Optimal Allocation and Sizing of Distributed Generation using Artificial Bee Colony Algorithm

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Abstract**-**This project presents a new optimization approach that employs an artificial bee colony (ABC) algorithm to determine the optimal DG-unit's size and location in order to minimize the total system real power loss and improve the voltage profile. The ABC algorithm is a new metaheuristic, population-based optimization technique inspired by the intelligent foraging behavior of the honeybee swarm. To reveal the validity of the ABC algorithm, sample radial distribution feeder systems are examined with different test cases.

Furthermore, the results obtained by the proposed ABC algorithm are compared with those attained via other methods. The outcomes verify that the ABC algorithm is efficient, robust, and capable of handling mixed integer nonlinear optimization problems. The ABC algorithm has only two parameters to be tuned. Therefore, the updating of the two parameters towards the most effective values has a higher likelihood of success than in other competing metaheuristic methods. IEEE 34 bus system is the test system taken for checking the reliability of the proposed algorithm and the results are checked in ETAP 12.6 and MATLAB.

Key words **—Artificial bee colony (ABC), distributed generation (DG), metaheuristic optimization algorithm, power losses reduction, voltage profile improvement**

1. INTRODUCTION

Utilities are continuously planning the expansion of their electrical networks in order to face the load growth and to properly supply their consumers. The traditional solution is the construction of new substations or the expansion of those already existent. The key objective of any electricity utility company in the current deregulating environment is to maximize the quality of services by providing acceptable level of voltage and reliability, also at the same time reduce the electricity cost for customers with lowering the investment, operation and maintenance costs. These goals together with the rising demands of customers have led to the increased growth of distributed generation (DG).

Distributed Generation (DG) system is defined as an electric power source of limited size (generally few kW to few MW) and connected directly to the distribution level at substation or distribution feeder; or at customer level. DG may employ either renewable or non-renewable energy to produce electricity with minimum emissions. There are many DG technologies including photovoltaic, wind turbine, fuel cells, small and micro-sized turbine packages, internal combustion engine generators, and reciprocating engine generators, several of these have only been developed in the last few decades.

Distribution systems are usually radial in nature for the operational simplicity. Radial distribution systems (RDSs) are fed at only one point which is the substation. The substation receives power from centralized generating stations through the interconnected transmission network. The end users of electricity receive electrical power from the substation through RDS which is a passive network. Hence, the power flow in RDS is unidirectional. High R/X ratios in distribution lines result in large 0voltage drops, low voltage stabilities and high power losses.

Due to uncertainty of system loads on different feeders, which vary from time to time, the operation and control of distribution systems is more complex particularly in the areas where load density is high. Because of the dynamic nature of loads, total system load is more than its generation capacity that makes relieving of load on the feeders not possible and hence voltage profile of the system will not be improved to the required level. In order to meet required level of load demand, DG units are integrated in distribution network to improve voltage profile, to provide reliable and uninterrupted power supply and also to achieve economic benefits such as minimum power loss, energy efficiency and load leveling. Such embedded generations in a distribution system are called dispersed generations or distributed generations.

Main reasons for the increasingly widespread usage of distributed generation can be summed up as follows

- It is easier to find sites for small generators
- Latest technology has made available plants ranging in capacities from 10 KW to 15 MW
- DG units are closer to customers so that Transmission and Distribution (T&D) costs are ignored or reduced
- It reduces the power loss and improves the voltage profile
- It provides high reliability and power quality improvement

This project aims at minimizing the total real power loss in radial distribution system by optimal allocation and sizing of distributed generation (DG) using Artificial Bee Colony Algorithm (ABC). The ABC algorithm is a new metaheuristic, population-based optimization technique inspired by the intelligent foraging behavior of the honeybee swarm. This technique was implemented in IEEE 34 bus radial distribution system for optimal allocation and sizing of distributed generation and the same is recorded in this project.

2. LOAD FLOW STUDY

The objectives of load flow study are:

- Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increased load demand and locating new transmission sites.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection.
- at all the buses and power flows through interconnecting power channels.
- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines. System transmission loss minimizes. Economic system operation with respect to fuel cost to generate all the power needed. The line flows can be known which helps in avoiding line overloading.

Step 1) Assume a suitable solution for all buses except slack bus. Assume Vp=1+j0.0 for p= 1, 2….n

Step 2) Convergence criterion is set to ∈ that means if the largest of absolute of the residues exceed ∈ the process repeated else terminated.

Step 3) Iteration count is set to K=0

Step 4) Bus count is set to p=1

Step 5) Say p is slack bus .If yes skip to step 10.

Step 6) Real and Reactive powers Pp *and* Qp are calculated respectively using equations

$$P_p=\sum_{q=1}^{n}\{e_p\left(e_qG_{pq}+f_pB_{pq}\right)+f_p(f_qG_{pq}-e_qB_{pq})\}$$

$$Q_p=\sum_{q=1}^{n}\{f_p\left(e_qG_{pq}+f_pB_{pq}\right)-e_p(f_qG_{pq}-e_qB_{pq})\}$$

Step 7) Calculate

$$\Delta P_p^k= P_{sp}-P_p^k.$$

Step 8) Check for bus to be generator bus, if yes compare the reactive power Qp with the upper and lower limits.

if $Qgen> Qmax$ set , $Qgen= Qmax$

else if $Qgen< Qmin$ set, $Qgen= Qmin$

else if the value is within the limit ,the value is retained. If the limits are not violated voltage residue is evaluated as

$$|\Delta Vp|^2=|Vp|^2_{spec}-\left|V_p^k\right|^2$$

and then go to step 10.

Step 9) Evaluate

$$\Delta Q_p^k= Q_{sp}-Q_p^k$$

Step 10) Bus count is incremented by 1, i. e p=p+1 and check if all buses have been accounted else, go to step 5.

Step 11) Determine the largest of the absolute value of residue. If the largest of absolute value of the residue is less than ∈ then go to step 16

Step 12) Jacobian matrix elements are evaluated.

Step 13) Voltage increments are calculated

Step 14) Calculate new bus voltages and phase angle

$$e_p^{k+1}=e_p^k+\Delta e_p^k$$
$$f_p^{k+1}=f_p^k+\Delta f_p^k$$

Step 15) Advance iteration count is K =K+1, then go to step 4

Step 16) Finally bus and line powers are evaluated and results printed.

3. ABC ALGORITHM

The artificial bee colony (ABC) algorithm is a new meta-heuristic optimization approach, introduced in 2005 by Karaboga. Initially, it was proposed for unconstrained optimization problems. Then, an extended version of the ABC algorithm was offered to handle constrained optimization problems. The ABC algorithm is a new meta-heuristic, population-based optimization technique inspired by the intelligent foraging behavior of the honeybee swarm.

The colony of artificial bees consists of three groups of bees: employed, onlookers, and scout bees. The employed bees are those which randomly search for food-source positions (solutions.) Then, by dancing, they share the information of that food source, that is., nectar amounts (solutions' qualities), with the bees waiting in the dance area of the hive. Onlookers are those bees waiting in the hive's dance area. The duration of a dance is proportional to the nectar content (fitness value) of the food source currently being exploited by the employed bee. Hence, onlooker bees watch various dances before choosing a food source position according to the probability proportional to the quality of that food source. Consequently, a good food-source position (solution) attracts more bees than a bad one. Onlookers and scout bees, once they discover a new food-source position (solution), may change their status to become employed bees. Furthermore, when the food-source position (solution) has been visited (tested) fully, the employed bee associated with it abandons it, and may once more become a scout or onlooker bee.

In a robust search process, exploration and exploitation processes must be carried out simultaneously. In the ABC algorithm, onlookers and employed bees perform the exploration process in the search space; while on the other hand, scouts control the exploration process. Inspired by the aforementioned intelligent foraging behavior of the honey bee, the ABC algorithm was introduced. One half of the colony size of the ABC algorithm represents the number of employed bees, and the second half stands for the number of onlooker bees.

For every food-source's position, only one employed bee is assigned. The number of trials for the food source to be called "exhausted" is controlled by the limit value of the ABC algorithm's parameter. The ABC algorithm creates a randomly distributed initial population of solutions (i=1,2,.....,Eb) , where i signifies the size of population and Eb is the number of employed bees. Each solution xi is a D-dimensional vector, where D is the number of parameters to be optimized.

The position of a food-source, in the ABC algorithm, represents a possible solution to the optimization problem, and the nectar amount of a food source corresponds to the quality (fitness value) of the associated solution. After initialization, the population of the positions (solutions) is subjected to repeated cycles of the search processes for the employed, onlooker, and scout bees (cycle=1,2,...,MCN) , where MCN is the maximum cycle number of the search process.

Then, an employed bee modifies the position (solution) in her memory depending on the local information (visual information) and tests the nectar amount (fitness value) of the new position (modified solution.) If the nectar amount of the new one is higher than that of the previous one, the bee memorizes the new position and forgets the old one. Otherwise, she keeps the position of the previous one in her memory. After all employed bees have completed the search process; they share the nectar information of the food sources and their position information with the onlooker bees waiting in the dance area. An onlooker bee evaluates the nectar information taken from all employed bees and chooses a food source with a probability related to its nectar amount. The same procedure of position modification and selection criterion used by the employed bees is applied to onlooker bees.

The probability for selecting a food-source *pi* by onlooker bees is calculated as follows:

$$p_i = \frac{\text{fitness}_i}{\sum_{i=1}^{E_b} \text{fitness}_i}$$

where fitness *i* is the fitness value of a solution , and Eb is the total number of food-source positions (solutions) or, in other words, half of the colony size. Furthermore, if a solution does not improve for a specified number of times (limit), the employed bee associated with this solution abandons it, and she becomes a scout bee and searches for a new random food-source position. Once the new position is determined, another ABC algorithm cycle (MCN) starts. The same procedures are repeated until the stopping criteria are met.

3.1 Control parameter of ABC

- Colony Size (CS): It represents the total number of bees present. One half of the colony size represents the number of employed bees and the second half stands for the number of the onlooker bees.

- Limit Value: It represents the number of trials for a food-source position (solution) to be abandoned.
- Maximum Cycle Number (MCN): The maximum number of times the search process has to be repeated.

4. FLOW CHART OF ABC ALGORITHM

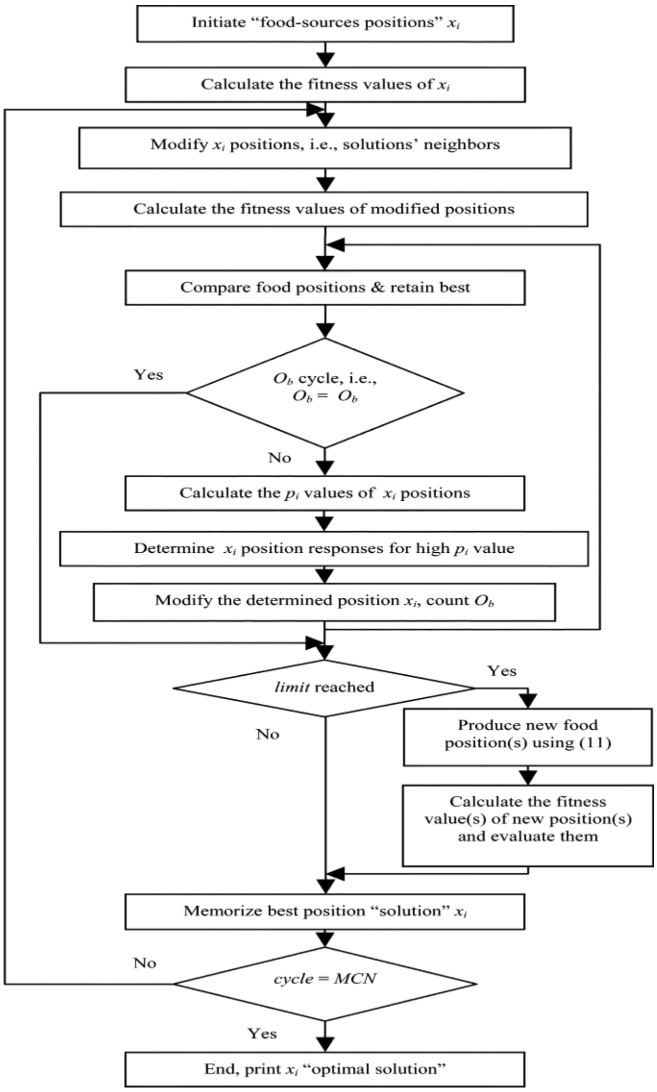

Fig 1 Flow chart of ABC

5. PROBLEM FORMULATION

The objective function is to minimize the total system real power loss

$$\text{Obj.Fun} = \min \sum_{i=0}^{n} \left(\frac{P_i^2 + Q_i^2}{V_i^2} \right) \times r_{i+1}.$$

n	=	Number of buses.
Pi	=	Real power flows
Qi	=	Reactive power flows
V_i	=	Bus voltage at bus i
r	=	Resistance of line
x	=	Reactance of line

$$\text{fitness}_i = \frac{1}{1 + \text{Obj. Fun.}_i}$$

Parameters of ABC

- Colony size, CS = 20
- Limit Value = 100
- Maximum Cycle Number =1200

6. STUDY OF TEST SYSTEM

The simulation is done on IEEE 34 bus test system.

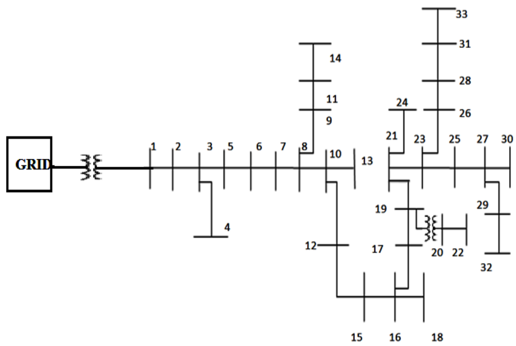

Fig 2 . 34 bus test system

Number of

-Buses = 34
-Source = 1
-Loads = 33

Rating of

Load = 1568 kW & 743 kVAr
Source = 69KV

BUS ID	BUS ID	R (Ω)	X (Ω)
34	1	0.0013368	0.0013343
1	2	0.0013368	0.0013343
2	3	0.0013368	0.0013343
3	4	0.0027995	0.0014855
3	5	0.0013368	0.0013343
5	6	0.0013368	0.0013343
6	7	0.00193	0.0014115
7	8	0.00193	0.0014115
8	9	0.0027995	0.0014855
8	10	0.00193	0.0014115
9	11	0.0027995	0.0014855
10	12	0.00193	0.0014115
10	13	0.0027995	0.0014855
11	14	0.0027995	0.0014855
12	15	0.00193	0.0014115
15	16	0.00193	0.0014115
16	17	0.00193	0.0014115
16	18	0.0027995	0.0014855
17	19	0.00193	0.0014115
19	20	0.003064467	0.006580539
19	21	0.00193	0.0014115
20	22	0.0013368	0.0013343
21	23	0.00193	0.0014115
21	24	0.0027995	0.0014855
23	25	0.00193	0.0014115
23	26	0.00193	0.0014115
25	27	0.00193	0.0014115
26	28	0.00193	0.0014115
27	29	0.00193	0.0014115
27	30	0.00193	0.0014115
28	31	0.00193	0.0014115
29	32	0.0019217	0.0014212
31	33	0.00193	0.0014115

Table 1. Line data

Table 2. Bus data

Sl.NO	BUS ID	P load (KW)	Q load (KW)
1	1	45	21.794
2	2	44	23.749
3	3	13.35	6.84
4	4	19	6.45
5	8	4.181	1.665
6	9	22.606	11.581
7	11	89.76	48.447
8	14	67.044	34.718
9	10	33.226	16.28
10	13	22.835	11.572
11	12	16.38	7.463
12	15	49.41	21.786
13	16	4.5	2.18
15	18	22.361	11.18
16	19	7.44	2.327
18	22	1.549	0.84
19	21	16.02	8.207
20	24	1.8	0.87
21	23	96.707	24.238
22	26	61.6	33.247
23	28	398	200
24	31	26.841	13.4
25	33	250	0
26	25	128	78.041
27	27	0.005	300
28	29	13.455	6.63
29	32	12.516	6.273
30	30	19.981	9.902

7. MATLAB RESULT

The Coding is done for 34 bus test system and the size and location of the DG units are found out.

- DG1 connected to BUS 28
- DG2 Connected to Bus 5
- Real Power Loss = 0.00013 MW
- Reactive Power Loss = 0.00011MVar
- DG Size1= 0.700000MW
- DG Size2 = 0.100000MW

Command Window

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	34	1	0.67	0.65	-0.67	-0.65	0.00001	0.00001
2	1	2	0.63	0.63	-0.63	-0.63	0.00001	0.00001
3	2	3	0.58	0.60	-0.58	-0.61	0.00001	0.00001
4	3	4	0.02	0.01	-0.02	-0.01	0.00000	0.00000
5	3	5	0.55	0.59	-0.55	-0.59	0.00001	0.00001
6	5	6	0.55	0.59	-0.55	-0.60	0.00001	0.00001
7	6	7	0.55	0.60	-0.55	-0.60	0.00001	0.00001
8	7	8	0.55	0.60	-0.55	-0.60	0.00001	0.00001
9	8	9	0.18	0.09	-0.18	-0.09	0.00000	0.00000
10	8	10	0.37	0.51	-0.37	-0.51	0.00001	0.00001
11	9	11	0.16	0.08	-0.16	-0.08	0.00000	0.00000
12	10	12	0.31	0.48	-0.31	-0.48	0.00001	0.00000
13	10	13	0.02	0.01	-0.02	-0.01	0.00000	0.00000
14	11	14	0.07	0.03	-0.07	-0.03	0.00000	0.00000
15	12	15	0.29	0.47	-0.29	-0.48	0.00001	0.00000
16	15	16	0.25	0.46	-0.25	-0.46	0.00000	0.00000
17	16	17	0.22	0.45	-0.22	-0.45	0.00000	0.00000
18	16	18	0.02	0.00	-0.02	-0.01	0.00000	0.00000
19	17	19	0.22	0.45	-0.22	-0.45	0.00000	0.00000
20	19	20	0.05	0.02	-0.05	-0.03	0.00000	0.00000
21	19	21	0.16	0.42	-0.16	-0.42	0.00000	0.00000
22	20	22	0.05	0.03	-0.05	-0.03	0.00000	0.00000
23	21	23	0.14	0.42	-0.14	-0.42	0.00000	0.00000
24	21	24	0.00	0.00	-0.00	-0.00	0.00000	0.00000
25	23	25	0.22	0.10	-0.22	-0.10	0.00000	0.00000
26	23	26	-0.17	0.29	0.17	-0.29	0.00000	0.00000
27	25	27	0.09	0.03	-0.09	-0.03	0.00000	0.00000
28	26	28	-0.20	0.28	0.20	-0.28	0.00000	0.00000
29	27	29	0.03	0.01	-0.03	-0.01	0.00000	0.00000
30	27	30	0.02	-0.01	-0.02	0.01	0.00000	0.00000
31	28	31	-0.59	-0.03	0.59	0.03	0.00001	0.00000
32	29	32	0.01	0.01	-0.01	-0.01	0.00000	0.00000
33	31	33	-0.62	-0.04	0.62	0.04	0.00001	0.00001
						Total:	0.00013	0.00011

Table 3 MATLAB Result

8. ETAP SIMULATION

The results obtained from MATLAB are simulated using ETAP and the losses and voltage profile are obtained.

Branch Losses Summary Report

CKT / Branch ID	From-To Bus Flow MW	From-To Bus Flow Mvar	To-From Bus Flow MW	To-From Bus Flow Mvar	Losses kW	Losses kvar	% Bus Voltage From	% Bus Voltage To	Vd % Drop in Vmag
Line1	-1.554	0.806	1.558	-0.804	3.2	1.6	99.7	99.8	0.08
Line2	1.509	-0.827	-1.507	0.828	2.1	1.0	99.7	99.7	0.05
Line3	1.463	-0.852	-1.452	0.857	10.9	5.1	99.7	99.4	0.23
Line4	0.019	0.003	-0.019	-0.006	0.0	-2.8	99.4	99.4	0.01
Line5	1.420	-0.868	-1.409	0.873	10.8	5.0	99.4	99.2	0.21
Line6	1.409	-0.873	-1.398	0.878	11.1	5.1	99.2	99.0	0.21
Line7	1.398	-0.878	-1.398	0.878	0.0	0.0	99.0	99.0	0.00
Line8	1.398	-0.878	-1.398	0.878	0.5	0.2	99.0	99.0	0.01
Line9	0.179	0.085	-0.179	-0.086	0.1	-0.8	99.0	99.0	0.03
Line10	1.214	-0.964	-1.201	0.968	13.3	4.3	99.0	98.7	0.28
Line11	0.157	0.074	-0.157	-0.078	0.2	-4.3	99.0	98.8	0.16
Line12	1.145	-0.995	-1.144	0.995	1.2	0.4	98.7	98.7	0.02
Line13	0.023	0.010	-0.023	-0.012	0.0	-1.5	98.7	98.7	0.01
Line14	0.067	0.030	-0.067	-0.035	0.0	-4.7	98.8	98.7	0.07
Line15	1.127	-1.003	-1.114	1.007	13.0	4.0	98.7	98.5	0.22
Line16	1.065	-1.028	-1.064	1.029	0.7	0.2	98.5	98.5	0.01
Line17	1.037	-1.038	-1.037	1.038	0.0	0.0	98.5	98.5	0.00
Line18	0.022	0.007	-0.022	-0.011	0.0	-4.5	98.5	98.4	0.02
Line19	1.037	-0.650	-1.037	0.650	0.0	0.0	98.5	98.5	0.00
Line20	1.029	-0.653	-1.024	0.653	4.4	0.4	98.5	98.3	0.16
T2	0.002	0.001	-0.002	-0.001	0.0	0.0	98.5	99.7	1.24
Line21	0.002	0.001	-0.002	-0.001	0.0	-0.1	99.7	99.7	0.03
Line22	1.006	-0.661	-1.001	0.662	5.1	0.4	98.3	98.1	0.18
Line23	0.002	0.000	-0.002	-0.001	0.0	-0.8	98.3	98.3	0.00
Line24	0.174	-0.205	-0.174	0.204	0.1	-1.1	98.1	98.1	0.00
Line25	0.730	-0.481	-0.730	0.481	0.1	-0.1	98.1	98.1	0.01
Line26	0.046	-0.282	-0.046	0.280	0.1	-1.5	98.1	98.1	0.03
Line27	0.669	-0.514	-0.668	0.514	0.6	-0.4	98.1	98.1	0.02
Line28	0.026	0.010	-0.026	-0.011	0.0	-0.2	98.1	98.1	0.00
Line29	0.020	0.009	-0.020	-0.010	0.0	-0.5	98.1	98.1	0.00
Line30	0.277	-0.422	-0.277	0.420	0.6	-1.7	98.1	98.1	0.01
Line31	0.013	0.004	-0.013	-0.006	0.0	-2.4	98.1	98.1	0.00
Line32	0.250	-0.433	-0.250	0.433	0.1	-0.2	98.1	98.1	0.00
T1	1.568	-0.743	-1.558	0.804	10.1	60.9	100.0	99.8	0.21

Table 4 Bus Losses report without DG

Branch Losses Summary Report

CKT / Branch ID	From-To Bus Flow MW	From-To Bus Flow Mvar	To-From Bus Flow MW	To-From Bus Flow Mvar	Losses kW	Losses kvar	% Bus Voltage From	% Bus Voltage To	Vd % Drop in Vmag
Line1	-0.805	0.677	0.806	-0.678	1.2	-0.4	99.8	99.8	0.01
Line2	0.760	-0.699	-0.759	0.699	0.8	-0.3	99.8	99.8	0.00
Line3	0.715	-0.722	-0.711	0.721	3.9	-1.9	99.8	99.8	0.00
Line4	0.019	0.003	-0.019	-0.006	0.0	-2.9	99.8	99.8	0.01
Line5	0.679	-0.731	-0.675	0.729	3.9	-2.1	99.8	99.8	0.02
Line6	0.764	-0.751	-0.760	0.750	4.6	-1.5	99.8	99.8	0.01
T4	-0.089	0.023	0.090	-0.019	0.9	3.3	99.8	100.0	0.17
Line7	0.760	-0.750	-0.760	0.750	0.0	0.0	99.8	99.8	0.00
Line8	0.760	-0.750	-0.759	0.750	0.2	0.0	99.8	99.8	0.00
Line9	0.180	0.085	-0.180	-0.086	0.1	-0.8	99.8	99.8	0.03
Line10	0.576	-0.836	-0.570	0.835	5.6	-1.4	99.8	99.8	0.02
Line11	0.157	0.074	-0.157	-0.078	0.2	-4.4	99.8	99.6	0.15
Line12	0.514	-0.861	-0.513	0.861	0.5	-0.1	99.8	99.8	0.01
Line13	0.023	0.010	-0.023	-0.012	0.0	-1.5	99.8	99.8	0.01
Line14	0.067	0.030	-0.067	-0.035	0.0	-4.8	99.6	99.6	0.07
Line15	0.497	-0.868	-0.491	0.867	5.6	-1.6	99.8	99.9	0.08
Line16	0.442	-0.889	-0.442	0.889	0.3	-0.1	99.9	99.9	0.01
Line17	0.415	-0.897	-0.415	0.897	0.0	0.0	99.9	99.9	0.00
Line18	0.022	0.007	-0.022	-0.011	0.0	-4.6	99.9	99.9	0.02
Line19	0.415	-0.498	-0.415	0.498	0.0	0.0	99.9	99.9	0.00
Line20	0.406	-0.501	-0.405	0.499	1.2	-2.1	99.9	99.9	0.01
T2	0.002	0.001	-0.002	-0.001	0.0	0.0	99.9	99.9	0.01
Line21	0.002	0.001	-0.002	-0.001	0.0	-0.1	99.9	99.9	0.03
Line22	0.387	-0.507	-0.386	0.505	1.4	-2.5	99.9	99.9	0.01
Line23	0.002	0.000	-0.002	-0.001	0.0	-0.8	99.9	99.9	0.00
Line24	0.174	-0.205	-0.174	0.204	0.1	-1.1	99.9	99.9	0.00
Line25	0.115	-0.324	-0.115	0.324	0.0	-0.2	99.9	99.9	0.00
Line26	0.046	-0.282	-0.046	0.280	0.1	-1.5	99.9	99.9	0.03
Line27	0.053	-0.357	-0.053	0.356	0.1	-0.7	99.9	99.9	0.02
Line28	0.026	0.010	-0.026	-0.010	0.0	-0.2	99.9	99.9	0.00
Line29	0.020	0.009	-0.020	-0.010	0.0	-0.5	99.9	99.9	0.00
Line30	0.277	-0.438	-0.277	0.436	0.6	-1.8	99.9	99.9	0.01
T3	-0.622	0.182	0.630	-0.155	7.7	27.0	99.9	100.0	0.07
Line31	0.013	0.004	-0.013	-0.006	0.0	-2.5	99.9	99.9	0.00
Line32	0.250	-0.450	-0.250	0.449	0.1	-0.3	99.9	99.9	0.00

Table 5 Bus Losses report with DG

9. RESULTS AND DISCUSSIONS

Bus No	Voltage Profile in Normal Condition	Voltage Profile After Adding DG
1	99.7	99.8
3	99.43	99.8
5	99.21	99.81
7	99	99.8
9	98.71	99.79
11	98.71	99.63
13	98.47	99.83
15	98.45	99.92
17	98.44	99.93
18	98.36	99.91
19	98.7	99.93
20	98.3	99.92
21	98.3	99.92
22	99.67	99.89
23	98.72	99.91
24	98.3	99.92
25	98.12	99.91
27	98.14	99.93
28	98.09	99.93
29	98.14	99.93
31	98.14	99
33	97	99.94

Table 6 Voltage profile before and after placement of DG

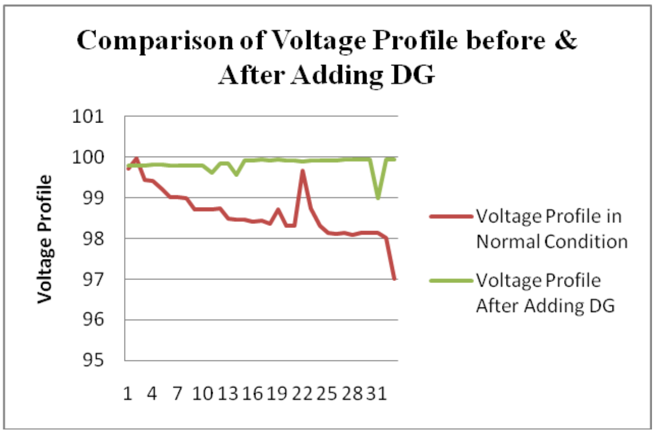

Chart 1. Schematic comparison of voltage profile

Bus No	Power loss in Normal Condition	Power loss After Adding DG
1	3.2	1.2
2	2.1	0.8
3	10.9	3.9
5	10.8	3.9
6	11.1	4.6
8	0.5	0.2
10	13.3	5.6
12	1.2	0.5
15	13.0	5.6
16	0.7	0.3
20	4.4	1.2
22	5.1	0.4
23	0.0	0.0
24	0.1	0.1
25	0.1	0.0
26	0.1	0.1
27	0.6	0.1
28	0.0	0.0
29	0.0	0.0
30	0.6	0.6
31	0.0	0.0
32	0.1	0.1

Table 7 Power loss before and after placement of DG

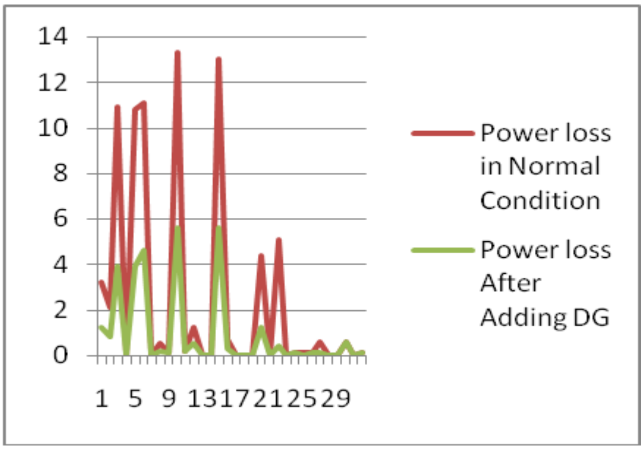

Chart 2. Schematic comparison of power loss

	Real power loss (KW)	Reactive power loss (KVar)
Before placement of DG	88.5	61.0
After Placement of DG	42.7	9.5

Table 8 Comparison of total power loss

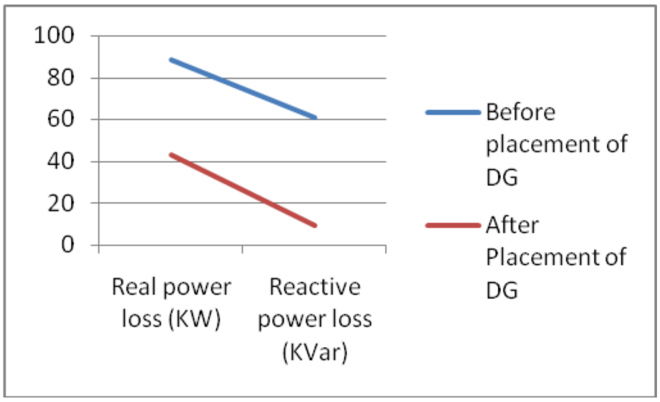

Chart 3 Schematic Comparison of total power loss

10. CONCLUSION

The DG is placed in the distribution system using Artificial Bee Colony Algorithm. The voltage profile of the system is improved and the real power losses are reduced. The result is verified using two software ETAP 12.6.0 and Matlab. ETAP is a real time software, hence the losses are more as it includes the losses of transformers and the equipments connected to the distribution system.

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