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Decline of Power Loss by Augmented ABC Algorithm

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ABSTRACT

This paper presents an algorithm for solving reactive power problem. Artificial Bee Colony algorithm is a global optimization algorithm, which is motivated by the foraging behaviour of honeybee swarms. Basic Artificial Bee Colony algorithm (ABC) has the advantages of strong robustness, fast convergence and high flexibility, fewer setting parameters, but it has the disadvantages premature convergence in the later search period and the accuracy of the optimal value, which cannot meet the requirements sometimes. The premature convergence issue in Artificial Bee Colony algorithm has been improved by increasing the number of scout and rational using of the global optimal value and by chaotic local Search. The Chaotic local Search ABC (CLABC) algorithm used to solve the reactive power dispatch problem and it has been tested in standard IEEE 30 Bus system.
Keywords : optimal reactive power, Transmission loss, Artificial Bee Colony Algorithm, Chaotic Local Search

I. INTRODUCTION

Optimal reactive power dispatch problem is one of the difficult optimization problems in power systems. The sources of the reactive power are the generators, synchronous condensers, capacitors, static compensators and tap changing transformers. The problem that has to be solved in a reactive power optimization is to determine the required reactive generation at various locations so as to optimize the objective function. Here the reactive power dispatch problem involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the loss and to enhance the voltage stability of the system. It involves a non linear optimization problem. Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1-2], Newton method [3] and linear programming [4-7].The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input-output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently global Optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow problem [8, 9]. ABC (Artificial Bee Colony) algorithm was proposed by Dervis Karaboga in 2005, which is based on the intelligent behavior of honeybee swarms finding nectar and sharing the information of food sources with each other [10-16]. ABC algorithm has the advantages of strong robustness, fast convergence and high flexibility, fewer control parameters. The premature convergence issue of the Artificial Bee Colony algorithm has been improved by increasing the number of scout and rational using of the global optimal value and chaotic local Search. The Chaotic local Search ABC (CLABC) algorithm used to solve the reactive power dispatch problem and it has been tested in standard IEEE 30 Bus system.

II. METHODS AND MATERIAL

2. Objective function

2.1. Minimization of Real Power Loss

It is aimed in this objective that minimizing of the real power loss (Ploss) in transmission lines of a power system. This is mathematically stated as follows.

$$P_{loss}=\sum_{\substack{k=1\\k=(i,j)}}^{n} g_{k(V_i^2+V_j^2-2V_i V_j \cos\theta_{ij})} \quad (1)$$

Where n is the number of transmission lines, gk is the conductance of branch k, Vi and Vj are voltage magnitude at bus i and bus j, and θij is the voltage angle difference between bus i and bus j.

2.2. Minimization of Voltage Deviation

It is aimed in this objective that minimizing of the Deviations in voltage magnitudes (VD) at load buses. This is mathematically stated as follows.

$$\text{MinimizeVD} = \sum_{k=1}^{nl} |V_k - 1.0| \qquad (2)$$

Where nl is the number of load busses and Vk is the voltage magnitude at bus k.

2.3. System Constraints

In the minimization process of objective functions, some problem constraints which one is equality and others are inequality had to be met. Objective functions are subjected to these constraints shown below.

Load flow equality constraints:

$$P_{Gi} - P_{Di} - V_{i\sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \cos\theta_{ij} \\ +B_{ij} & \sin\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots., nb \qquad (3)$$

$$Q_{Gi} - Q_{Di} V_{i\sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \cos\theta_{ij} \\ +B_{ij} & \sin\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots., nb \qquad (4)$$

where, nb is the number of buses,

Generator bus voltage (VGi) inequality constraint:

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \qquad (5)$$

Load bus voltage (VLi) inequality constraint:

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \qquad (6)$$

Switchable reactive power compensations (QCi) inequality constraint:

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \qquad (7)$$

Reactive power generation (QGi) inequality constraint:

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \qquad (8)$$

Transformers tap setting (Ti) inequality constraint:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in nt \qquad (9)$$

Transmission line flow (SLi) inequality constraint:

$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \qquad (10)$$

Where, nc, ng and nt are numbers of the switchable reactive power sources, generators and transformers.

3. ABC Algorithm

The artificial bee colony contains three groups: employed bee, onlooker bee and scout. The bee going to the food source which is visited by itself previously is employed bee. The bee waiting on the dance area for making decision to choose a food source is onlooker bee. The bee carrying out random search is scout bee. The onlooker bee with scout also called unemployed bee [10-11]. In the ABC algorithm, the collective intelligence searching model of artificial bee colony consists of three essential components: employed, unemployed foraging bees, and food sources. The employed and unemployed bees search for the rich food sources, which close to the bee's hive. The employed bees store the food source information and share the information with onlooker bees. The number of employed bees is equal to the number of food sources and also equal to the amount of onlooker bees. Employed bees whose solutions cannot be improved through a predetermined number of trials, specified by the user of the ABC algorithm and called “limit”, become scouts and their solutions are abandoned [16].

3.1. The Procedure of ABC

The classical ABC includes four main phases.

Initialization Phase: The food sources, whose population size is SN, are randomly generated by scout bees. The number of Artificial Bee is NP. Each food source xm is a vector to the optimization problem, xm has D variables and D is the dimension of searching space of the objective function to be optimized. The initiation food sources are randomly produced via the expression (11).

$$x_m = l_i + \text{rand}(0.1) * (u_i - l_i) \quad (11)$$

where ui and li are the upper and lower bound of the solution space of objective function, rand(0,1) is a random number within the range [0,1].

Employed Bee Phase: A employed bee flies to a food source and finds a new food source within the neighborhood of the food source. The higher quantity food source will be selected. The food source information stored by employed bee will be shared with onlooker bees. A neighbor food source vmi is determined and calculated by the following equation (12).

$$v_{mi} = x_{mi} + \Phi_{mi}(x_{mi} - x_{ki}) \quad (12)$$

where xk is a randomly selected food source, i is a randomly chosen parameter index, Φ_{mi} is a random number within the range [-1,1]. The range of this parameter can make an appropriate adjustment on specific issues. The fitness of food source is essential in order to find the global optimal. The fitness is calculated by thefollowing formula (13). After that a greedy selection is applied between xm and vm.

$$fit_m(x_m) = \begin{cases} \frac{1}{1+f_m(x_m)}, f_m(x_m) > 0 \\ 1 + |f_m(x_m)|, f_m(x_m) < 0 \end{cases} \quad (13)$$

where fm(xm) is the objective function value of xm.

Onlooker Bee Phase: Onlooker bees observe the waggle dance in the dance area and calculate the profitability of food sources, then randomly select a higher food source. After that onlooker bees carry out randomly search in the neighborhood of food source. The quantity of a food source is evaluated by its profitability and the profitability of all food sources. Pm is determined by the formula

$$P_m = \frac{fit_m(x_m)}{\sum_{m=1}^{SN} fit_m(x_m)} \quad (14)$$

where fitm(xm) is the fitness of xm.

Onlooker bees search the neighborhood of food source according to the expression (15)

$$v_{mi} = x_{mi} + \Phi_{mi}(x_{mi} - x_{ki}) \quad (15)$$

Scout Phase: If the profitability of food source cannot be improved and the times of unchanged greater than the predetermined number of trials, which called "limit" and specified by the user of the ABC algorithm, the solutions will be abandoned by scout bees. Then, the scouts start to randomly search the new solutions. If solution xi has been abandoned, the new solution xm will be discovered by the scout. The xm is defined by expression (16)

$$x_m = l_i + rand\ (0.1) * (u_i - l_i) \quad (16)$$

Where x_m is the new generated food source, rand(0,1) is a random number within the range [0,1], ui and li are the upper and lower bound of the solution space of objective function.

3.2. The Main Concepts of ABC Algorithm

Food sources: According to different problems, the initial food sources are randomly generated in the search space.

Local optimization strategy: In the employed bee phase, employed bees look for the local optimization value in the neighborhood of food source. Generally, different local search strategies will are used for different problems.

Random selection strategy in accordance with probability: In the onlooker bee phase, the random selection strategy will be used to looking for local optimization value in the neighborhood of food source and the higher probability solution will be chosen by onlooker bees.

Feedback strategy: In scout bee phase, food sources which are initially poor or have been made poor by exploitation will be abandoned, this means that if a solution cannot be improved and the unchanged times greater than the predetermined “limit” parameter, the new solution will be discovered by the scout using the negative feedback strategy.

Global optimization strategy: After local optimization and random selection carried out, the global optimization strategy will be used to obtain global optimal value.

4. Chaotic Local Search ABC

In the basic Artificial Bee Colony algorithm, the best solution founded by onlooker bee which adopted the local search strategy is unable to reach the ideal level of accuracy [11]. In order to improve the accuracy of optimal solution and obtain the fine convergence ability, we use the chaotic search method to solve this problem [10]. In the Chaotic local Search ABC algorithm, onlooker bees apply chaotic sequence to enhance the local searching behavior and avoid being trapped into local optimum [13]. In onlooker bee phase, chaotic sequence is mapped into the food source. Onlooker bees make a decision between the old food source and the new food source according to a greedy selection strategy. In this paper, the well-known logistic map which exhibits the sensitive dependence on initial conditions is employed to generate the chaotic sequence [14]. The chaos system used in this paper is defined by

$$x_{i+1} = \mu * x_i * (1 - x_i) \quad (17)$$

$$x = x_{mi} + R * (2 * x_i - 1) \quad (18)$$

Where x is the new food source and xi is the chaotic variable, R is the radius of new food source being generated. The food source xmi is in the central of searching region. After the food source has been generated, onlooker bee will exploit the new food source and select the higher profitable one using a greedy selection.

Chaotic search method includes the following steps:
Step1. Setting the iterations (cycle parameter) of chaotic search and produce a vector $x_0 = [x_{0,1} x_{0,2} x_{0,3}]$, which is the initial value of chaotic search;

Step2. The chaotic sequence is generated according to expression (17) and a new food source, which combining the chaotic sequence with the original food source, is obtained following the equation (18);

Step3. Calculating the profitability of the new food source and using the greedy selection select the higher profitability food source;

Step4. If the number of chaotic search iterations greater than maximum, the artificial bee algorithm will enter the scout bee phase, or else enter the next chaotic search iteration.

4.1. Global Search Strategy

In the basic Artificial Bee Colony algorithm only one scout, but we added another one into the modified Artificial Bee Colony algorithm in order to improve the global convergence ability. When a scout bee find the food source unchanged times greater than the limit parameter, it will produce a new food source and replace the original one .Scout bee discover the new food source using the best optimal value strategy which accelerate the global convergence rate. Assume that the solution x_i has been abandoned and the scout bee will generate the new solution x_m using the following equation

$$x_m = x_{best} \quad (19)$$

$$x_m(i) = x_{best}(i) + \Phi_{mi} * (x_{best}(i) - x_{neighbor}(i)) \quad (20)$$

Where x_m is new food source produced by scout bee using the global optimal value x_{best} and Φ_{mi} is a random number within the range [-1,1].

4.2 The Procedure of CLABC

The procedure of CLABC is as following:
% Initial Phase
According to equation (11) discovering the initial food sources Itertime = 1;
While (Itertime <= MaxCycle)
% Employed Bee Phase
Step1. According to expression (12) searching the neighbourhood food source;
Step2. Calculate the function value;
Step3. According to formula (13) evaluate fitness of the food sources.
% Onlooker Bee Phase
Step1. According to expression (14) calculate the profitability;
Step2. Onlooker bee in the guide of equation (15) and (16) exploiting the local optimal solution;
Step3. Calculating the function value of new food source;
Step4. Evaluating the new food source fitness according to equation (16).
% Scout Bee Phase
if (trial>limit)
Step1. The first scout randomly discovering the new food source;
Step2 The second scout bee updating the food source, which hit the limit parameter, according to formula (19) and (20).
% Search the global optimal value
Global Min
End while

III. RESULTS AND DISCUSSION

Simulation Results

Proposed approach has been applied to solve reactive power problem. In order to demonstrate the efficiency and robustness of proposed CLABC which is tested on standard IEEE30-bus test system .The test system has six generators at the buses 1, 2, 5, 8, 11and 13 and four transformers with off-nominal tap ratio at lines6-9, 6-10, 4-12, and 28-27 and, hence, the number of the optimized control variables is 10 in this problem. Table 1& 2 gives the simulation results & comparison.

Table 1. Best Control Variables Settings for Different Test Cases of Proposed Approach

Control Variables setting	Case 1: Power Loss	Case 2: Voltage Deviations
VG1	1.01	0.95
VG2	1.03	0.94
VG5	1.05	1.00
VG8	1.01	1.00
VG11	1.02	1.01
VG13	0.90	1.02
VG6-9	1.00	0.90
VG6-10	1.06	1.01
VG4-12	1.69	1.00
VG27-28	1.00	0.90
Power Loss (Mw)	3.68219	3.546
Voltage deviations	0.6941	0.1842

Table 2. Comparison of the Simulation Results for Power Loss

Control Variables Setting	CLABC	GSA [18]	Individual Optimizations [17]	Multi Objective EA [17]	As Single Objective [17]
VG1	1.01	1.049998	1.050	1.050	1.045
VG2	1.03	1.024637	1.041	1.045	1.042
VG5	1.00	1.025120	1.018	1.024	1.020
VG8	1.01	1.026482	1.017	1.025	1.022
VG11	1.00	1.037116	1.084	1.073	1.057
VG13	0.90	0.985646	1.079	1.088	1.061
T6-9	1.00	1.063478	1.002	1.053	1.074
T6-10	1.02	1.083046	0.951	0.921	0.931
T4-12	1.69	1.100000	0.990	1.014	1.019
T27-28	1.00	1.039730	0.940	0.964	0.966
Power Loss (Mw)	3.68219	4.616657	5.1167	5.1168	5.1630
Voltage Deviations	0.6941	0.836338	0.7438	0.6291	0.3142

IV. CONCLUSION

In this paper a novel approach CLABC algorithm used to solve reactive power problem. To handle the mixed variables a flexible representation scheme was proposed. The effectiveness of the proposed method is demonstrated on IEEE 30-bus system & simulation results revals about the better efficiency of the proposed CLABC algorithm.

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