ISSN 2321-807X
Volume 12 Number20
Journal of Advances in chemistry

MITIGATE THE REAL POWER LOSSES IN RADIAL DISTRIBUTED NETWORK USING DG BY ABC ALGORITHM

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ABSTRACT

Recently, integration of Distributed generation (DG) in distribution system has increased to high penetration levels. The impact of DG on various aspects of distribution system operation, such as reliability and energy loss depend highly on DG location in distribution feeder .Optimal DG placement plays an important role . This project presents a new methodology using Artificial Bee Colony algorithm (ABC) to find the optimal size and optimum location for the placement of DG in the radial distribution networks for active power compensation by reduction in real power losses .The proposed technique is tested on standard IEEE-33 bus test system.

Keywords

Distributed generation (DG), placement, Artificial Bee Colony algorithm, Radial distribution..

1.INTRODUCTION

The anguish about rising environmental population and also the concern about the fossil fuels problems and limitations led to the installation of Distributed Generation (DG) which increases annually. In order to improve voltage profile, stability, reduction of power losses and etc, it is necessary that this increasing of installation of DGs in Distribution system should be systematically .Most countries generate electricity in large centralized facilities, such as fossil fuel (coal, gas powered), nuclear, large solar power plants or hydropower plants. These plants have excellent economies of scale, but usually transmit electricity long distances and can negatively affect the environment. Distributed generation allows collection of energy from many sources and may give lower environmental impacts and improved security of supply. Distributed generation (DG) is not a new concept but it is an emerging approach for providing electric power in the heart of the power system. It mainly depends upon the installation and operation of a portfolio of small size, compact, and clean electric power generating units at or near an electrical load (customer). Surveying DG concepts may include DG definitions, technologies, applications, sizes, locations, DG practical and operational limitations, and their impact on system operation and the existing power grid. This work focuses on surveying different DG types, technologies, definitions, their operational constraints, placement and sizing with new methodology particle swarm optimization and Artificial Bee Colony Algorithm(ABC) . Artificial Bee Colony Algorithm is used in this paper in order to find solution to optimization problems, optimal size and site of DG in 33- bus system. The aim of this paper reduction in real power losses, reactive power and improving the voltage profile. The simulation test systems were simulated in MATLAB.

2. Total Real Power Loss In A System

The total power loses in a distribution system having N number of branches

$$P_{LT} = \sum_{I=1}^{N} I_i^2 Ri \qquad (1)$$

Ii is the magnitude of the branch current and Ri is the resistance of the I th branch respectively. The branch current can be obtained from load flow analysis. The branch current has two components (Ir) reactive component and active component (Ia).The loss associated with each components of branch current can be written as:

$$P_{La} = \sum_{I=1}^{N} I_{ai}^2 Ri \qquad (2)$$

$$P_{Lr} = \sum_{I=1}^{N} I_{ri}^2 Ri \qquad (3)$$

2.1 Optimal DG Size And Location

The optimal size of DG is calculated at each bus using the exact loss formula and the optimal location of DG is found by using the loss sensitivity factor. The loss sensitivity factor is used for the placement of DG is explained as, the real power loss in the system is given by

$$P_L = \sum_{i=1}^{N}\sum_{i=1}^{N}[\alpha_{ij}(P_i P_j + Q_i Q_j) + \beta_{ij}(Q_i P_j + P_i Q_j) \quad (4)$$

Where

$$\alpha_{ij} = \frac{r_{ij}}{v_i v_j}\mathrm{Cos}(\delta_i - \delta_j) \quad (5)$$

$$\beta_{ij} = \frac{r_{ij}}{v_i v_j}\mathrm{Sin}(\delta_i - \delta_j) \quad (6)$$

and

$$z_{ij} = r_{ij} + jx_{ij}$$

ij are the element of Z bus matrix

$P_i = P_{Gi} - P_{Di}$ and $Q_i = Q_{Gi} - Q_{Di}$

P_{Gi} & Q_{Gi} are power injection of generators to the bus.

P_{Di}, Q_{Di} are the loads.

P_i, Q_i is active and reactive power of the buses.

The sensitivity factor of real power loss with respect to real power injection from the DG is given by

$$\alpha_i = \frac{\partial P_L}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{\substack{j=1\\ j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j) \quad (7)$$

Sensitivity factor are evaluated at each bus by using the values obtained from the base case load flow. The bus having lowest loss sensitivity factor will be best location

$$\frac{\partial P_L}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{\substack{j=1\\ j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j) = 0 \quad (8)$$

for the placement of DG.The total power loss against injected power is parabolic function and at a minimum losses ,the rate of changes of loss with respect to injected power is zero.

Then the above equation becomes

$$P_i = \frac{1}{\alpha_{ii}}\left[\sum_{\substack{j=1\\ j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)\right] \quad (9)$$

Where P_i is the real power injection at node i, which is the difference between real power generation and the real power demand on that node

$$P_i = (P_{DCi} - P_{Di}) \quad (10)$$

Where P_{DGi} is the real power injection from DG placed at node i, and P_{Di} is the load demand at node i. By combining the above we get.

$$P_{DGi} = P_{Di} - \frac{1}{\alpha_{ii}} \left| \sum_{\substack{j=1 \\ j \neq i}}^{N} (\alpha_{ij} P_j - \beta_{ij} Q_j) \right| \quad (11)$$

The above equation gives the optimum size of DG for each bus i, for the real power loss to be minimum and any size of DG other than Pdgi placed at bus i,means it will create a higher loss.

3. OPTIMAL LOCATION OF DG:

The allocating optimal location is find for the placement of accurate size of DG at the respective bus as shown in fig (1) and which will produce the lowest loss due to the placement of DG at the respective bus is shown fig(2).and this figure is for single DG placement in a bus system .

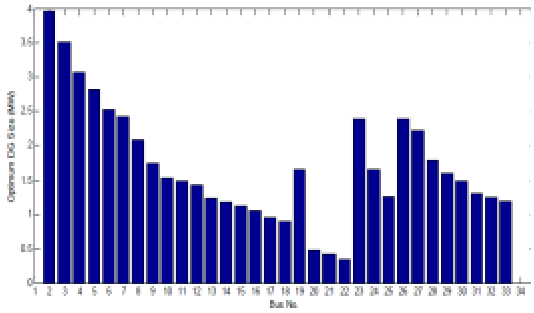


Figure 1. Optimum size of DG at various locations for 33 bus distribution system

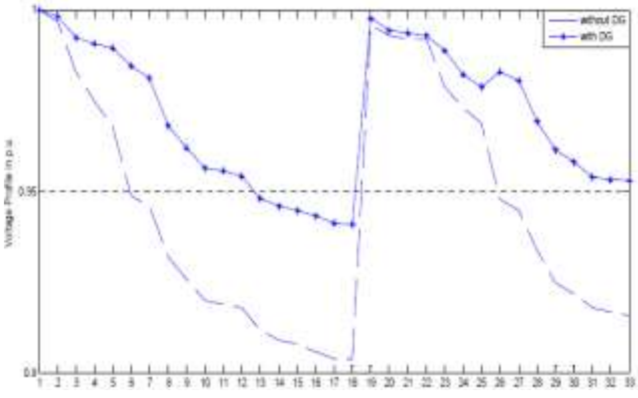


Figure 2. Variation of voltage profile by without DG method.

3.1 Voltage limits

The voltage limits depend on the voltage regulation limits should be satisfied this voltage constrained equation:

$$V_i^{\min} \leq V_i \leq V_i^{\max} \quad (12)$$

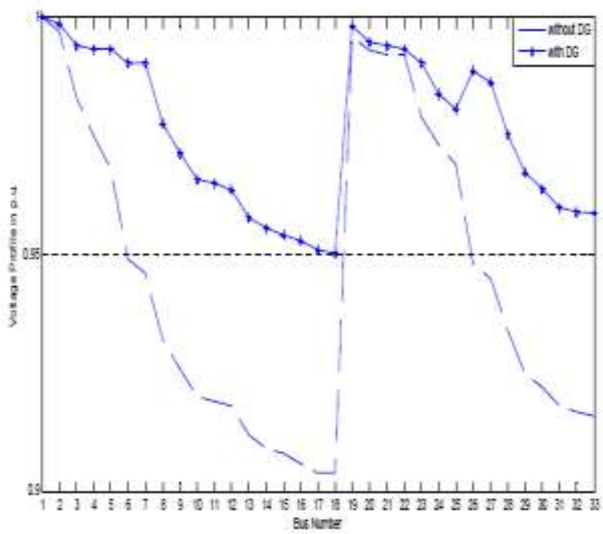


Figure 3. Variation of voltage profile by analytical method.

3.2 Multiple Dg Placement:

This paper introduces the Multiple objective function (MOF) for placing the DG in distribution network to reduces the losses in the systems.

Max f (P_{loss}, Q_{loss}, I_{SC}, V_{level}).

Where:

$$f(P_{loss}, Q_{loss}, Isc, V_{level}) = w_1F_p + w_2F_q + w_3F_i + w_4F_v \tag{13}$$

3.3 Power-conservation limits:

The algebraic sum of all the incoming and outgoing power including line losses over the whole distribution network and power generated from DG unit should be equal to zero.

$$P_{Gen} + P_{DG} - \sum_{i=1}^{n} P_D - P_{total}^{Loss} = 0 \tag{14}$$

3.4 Distribution line capacity limits:

Power flow through any line must not exceed the thermal capacity of the line

$$S_{ij} < S_{ij}^{\max} \tag{15}$$

4.1 PROBLEM FORMULATION

Distribution systems may be either positive or negative depending on the system's operating condition DGs characteristics and location. The potential positive impacts are improving system reliability, loss reduction, and deferment of new generation and improving power quality. To achieve these benefits, DG must be reliable, dispatchable, of appropriate size, and at suitable locations. More important, DGs should be properly coordinated with protection systems.

The planning of the electric system with the presence of DG requires several factors to be taken into considerations, such as: the best technology to be used, the number and the capacity of the units, the best location, the type of network connection, etc. The impact of DG in system operating characteristics, such as electric losses, voltage profile, stability and reliability needs to be appropriately evaluated.

The problem of DG allocation and sizing is of great importance. The installation of DG units at non-optimal places can result in an increase in system losses, implying in an increase in costs and, therefore, having an effect opposite to the desired. For that reason, the use of an optimization method capable of indicating the best solution for a given distribution network can be very useful for the system planning engineer.

4.2 PROPOSED METHOD

In this paper to reduce the losses in the system and allocate optimal location and size Artificial Bee colony Technique is used. The solving of placement and sizing of DG units problem requires to define the Fitness Function that can be optimized in the presence of some constraints. The fitness function is selected for reducing power losses and increasing of voltage stability margin in the system or reducing cumulative voltage deviation.ABC starts the process by automatically proposing different DG sizes within the proposed DG size limits and internally executes the load flow program which is properly linked till the minimum solution is obtained for the suggested location. This process is repeated for each of the proposed locations. Different scenarios are proposed to consider multiple of DG's at different suggested locations and to consider both DG PV and PQ models to determine the best location and size of the DG's. The suggested algorithm is programmed under MATLAB software.

5.ARTIFICIAL BEE COLONY ALGORITHM (ABC)

Artificial Bee Colony (ABC) algorithm, proposed by Karaboga for optimizing numerical problems in, simulates the intelligent foraging behavior of honey bee swarms. In ABC algorithm, the colony of artificial bees contains three groups of bees: employed bees, and unemployed bees: onlookers and scouts. In ABC, first half of the colony consists of employed artificial bees and the second half constitutes the artificial onlookers.

The employed bee whose food source has been exhausted becomes a scout bee. In ABC algorithm, the position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (*fitness*) of the associated solution. The number of the employed bees is equal to the number of food sources, each of which also represents a site, being exploited at the moment or to the number of solutions in the population. In ABC optimization, the steps given below are repeated until a stopping criteria is satisfied. Initialize the food source positions:

REPEAT

Employed Bees Phase

Onlooker Bees Phase

Scout Bee Phase

Memorize the best solution achieved so far

UNTIL (cycle= Maximum Cycle Number (MCN))

5.1 INITIALIZATION PHASE

The population of solutions xij is initialized in the range of the parameter j. The following definition might be used for this purpose.

$$x_{ij}=x_{minj}+rand(0,1)*(x_{maxj}-x_{minj}) \qquad (16)$$

where, *xminj* is the lower bound of the parameter j and xmaxj is the upper bound of the parameter j.

5.2 EMPLOYED BEES PHASE

Each employed bee determines a food source vij which is also representative of a site, within the neighbourhood of the food source in her memory xij for example using the formula, and evaluates its profitability. Each employed bee shares her food source information with onlookers waiting in the hive and then each onlooker selects a food source site depending on the information taken from employed bees.

$$v_{ij}=x_{ij}+ij.(x_{ij}-x_{kj}) \qquad (17)$$

where,

xk is a randomly selected solution, j is a randomly chosen parameter, *ij* φ is a random number within the range [-a,a].

After producing a new solution vi a greedy selection is applied between vi and xi In order to simulate the information sharing by employed bees in the dance area, probability values Pi are calculated for the solutions xi by means of their fitness values.

5.3 ONLOOKER BEES PHASE

As mentioned before, the nectar amount of a food source corresponds to the quality of the solution represented by that food source position. Onlookers are placed onto the food source sites by using a fitness based selection technique, for example roulette wheel selection method. New solutions vi are produced for the onlookers from the solutions xi by, selected depending on pi , and the new solutions are evaluated. As for employed bees, a greedy selection is applied between vi and xi.

5.4 SCOUT BEE PHASE

Employed bees whose sources have been abandoned become scout and start to search a new food source randomly, for example by equation. Every bee colony has scouts that are the colony's explorers. The explorers do not have any guidance while looking for food. They are primarily concerned with finding any kind of food source. In case of artificial bees, the artificial scouts might have the fast discovery of the group of feasible solutions. In ABC, the artificial employed bee whose food source nectar has been exhausted or the profitability of the food source drops under a certain threshold level is selected and classified as the artificial

scout. The classification is controlled by a control parameter that is called ''abandonment criteria" or "limit''. If a solution representing a food source position is not improved until a predetermined number of trials, then that solution is abandoned by its employed bee and the employed bee becomes a scout. The number of trials for releasing a solution is equal to the value of ''limit''.

In ABC, a population based algorithm, the position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution. The number of the employed bees is equal to the number of solutions in the population. At the first step, a randomly distributed initial population (food source positions) is generated. After initialization, the population is subjected to repeat the cycles of the search processes of the employed, onlooker, and scout bees, respectively.

5.5 ARTIFICIAL BEE COLONY ALGORITHM FOR OPTIMIZATION PROBLEMS.

Constrained optimization (CO) finds parameter vector *x,* that minimizes an objective function $f(x)$ subject to inequality and/or equality constraints.

$$\text{Minimize} f(x), x = (x1, x2, x3, x4, \ldots xn) \in Rn \qquad (18)$$

$l \le x \le u$ i = 1,2, …n

Subject to:

$g(x) \le 0\ j$ for j=1,2,..q

$h(x) = 0\ j$ for j=q+1,m

The objective function f is defined on a search space, *S*, which is defined as a *n*-dimensional rectangle in *Rn* ($S \subseteq Rn$) Domains of variables are defined by their lower and upper bounds. A feasible region $F \subseteq S$ is defined by a set of *m* additional constraints ($m \ge 0$) and $xinF \in S$. At any point *xinF* , constraints gk that satisfy $g(x)\ k$ are called active constraints at *x* . By extension, equality constraints hj are also called active at all points.

Constrained optimization problems are hard to optimization algorithms but no single parameter (number of linear, nonlinear, active constraints, the ratio $\rho = F / S$, type of the function, number of variables is proved to be significant as a major measure of difficulty of the problem.

5.6 APPLICATION ABC TO FOUND DG SIZE

Standard ABC algorithm is effectively used for solving unit-modal and multi-modal numerical optimization problems and also to solve many difficult continuous, unconstrained optimization problems. Improved versions of ABC introduced for constrained optimization problems. Constrained Optimization problems are encountered in numerous applications in scientific field such as target identification, Structural optimization, engineering design, VLSI design, allocation and location problems, economics and in many other fields .

The proposed artificial bee colony algorithm is summarized as follows:

1) Input line and bus data, and bus voltage limits

2) Initial Bee population Xij as each bee is formed by sizes of DG units

3) Evaluate the population for each employed bee by using the following the equation.

4) Cycle=1; repeat

5) Generate new population vij in the neighborhood of xij for employed bees using equation (16) and evaluate them.

6) Apply the greedy selection process between xi and vi

7) Calculate the probability values Pi for the solutions xi by means of their fitness values using the equation.

8) Produce the new solutions (new positions) vi for the onlookers from the solutions xi, selected depending on Pi, and evaluate them.

9) Apply the greedy selection process for the onlookers between xi and vi

10) Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution xi for the scout using the equation.

11) Memorize the best food source position (solution) achieved so far.

12) Cycle=cycle+1.

13) Until cycle= Maximum Cycle Number (MCN).

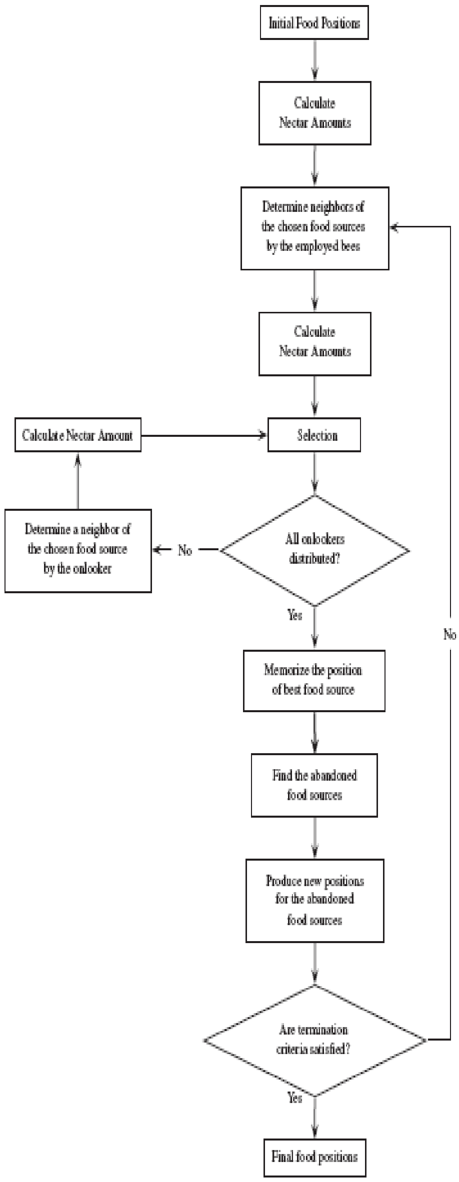


Figure 4 : Flowchart for Artificial Bee Colony Algorithm

The current position can be modified based on the new velocity of the search particle

$$s_{id}^{k+1} = s_{id}^{k} + v_{id}^{k+1}, i = 1,2,...,n \,. \qquad (19)$$

Where, d=1,2,3….m

6. RESULTS AND DISCUSSION:

The algorithm of this method was programmed in MATLAB. The ABC algorithm for distribution system was tested the 33 bus systems. The 33 bus system has 32 sections with the total load 3.72 MW and 2.3MVar shown in Figure 5..

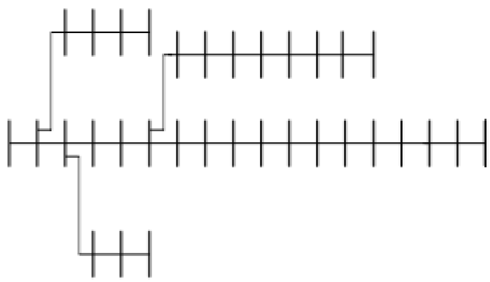
.The original total real power loss and reactive power loss in the system is 221.4346 kW and150.1784 kVar, respectively. For the first iteration the maximum saving is occurring at bus 6. The candidate location for DG is bus 6 with a loss saving of 99.875 kW. The optimum size of DG at bus 6 is 2.67 MW. By assuming 2.670 MW DG is connected at bus

6 of base system and is considered as base case. Now the candidate location is bus 15with 0.5757 MW size and the loss saving is 11.947 KW.

Case / Iteration No.	bus locations / Bus No.	DG Sizes / Total Size / DG (MW)	Losses before DG installation / loss after DG installation / Loss reduction (KW)	saving KW / Saving in DG / Saving (KW)
1	6	2.590	106.32	99.87
2	15	0.5757	210.0	11.947
3	25	0.7826	213.63	7.6936
4	32	0.6538	213.23	8.1415

Table 1: Single DG placement with loss reduction

Matlab output



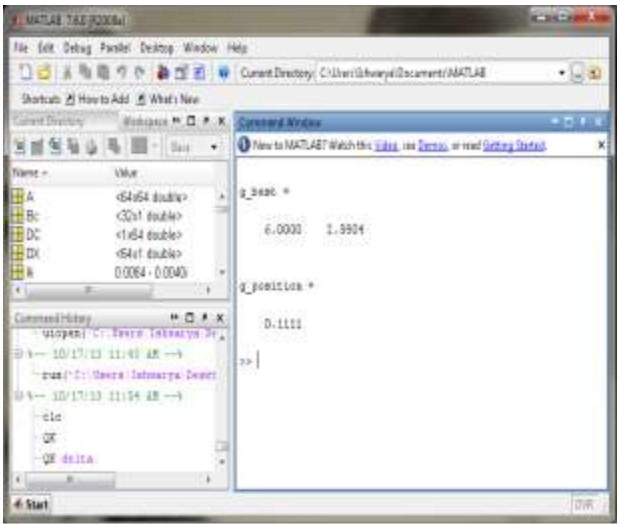


Figure5: Matlab output single DG

Based on the analytical expression, the optimum size of DG is calculated at each bus for the test system and bus having least total power loss will be the optimal location for the placement of DG; the best location is bus 6 with a total power loss of 111.2 kW, but this approach violates the voltage limits .The optimal placement of DG by loss sensitivity approach is not able to identify the best location. The optimal placement of DG by repeated load flow with loss of 111.02kW violate the voltage limits, If voltage limits are taken into consideration then size of DG will increase but if the same is done by PSO and ABC technique by taking the voltage limit constraints into consideration the size of DG will decrease drastically

I	6	2.67	2.67	221	106	99.9	39.9
II	6	1.97	2.55		90	114	44.8
	15	0.58					

Table :II Two DG placement by ABC algorithm

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 above. The sizes of DGs are dependent on the number of DG locations. Generally it is not possible to install many DGs ina given radial system. Here 2 cases are considered. In case1 only one DG installation is assumed. In case 2 have two DGs are assumed to be installed. DG sizes in the two optimal locations, total real power losses before and after DG installation for two cases are given in Table II.

Saving 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.

The above figure represents the particle searching about the best location of DG and where the particles are more in a searching path is the best converge solution and also it shows the best location and the size of the DG

Figure 6: Searching of a best solution for placement of DG

Table III 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 two cases.

Table III : Voltage profile improvement by ABC algorithm

case No.	Min Voltage		% improvement	
	PM	AM	PM	AM
Base case	0.9118	---		
case1	0.9508	0.9486	2.14	1.98
case2	0.9543	0.9596	2.53	2.35

Table IV : Comparison of Proposed method with analytic method

Case	Bus	sizes(Mw)		Total Size(Mw)		saving(Kw)	
		PM	AM	PM	AM	PM	AM
1	6	2.67	2.489	2.67	2.489	98.88	92.18
2	6	1.971	1.898	2.546	2.468	113.9	96.35
	15	0.576	0.57				

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.

Table V: Comparison of GA, PSO and ABC

Methodology	Optima location	DGSize (Mw)	Power Loss(in KW)		losreduction (kw)
			Without -DG	With DG	
Heuristic	6	2.490	223.34	132.83	83.17
GA	6	2.380	223.34	132.64	83.36
PSO	6	2.590	223.34	111.1	92.17
ABC	6	2.67	223.34	106.32	99.87

Table V shows optimal location for all the bus is same but DG size is high in PSO method and ABC when compared to other methods. In Heuristic and GA power loss with DG is high 132.8 and 132.6 respectively, but in case of ABC loss will be reduced up to 106.32 and loss reduction is 99.8.

To demonstrate the supremacy of the proposed method the results are compared with the results of PSO algorithm as shown in Table VI. Though the number of iterations is more is compared with an existing analytical method. When compared to PSO the swarm size is also comparitievly reduced in ABC algorithm.Average number of itration is also increasing in PSO method.The comparison is shown in Table VI.Output of the DG is increased while using PSO optimization algorithm but Artificial Bee colony algorithm reducing the output size of the DG also it will reduce the overall cost of the system Mean of best fuction is also shown in figure 7.

Table VI:Comparison performance of Optimization Technique

	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	2.67	2.59	1.971	1.679	1.757	1.654	1.077	1.077
			0.576	0.457	0.576	0.457	0.576	0.576
					0.783	0.773	0.782	0.782
							0.654	0.654
Swarm size	40	50	40	50	40	50	40	50
Avg. No. of iterations	88.8	103	141.3	118.2	192.4	148.1	212.6	160
Avg. time(sec.)	6.93	11.2	10.07	12.54	15	15.82	16.11	16.6

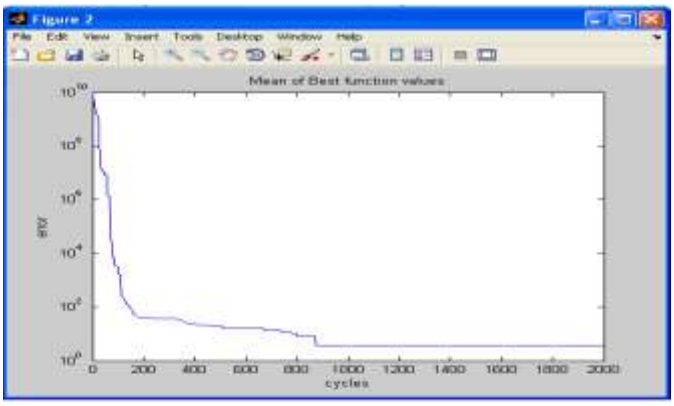


Figure :7 Mean Of Best Function

Table VII: Comparison result of ABC and PSO Algorithms

Case	I	II
PSO	8.23	11.42
ABC	4.52	11.65

ABC found the optimum value within the given cycle duration while PSO could not and it takes more times to find the global position. The results proved that the ABC algorithm is simple in nature than GA and PSO so it takes less computation time

7.CONCLUSIONS

ABC algorithm is very simple and very flexible when compared to other swarm based algorithms as ABC does not require external parameters such as cross over rate and mutation rate etc., as in case of genetic algorithms, differential evolution and other evolutionary algorithms**.** In this project, a two-stage methodology of finding the optimal locations and sizes of DGs for maximum loss reduction of radial distribution systems is presented. Single DG placement method is proposed to find the optimal DG locations and ABC algorithm is used to find the optimal DG sizes. The validity of the proposed method is proved from the comparison of the results of the proposed method with other existing methods. 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.

Many studies have compared the performance of ABC with other swarm based algorithms such as Particle Swarm Optimization (PSO), Differential evolution (DE) and also with classical optimization algorithms in some cases. Most of the studies indicated that ABC outperformed or the performance was equal to other methods. This work compared the performance of ABC algorithm with those of GA, DE, PSO and ES algorithms on a large set of unconstrained test functions. From the results obtained in this work, it can be concluded that the performance of ABC algorithm is better than or similar to that of these algorithms although it uses less control parameters and it can be efficiently used for solving multimodal and multidimensional optimization problems.

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