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Minimization of RPL and Voltage Deviation by Distributed Generation Placement Using ABC

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ABSTRACT
This paper presents an artificial bee colony (ABC) algorithm based optimal location and sizing of Distributed Generation (DG) unit in order to minimize the real power loss and Voltage Deviation of the radial distribution system. The presence of a DG in the distribution system is capable of delivering real power and which impacts of the power loss and voltage deviation of the system. The artificial bee colony algorithm is followed on the intelligent foraging behavior of honey bee swarm with consist of three bees namely employed, onlooker and scout bees. The proposed approach is examined and tested on 38 bus radial test system.
Keywords - artificial bee colony, distributed generation, Radial distribution system, real power loss, voltage deviation.

I. INTRODUCTION

The location of DG is defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the customer site of the meter [1]. The authors discussed in the determination of optimal location and sizing of DG units using multi objective performance index (MOPI) for enhancing the voltage stability of the radial distribution system [2]. The analytical expressions used for finding the optimal size and power factor of different types of distributed generators for minimizing losses in primary distribution systems in [3]. The genetic algorithm (GA) based approach to minimize the power loss of the system for evaluated the optimal placement and size of a DG with different loading conditions is reported in [4]. The introduction of combined GA and particle swarm optimization (PSO) methods and which is used to calculate the placement and sizing of DG in the distribution system [5]. The bacterial foraging optimization (BFO) algorithm based optimal placement and size of DG in the distribution system for considering the real power losses, operational costs and voltage stability [6]. The authors proposed the objective is to optimize the reactive power flow in a power system by minimizing the real power loss and sum of load bus voltage deviations using a Gravitational Search algorithm (GSA) in [7].

The efficient forward and backward propagation based load flow solution technique has been implemented in the radial networks is reported [8].

In a robust search process, exploration and exploitation processes must be carried out together. In the ABC algorithm, while onlookers and employed bees carry out the exploitation process in the search space, the scouts control the exploration process [9]. The ABC algorithm is imitates the behaviour of real bees in searching food sources and sharing the information with other bees [10]. The performance of the ABC is compared with other population based algorithms with the benefit of employing less number of control parameters [11]. The modified versions of ABC algorithm have been introduced in [12, 13] and it is used to solving the real-parameter optimization problems.

This paper proposes a methodology for optimal location and size of DG unit for minimization of real power loss and node voltage deviation and also to improve the voltage profile with accounting equality & inequality constraints.

II. PROBLEM FORMULATION

The combined objective for the optimal placement and sizing of DG is to minimize the real power loss and voltage deviation in the radial distribution system which can be described as follows,

$$OF = \omega . P_L + (1-\omega).VD \quad (1)$$

$$P_L = \sum_{i,j \in NL} \frac{P_{ij}^2 + Q_{ij}^2}{|V_i|^2} r_{ij} \quad (2)$$

$$VD = \sum_{i=1}^{NB} \sqrt{\left(V_i - V_{ref}\right)^2} \quad (3)$$

where,

P_L = total system real power loss (MW)
P_{ij}, Q_{ij} = real and reactive power flow in line i-j
V_i = voltage at i^{th} bus
r_{ij} = line resistance of i-j

NL = number of lines.
NB = number of bus
VD = voltage deviation
ω = weighing factor

While minimizing the value of above functions is subject to a number of following constraints as,

a) Power Balance Constraints

The algebraic sum of the entire receiving power is equal to the sum of entire sending power plus line loss over the complete distribution network and power generated from DG unit.

$$P_{SS} = \sum_{i=2}^{NB} P_D(i) + \sum_{j=1}^{NL} P_L(j) - \sum_{k=1}^{NDG} P_{DG}(k) \qquad (4)$$

where,

P_D - Total system real power demand (MW)
P_L - Total system real power loss (MW)
P_{DG} - Total real power generated by Distributed Generation (MW)
NDG - Number of DG.

b) DG Real Power Generation Limits

The real power generation of DG unit is controlled by its lower and higher limits as follows,

$$P_{DG}^{\min} \le P_{DG} \le P_{DG}^{\max} \qquad (5)$$

c) Voltage Profile Limits

The voltage at each node of the radial distribution network is defined as,

$$V_i^{\min} \le V_i \le V_i^{\max} \qquad (6)$$

$$0.95 \le V_i \le 1.03$$

d) Line Thermal Limits

The power carrying capacity of feeders should not exceed the thermal limit of the lines (S).

$$S_{(i,j)} \le S_{(i,j)}^{\max} \qquad (7)$$

III. ARTIFICIAL BEE COLONY (ABC) ALGORITHM

The artificial bee colony (ABC) algorithm proposed by Karaboga attracts much attention in the recent past because of its flexibility and robustness in solving optimization problems. It is developed based on the foraging behaviour of honey bees. This colony contains three groups of bees namely employed bees, onlooker bees and scout bees. The employed bees are searching with specific food sources and presented to the dance area. The onlooker bees are waiting on the dance area for making the decision to select a food source. If a particular food source is not converged for some cycles, bees search for food sources randomly called scout. Both onlooker and scouts bees are called as unemployed bees. The important steps of the ABC algorithm are as follows:

Step 1: Initialize the random population of food source, limit and maximum cycle number.
Step 2: Apply the employed bee procedure to modify the food source and evaluate the fitness function.
Step 3: Modify the food source based on onlooker bee procedure and evaluate the fitness function.
Step 4: The particular food source of the solution is abandoned; it is replaced by applying the scout bees.

The Implementation of ABC algorithm for optimal location and sizing of DG in the test system as follows:

1. Initialization: Set the colony size (CS) and D-dimensional parameter vectors in the artificial bee colony algorithm

$$x_{mi}; \qquad m = 1,2,\ldots.., CS \qquad (8)$$

The generation m with CS should be constant over the complete process of the optimization. The population vectors depending on size and location of DG unit is generated randomly and within the limits. Initialize the control parameter such as food number (CS/2), Limit (L), k and Maximum Cycle Number (MCN).

2. Create the random population vector using the equation and maintain the limit as,

$$x_{mi} = lb_i + rand\,[0,1] * (ub_i - lb_i)$$
$$i = 1,2,\ldots N \qquad (9)$$

where, N is the number of control variables. In this approach, the location of the DG unit is considered as the integer variable of the food source. The ABC algorithm handles the integer variables, regarding the rounding off food source position to the nearest integer.

3. Calculate the fitness value of the objective function by using

$$fitness = \frac{1}{1 + objective\ function} \qquad (10)$$

4. Set cycle = 1.
5. Employed bee phase: Create the new solutions for the employed bees by using equation as,

$$v_{mi} = x_{mi} + rand\,[-1,1] * (x_{mi} - x_{ki}) \qquad (11)$$

The new solution is called the modified neighbour of food source and maintaining the permissible limit. Using this parameter applied the objective function and should be satisfied the constraints. Further, evaluates the fitness value, and then applied the greedy selection between the current solutions and its perturbed.

6. Evaluate the probability values for the solutions by using the equation as,

$$p_m = \frac{fit(\vec{x}_m)}{\sum_{m=1}^{SN} fit(\vec{x}_m)} \qquad (12)$$

7. Onlooker bee phase: Generate the new solutions for modified food source depending on probability and evaluate them. Using these food source to apply the objective function and should be satisfied the constraints. Further, evaluates the fitness value, and then applied the greedy selection between the current solutions and its perturbed.
8. Scout bee phase: If the trial counters greater than the assigned limit value, newly created the random solution by using as,

$$v_{mi} = lb_i + rand\,[0,1]*\left(ub_i - lb_i\right) \quad (13)$$

and maintaining the limits of the problem.

9. Memorize the best solution achieved so far.
10. Cycle = cycle + 1
11. If the cycle is smaller than MCN, go to step 5, otherwise go to step 13.
13. STOP and print the result.

The proposed method has been implemented using MATLAB R2014A running on core i3 computer and reasonable computational time.

IV. NUMERICAL RESULTS

The proposed approach has been implemented on the 38-node radial distribution system consisting of base values used are 100 MVA and 23 KV. The size of the DG unit is considered in a practical range of 0 - 1.2 p.u. and unity p.f. for 38-node system. The system and load data of the 38-node system is taken from the reference [4]. In ABC algorithm, the control parameters are selected as, CS = 50, MCN = 200 and L = 0.5 x CS x D for both cases.

Table 1
Minimization of objective function terms for 38-node system

Parameter	Basecase	ABC algorithm
P_L (p.u.)	0.1888	0.1283
Q_L (p.u.)	0.1258	0.0878
VD	1.9302	1.0007
min OF	-	0.3899
Optimal location-size (p.u.) pair	-	16 @ 1.2

The table 1 listed the complete results of minimization of objective function, power loss, voltage deviation and optimal location and sizing of DG unit for constant load models obtained by an ABC algorithm. The total real and reactive power loads of the system are 3.715 *p.u.* and 2.3 *p.u.*, respectively. From table 1, it can be observed that the real and reactive power loss of the system which does not have any DG is 0.1888 p.u. and 0.1258 p.u. When the placing of DG unit in the distribution system, the real and reactive power losses are reduced to 0.1283 p.u. and 0.0878 p.u., respectively. The voltage deviation of the system in without DG condition is 1.9302 and 1.0007 with presence of DG. The optimal result of the proposed ABC algorithm is 0.3899 and optimal location and size pair of the 38-node system is 16 and 1.2 p.u., respectively.

The result of voltage deviation of the test system is greatly reduced with impacts of DG. The voltage profile of the test system is greatly improved which significantly reduced that the deviation of the voltage. The voltage profile of constant load model in the 38-node radial distribution system is shown in Fig. 1. The table 2 listed the line flow result of test system. In this result, clearly indicated that the both basecase and proposed ABC algorithm line flow value should maintained the within limit.

Table 2
Line flow results of 38-node system

Node No.	Basecase	ABC
1	4.5952	3.5621
2	4.0746	3.0679
3	2.8897	1.9959
4	2.725	1.8547
5	2.6395	1.7901
6	1.2132	0.53873
7	0.98547	0.52361
8	0.75725	0.60015
9	0.68973	0.64267
10	0.62298	0.68912
11	0.5689	0.7197
12	0.4989	0.76644
13	0.4268	0.81983
14	0.28511	0.92724
15	0.22503	0.98886
16	0.16189	0.1619
17	0.098549	0.098541
18	0.39534	0.39534
19	0.29666	0.29666
20	0.19717	0.19717
21	0.098548	0.098548
22	1.0442	1.0441
23	0.93786	0.93779
24	0.46668	0.46667
25	1.3587	1.3569
26	1.2967	1.2949
27	1.2345	1.2328
28	1.1662	1.1649
29	1.0269	1.0259
30	0.47177	0.47177
31	0.30442	0.30443
32	0.072132	0.072131
33	0	0

34	0	0
35	0	0
36	0	0
37	0	0

The voltage at each and every node of the test system is increased in this approach, and within a limit due to the presence of DG compared to the absence has been accepted.

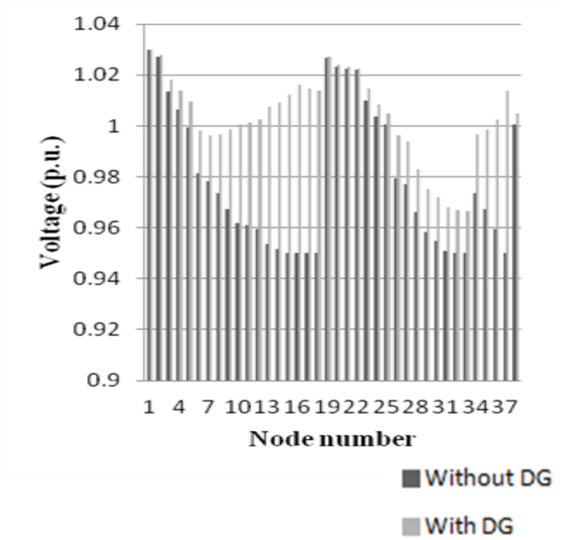

Fig.1. Voltage Profile of 38-node system

V. CONCLUSION

The ABC algorithm has been implemented for the evaluation of optimal location and sizing of DG unit in the test system. It has been successfully implemented to the 38-node system for minimization of real power loss and voltage deviation. The DG unit is placed in the test system for better improvement of voltage profiles and which is proved to compare with basecase condition. The proposed algorithm can be implemented for the solution of the large scale system.

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