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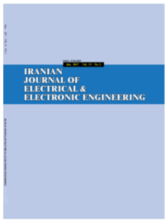

Optimal Placement and Sizing of Multiple Renewable Distributed Generation Units Considering Load Variations Via Dragonfly Optimization Algorithm

A. Boukaroura*, L. Slimani**, and T. Bouktir**(C.A.)

Abstract: The progression towards smart grids, integrating renewable energy resources, has increased the integration of distributed generators (DGs) into power distribution networks. However, several economic and technical challenges can result from the unsuitable incorporation of DGs in existing distribution networks. Therefore, optimal placement and sizing of DGs are of paramount importance to improve the performance of distribution systems in terms of power loss reduction, voltage profile, and voltage stability enhancement. This paper proposes a methodology based on Dragonfly Optimization Algorithm (DA) for optimal allocation and sizing of DG units in distribution networks to minimize power losses considering variations of load demand profile. Load variations are represented as lower and upper bounds around base levels. Efficiency of the proposed method is demonstrated on IEEE 33-bus and IEEE 69-bus radial distribution test networks. The results show the performance of this method over other existing methods in the literature.

Keywords: Power Distribution Network, Renewable Distributed Generation, Load Variations, Dragonfly Algorithm, Power Losses, Cost of Energy Losses.

1 Introduction

INTEGRATION of Distributed Generations (DGs) in conventional distribution networks are the main milestones in forming smart grids. The integration of DGs in distribution networks is used for numerous objectives such as reducing power losses, improving the voltage profile along feeders and increasing the maximum transmitted power in cables and transformers [1]. The optimal location and sizing of DGs units is the key factor for obtaining the maximum possible benefits of these units [2].

Several interesting techniques and algorithms have been proposed for achieving the optimal placement and sizing of single and multiple types of DGs sources [3-8]. In [3], GA based method has been proposed to investigate the problem of locating and sizing DG units in low voltage networks for service restoration under cold load pickup. In [4] an improved analytical-based approach is proposed to find the best location for different types of renewable DG sources. In [5], Particle Swarm Optimization (PSO) algorithm has been presented to seek the optimal size and location of multiple DGs in power distribution network to minimize the real power loss. Authors of [6] examined the effectiveness of the Artificial Bee Colony (ABC) optimization algorithm in the optimal placement of multiple DG units. The objective was the minimization of the real power loss and the improvement of voltage profiles of distribution systems. In [7], Harmony Search Algorithm (HSA) is proposed to minimize the real power losses and enhance the voltage profile of the radial distribution network with optimally locating multiple DGs in the system. In [8], the authors used Stud Krill Herd Algorithm (SKHA) for solving the problem of DG location and sizing in order to obtain

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minimum real power losses.

In recent years, there is a noticeable increase in the number of developed optimization algorithms inspired by diverse behavioral rules. The application of new algorithms in optimal allocation of DGs is motivated by the “No Free Lunch” theorem which states that there is no one optimization technique that works best for all optimization problems. Dragonfly Algorithm (DA) [9] is becoming very attractive for researchers and has effectively applied for solving different optimization problems. In this paper, the DA algorithm is used to solve the problem of optimal placing and sizing of single and multiple DGs in radial distribution networks. The main objective is to minimize the real power losses in the distribution networks. The DA method is examined on IEEE 33-bus and IEEE 69-bus test systems at various load levels to prove their validity and performance. The results show the efficiency of the proposed technique in minimizing the total losses as well as in improving voltage profiles.

This paper is organized in the following manner. The mathematical problem for optimal allocation of DGs is formulated in Section 2. Section 3 presents the general overview of the DA optimization method and the proposed methodology for optimum DGs placement and sizing. The numerical results and a detailed discussion are presented in Section 4. Finally, conclusions based on the obtained results are presented in Section 5.

2 Problem Formulation

The main objective behind the optimal location and sizing of DG in distribution network is to minimize the active power losses. The placement and sizing are determined from the solution of load flow equations in amalgamation with an optimization method to minimize the total active power losses in the system. In this study, the load flow method is based on backward forward sweep and the model of DG units used is the photovoltaic systems or micro turbines in which the DGs supply active power with unity power factor. The objective function can be defined as in (1):

$$\min f = \min TP_{Loss} = \min \sum_{i=1}^{n} P_{Loss,i} \tag{1}$$

where, P_{loss} is power loss in each brunch; n is the number of branches.

Two types of constraints, which include equality and inequality constraints, are considered in the optimization problem. The nonlinear recursive load flow equations. related to active and reactive power flow in all the lines of distribution network serve as the equality constraints. Load bus voltage magnitude limits and DGs capacity limits as the inequality constraints.

2.1 Equality Constraints

The power flow equations are defined as equality constraints in the optimal allocation of DGs problem. The mathematical model is given by [10]:

$$P_{G,i} - P_{l,i} = |V_i| \sum_{j=1}^{N_{bus}} |Y_{ij}||V_j| \cos\left(\delta_i - \delta_j - \theta_{ij}\right) \tag{2}$$

$$Q_{G,i} - Q_{l,i} = |V_i| \sum_{j=1}^{N_{bus}} |Y_{ij}||V_j| \sin\left(\delta_i - \delta_j - \theta_{ij}\right) \tag{3}$$

where $P_{G,i}$ is the active power output of the generator at bus I, $P_{L,i}$ is the active power of load at bus i, $Q_{G,i}$ is the reactive power output of the generator at bus i, $Q_{L,i}$ is the reactive power of load at bus i, and Y_{ij} and θ_{ij} are the modulus and angle of i-th element in the admittance matrix of the system related to bus i and bus j, respectively.

2.2 Inequality Constraints

The inequality constraints subjected to DG setting and sizing problems include [11]:

- Bus voltage:

$$V_{\min} \le |V_i| \le V_{\max} \quad i = 1, 2, ..., N_{bus} \tag{4}$$

where V_{min} and V_{max} are taken as 0.95 and 1.05 (p.u), respectively.

- Branch current:

$$I_i \le I_{i\max} \quad i = 1, 2, ..., N_{br} \tag{5}$$

- Size of DG:

$$P_{DG}^{\min} \le |P_{DGi}| \le P_{DG}^{\max} \tag{6}$$

- Position of DG:

$$2 \le |DG_{bus}| \le N_{bus} \tag{7}$$

where N_{bus} is the total number of buses, DG_{bus} is the bus number of the DG installation, V_i is the bus voltage, I_i is the current of the DG at branch i, P_{DG} is the total power of DG, N_{br} is the total number of branches.

The annual cost of energy losses can be calculated using the following equation [12]:

$$C_{Loss} = TP_{Loss} \times \left(K_p + K_e + L_{sf} \times 8760\right) \$ \tag{8}$$

where, K_p is annual demand cost of power loss ($/kW); K_e is the annual cost of energy loss ($/kWh); L_{sf} is the loss factor is expressed as:

$$L_{sf} = k \times L_f + (1 - k) \times L_f^2 \tag{9}$$

In this work, $k = 0.2$; $L_f = 0.47$; $K_p = 57.6923$ $/kW; $K_e = 0.00961538$ $/kWh [12].

3 Methodology

3.1 Dragonfly Optimization Algorithm

Dragonfly Algorithm (DA) was first developed by Mirjalili in 2015 [9]. It mimetic the demeanor of dragonfly insects in nature. Generally, the dragonfly groups are both dynamic and static in the nature. The dynamic groups or the so-called migratory swarms form as large groups fly in a single path and travel for long distance as shown in Fig. 1. Static swarms in which the dragonfly insects hunting prey, through this procedure, dragonflies fly in small groups commonly around a well-defined small area and close to the land as shown in Fig. 2. By nature, each individual in the group attract to the nutrition sources and distract outward scamper. From these two behaviors that the DA algorithm is derived.

The location updating of each individual is mathematically explicated as follows [14].

Separation (S): In this step, the groups are detached from other individuals to avoid the collision with their neighbors.

$$S_i = \sum_{j=1}^{n} X - X_j \tag{10}$$

where X and X_j are the locations of the current individual and the jth neighboring individual, respectively. n is the number of neighboring.

Alignment (A): In this step, the speed of each individual is coincided with the other. The alignment is given by Eq. (11).

$$A_i = \frac{\sum_{j=1}^{n} V_j}{n} - X \tag{11}$$

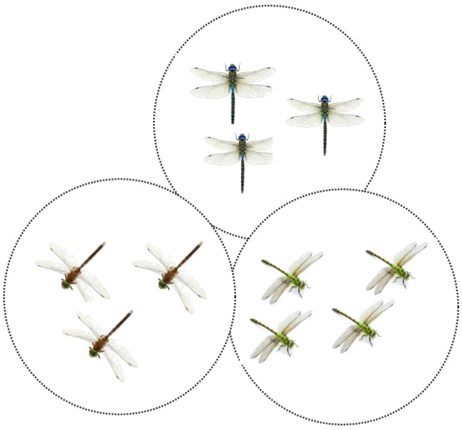

Fig. 1 Dynamic dragonfly swarms [13].

Fig. 2 Static dragonfly swarms [13].

where V_j is the speed of neighboring individual j.

Cohesion (C): Denotes the attraction of the individuals towards the center of the swarm's group:

$$C_i = \frac{\sum_{j=1}^{n} X_j}{n} - X \tag{12}$$

Attraction towards nutrition source (F): This step is represented by:

$$F_i = X^{+} - X \tag{13}$$

where X^+ denotes the position of the nutrition source.

Distraction outwards a scamper (E): is computed using (14):

$$E_i = X^{-} - X \tag{14}$$

where X^- shows the position of the scamper.

The position of each individual is updated based on step vector ΔX calculated using the following equation.

$$\Delta X_i = \left(sS_i + aA_i + cC_i + fF_i + eE_i\right) + w\,\Delta X_t \tag{15}$$

where s, a, and c represent, the separation, alignment, and cohesion weights, f and e are the food and the enemy factors, respectively, w is the inertia weight, and t is the iteration counter. The updated location vector is determined as follows.

$$X_{t+1} = X_t + \Delta X_{t+1} \tag{16}$$

In the case of no neighboring solutions established, dragonflies fly nearby the search space using arbitrary walk, or Lévy flight [9], to improve their arbitrariness, stochasticity, and exploration. They update their position based on the following equation [9]:

$$X_{t+1} = X_t + Lévy\left(d\right) \times X_t \tag{17}$$

where t is the current iteration and d is the dimension of the search space. Lévy flight is given by [14]:

$$Lévy\left(x\right) = 0.01 \times \frac{r_1 \times \sigma}{\left|r_2\right|^{\frac{1}{\beta}}} \tag{18}$$

where r_1 and r_2 are the arbitrary numbers in the range of [0, 1], β is a constant, and σ is given by (19).

$$\sigma - \left(\frac{\Gamma\left(1+\beta\right) \times \sin\left(\frac{\pi\beta}{2}\right)}{\Gamma\left(\frac{1+\beta}{2}\right) \times \beta \times 2\left(\frac{\beta-1}{2}\right)} \right)^{\frac{1}{\beta}} \tag{19}$$

where, $\Gamma(x) = (x\text{-}1)!$.

3.2 Proposed Algorithm for DGs Allocation

The DA method is more powerful and robust compared to other meta-heuristic techniques for solving non-convex and large scale optimization problems [15]. Therefore, it is applied in this work. The flowchart of the optimal allocation of DGs for power loss reduction using this technique is described in Fig. 3.

In this study, four cases are considered with different load levels (light load (50 %), medium load (100 %) and peak load (150 %)):

Case 1: Active power losses are computed before the consideration of DGs.

Case 2: Single DG is to be allocated optimally in the test systems.

Case 3: Two DGs are to be placed and sized optimally in the distribution networks.

Case 4: Three DGs are to be sited and sized optimally in the test systems.

In all cases, parameters of DA have been taken as follows: Population size = 100, maximum number of iteration = 200 and the limits of DGs capacities are as follows: for light load (50%) 0.01 MW ≤ DG size ≤ 1.5 MW, for medium load (100%) 0.01 MW ≤ DG size ≤ 3 MW and for peak load (150%) 0.01 MW ≤ DG size ≤ 4.5 MW.

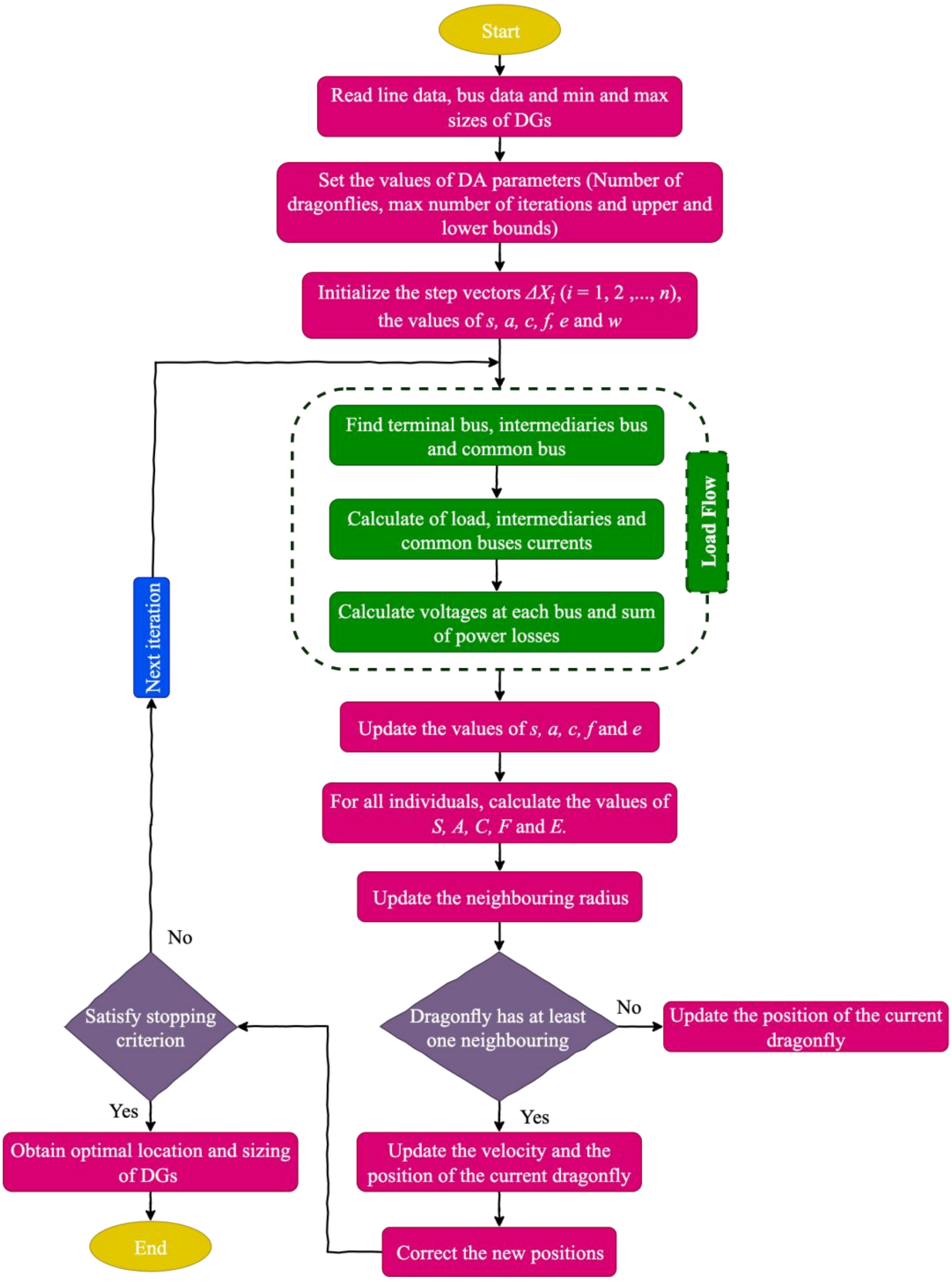

Fig. 3 Flowchart of optimal allocation of DGs using the DA algorithm.

4 Tests and Results

The IEEE 33-bus and IEEE 69-bus radial distribution networks are used as test systems to demonstrate the performance and robustness of the proposed methodology.

4.1 IEEE 33-Bus Test System

The first is the IEEE 33-bus standard test radial distribution system. It consists of 33 buses, 32 branches along with a total load of 3.72MW and 2.30MVAr. The substation voltage is 12.66kV. The single line diagram of the IEEE 33-bus system is shown in Fig. 4 and the overall data of this system is available in [16].

The DA optimization algorithm is used to identify the optimum location and sizing of DGs for the four simulated cases. Figs. 5, 6, and 7 show, respectively, the DA convergence characteristics based load levels (50%, 100% and 150%) for one, two and three DGs integrated into the IEEE 33-bus radial distributed network.

Figs. 8, 9, and 10 show the voltage profile under different load levels. From these figures, it is clear that the voltage profiles are improved after the integration of DGs. It can be seen also that the load decrease has a positive effect on the voltage profile. On the other hand, as the load is increased, the voltage profile is enhanced. The worst voltage profile is experienced by 50% increase the minimum magnitude of the voltage is at bus 18. In this case, the best profile is obtained with the integration of two or three DGs.

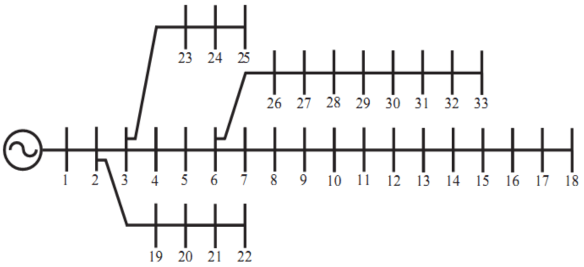

Fig. 4 Single line diagram of the IEEE 33-bus distribution network.

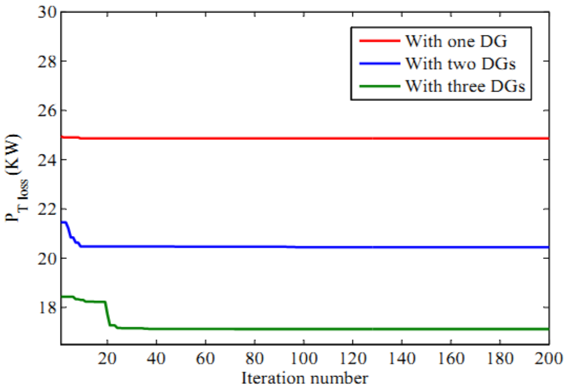

Fig. 5 DA convergence characteristics for the IEEE 33-bus system with load decreased by 50 %.

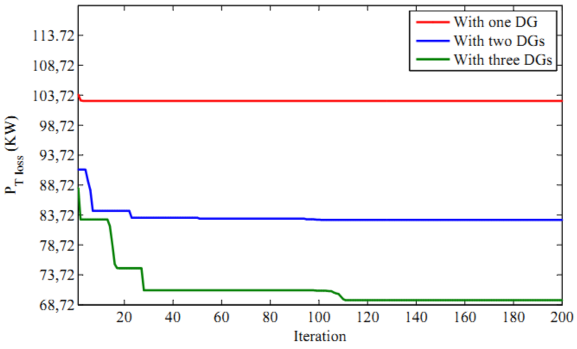

Fig. 6 DA convergence characteristics for the IEEE 33-bus system in the base case.

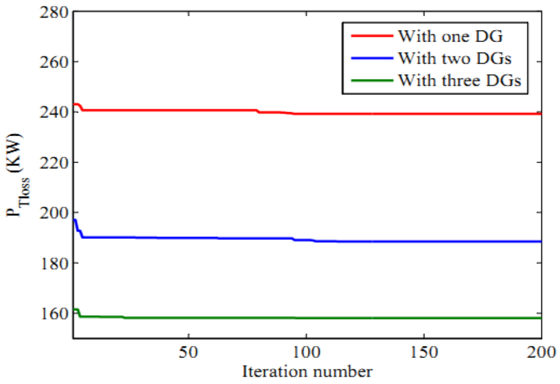

Fig. 7 DA convergence characteristics for the IEEE 33-bus system with load increased by 50 %.

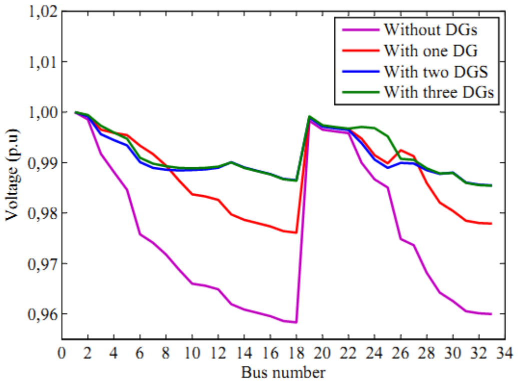

Fig. 8 Voltage magnitude of the IEEE 33-bus system with load decreased by 50 %.

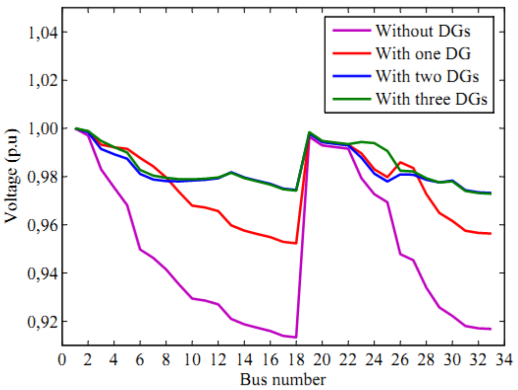

Fig. 9 Voltage magnitude of the IEEE 33-bus system in the base case.

The optimal location of DGs, DGs sizes, real power losses, and cost energy losses under different loading levels (50%, 100%, and 150%) are shown in Tables 1, 2, and 3. Before integrating any DG, the active power loss was 201.89 kW. In the second case, the DA algorithm gives the optimum location of one DG at the 6th bus. It can be observed also as with the use of one DG; the real power loss of the system is reduced for deferent load levels. It can be inferred from the Table 2 (base case) that the proposed method yields less loss reduction in comparison to the solutions obtained by improved analytical (IA) method [4], Sensitivity Approaches (SA) [12], Particle Swarm Optimization (PSO) [5], Artificial Bee Colony algorithm (ABC) [6], Harmony Search Algorithm (HSA) [7] and Stud Krill Herd Algorithm (SKHA) [8].

The optimal DGs locations obtained by DA algorithm for deferent load levels are the buses 13 and 30 for the case 3 and 14, 30, and 24 for the case 4. Lowest real power losses are achieved by the DA algorithm as compared to other optimization algorithms (see Tables 1, 2, and 3).

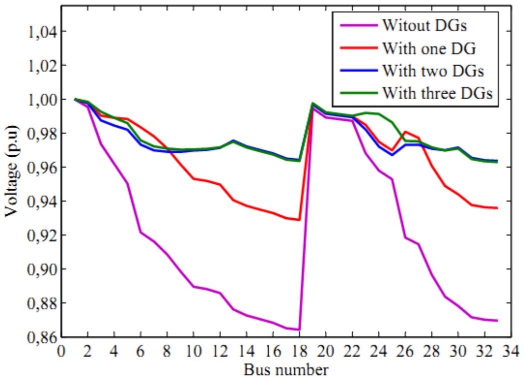

Fig. 10 Voltage magnitude of the IEEE 33-bus system with load increased by 50 %.

Table 1 Cases 1 to 4 results of the IEEE 33-bus system with load decreased by 50 %.

Simulation case	Optimal location (bus number)	DG size [MW]	Total capacity added [MW]	Power loss [kW]	Loss reduction [%]	Cost of energy losses [$]
Case 1: No DG	-	-	-	47.00	00.00	3780.21
Case 2: One DG	6	1.25	1.25	24.86	47.09	1999.49
Case 3: Two DGs	13 30	0.42 0.57	0.99	20.45	56.49	1644.79
Case 4: Three DGs	14 24 30	0.37 0.53 0.53	1.43	17.10	63.59	1375.35

Table 2 Cases 1 to 4 results of the IEEE 33-bus system in the base case.

Simulation case	Method	Optimal location (bus number)	DG size [MW]	Total capacity added [MW]	Power loss [kW]	Loss reduction [%]	Cost of energy losses [$]
Case 1 : No DG	-	-	-	-	201.89	0.00	16238.01
Case 2 : One DG	DA	6	2.58	2.58	102.78	49.08	8266.59
	IA [4]	6	2.60	2.60	111.10	47.39	8935.77
	SA [12]	6	2.49	2.49	111.14	47.32	8938.99
	PSO [5]	6	2.59	2.59	111.03	47.38	8930.14
	ABC [6]	6	2.57	2.57	105.02	48.49	8446.75
	HSA [7]	6	2.59	2.59	111.00	47.39	8927.73
	SKHA [8]	6	2.59	2.59	111.01	47.38	8928.53
Case 3: Two DGs	DA	13 30	0.85 1.19	2.04	82.89	58.94	6666.84
	IA [4]	13 30	0.85 1.19	2.04	91.63	56.61	7369.80
	PSO [5]	13 30	0.85 1.16	2.01	87.17	58.69	7011.08
	ABC [6]	6 15	1.97 0.57	2.54	89.96	55.88	7235.48
	HAS [7]	6 15	1.69 0.71	2.40	91.54	56.61	7362.56
	SKHA [8]	13 30	0.85 1.15	2.00	87.16	58.68	7010.27
Case 4: Three DGs	DA	14 24 30	0.76 1.07 1.10	2.93	69.38	65.63	5580.23
	IA [4]	6 12 31	0.90 0.90 0.72	2.52	81.05	61.62	6518.85
	PSO [5]	14 24 30	0.77 1.09 1.07	2.93	72.79	65.50	5854.49
	ABC [6]	6 15 25	1.75 0.57 0.78	3.10	79.25	61.13	6374.07
	HAS [7]	6 15 33	1.54 0.56 0.33	2.43	79.69	62.23	6409.46
	SKHA [8]	13 24 30	0.80 1.09 1.05	2.94	72.78	65.50	5853.69

4.2 IEEE 69-Bus System

The second is the IEEE 69-bus test system [17] illustrated in Fig. 11. It contains 69 buses and 68 lines with a total load of 3.80MW and 2.69MVAr.

The DA convergence characteristics and the voltage profiles for various case studies are shown in Figs. 12 to 17. Tables 4 to 6 illustrate the comparison of the fond optimal results using DA algorithm with IA [4], PSO [5], HAS [7], SKHA [8] and SA [12].

Table 3 Cases 1 to 4 results of the IEEE 33-bus system with load increased by 50 %.

Simulation case	Optimal location (bus number)	DG size [MW]	Total capacity added [MW]	Power loss [kW]	Loss reduction [%]	Cost of energy losses [$]
Case 1 : No DG	-	-	-	492.87	00.00	39641.53
Case 2 : One DG	6	4.01	4.01	239.22	51.46	19240.46
Case 3: Two DGs	13 30	1.29 1.84	3.13	188.53	61.74	15163.46
Case 4: Three DGs	14 24 30	1.15 1.60 1.70	4.45	157.84	67.97	12695.07

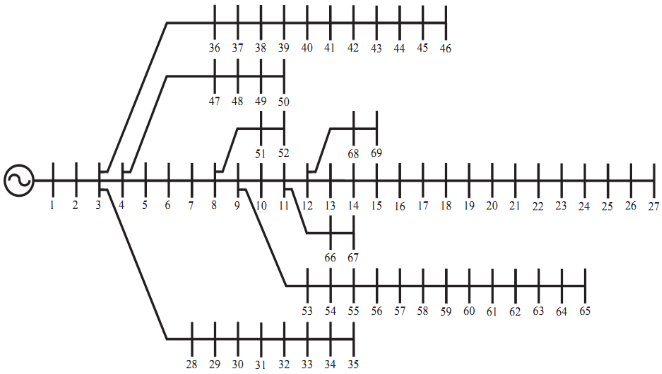

Fig. 11 Single line diagram of the IEEE 69-bus distribution network.

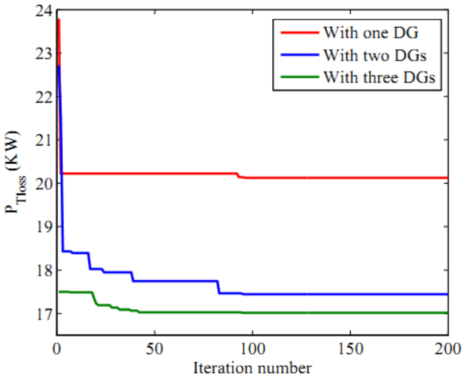

Fig. 12 DA convergence characteristics for the IEEE 69-bus system with load decreased by 50 %.

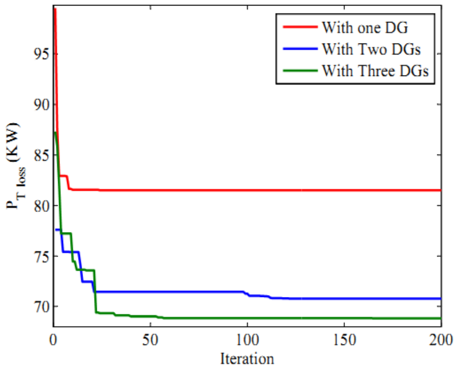

Fig. 13 DA convergence characteristics for the IEEE 69-bus system in the base case.

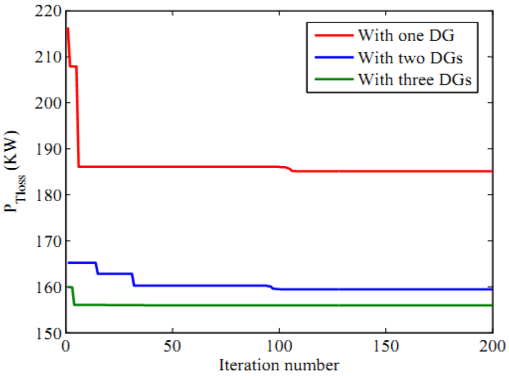

Fig. 14 DA convergence characteristics for the IEEE 69-bus system with load increased by 50 %.

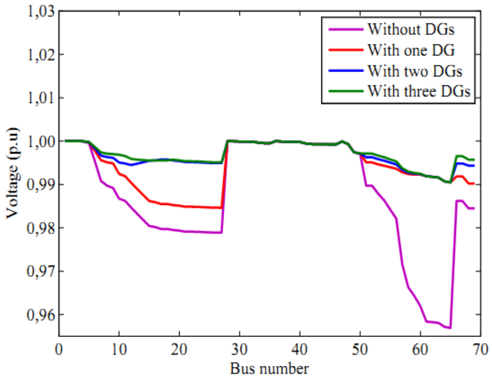

Fig. 15 Voltage magnitude of the IEEE 69-bus system with load decreased by 50 %.

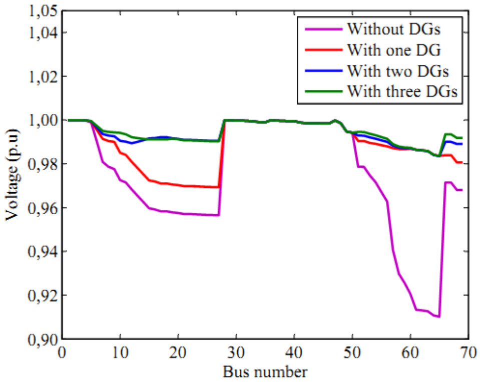

Fig. 16 Voltage magnitude of the IEEE 69-bus system in the base case.

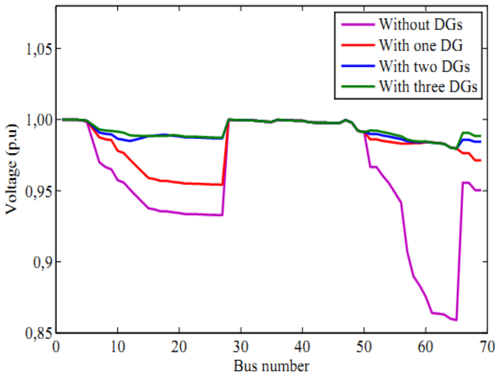

Fig. 17 Voltage magnitude of the IEEE 69-bus system with load increased by 50 %.

Table 4 Cases 1 to 4 results of the IEEE 69-bus system with load decreased by 50 %.

Simulation case	Optimal location (bus number)	DG size [MW]	Total capacity added [MW]	Power loss [kW]	Loss reduction [%]	Cost of energy losses [$]
Case 1 : No DG	-	-	-	51.58	00.00	4148.57
Case 2 : One DG	61	0.92	0.92	20.12	60.99	1618.25
Case 3: Two DGs	17 61	0.26 0.88	1.14	17.44	66.18	1402.69
Case 4: Three DGs	11 19 61	0.25 0.18 0.85	1.28	16.98	67.07	1365.70

Table 5 Cases 1 to 4 results of the IEEE 69-bus system in the base case

Simulation case	Method	Optimal location (bus number)	DG size [MW]	Total capacity added [MW]	Power loss [kW]	Loss reduction [%]	Cost of energy losses [$]
Case 1 : No DG	-	-	-	-	224.55	00.00	18060.55
Case 2 : One DG	DA	61	1.88	1.88	81.50	63.70	6555.04
	IA [4]	61	1.90	1.90	81.33	62.91	6541.37
	SA [12]	61	1.83	1.83	83.19	63.00	6690.97
	PSO [5]	61	1.87	1.87	83.22	63.01	6693.38
	HSA [7]	63	1.79	1.79	86.97	61.17	6994.99
	SKHA [8]	61	1.86	1.86	81.60	62.99	6563.08
Case 3: Two DGs	DA	17 61	0.52 1.90	2.31	70.43	68.63	5664.68
	IA [4]	17 61	0.51 1.70	2.21	70.30	67.94	5654.22
	PSO [5]	17 61	1.87 0.53	2.31	71.68	68.14	5765.22
	HSA [7]	18 63	0.49 1.68	2.17	75.03	66.50	6034.66
	SKHA [8]	17 61	0.52 1.77	2.29	70.40	68.07	5662.27
Case 4: Three DGs	DA	11 19 61	0.49 0.37 1.76	2.62	68.68	69.38	5523.93
	IA [4]	11 17 61	0.34 0.51 1.70	2.55	68.38	68.82	5499.80
	PSO [5]	11 17 61	0.51 0.38 1.67	2.56	69.54	69.06	5593.10
	HSA [7]	18 61 63	0.52 1.45 0.29	2.26	71.58	68.04	5757.17
	SKHA [8]	11 17 61	0.52 0.37 1.71	2.60	68.15	69.09	5481.30

Table 6 Cases 1 to 4 results of the IEEE 69-bus system with load increased by 50 %.

Simulation case	Optimal location (bus number)	DG size [MW]	Total capacity added [MW]	Power loss [kW]	Loss reduction [%]	Cost of energy losses [$]
Case 1 : No DG	-	-	-	557.12	00.00	44809.16
Case 2 : One DG	61	2.88	2.88	185.12	66.77	14889.20
Case 3: Two DGs	17 61	0.79 2.74	3.53	159.41	71.38	12821.34
Case 4: Three DGs	11 19 61	0.71 0.57 2.66	3.94	155.60	72.07	12514.90

From Figs. 16 and 17 we can see that for the first case (without DGs) and for the 100% and 150% load levels the expected voltage values of the majority of the buses are below 0.95 p.u. For the purpose of enhancing this voltage profile, integration of DG units is one of the realistic and effective solutions. The results in these figures show how the integration of one, two, and three DGs affects the voltage profile of the system. The figures indicate that the results obtained by using three DGs are better. As seen in tables 4, 5, and 6 increasing the load significantly increases the real power losses of the network and vice versa.

The integration of DGs can benefit the power losses and the cost of energy losses. This benefit is depending on the number of DGs in the network. The integration of one DG in IEEE 69-bus can expect an annual cost saving of $11505.51. The expected annual saving increase with the increased number of DGs and it would be $12395.87 with two DGs and $12536.62 with three DGs. It can be seen also from these tables that, in all the case studies, the proposed method gives better results compared to other methods in the literature.

5 Conclusion

In this paper, optimal allocation of single and multiple DG units, in a radial distribution network, is determined through Dragonfly Optimization Algorithm (DA). The selection of the best DGs locations and size is formulated as an optimization problem where the objective is to minimize the real power losses in the network. To demonstrate the ability of the proposed method, it has been applied to the IEEE 33-bus and IEEE 69-bus system. The effect of load growth on the distribution system is presented. The results have been obtained for real power losses, voltage profile, cost of energy losses, the locations of DGs, and their sizes. The following conclusions can be drawn:

- The proposed method is appropriate for finding the optimal locations and sizing of DGs in a distribution network;
- The total real power losses and cost of energy losses are reduced with the optimal integration of DGs using DA algorithm;
- Numerical results show that the performance of the proposed method is superior to the other methods in the literature.

References

[1] R. Sirjani, A. Mohamed, and H. Shareef, “Heuristic optimization techniques to determine optimal capacitor placement and sizing in radial distribution networks: A Comprehensive Review,” *Przegląd Elektrotechniczny*, Vol. 7, No. 12, pp. 1–7, 2012.

[2] O. Amanifar and M. O. Hamedani Golshan, “Optimal distributed generation placement and sizing for loss and THD reduction and voltage profile improvement in distribution systems using particle swarm optimization and sensitivity analysis,” *International Journal on Technical and Physical Problems of Engineering*, Vol. 3, No. 2, pp. 47–53, 2011.

[3] V. Kumar, R. Kumar, I. Gupta, and H. O. Gupta. “DG integrated approach for service restoration under cold load pickup,” *IEEE Transaction Power Delivery*, Vol. 25, No. 1, pp. 398–406, 2010.

[4] D. Q. Hung, N. Mithulananthan, and R. C. Bansal, “Multiple distributed generators placement in primary distribution networks for loss reduction,” *IEEE Transaction on Industrial Electronics*, Vol. 60, No. 4, pp. 1700–1708, 2013.

[5] S. Kansal, V. Kumar and B. Tyagi, “Hybrid approach for optimal placement of multiple DGs of multiple types in distribution networks,” *International Journal of Electrical Power and Energy Systems*, 2016, Vol. 75, pp. 226–235, 2016.

[6] M. Padma Lalitha, N. Sinarami Reddy, and V. C. Veera Reddy, “Optimal DG placement for maximum loss reduction in radial distribution system using ABC algorithm,” *International Journal of Reviews in Computing*, Vol. 3, pp. 44–52, 2010.

[7] K. Srinivasa Rao and M. Nageswara Rao, “Multiple Distributed Generator Allocation by Harmony Search Algorithm for Loss Reduction,” in *International Conference on Emerging Trends in Electrical Engineering and Energy Management*, pp. 59–64, 2012.

[8] S. A. Chithra Devi, L. Lakshminarasimman, and R. Balamurugan, "Stud Krill herd Algorithm for multiple DG placement an sizing in a radial distribution system," *Engineering Science and Technology, an International Journal*, Vol. 20, No. 2, pp. 748–759, 2017.

[9] S. Mirjalili, "Dragonfly algorithm: A new meta-heuristic optimization technique for solving single-objective, discrete, and multi-objective problems," *Neural Computing and Applications*, Vol. 27, No. 4, pp. 1053–1073, 2015.

[10] M. Kefayat, A. Lashkar Ara, and S. A. Nabavi Niaki, "A hybrid of ant colony optimization and artificial bee colony algorithm for probabilistic optimal placement and sizing of distributed energy resources," *Energy Conversion and Management*, Vol. 92, pp. 149–161, 2015.

[11] T. P. Nguyen and D. N. Vo, "A novel stochastic fractal search algorithm for optimal allocation of distributed generators in radial distribution systems," *Applied Soft Computing*, Vol. 70, pp. 773–796, 2018.

[12] V. V. S. N. Murthy and A. Kumar, "Comparison of optimal DG allocation methods in radial distribution systems based on sensitivity approaches," *Electrical Power and Energy Systems*, Vol. 53, pp. 450–467, 2013.

[13] M. Amroune, T. Bouktir, and I. Musirin, "Power system voltage stability assessment using a hybrid approach combining dragonfly optimization algorithm and support vector regression," *Arabian Journal for Science and Engineering*, Vol. 43, 3023, 2018.

[14] R. Klages, G. Randos, and I. Sokolov, *Anomalous transport foundations and applications*. John Wiley & Sons, 2008.

[15] V. Suresh and S. Sreejith, "Generation dispatch of combined solar thermal systems using dragonfly algorithm," *Computing*, Vol. 99, No. 1, pp. 59–80, 2016.

[16] A. Khodabakhshian and M. H. Andishgar, "Simultaneous placement and sizing of DGs and shunt capacitors in distribution systems by using IMDE algorithm," *Electric Power and Energy Systems*, Vol. 82, pp. 599–607, 2016.

[17] M. E. Baran and F. F. Wu, "Network reconfiguration in distribution systems for loss reduction and load balancing," *IEEE Transaction on Power Delivery*, Vol. 4, No. 1, pp. 725–734, 1989.

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