Optimal Location and Size of Distributed Generation in Distribution System by Artificial Bees Colony Algorithm

Nguyen Tung Linh and Dam Xuan Dong

***Abstract*—Distributed generation (DG) application has received increasing attention during recent years. 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 is an important. This paper presents a new methodology using artificial bee's conoly algorithm (ABC) for the placement and size of Distributed Generators (DG) in the radial distribution systems. The proposed method is tested in standard IEEE 33 bus test system and the results are presented.**

***Index Terms*—Radial distribution network, distributed generators, artificial bee colony algorithm, power loss.**

I. Introduction

In recent times, due to the increasing interest on renewable sources such as; hydro, wind, solar, geothermal, biomass and ocean energy, all over the world, the number of studies on integration of distributed resources to the grid have rapidly increased. Distributed generation (DG), which consists of distributed resources, can be defined as electric power generation within distribution networks or on the customer side of the network [1].

Distributed generation (DG) is defined as small generation units installed in distribution systems. It is predicted that DG would have a share of about 20% of new generating units being onlined [1]. Even though the concept of DG application in distribution system is not new, there is an increasing trend towards DG application in power systems. Environmental concerns, economical consideration, technological advancements and power system deregulation are known as accelerating factors for DG application. DG application results in positive and negative side effects for both utility and customers [2]. Generally, DG impacts on distribution system depend on several factors such as DG location, technology and capacity as well as the mode of DG operation with network. Application of DG in distribution networks can lead to considerable reliability enhancement, loss reduction and power cost saving. In contrast, power quality issue, islanding operation and voltage control problems are among troublesome impacts of DG application.

In order to minimize line losses of power systems, it is crucially important to determine the location and size generation to be placed. There have been number of studies to define the optimum location of DG. The mathematical approaches on the optimum DG location for minimum power losses are as follows: optimal load flow with second order algorithm method [3], genetic algorithm and Hereford Ranch algorithm which can find optimum [4], Fuzzy-GA method [5], tabu search approach [6], the algorithm to determine the near optimal [7], 2/3 rule, which is often used in capacitor location studies [8], and analytical approach in radial as well as networked systems [9], application on ABC for reconfiguration network distribution [10].

In recent times, the optimal location and sizing of generation units on the distribution network has been continuously studied in order to achieve different aims has presented by Genertic Algorithm, Particle Swarm Optimization (PSO), Fuzzy and PSO…In paper, the author propose method application artificial bee conoly algrithm to slove problem optimal. Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Dervis Karaboga in 2005, motivated by the intelligent behavior of honey bees. It is as simple as Particle Swarm Optimization (PSO) and Differential Evolution (DE) algorithms, and uses only common control parameters such as colony size and maximum cycle number. ABC as an optimization tool, provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar.

The present paper describes a applycation artificial bee conolony algorithm for determining the location and size DG connect for a radial distribution system. Artificial Bee Colony (ABC) algorithm, proposed by Karaboga for optimizing numerical problems, simulates the intelligent foraging behavior of honey bee swarms [11]. The method is tested in standard IEEE distribution test systems are the 33 bus [12], and the results are presented.

II. Problem Formulation

The total I^2 R loss in distribution system include n bus, using the following equation (1):

$$P_{lt} = \sum_{i=1}^{n} I_i^2 .R_i \tag{1}$$

where:

I_i is the magnitude in branch current. The branch in has two includes, the active component (i_a) and the reactive component (i_r), and R_i is the resistance of the i branch.

The loss in distribution includes loss active and losse reactive, calculate the following equation (2), (3);

$$P_{La} = \sum_{i=1}^{n} I_{ai}^2 .R_i \tag{2}$$

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

In the distribution network, loss active (P_{La}) can't be minimized because all active must be supplied for the souce. However, by location DG, the loss can be reduce. The paper present method to minimize the loss by location DG.

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_{ai}^{new} of the i[th] branch is give by equation (4)

$$I_{ai}^{new} = I_{ai} + D_i . I_{DG} \qquad (4)$$

where: If branch i $\in \alpha$ then $D_i = 1$, else $D_i = 0$

Therefore the loss of branch current in new system when DG is connect will calculate the following equation (5)

$$P_{la}^{new} = \sum (I_{ai} + D_i . I_{DG})^2 . R_i \qquad (5)$$

Therefore saving S_{save} is the difference between equation (3) and (5), following equation:

$$S_{save} = P_{la} - P_{la}^{new} = -\sum (2 D_i . I_{ai} . I_{DG} + D_i^2 I_{DG}^2) R_i \qquad (6)$$

S_{save} maximum when: $\dfrac{\partial S_{save}}{\partial I_{DG}} = 0$

$$\Leftrightarrow 2 \sum_{i=1}^{n} (Di . I_{ai} + D_i^2 . I_{DG}) . R_i = 0 \qquad (7)$$

$$\Rightarrow I_{DG} = - \frac{\sum_{i=1}^{n} D_i . I_{ai} . R_i}{\sum_{i=1}^{n} D_i^2 . R_i} = = - \frac{\sum_{i=1}^{n} I_{ai} . R_i}{\sum_{i=1}^{n} D_i . R_i} \qquad (8)$$

If DG connect bus i, then D_i =1 therefore I_{DG} will be caclulate the follwing equation:

$$\Rightarrow I_{DG} = - \frac{\sum_{i=1, i \in \alpha}^{n} . I_{ai} . R_i}{\sum_{i=1, i \in \alpha}^{n} R_i} \qquad (9)$$

Therefore P_{DG} will be calculate the follwing equation (10);

$$P_{DG} = V_m . I_{DG} \qquad (10)$$

where: V_{iDG} is the magnitude of voltage for the bus m.

The optimized size of DG for each bus is calculated by equation (10). Determine loss saving (Ssave) using equation (6), from *i*=2 for all buses except source bus. When the candidate bus is identified and DG is location, the above technique can also be used to identify the next and subsequent bus to be compensated for loss reduction. The algrithm determine DG can present by diagram algorithm: Fig.1

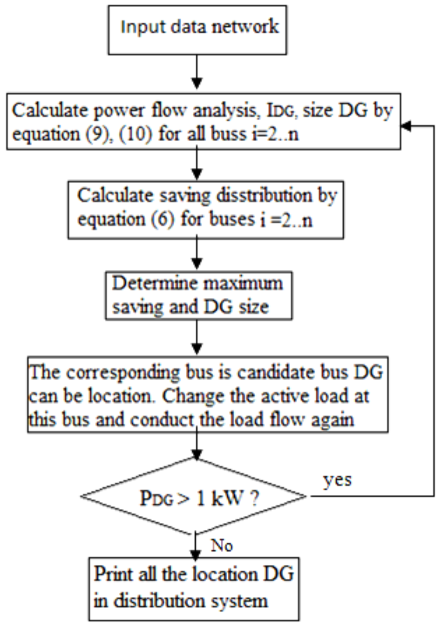

Fig. 1. Diagram algorithm flow chart

Futher the DG are add to the distribution network, 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 location in the system by using ABC algorithm. This method is present in next section.

III. Overview of Artificial Bee Colony Algorithm (ABC)

A. *Over View of Artificial Bee Conlony Algorithm (ABC)*

Artificial Bee Colony (ABC) algorithm, proposed by Karaboga for optimizing numerical problems in [6], 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 (f_{itness}) 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 farUNTIL (cycle= Maximum Cycle Number (MCN))

B. Initialization Phase

The population of solutions x_{ij} are initialized in the range of the parameter j. The following definition might be used for this purpose (15):

$$x_{ij} = x_{minj} + rand\,(0,1) * (x_{maxj} - x_{minj}) \tag{11}$$

where x_{minj} is the lower bound of the parameter j and x_{maxj} is the upper bound of the parameter j.

C. Employed Bees Phase

Each employed bee determines a food source v_{ij} which is also representative of a site, within the neighbourhood of the food source in her memory x_{ij} for example using the formula (14) 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:

$$v_{ij} = x_{ij} + \phi_{ij}\,(x_{ij}-x_{kj}) \tag{12}$$

where *xk* is a randomly selected solution, j is a randomly chosen parameter, ϕ_{ij} is a random number within the range [-a,a]. After producing a new solution v_i a greedy selection is applied between v_i and x_i

In order to simulate the information sharing by employed bees in the dance area, probability values P_i are calculated for the solutions x_i by means of their fitness values, f_{iti}. For example, using the following equation (13).

$$p_i = \frac{f_{iti}}{\sum_{i=1}^{SN} f_{iti}} \tag{13}$$

The fitness values might be calculated using the following definition for minimization problems (17)

$$f_{iti} = \begin{cases} \dfrac{1}{1+f_i} & \text{If } f_i \geq 0 \\ 1+abs(f_i) & \text{If } f_i < 0 \end{cases} \tag{14}$$

where f_i is the cost value of the objective function.

D. 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 [13]. New solutions vi are produced for the onlookers from the solutions x_i by (15), selected depending on p_i , and the new solutions are evaluated. As for employed bees, a greedy selection is applied between v_i and x_i.

E. Scout Bee Phase

Employed bees whose sources have been abandoned become scout and start to search a new food source randomly, for example by (14). 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''.

F. Artificial Bee Colony Algorithm for Optimization Problems.

Constrained optimization (CO) finds parameter vector $\vec{x}$ (18) that minimizes an objective function $f(\vec{x})$ subject to inequality (7) and/or equality (8) constraints [6]

$$\text{Minimize } f(\vec{x}),\ \vec{x} = (x_1, x_2, x_3, x_4, \ldots x_n) \in R^n \tag{15}$$

$$l_i \leq x_i \leq u_i \quad i = 1,2, \ldots n \tag{16}$$

Subject to:

$$g_j(\vec{x}) \leq 0 \quad \text{for } j=1,2,..q \tag{17}$$

$$h_j(\vec{x}) = 0 \quad \text{for } j=q+1, ...m \tag{18}$$

The objective function f is defined on a search space, *S*, which is defined as a *n*-dimensional rectangle in $R^n (S \subseteq R^n)$ Domains of variables are defined by their lower and upper bounds (15). A feasible region $F \subseteq S$ is defined by a set of *m* additional constraints ($m \geq 0$) and $\vec{x}inF \in S$. At any point $\vec{x}inF$, constraints gk that satisfy $g_k(\vec{x})$ are called active constraints at $\vec{x}$. By extension, equality constraints hj are also called active at all points of S [14]. 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 [15].

IV. Application ABC to Found DG Size

The proposed artificial bee colony algorithm is summarized as follows:

1) Input line and bus data, and bus voltage limits
2) Initial Bee population X_{ij} as each bee is formed by sizes of DG units
3) Evaluate the population for each employed bee by using the following the equation:

$$f_{itnes} = \frac{1}{1 + P_{losse}} \tag{19}$$

4) Cycle=1; repeat
5) Generate new population v_{ij} in the neighborhood of x_{ij} for employed bees using equation (12) and evaluate them;
6) Apply the greedy 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 (13);
8) Produce the new solutions (new positions) v_i for the onlookers from the solutions x_i, selected depending on P_i, and evaluate them;
9) Apply the greedy selection process for the onlookers between x_i and v_i
10) Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution x_i for the scout using the equation (11);
11) Memorize the best food source position (solution) achieved so far
12) Cycle=cycle+1.
13) Until cycle= Maximum Cycle Number (MCN).

V. Test Example

The algorithm of this method was programmed in MATLAB and C++, program run on a computer Centrino 1.9GHz, Ram 1Gb. The ABC algorithm for distribution system was tested the 33 bus [16] systems. The 33 bus system has 32 sections with the total load 3.72 MW and 2.3 MVar shown in Figure 2. The original total real power loss and reactive power loss in the system are 221.4346 kW and 150.1784 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 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 15with 0.4406 MW size and the loss saving is 11.4385 KW.

TABLE I: Single DG Placement Results

No	Bus number	Power DG (MW)	Saving (KW)
1	6	2.509	92.65
2	15	0.465	11.76
3	25	0.653	7.782
4	32	0.445	8.232

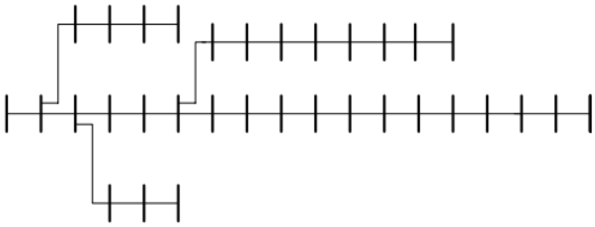

Fig. 2. The 33 bus radial distribution system

This process is repeated till the loss saving is insignificant.

The results areshown in Table I.

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 1 only one DG installation is assumed. In case 2 have two DGs, in case 2 have three DGS and in the last case 4 have 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: Result Application ABC for 33 Bus

Case	Bus no	DG size (Mw)	Total Size (Mw)	Loss affter DG connect (Kw)	Save (KW)
1	6	2.563	2.563	106.32	97.580
2	6 15	1.924 0.587	2.501	91.721	112.171
3	6 15 25	1.743 0.543 0.763	3.049	82.323	121.577
4	6 15 25 32	1.054 0.573 0.762 0.632	3.021	68.018	135.882

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. 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 four cases, for the two methods discussed, are shown in this Table III.

TABLE III: Result Min Voltage , % Improve and Time run CPU

Case	Min Voltage	% Improver	Time CPU (Sec)
Not connect DC	0.9118		
Case 1	0.9467	2.21	7.41
Case 2	0.9541	2.532	11.42
Case 3	0.9541	2.532	15.89
Case 4	0.9671	6.165	16.45

Comparison of results of ABC and PSO algorithms are shown in this Table IV.

TABLE IV: Comparison of Results of ABC and PSO Algorithms

Case	1	2	3	4
ABC (time) –s	7.41	11.42	15.89	16.45
PSO (time) - s	8.23	11.65	16.43	17.01

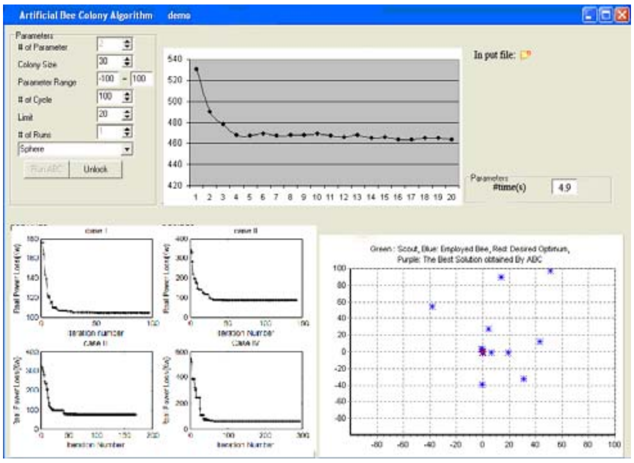

Fig. 3. Program ABC for optimal location and size DG

VI. Conclusion

In this paper, a new approach by the associate with ABC has been developed for finding the optimal locations and sizes of DGs. Single DG placement method is proposed to find the optimal DG locations and ABC algorithm is proposed 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. 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 constrains such as time varying load and different types of DG units and discrete DG unit sizes into the propose algorithm is the future of this work.

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