0931	30	1.0829 -0.0969			0.69114	101.076	68.8024	50.0610	49.0729
	PSO	14	0.8834 -0.0812	30	1.2837 -0.1159			0.6316	103.358	71.1981	48.9337	47.2996
	ICA	24	1.0682 -0.0957	13	0.8671 -0.0800	30	1.021725 -0.09175	0.6285	88.0783	60.4964	56.4830	55.2209
	PSO	14	0.8185 -0.0768	24	1.4053 -0.1290	31	0.974773 -0.08800	0.6070	90.8400	63.0638	55.1185	53.3206

9 Conclusion

In this paper, an Imperialist Competitive Algorithm (ICA) is used for optimal placement and sizing of DGs in order to decreasing radial distribution system losses and improving voltage profile. Test results indicate that ICA method can obtain better results than the PSO method on the 33-bus radial distribution systems. It is also seen that optimal placement and sizing of multiple DGs are more beneficial than the placement of a single DG so that three DGs gives the results with higher quality. The role of each objective was magnified by changing the value of λ. The analysis shows that the real power losses can be reduced by increasing the value of λ and voltage profile improvement is obtained by decreasing the value of λ. The other benefits of DGs as well as economics of it can be considered in future research work.

References

[1] Ackermann T, Andersson G.Distributed generation: A definition.Electric Power Systems Research. 2001; 57(3): 195-204. http://dx.doi.org/10.1016/S0378-7796(01)00101-8

[2] Wang MHNehrir, Analytical approaches for optimal placement of distributed generation sources in power systems, IEEE Trans. Power Syst. 2004; 4: 2068-2076. http://dx.doi.org/10.1109/TPWRS.2004.836189

[3] Haesen E, Espinoza M. Optimal placement and sizing of distributed generator units using genetic optimization algorithms. Electr Power QualUtil J. 2006; 11(1).

[4] Nara K, Hayashi Y, Ikeda K, Ashizawa T. Application of Tabu Search to optimal placement of distributed generators. In: Proc IEEE power engineering society winter meeting. 2001; 2: 918-23.

[5] M. Sedighizadeh, A. Rezazadeh. Using genetic algorithm for distributed generation allocation to reduce losses and improve voltage profile, Eng. Technol. 2008; 37: 251-256.

[6] M. Sedighi, A. Igderi, Sitting and sizing of DG in distribution network to improve of several parameters by PSO algorithm, in: Proceedings of the International Conference on Mechanical and Electrical Technology. 2010; 533-538. http://dx.doi.org/10.1109/ICMET.2010.5598418

[7] Khalesi N, Rezaei N, Haghifam M-R. DG allocation with application of dynamic programming for loss reduction and reliability improvement. Int J Elect Power Energy Syst. 2011; 33(2): 288-95. http://dx.doi.org/10.1016/j.ijepes.2010.08.024

[8] M.P. Lalitha, V.C. Reddy, N.S. Reddy. Application of fuzzy and ABC algorithm for DG placement for minimum loss in radial distribution system, Iran. J. Electr. Electron. Eng. 2010; 4: 248-256.

[9] R.A. Jabr, B.C. Pal, Ordinal optimization approach for locating and sizing of distributed generation, IET generation, Transm. Distrib. 2009; 8: 713-723.

[10] A. Soroudi, M.Ehsan. A Heuristic Method for Distributed Generation Placement in Distribution Networks. 25th International Power System Conference. 2010.

[11] X.Q. Ding, J.H. Wu, F. Zhao. Optimal location and capacity of distributed generation based on scenario probability, in: Proceedings of the International Conference on Sustainable Power Generation and Supply. Nanjing. 2009; 1-5. http://dx.doi.org/10.1109/SUPERGEN.2009.5348224

[12] Jen-HaoTeng.A Direct Approach for Distribution System Load Flow Solutions. 2003; 18(3): 882-887.

[13] W. Prommee, W. Ongsakul.Optimal multi-Distributed generation placement by Adaptive weight particle swarm optimization. International Conference on Control. Automation and Systems. 2008.

[14] Hawary, S.A.Soliman, M.A.Moustafa, M.M.Mansour.New Heuristic Strategies for Reactive Power Compensation of Radial Distribution Feeders. IEEE trans. Power Delivery. 2002; (17): 1128-1135.

[15] Y. Shi, R. C. Eberhart.Empirical Study of Particle Swarm Optimization. Proceedings IEEE. 1999; 1945-1950.

[16] H. Y. Fukuyama.Fundamentals of Particle Swarm Optimization Techniques. Chapter 5, pp. 1-5.

[17] The Hutchinson Dictionary of World History. Oxford: Helicon Publishing. 1999.

[18] M E. Atashpaz. Gargari, C. Lucas.Imperialist Competitive Algorithm: An Algorithm for Optimization Inspires by Imperialistic Competition. 2007 IEEE Congress on Evolutionary Computation. Singapore. 2007. http://dx.doi.org/10.1109/CEC.2007.4425083

[19] M. Jasour, E. Atashpaz, C. Lucas.Vehicle Fuzzy Controller Design Using Imperialist Competitive Algorithm. Second First Iranian Joint Congress on Fuzzy and Intelligent Systems. Tehran. Iran. 2008.

[20] M.A. Kashem, V. Ganapathy, G.B. Jasmon, M.I. Buhari.A Novel Method for Loss Minimization in Distribution Networks. proceeding of International Conference on Electric Utility Deregulation and Restructuring and Power Technologies. 2000; 251-255.

[21] M. Zarringhalami, S. M. Hakimi, M. Javadi. Optimal Regulation of STATCOM Controllers and PSS Parameters Using Hybrid Particle Swarm Optimization. IEEE conference. 2010.

[22] S. Panda, N. Padhy.Comparison of particle swarm optimization and Genetic Algorithm for FACTS-based controller design. International journal of Applied Soft Computing. 2008; 1418-1427.

[23] Kim. T, H. Maruta, I. Sugie. Robust PID controller tuning based on the constrained particle swarm optimization, Automatics. 2008; 44 (4): 1104-1110. http://dx.doi.org/10.1016/j.automatica.2007.08.017