

DG Placement for Maximum Loss Reduction In Radial Distribution System Using ABC Algorithm

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Abstract

Distributed Generation (DG) is a promising solution to many power system problems such as voltage regulation, power loss, etc. This paper presents a new methodology using a new population based meta heuristic approach namely Artificial Bee Colony algorithm(ABC) for the placement of Distributed Generators(DG) in the radial distribution systems to reduce the real power losses and to improve the voltage profile.

A two-stage methodology is used for the optimal DG placement. In the first stage, single DG placement method is used to find the optimal DG locations and in the second stage, ABC algorithm is used to find the sizes of the DGs corresponding to maximum loss reduction. The proposed method is tested on standard IEEE 33-bus test system and the results are presented and compared with different approaches available in the literature. The proposed method has outperformed the other methods in terms of the quality of solution and computational efficiency.

Keywords: *DG placement, Meta heuristic methods, ABC Algorithm, loss reduction, radial distribution system.*

1. INTRODUCTION

Distributed generation is small-scale power generation that is usually connected to or embedded in the distribution system. The term DG also implies the use of any modular technology that is sited throughout a utility's service to lower the cost of service [1]. The benefits of DG are numerous [2, 3] and the reasons for implementing DGs are rational use of energy, deregulation policy, diversification of energy sources, ease of finding sites for smaller generators, shorter construction times and lower capital costs of smaller plants and proximity of the generation plant to heavy loads. The reduction in gaseous emissions (mainly CO₂) offered by DG is a major legal driver for DG implementation [4]. Numerous studies used different approaches to evaluate the benefits from DGs to a network in the form of loss reduction, loading level reduction [6-8].

Naresh Acharya has suggested a heuristic method in [9] to select appropriate location and to calculate DG size for minimum real power losses. Though the method is effective in selecting location, it requires more computational efforts as heuristic search requires exhaustive search for all possible locations which may not be

applicable to more than one DG. This method uses approximate loss formula which may lead to inappropriate solution.

In the literature, genetic algorithm and PSO have been applied to DG placement [10-13]. In all these works both sizing and location of DGs are determined. This paper presents a new methodology using ABC algorithm [14-17] for the placement of DG in the radial distribution systems. The ABC algorithm is a new population based meta heuristic approach inspired by intelligent foraging behavior of honeybee swarm. The advantage of ABC algorithm is that it does not require external parameters such as cross over rate and mutation rate as in case of genetic algorithm and differential evolution. The other advantage is that the global search ability is implemented by introducing neighborhood source production mechanism which is similar to mutation process.

In this paper, locations of distributed generators are identified by single DG placement method [18] and ABC algorithm which takes the number and location of DGs as input has been developed to determine the optimal size(s) of DG to minimize real power losses in distribution systems. The advantages of relieving ABC method from determination of locations of DGs are improved convergence characteristics and less computation

time. Voltage and thermal constraints are considered. The algorithm was as tested on 33-Bus Distribution System [19]. To demonstrate the effectiveness of proposed method, results are compared with different approaches available in the literature.

2. THEORETICAL BACKGROUND

The total I^2R loss in distribution system having n number of branches is given by:

$$P_L = \sum_{i=1}^n I_i^2 R_i \dots \dots \dots (1)$$

Here I_i is the magnitude of the branch current and

R_i is resistance of the i^{th} branch respectively. The branch current has two components, active component (I_a) and reactive component (I_r).

The loss associated with the active and reactive components of branch currents can be written as:

$$P_{La} = \sum_{i=1}^n I_{ai}^2 R_i \dots \dots \dots (2)$$

$$P_{Lr} = \sum_{i=1}^n I_{ri}^2 R_i \dots \dots \dots (3)$$

For a given configuration of a single-source radial network, the loss P_{La} cannot be minimized because all active power must be supplied by the source. However by placing

DGs, this loss can be reduced. This paper presents a method to minimize this loss by placing DGs and thereby reduces the total loss in the distribution system.

3. IDENTIFICATION OF OPTIMAL DG LOCATIONS BY SINGLE DG PLACEMENT ALGORITHM

This algorithm determines the optimal size and location of DG units that should be placed in the system to minimize loss. First optimum sizes of DG units for all nodes are determined for base case and best one is chosen based on the maximum loss saving. This process is repeated if multiple DG locations are required by modifying the base system by inserting a DG unit into the system one-by-one.

Methodology

Assume that a single-source radial distribution system with n branches and a DG is to be placed at bus m and α be a set of branches connected between the source and bus m . The DG produces active current I_{DG} , and for a radial network it changes only the active component of current of branch set α . The currents of other branches are unaffected. Thus new active current I^{new} of

The i^{th} branch is given by i

$$I_{ai}^{new} = I_{ai} + D_i I_{DG} \quad \dots(4)$$

Determined using eqn (9). Then saving for

where $D_i = 1$; if branch $i \in \alpha = 0$; otherwise

The loss P_{La}^{com} associated with the active component of branch currents in new system (when DG is connected) is given by

$$P_{La}^{com} = \sum_{i=1}^n (I_{ai} + D_i I_{DG})^2 R_i \quad (5)$$

The saving S is the difference between equation 3 and 5 and is given by

$$S = P_{La} - P_{La}^{com} \quad \dots(6)$$

$$= - \sum_{i=1}^n (2D_i I_{ai} I_{DG} + D_{DG} I_{DG}^2) R_i$$

The DG current I_{DG} that provides maximum saving can be obtained from

$$\frac{\partial S}{\partial I_{DG}} = -2 \sum_{i=1}^n (D_i I_{ai} + D_i I_{DG}) R_i = 0 \quad (7)$$

The DG current for maximum saving is

$$I_{DG} = - \frac{\sum_{i=1}^n I_{ai} R_i}{\sum_{i=1}^n R_i} = - \frac{\sum_{i \in \alpha} I_{ai} R_i}{\sum_{i \in \alpha} R_i} \quad \dots(8)$$

The corresponding DG size is

$$P_{DG} = V_m I_{DG} \quad \dots(9)$$

V_m is voltage magnitude of bus- m . The optimum size of DG at each bus is determined using eqn (6). The DG with highest saving is candidate location for single DG

placement. When the candidate bus is identified and DG is placed, the process is repeated to identify subsequent buses for DG placement.

2. Algorithm for Single DG Placement

Step 1: Conduct load flow analysis for the original system.

Step 2: Calculate I_{DG} and DG size using equations 8 & 9 for buses $i=2 \dots n$.

Step 3: Determine saving using equation 6, for buses $i=2 \dots n$.

Step 4: Identify the maximum saving and the corresponding DG size.

Step 5: The corresponding bus is candidate bus where DG can be placed. Modify the active load at this bus and conduct the load flow again.

Step 6: Check whether the saving obtained is more than 1kW. If yes, go to step 2. Otherwise, go to next step.

Step 7: print all the candidate locations to place DG sources and the sizes.

Since the DGs are added to the system one by one, the sizes obtained by single DG placement algorithm are local optima not global optimum solution. The global optimal solution is obtained if multiple DGs are simultaneously placed in the system by using ABC algorithm.

This method is explained in next section.

4. IDENTIFICATION OF OPTIMAL DG SIZES BY ABC ALGORITHM

ABC Algorithm

The colony of artificial bees contains three groups of bees: employed bees, onlookers and scouts. A bee waiting on the dance area for making decision to choose food source is called an onlooker and a bee going to the food source visited by it previously is named employed bee. A bee carrying out random search is called scout. In the ABC algorithm, first half of the colony consists of employed artificial bees and the second half constitutes the onlookers. For every food source, there is only one employed bee. The employed bee whose food source is exhausted by the employed and onlooker bees becomes a scout. At initialization stage, a set of food source positions are randomly selected by the bees and their nectar amounts are determined. These bees come in to hive and share the nectar information of sources with the bees waiting on

$$P_i = \frac{fit_i}{\sum_{n=1}^{S_N} fit_n} \dots\dots\dots(10)$$

Where fit_i is fitness of the solution represented by food source i and S_N is total number of food sources. After all onlookers have selected their

food sources, each of them determines a food source in the neighborhood of his chosen food source and computes its fitness. The best food source among all the neighboring food sources determined by the onlookers associated with a particular food source i will be the new location of the food source i . If a solution represented by a particular food source does not improve for a predetermined number of iterations then that food source is abandoned by its associated employed bee and it becomes a scout. This tantamount to assigning a randomly generated food source to this scout and changing its status again from scout to employed. After the new location of each food source is determined, another iteration of ABC algorithm begins. The whole process is repeated again and again till the termination condition is satisfied. The food source in the neighborhood of a particular food source is determined by altering the value of one randomly chosen solution parameter and keeping other parameters unchanged. Suppose each solution consists of d parameters and let $X_i = (X_{i1}, X_{i2}, X_{i3}, \dots, X_{id})$ be a solution. In order to determine a solution v_i in neighborhood of X_i , a solution parameter j and other solution $X_k = (X_{k1}, X_{k2}, X_{k3}, \dots, X_{kd})$ are selected randomly. Except for the values of the selected parameter j , all other parameter values of v_i are same as X_i , i.e., $v_i = (X_{i1}, X_{i2}, \dots, X_{ij-1},$

1), $X_{ij}, X_{i(j+1)}, \dots, X_{id}$). The value v_i of the selected parameter j in v_i is determined by

$$v_{ij} = x_{ij} + u(x_{ij} - x_{kj}) \dots (11)$$

where u is an uniform variate in $[-1, 1]$. If the resulting value falls outside the acceptable range of j , it is set to the corresponding extreme value in that range.

ABC Algorithm to find DG sizes

The proposed ABC algorithm for finding sizes of DGs at selected locations to minimize the real power loss is as follows:

1. Read the input data.
2. Construct initial Bee population X_{ij} as each bee is formed by sizes of DG units.
3. Evaluate fitness value for each employed bee by the formula

$$fitness = \frac{1}{1 + Power\ Loss} \dots (12)$$
4. Initialize iteration=1.
5. Generate new population (solution) v_{ij} in the neighborhood of X_{ij} for employed bees using equation (11) and evaluate them.

6. Apply selection process between X_i and v_i .

7. Calculate the probability values P_i for the solutions X_i by means of their fitness values using the equation (10).

8. Produce the new populations v_i for the onlookers from the populations X_i , selected depending on P_i by applying roulette wheel selection process, and evaluate them.

9. Apply selection process for the onlookers between X_i and v_i .

10. Determine the abandoned solution, if exists, and replace it with a new randomly produced solution X_i for scout bees using the following equation

$$x_{ij} = min_j + rand(0,1) * (max_j - min_j); \dots (13)$$

11. Memorize the best solution achieved so far. If the difference between two successive values is less than specified value stop.

12. Increase the iteration number by one.

13. If iterations are less than specified go to step 5, otherwise stop.

5. RESULTS AND DISCUSSION

First load flow is conducted for IEEE 33- bus test system. The power loss due to active component of current is 136.9836 kW and power loss due to reactive component of the current is 66.9252 kW. A program is written in “MATLAB” to implement single DG placement algorithm. For the first iteration the maximum saving is occurring at bus 6. The

candidate location for DG is bus 6 with a loss saving of 92.1751 kW. The optimum size of DG at bus 6 is 2.4886 MW. By assuming 2.4886 MW DG is connected at bus 6 of base system and is considered as base case. Now the candidate location is bus 15 with 0.4406 MW size and the loss saving is 11.4385 KW. This process is repeated till the loss saving is insignificant. The results are shown in Table I.

Table I: Single DG placement results

iteration No.	Bus No.	DG Size (MW)	Saving (KW)
1	6	2.4886	92.1751
2	15	0.4406	11.4385
3	25	0.6473	7.6936
4	32	0.4345	8.1415

The candidate locations for DG placement are taken from single DG placement algorithm i.e. 6, 15, 25, 32. With these locations, sizes of DGs corresponding to global solution are determined by using ABC Algorithm described in section 4. The sizes of DGs are dependent on the number of DG locations. Generally it is not possible to install many DGs in a given radial

system. Here 4 cases are considered. In case I only one DG installation is assumed. In case II two DGs, in case III three DGs and in the last case four DGs are assumed to be installed. DG sizes in the four optimal locations, total real power losses before and after DG installation for four cases are given in Table II.

Table II: Results of IEEE 33 bus system

Case	bus locations	DG sizes(Mw)	Total Size(MW)	Losses before DG installation (Kw)	Loss after DG installation (Kw)	Saving (Kw)	saving/ DG Size
I	6	2.5775	2.5775	203.9088	105.0231	98.8857	39.9
II	6	1.9707	2.5464		89.9619	113.9469	44.75
	15	0.5757					
III	6	1.7569	3.1152		79.2526	124.6562	40.015
	15	0.5757					
	25	0.7826					
IV	6	1.0765	3.0884		66.5892	137.3196	44.86
	15	0.5757					
	25	0.7824					
	32	0.6538					

The last column in Table II represents the saving in Kw for 1 MW DG installation. The case with greater ratio is desirable. As the number of DGs installed is increasing the saving is also increasing. In case4 maximum saving is achieved but the number of DGs is four. Though case4 is optimal it is

not economical by considering the Table III shows % improvements in power loss due to active component of branch current, reactive component of branch current and total active power loss of the system in the four cases considered. The loss due to active component of cost of installation of 4 DGs.

But in view of reliability, quality and future expansion of the system it is the best solution.

The voltage profile for all cases is shown in Figure1. In all the cases voltage profile is

improved and the improvement is significant. Branch current is reduced by more than 68% in least and nearly 96% at best. From Table III it is observed that the total real power loss is reduced by 48.5% in case 1 and 67% in case 4.

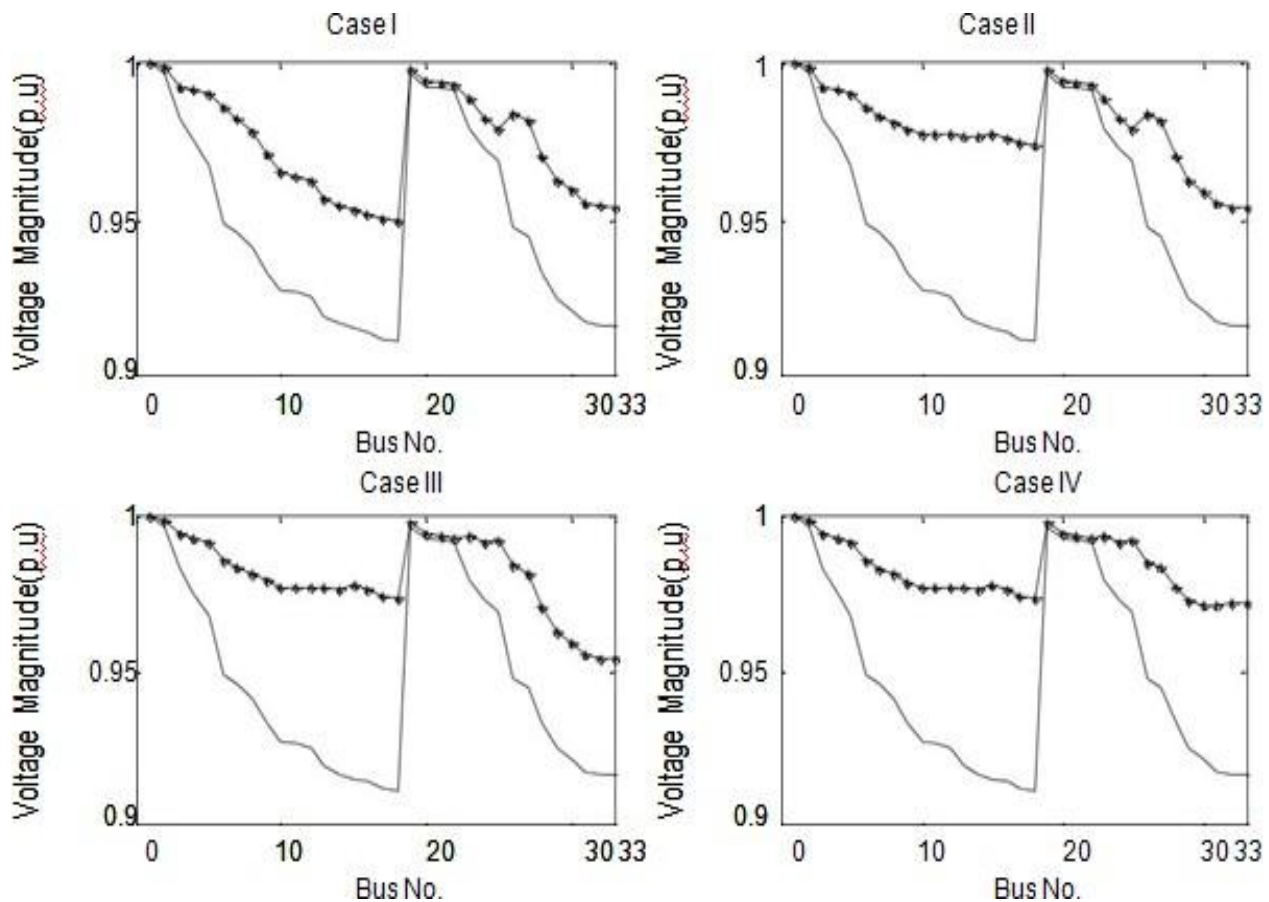


Fig.1: Voltage profile with and without DG placement for all Cases

Table III: Loss reduction by DG placement

P_{La}	(kW)	P	(kW)	P_{Lt}	(kW)	
case No.		%Saving		%Saving		%Saving
Basecase	136.98	----	66.9252	----	203.909	----
Case1	43.159	68.49	61.8645	7.56	105.023	48.49
Case2	28.523	79.18	61.4392	8.2	89.9619	55.88
Case3	18.086	86.8	61.1657	8.6	79.2515	61.134
Case4	5.5676	95.94	61.0215	8.82	66.5892	67.34

The convergence characteristics of ABC algorithm for all cases are shown in figure2

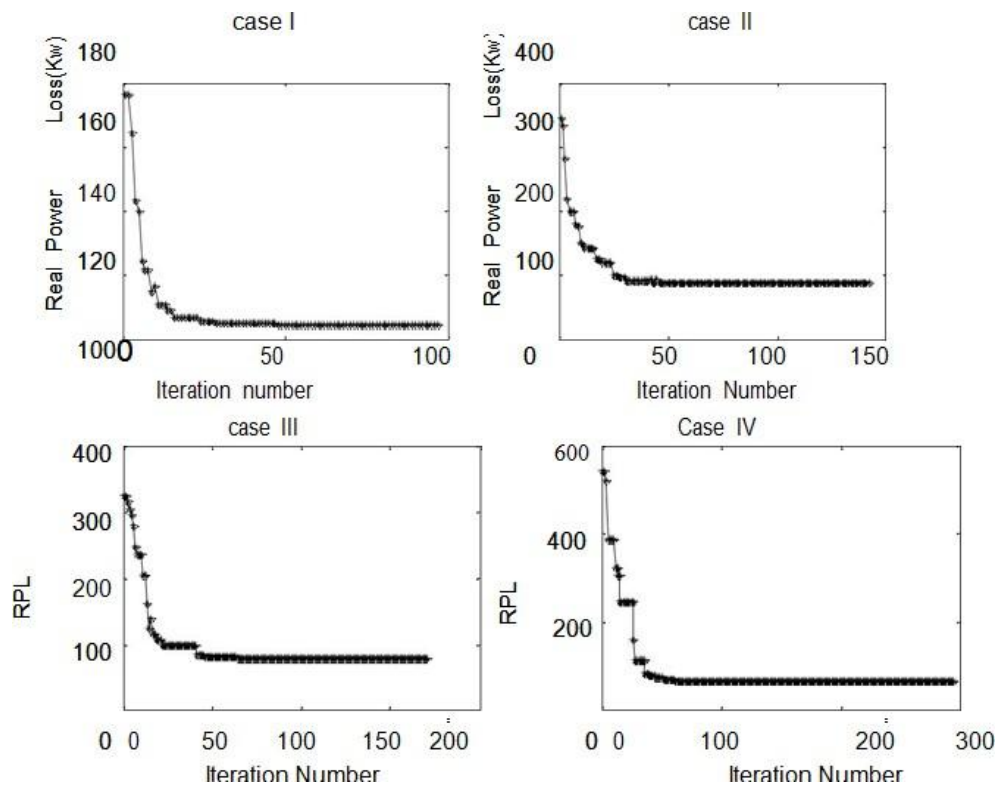


Figure2: Convergence characteristic of ABC algorithm for 33-bustest system.

5.1. Comparison Performance

To demonstrate the validity the proposed method the results of proposed method is

compared with an existing analytical method. The comparison is shown in Table IV.

Table IV: Comparison between proposed method and other existing method

Case	Bus No	sizes(Mw)		Total Size(Mw)		saving(Kw)	
		PM	AM	PM	AM	PM	AM
1	6	2.5775	2.4886	2.5775	2.4886	98.8857	92.1751
2	6	1.9707	1.8981	2.5464	2.4676	113.9469	113.859
	15	0.5757	0.5695				
3	6	1.7569	1.6923	3.1152	3.034	124.6562	124.579
	15	0.5757	0.5695				
	25	0.7826	0.7722				
4	6	1.0765	1.0188	3.0884	3.0107	137.3196	137.247
	15	0.5757	0.5695				
	25	0.7824	0.7722				
	32	0.6538	0.6502				

Savings by ABC algorithm are a little higher than the existing analytical method. The reason for this is in analytical method approximate loss

formula is used. Table V shows comparison of voltage profile improvement by the two methods. The minimum voltage and %

improvement in minimum voltage compared to base case for all the four cases, for the two methods discussed, are shown in the Table V.

From the above tables it is clear that beyond producing the results that matches with those of existing method, proposed method has the added advantage of easy implementation of real time constraints on the system like time varying loads, different types of DG units etc., to effectively apply it to real time operation of a

system.

To demonstrate the supremacy of the proposed method the results are compared with the results of PSO algorithm as shown in Table VI. Both methods give same sizes for DGs for all cases.

Though the number of iterations is more for ABC algorithm it takes less computation time because of its simplicity when compared to PSO method.

Table V: Comparison of Voltage improvement

case No.	Min Voltage		%improvement	
	PM	AM	PM	AM
Base Case	0.9118		---	
case1	0.9498	0.9486	2.149	1.985
case2	0.9543	0.9596	2.533	2.358
case3	0.9544	0.9621	2.533	2.358
case4	0.9716	0.98	6.153	5.933

Table VI: Comparison of results of ABC and PSO algorithms

	Case I		Case II		Case III		Case IV	
	ABC	PSO	ABC	PSO	ABC	PSO	ABC	PSO
Locations	6	6	6	6	6	6	6	6
			15	15	15	15	15	15
					25	25	25	25
							32	32
DG sizes	2.5775	2.5775	1.9707	1.9707	1.7569	1.7569	1.0765	1.0765
			0.5757	0.5757	0.5757	0.5757	0.5757	0.5757
					0.7826	0.7826	0.7824	0.7824
							0.6538	0.6538
Swarm size	30	50	30	50	30	50	40	50
Avg. No. of iterations	88.75	102.56	141.28	118.23	192.36	148.07	212.57	159.98
Avg. time(sec.)	6.9255	11.16	10.074	12.537	15	15.82	16.1129	16.595

1. CONCLUSIONS

optimal DG locations and ABC algorithm is proposed

In this paper, a two-stage methodology of finding the to find the optimal DG sizes.

optimal locations and sizes of DGs for maximum loss

reduction no fra dial distribution systems is presented. The validity of the proposed method is proved

Single DG placement method is proposed to find the from the comparison of the results of the proposed

method with other existing methods. The results proved that the ABC algorithm is simple in nature than GA and PSO so it takes less computation time. By installing DGs at all the potential locations, the total power loss of the system has been reduced drastically and the voltage profile of the system is also improved. Inclusion of the real time constraints such as time varying loads and different types of DG units and discrete DG unit sizes into the proposed algorithm is the future scope of this work.

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