Application artificial bee colony algorithm (ABC) for reconfiguring distribution network

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***Abstract*—In Power Systems, distribution networks really spend amount of power loss . To reduce the power loss there are some solutions such as upgrading networks, setting capacitors at some places in networks, etc. This paper is concentrated on re-configuring networks to reduce power loss. This means looking for a optimal configuration to operate the distribution system. This paper presents a new method which applies an artificial bee colony algorithm (ABC) for determining the sectionalizing switch to be operated in order to solve the distribution system loss minimization problem. To demonstrate the validity of the proposed algorithm, computer simulations are carried out on 14, 33 bus systems and compared with different approaches available in the literature.**

Keywords-component: Radial distribution network, distribution network reconfiguration network, artificial bee colony algorithm, power loss.

I. INTRODUCTION

Electrical power distribution system delivers power to the customers from a set of distribution substation feeders, usually placed in radial configuration so as to simplify over current protection, lower short circuit, simple switching and protecting equipment with lower reliability. Very often, it is observed that electrical power utilities distribution system lacks in meeting the quality and reliability [1], firstly due to the technological factors and secondly due to the operating factors concerning deployment of electrical power distribution equipments and their loads [2].

As reported about 30-40% of total investment is for distribution system in an electric power sector. Therefore, loss reduction in distribution system can be efficient to reduce transmission loss in the whole power system. With this view, The concept of reconfiguring the topology of the distribution network to minimize losses can immediately be recognized as being cost efficient and consequently of interest to efficiency conscious electric utilities.

Consumer demands vary with time of day, day of the week, and season; therefore, feeder reconfiguration enables load transfers from heavily to weakly loaded regions. Network reconfiguration can also be used in planning studies, in order to determine the optimal configuration of the network during the overall planning procedure. Furthermore, online configuration management becomes an important part of distribution automation when remote-controlled switches are employed [3].

Since a typical distribution system may have hundreds of switches, a combinatorial analysis of all possible options is not a practical proposition. The radiallity constraint and the discrete nature of the switch values prevent the use of classical optimization techniques to solve the reconfiguration problem. Therefore, most of the algorithms in the literature are based on heuristic search techniques, using either analytical or knowledge-based engines.

The present paper describes a applycation artificial bee conolony algorithm for determining the minimum loss configuration of 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 [4]. A IEEE 14, 33-bus radial distribution test system is taken as a study system for performing the test of ABC aglorithm. The proposed reconfiguration algorithm has been found to give better network reconfiguration result than those obtained by some other recent methods reported in literature.

II. PROBLEM FORMULATION

Consider a line shown in Fig. 1 connecting bus i to bus $i+1$ with line impedance of $z_i = r_i + j.x_i$ (1)

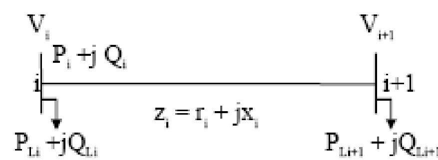

Figure 1. Distribution one-line

The power loss on this distribution line can be calculated as follows:

Real power loss:

$$P_{losse} = r_i(P_i^2 + Q_i^2)/V_i^2 \quad (2)$$

Reactive power loss:

$$Q_{losse} = x_i(P_i^2 + Q_i^2)/V_i^2 \quad (3)$$

Where P_i and Q_i are the real and reactive injected powers, respectively, at bus i.

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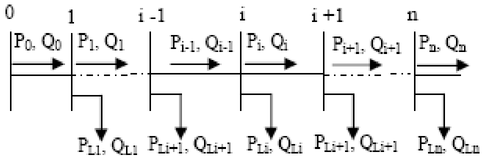

Figure 2. Radial distribution - online

Power flow equations for a radial distribution network in Fig 2, proposed by Baran and Wu [5] are given below:

$$P_{i+1} = P_i - r_i(P_i^2 + Q_i^2)/V_i^2 - P_{L,i+1} \tag{4}$$

$$Q_{i+1} = Q_i - x_i(P_i^2 + Q_i^2)/V_i^2 - Q_{L,i+1} \tag{5}$$

$$V_{i+1}^2 = V_i^2 - 2(r_iP_i + x_iQ_i) + (r_i^2 + x_i^2)(P_i^2 + Q_i^2)/V_i^2 \tag{6}$$

$$P_{lossei,i+1} = r_i(P_i^2 + Q_i^2)/V_i^2 = P_i - P_{i+1} - P_{L,i+1} \tag{7}$$

$$Q_{lossei,i+1} = x_i(P_i^2 + Q_i^2)/V_i^2 = Q_i - Q_{i+1} - Q_{L,i+1} \tag{8}$$

The network is reconfigured by on/off switching, the power flows in the network will be changed and hence the losses on the branch i will become.

$$P'_{lossei} = r_i(P'^2_i + Q'^2_i)/V'^2_i = P'_i - P'_{i+1} - P'_{L,i+1} \tag{8}$$

$$Q'_{lossei} = x_i(P'^2_i + Q'^2_i)/V'^2_i = Q'_i - Q'_{i+1} - Q'_{L,i+1} \tag{9}$$

The total power loss of the feeder $P_{F,\,Loss}$ is determined by summing up the losses of all line sections of the feeder, which is given by:

$$P_{T,losse} = \sum_{i=0}^{n} P_{lossei,i+1} \tag{10}$$

Where the total system power loss $P_{T,\,Loss}$ is the sum of power losses of all feeders in the system.
The objective function for the minimization of power loss is described as:

Minimize $f = \min(P_{T,losse})$ (11)

Subjected to $V_{min} \le |V_i| \le V_{max}$ (12)

$I_{max} \le |I_i| \le I_{min}$ (13)

III. OVER VIEW 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 (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))

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 (14):

$$x_{ij} = x_{minj} + \text{rand}(0,1) * (x_{maxj} - x_{minj}) \tag{14}$$

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:

$$v_{ij} = x_{ij} + \phi_{ij}\,(x_{ij} - x_{kj}) \tag{15}$$

Where x_k 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 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 P_i are calculated for the solutions x_i by means of their fitness values, f_{iti}. For example, using the following equation (3).

$$p_i = \frac{f_{iti}}{\sum_{i=1}^{SN} f_{iti}} \tag{16}$$

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

$$f_{iti} = \begin{cases} \dfrac{1}{1+f_i} & \text{If } f_i \ge 0 \\ 1 + abs(f_i) & \text{If } f_i < 0 \end{cases} \tag{17}$$

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 [7]. New solutions v_i 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]

Minimize $f(\vec{x})$, $\vec{x}$ =(x_1, x_2, x_3, x_4,…x_n) $\in R^n$ (18)

$$l_i \le x_i \le u_i \quad i = 1,2, \ldots n \tag{19}$$

Subject to:

$$g_j(\vec{x}) \le 0 \qquad \text{for } j=1,2,..q \tag{20}$$

$$h_j(\vec{x}) = 0 \qquad \text{for } j=q+1, ...m \tag{21}$$

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 (18). A feasible region $F \subseteq S$ is defined by a set of m additional constraints ($m \ge 0$) and $\vec{x} inF \in S$. At any point $\vec{x} inF$, constraints g_k that satisfy $g_k(\vec{x})$ are called active constraints at $\vec{x}$. By extension, equality constraints h_j are also called active at all points of S [8]. 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 [9].

IV. APPLICATION ABC FOR DISTRIBUTION NETWORK RECONFIGURATION

The proposed artificial bee colony algorithm is summarized as follows:

1. Read the one-line input data; Initialize MNC (Maximum Iteration Count) and base case as the best solution;
2. Initialize the population of solutions xi,j. as each bee is formed by the open switches in the configuration and the number of employed bees are equal to onlooker bees;
3. Evaluate the population for each employed bee by using the following the equation:

$$f_{itnes} = \frac{1}{1 + P_{losse}} \tag{22}$$

4. cycle=1; repeat
5. Generate new population v_{ij} in the neighborhood of x_{ij} for employed bees using equation (15) 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 (16);
8. Produce the new solutions (new positions) v_i for the onlookers from the solutions x_i, selected depending on Pi, 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 xi for the scout using the equation (14);
11. Memorize the best food source position (solution) achieved so far
12. cycle=cycle+1
13. until cycle= Maximum Cycle Number (MCN).

V. EXAMPLE SYSTEM

The ABC algorithm for distribution was tested on 14 bus [10]. Fig. 3 shows an example found in the literature. The system consists of three feeders with 13 sectionalizing switches and three tie switches:

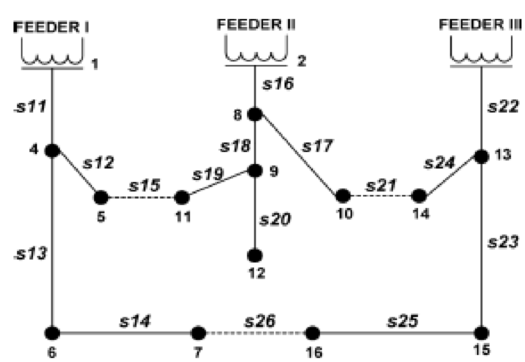

Figure 3. Three-feeder example circuit

The algorithm of this method was programmed in MATLAB and C++, program run on a computer Centrino 1.9GHz, Ram 1Gb. Show fig 4

The example 14 bus, the substation voltage is considered as 1.0 p.u. and all the tie and sectionalizing switches are considered as candidate switches for reconfiguration problem. The total active and reactive power loads on the system are 28.7 MW and 16.3 MVAr. The system load is assumed to be constant and base MVA and voltage ratings of the system are selected as 100 MVA and 11 kV. The initial power loss obtained for the original configuration shown in fig. 3 is 511.4 kW. The minimum voltage in the system before reconfiguration is 0.9693 p.u which occur at node 9. The input data 14-bus in table 1:

TABLE I. INPUT DATA FOR 14-BUS SYSTEM

Bus to bus	Resis-tance (pu)	Reac - tance (pu)	Real Load (End bus)	Reac -tive Load	Fixd capatior (MVAr)
1-4	0.075	0.1	2.0	1.6	1.1
4-5	0.08	0.11	3.0	1.5	1.2
4-6	0.09	0.18	2.0	0.8	
6-7	0.04	0.04	1.5	0.2	
2-8	0.11	0.11	4.0	2.7	
8-9	0.08	0.11	5.0	3.0	1.2
8-10	0.11	0.11	1.0	0.9	
9-11	0.11	0.11	0.6	0.1	0.6
9-12	0.08	0.11	4.5	2.0	3.7
3-13	0.11	0.11	1.0	0.9	
13-14	0.09	0.12	1.0	0.7	1.8
13-15	0.08	0.11	1.0	0.9	
15-16	0.04	0.04	2.1	1.0	1.8
5-11	0.04	0.04			
10-14	0.04	0.04			
7-16	0.12	0.12			

For this test case 14 bus system, acooding ABC, the number bees population is 30 and the number of employed bees is equal to onlooker bees. The scout bee is 1. For this example maximum iteration count is taken as 20.

The convergence characteristic is shown in fig.5. The optimal power loss after reconfiguration is obtained as 464.6kW. The minimum voltage at node 9 is improved to 0.9832 p.u. The results of the proposed algorithm are compared with the algorithms of Simulated Annealing [11] and Differential Evolution [12] and shown in Table 2.

TABLE II. RESULT TEST AND COMPARED WITH SA & DE

Item	Tie switche	P-losse kW	Min. Node Voltage(pu)	Savin g (%)	Cpu Time
Proposed Method	19, 17,26	464.1	0.98 Node 9	8.15	4.9
DE	19, 17,26	466.1	0.97 Node 9	8.86	8.3
SA	19, 17,26	466.1	0.97 Node 9	8.86	7.7

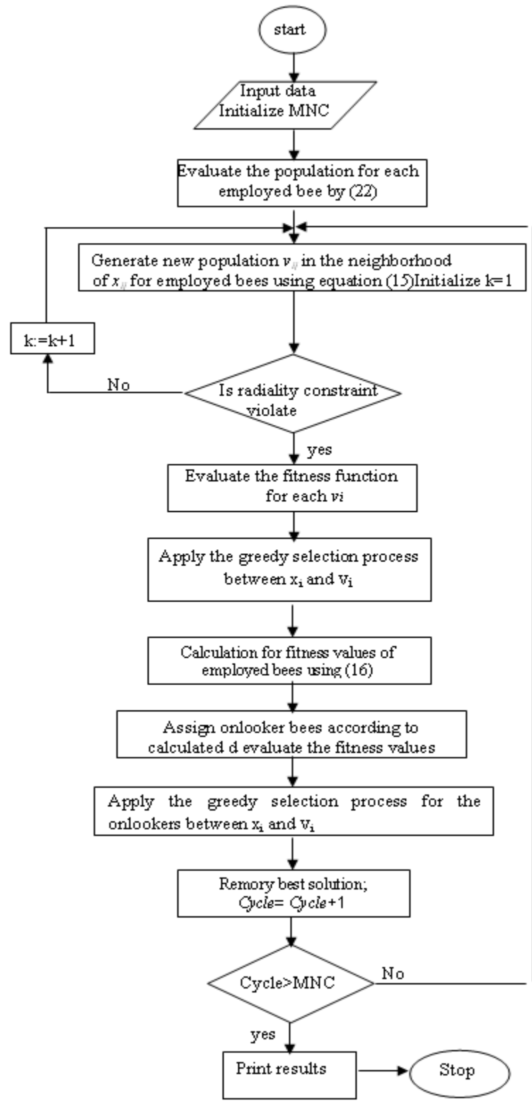

Figure 4. Diagram of the proposed algorithm

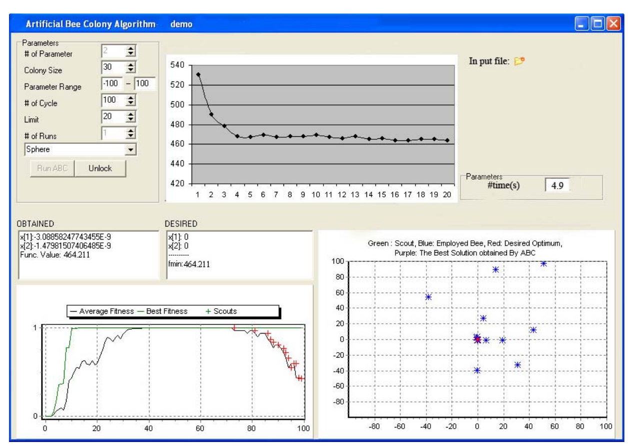

Figure 5. Program ABC for Reconfiguation

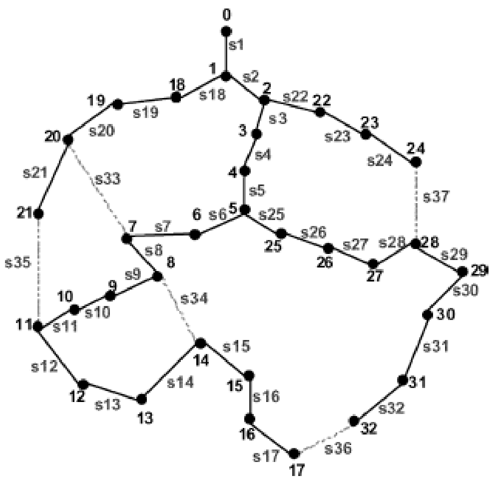

Figure 6. Thirty-three bus test system in Bran and Wu

The 12.66-kV system [13] is shown in Fig. 6 and consists of 33 buses and five tie lines; the total load conditions are 5058.25 kW and 2547.32 kvar. The normally open switches s33, s34, s35, s36, and s37 are represented by doted lines. The normally closed switches s1 to s32 are represented by solid lines. For this case, the initial losses are 202.68 kW.

For this test case, the bee colony population size is taken as 50 and the number of employed bees is and onlooker bees. The scout bee is taken as 1. The maximum iteration count (MNC) is taken as 100. Simulations are carried from 10 to 100 iterations and all are converged to same solution after 8 iterations.

The results of the proposed algorithm are compared with the algorithms of McDermott [14] shown in Table 3

TABLE III. RESULT TEST AND COMPARED WITH MC

Item	Tie switche	P-losse kW	Min. Node Voltage(pu)	P-loss Reduction	Cpu Time
Proposed Method	7,9,14, 32,37	132,13	0.98	31,6 %	1,67
Mc Derott	7,9,14, 32,37	136,57	0.97	30,8 %	1,99

VI. CONCLUSIONS

In this paper, a new approach by the associate with ABC has been developed for the distribution network reconfiguration to mininiizc line losses. The main objectives considered in the present problem are minimization of real power loss, voltage profile improvement and feeder load balancing subject to the radial network structure in which all loads must be energized. Ideas presented in this paper has test on 14 bus and 33 bus. The result of the proposed algrithm are compared with the SA, DE, Mc Dermott, and obtained by the proposed method out perform the other methods in terms of quality of the solution and computation.

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