Impact Of Distributed Generation On Unbalanced Radial Distribution System

G V K Murthy, CH V Suresh, K Sowjankumar, B Hanumantharao

Abstract: Now a day's, Distributed generators (DGs) penetration level is rapidly increasing pertaining to electricity market restructuring and environmental issues. DGs also playing a role of minimizing line losses in power system network; the sizing and placement of DG's should be done with utmost care to avail the maximum benefits. The inherent features of radial distribution network with large number of nodes and variable X/R ratio's out ruled the conventional techniques for DG's sizing and optimum placement. So, artificial bee colony method is presented in this paper to obtain the optimal location and sizing of DG with loss minimization. The proposed method is tested on 25-bus unbalanced radial distribution system and the results are compared with those of particle swarm optimization (PSO) and improved group search algorithm methods to show the superiority of proposed methodology.

Index Terms: Distributed generation, artificial bee colony algorithm, improved group search optimizer algorithm, loss reduction, unbalanced radial distribution network.

1 INTRODUCTION

AS a conventional energy resources are about to extinct, alternate sources for power generation are giving the high priority to meet the growing energy demand in near future. Usually DGs refers to power generation from a few KWs to hundreds of MWs. A volume of articles are available in literature for DG placement and sizing. There is no unanimity on exact description and definition of DG, there are many significant efforts made in the literature to define the concept [1,2]. In addition to the line loss minimization, there will be the improvement in system voltage profile and system reliability can be achieved by placing DGs in distribution system [3]. Unit price of renewable energy is high compared to the conventional one due to high capital investment. The environmental and social issues are not taken to account in the unit price of renewable energy generation. However, in the long run renewable energy unit price is more beneficiary compared to the traditional due to fuel prices, equipment depreciation and other factors. In [4] the optimal local and sizing of four DGs are done independently using Heuristic-curve fitted technique on 33-bus and 69-bus feeder systems. Author's in [5] concentrated on minimization of total power system losses in addition to optimal location and sizing of DG using artificial bee colony meta heuristic algorithm. A multi objective optimization problem consisting of minimization of generation cost, generation, losses, emissions and voltage deviations is considered and Honey bee mating optimization (HMBO) algorithm is implemented [6]. In [7], improved particle swarm optimization methodology is implemented for multiple DGs penetration considering optimal size as continuous optimization and location as discrete optimization problem. Harmony search algorithm, modified teaching learning based algorithm, PFDE algorithm for optimal placing of multiple DGs in power system network [8-10] respectively.

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Backtracking search algorithm, is implemented for multi type DGs integration in radial distribution system [11]. The loading capability of radial distribution system is improved by considering some technical aspects [12]. In [13] PSO algorithm is implemented to integrate the multiple DGs in radial distribution system to capitalize the annual income and savings. Big Bang-Big Crunch algorithm, Krill herd algorithm is implemented in [14-15] respectively. On careful literature survey, came to know that lot of work is concentration on optimal sizing and allocation of DGs in radial distribution system under balanced condition. This paper focuses on placing DGs in optimal location with optimal capacity or size using artificial bee colony optimization algorithm.

In the following sections, problem formulation is presented in Section2, particle swarm optimization, improved group search optimizer and artificial bee colony methods are explained in Section 3, results and discussions are presented in Section 4. Finally, the conclusion of the paper is summarized in Section 5.

2 PROBLEM FORMULATION

The power losses in a given distribution system can be minimized by placing DG in an optimal location with appropriate size. Sometime losses are increased as the DG size is increased. Hence, DG size is limited to within its boundary values. In this work, optimal placement of DG is identified by minimizing total real power losses. The objective function can be expressed as

Objective function: $$TPL = min \sum_{k=1}^{ln} \left| I_k \right|^2 R_k \quad (1)$$

Where TPL = Total system real power loss
Ik = Current flowing through the branch k
Rk = Resistance of branch k
ln = Total number of lines.

Subjected to following inequality constraints

i) The voltage magnitude at the system buses can be kept within ± 5% of the nominal value

$$V_{max}^{sys} \geq V_i^{sys} \geq V_{min}^{sys}$$

ii) The DG-unit size range is $S_{max}^{DG} \geq S_i^{DG}$

$$S_{max}^{DG} = 20\% \ of \ S_{load}$$

3 OPTIMIZATION METHODS

In this paper the optimization methods are proposed for loss reduction. The optimization methods i.e. Particle Swarm Optimization (PSO), Improved Group Search Optimizer (IGSO) and Artificial Bee Colony (ABC) methods are explained in detailed in the following sessions.

3.1 Particle Swarm Optimization (PSO) method

The basic Particle Swarm Optimization (PSO) algorithm works based on the random generation of control parameters. Based on the social behavior of bird flocking and fish schooling, Dr. Eberhart and Dr. Kennedy developed this algorithm. The complete details are used from [16].

3.2 Improved Group Search Optimizer (IGSO) method

In IGSO, the position of the fth member at the t iteration is defined $X_f^t \in R^n$ in l-dimensional space, X_{pd}^t denotes its position in the dth (d = 1,. . .,l) dimensional coordinate. The producer position update, the scroungers and the rangers are defined as follows, that is producing, scrounging and ranging respectively [17].

3.2 Artificial Bee Colony (ABC) method

An artificial bee colony method (ABC) is intended by the intelligent behavior of honeybees and it absolutely was outlined by Dervis Karaboga in 2005. At first an optimization tool provides a population based mostly search procedure and also the colony of artificial bees consists of 3 groups: employed bees, onlookers and scouts [18].

4 RESULTS AND ANALYSIS

To check the validity of the proposed methods, 25-bus unbalanced radial distribution system has been considered. The line and load data of 25- bus unbalanced radial distribution system is taken from [19].

TABLE 1
CONTROL PARAMETERS OF 25 BUS UNBALANCED RADIAL DISTRIBUTION SYSTEM

PSO	IGSO	ABC
Number of generations =100 Population size=20 Wmax=0.9, Wmin=0.2 c1 = 2, c2 = 2	Population size =20 Number of generations =100	Colony size=20 Max Cycle=100

The distributed generators are placed at optimal locations and the load flow solution is performed to observe the reduction of loss and improvement of voltage profile in the test system. For validation of results four DGs are placed in the system as existing method [20].

TABLE 2
SUMMARY OF TEST RESULTS OF 25 BUS UNBALANCED RADIAL DISTRIBUTION SYSTEM

Description	Before DG placement			Existing method (10,11,12,13)			After DG placement by PSO (7,25,17,10)			After DG placement by IGSO (15,11,18,23)			After DG placement by ABC (23,11,18,15)		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
Distributed generators placed size of DG (kW)	-	-	-	215	215	215	210	210	210	215	215	215	215	215	215
				215	215	215	210	210	210	205	205	205	215	215	215
				45	45	45	215	215	215	215	215	215	215	215	215
				30	30	30	205	205	205	215	215	215	215	215	215
Total DG size (kW)	-	-	-	505	505	505	840	840	840	850	850	850	860	860	860
Minimum voltage	0.9284	0.9284	0.9366	0.9651	0.9653	0.9692	0.9764	0.9762	0.9783	0.9834	0.9834	0.9835	0.9842	0.9841	0.9842
Max. Volt. regulation	7.16	7.16	6.34	3.49	3.47	3.08	3.26	2.38	2.17	1.66	1.66	1.65	1.58	1.59	1.58
Improvement of max. voltage regulation	-	-	-	51.26	51.54	51.42	54.47	66.76	65.88	76.82	76.82	73.97	77.93	77.79	75.08
Total active power loss (kW)	52.82	55.44	41.86	20.78	21.09	16.31	7.97	8.61	6.97	4.65	5.04	4.13	4.43	4.78	3.93
Total system active power loss (kW)	Best	-			58.17			23.55			13.82			13.14	
	Worst	-			58.47			41.25			36.10			45.66	
	Average	-			58.18			25.38			15.45			17.17	
Total active power loss reduction (%)	-	-	-	60.67	61.96	61.05	84.91	84.47	83.34	91.19	90.91	90.13	91.61	91.38	90.61
Total reactive power loss (kVAr)	58.32	53.29	55.69	22.74	20.37	21.50	7.66	7.41	7.55	4.62	4.44	4.74	4.39	4.21	4.49
Total reactive power loss reduction (%)	-	-	-	61.01	61.78	61.39	86.87	86.09	86.44	92.08	91.67	91.49	92.48	92.10	91.94
Total real power demand (kW)	1126.12	1138.74	1125.16	591.00	602.16	596.13	245.15	256.17	253.34	238.46	249.38	246.56	227.88	238.77	236.09
Total released real power demand (kW)	-	-	-	535.12	536.58	529.03	880.97	882.57	871.82	887.66	889.36	878.60	898.24	899.97	889.07
Total reactive power demand (kVAr)	850.32	854.29	855.69	503.25	509.56	510.55	280.03	288.28	288.74	275.68	283.78	284.34	268.84	276.98	277.54
Total released reactive power demand (kVAr)	-	-	-	347.07	344.73	345.14	570.29	566.01	566.95	574.64	570.95	571.35	581.48	577.31	578.15
Total feeder capacity (kVA)	1411.09	1423.57	1413.57	776.23	788.82	784.88	372.18	385.65	384.13	364.50	377.79	376.35	352.43	365.69	364.37
Total released feeder capacity (kVA)	-	-	-	637.82	637.78	631.66	1049.45	1048.47	1039.95	1057.43	1056.86	1048.04	1070.03	1069.22	1060.52

The control parameters of PSO, IGSO and ABC methods are given in Table 1. The summary of test results of 25– bus unbalanced radial distribution system is given in Table 2. The work proposes particle swarm optimization, improved group search optimization and artificial bee colony algorithm for finding DG sizes and optimal locations for real power injection is studied. The results of multiple DGs placement by proposed and existing methods are given in table 2. From the table 2, it is observed that the total size of DG's for existing and proposed methods for each phase are 505 kW, 840 kW, 850 kW and 860 kWfor total system real power loss of 58.17 kW, 23.55 kW, 13.82 kW and 13.14 kW at optimal locations of 10,11,12,13; 7,25,17,10; 15,11,18,23; and 23,11,18,15 respectively.

From Table 2, it is also observed that the minimum voltages in phases A, B and C are improved from 0.9284 p.u, 0.9284 p.u and 0.9366 p.u to 0.9651 p.u, 0.9653 p.u and 0.9692 p.u by existing method, 0.9764 p.u, 0.9762 p.u and 0.9783 p.u by PSO, 0.9834 p.u, 0.9834 p.u and 0.9835 p.u by IGSO and 0.9842 p.u, 0.9841p.u and 0.9842 p.u by ABC method respectively. Also observed that the active power loss in phases of A, B and C is reduced from 52.82 kW, 55.44 kW and 41.86 kW to 20.78 kW, 21.09 kW and 16.31 kW by existing method, 7.97 kW, 8.61 kW and 6.97 kW by PSO method, 4.65 kW, 5.04 kW and 4.13 kW by IGSO method and 4.43 kW, 4.78 kW and 3.93 kW by ABC method respectively.

The reactive power loss in phases A, B and C is reduced from 58.32 kVAr, 53.29 kVAr and 55.69 kVAr to 22.74 kVAr, 20.37 kVAr and 21.50 kVAr by existing method, 7.66 kVAr, 7.41 kVAr and 7.55 kVAr by PSO method, 4.62 kVAr, 4.44 kVAr and 4.74 kVAr by IGSO method and 4.39 kVAr, 4.21 kVAr and 4.49 kVAr by ABC method respectively. The total real power demand released due to DGs placement in phases A, B and C are 535.12 kW, 536.58 kW and 529.03 kW by existing method, 880.97 kW, 882.57 kW and 871.82 kW by PSO method, 887.66 kW, 889.36 kW and 878.60 kW by IGSO method and 898.24 kW, 899.97 kW and 889.07kW by ABC method respectively. The total reactive power load demand released due to DGs placement in phases A, B and C are 347.07 kVAr, 344.73 kVAr and 345.14 kVAr by existing method, 570.29 kVAr, 566.01 kVAr and 566.95 kVAr by PSO method, 574.64 kVAr, 570.95 kVAr and 571.35 kVAr by IGSO method and 581.48 kVAr, 577.31 kVAr and 578.15 kVAr by ABC method respectively.

Due to release of real and reactive power demand in the system the feeder capacity is reduced. The total feeder capacity of the test system is reduced from 1411.09 kVA, 1423.57 kVA and 1413.57 kVA to 776.23 kVA, 788.82 kVA and 784.88 kVA by existing method, 372.18 kVA, 385.65 kVA and 384.13 kVA by PSO method, 364.50 kVA, 377.79 kVA and 376.35 kVA by IGSO method and 352.43 kVA, 365.69 kVA and 364.37 kVA by ABC method respectively.

5 CONCLUSIONS

The proposed ABC, IGSO, PSO methods successfully achieved the optimal solutions. The results of the proposed methods were compared with existing method for multi DG unit's placement. The proposed methods shows that the presence of DG unit's at appropriate location and sizes of DG reduces energy loss significantly than the location and sizes of DG obtained by existing method. The real and reactive power demand effect is reduced on central system due to DGs placement. The minimum voltage is improved by proposed methods than existing method.

REFERENCES

[1] T. Ackermann, G. Anderson and L. Söder, "Distributed generation: a definition,"Electrical Power System Research,vol.57, pp. 195–204, 2001.

[2] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans and W. D'haeseleer, "Distributed Generation: definition, benefits and issues,"Energy Policy, vol. 33, pp. 787–798, 2005.

[3] H. Lee Willis and W.G. Scott, "Distributed Power Generation. Planning and Evaluation,"Marcel Dekker, 2000.

[4] F.S. Abu-Mouti, and M.E. El-Hawary, "Heuristic curve-fitted technique for distributed generation optimization in radial distribution feeder systems," IET Gener., Transm., Distrib, vol. 5, no. 2, pp. 172-180, 2011.

[5] F.S. Abu-Mouti, and M.E. El-Hawary, "Optimal distributed generation allocation and sizing in distribution systems via artificial bee colony algorithm," IEEE Trans. on power delivery, vol. 26, no. 4, pp. 2090-2101, 2011.

[6] T. Niknam, S.I. Taheri, J. Aghaei, S. Tabatabaei, and M. Nayeripour, "A modified honey bee mating optimization algorithm for multi-objective placement of renewable energy resources," Applied Energy, vol.88, no. 12, pp. 4817-4830, 2011.

[7] M.R. AlRashidi, and M.F. AlHajri, "Optimal planning of multiple distributed generation sources in distribution networks: A new approach," Energy conversion and management, vol. 52, no. 11, pp.3301-3308, 2011.

[8] K. Nekooei, M. M. Farsangi, H. Nezamabadi-Pour, and K.Y. Lee, "An improved multi-objective harmony search for optimal placement of DGs in distribution systems," IEEE Transactions on smart grid, vol.4, no. 1, pp. 557-567, 2013.

[9] J.A.M. García, and A.J.G. Mena, "Optimal distributed generation location and size using a modified teaching–learning-based optimization algorithm," International journal of electrical power & energy systems, vol.50 pp. 65-75, 2013.

[10] M.H. Moradi, S.M.R. Tousi, and M. Abedini, "Multi-objective PFDE algorithm for solving the optimal siting and sizing problem of multiple DG sources," International Journal of Electrical Power & Energy Systems, vol. 56, pp.117-126, 2014.

[11] A. El-Fergany, "Optimal allocation of multi-type distributed generators using backtracking search optimization algorithm," International Journal of Electrical Power & Energy Systems, vol. 64, pp. 1197-1205, 2015.

[12] K.D. Mistry, and R. Roy, "Enhancement of loading capacity of distribution system through distributed generator placement considering techno-economic benefits with load growth," International Journal of Electrical Power & Energy Systems, vol. 54, pp. 505-515, 2014.

[13] N. Kanwar N et al., "Simultaneous allocation of distributed energy resource using improved particleswarmoptimization,"AppliedEnergy, vol. 185, pp. 1684-1693, 2017.

[14] M.M. Othman, W. El-Khattam, Y.G. Hegazy, and A.Y. Abdelaziz, "Optimal placement and sizing of distributed generators in unbalanced distribution systems using supervised Big Bang-Big Crunch method," IEEE Transactions on Power Systems, vol. 30, no. 2, pp. 911-919, 2015.

[15] S. Sultana, and P.K. Roy, "Krill herd algorithm for optimal location of distributed generator in radial distribution system," Applied Soft Computing, vol.40, pp.391-404, 2016.

[16] M.Padma Lalitha, V.C. Veera Reddy and V. Usha, "Optimal DG placement for minimum real power loss in radial distribution systems using PSO," Journal of Theoretical and Applied Information Technology, pp. 107-116, 2010.

[17] Qi Kang, Tian Lan, Yong Yan, Lei Wang and Qidi Wu, "Group search optimizer based optimal location and capacity of distributed generations," Neuro computing, vol. 78, pp. 55-63, 2012.

[18] G.V.K Murthy, S Sivanagaraju, S Satyanarayana and B Hanumantharao, "Voltage stability analysis of radial distribution networks with distributed generation," International Journal on Electrical Engineering and Informatics – Vol. 6, pp. 195-204, 2014.

[19] J. B. V. Subrahmanyam and C. Radhakrishna, "Distributed generator placement and sizing in unbalanced radial distribution system," World Academy of Science, Engineering and Technology, vol. 52, 2009, pp. 737-744.

[20] Puthireddy Umapathi Reddy, Sirigiri Sivanagaraju and Prabandhamkam Sangameswararaju, "Optimal distributed generator placement for loss minimization of unbalanced radial distribution system using particle swarm optimization method," International Journal of Advances in Science and Technology, vol. 3, no. 6, 2011, pp. 126-140.