Artificial Bee Colony Algorithm for Solving Optimal Power Flow Problem

Priyanka Shankya
Research Scholar
Department of Electrical Engineering
Jaipur National University, Jaipur
Rajasthan, India

Ashalam Parwaz
Research Scholar
Department of Electrical Engineering
Jaipur National University, Jaipur
Rajasthan, India

Vivek Kumar Jain
Assoc. Prof./Ph.D. Scholar
Department of Electrical Engineering
Jaipur National University, Jaipur
Rajasthan, India

ABSTRACT

This paper proposes an artificial bee colony (ABC) algorithm for solving optimal reactive power flow problem. The proposed ABC can deal with different objectives of the problem such as minimizing the real power losses, improving the voltage profile, and enhancing the voltage stability and properly handle various constraints for reactive power limits of generators and switchable capacitor banks, bus voltage limits, tap changer limits for transformers, and transmission line limits. The proposed approach has been observed and tested on different IEEE bus test system. The performance of ABC to be better in terms of solution superiority and computational time.

Keywords

Artificial bee colony(ABC), reactive power optimization, loss minimization and fuel cost.

1. INTRODUCTION

Reactive power dispatch is a problem of the optimal power-flow (OPF), which determines all kinds of suitable variables, such as reactive-power outputs of generators and taps settings of transformers and shunt VAR (capacitors/reactors) etc., The minimization of transmission losses in power systems, while rewarding a given set of physical and operating constraints. The problem of optimal dispatch is unswervingly disturbed not only with once-over quality and consistency of supply, but also economy and security of the power system. Therefore, the power system reactive power dispatch problem directly influences the power system stability and power superiority.

Recently, due to the basic efficiency of interior-point methods, which offer fast convergence and convenience in handling Inequality constraints in comparison with other methods, interior-point linear programming, quadratic programming, and nonlinear programming [1-5] methods have been widely used to solve the reactive power optimization problem of large-scale power systems. However, these techniques have severe limitations in handling nonlinear, discontinuous functions and constraints, and function having multiple local minima. Regrettably, the original reactive power problem does have these Properties. In the last decade, many new stochastic search methods have been developed for the global optimization problems, such as simulated annealing, genetic algorithms and particle swarm optimization. Artificial bee colony (ABC) is one of them evolutionary computation techniques [14]. It was developed through simulation of a Simplified social system, and has been found to be robust in solving continuous nonlinear optimization Problems. Although the PSO seems to be sensitive to the tuning of some weights or parameters, many researches are still in progress for proving its potential in solving complex power system problems [2].

In normally, artificial bee colony has a more global searching ability at the begin of the run and a local search near the end of the run. With more optimal solution for reactive power dispatch problem.

For the reasons, a reliable global move toward to power system optimization problems would be of considerable value to power engineering society. We subsequently use SA [7-13] and GA [9] are originate in the journalism for solving reactive power problem. In recent times, evolutionary algorithms [11] have become very all of the range as optimization techniques. Differential evolution (DE) [9-12], artificial bee colony (ABC) [9-10] methods both under the category of Evolutionary Algorithms have been implemented independently as optimization techniques. In this paper, a propose approach employs In this paper ABC algorithm inspired by foraging behavior of honey bees is presented for solving the optimal power flow problem.

2. PROBLEM FORMULATION

Here the optimal power flow problem is treated as a single objective optimization problem by linear combination of two objective functions i.e. P_{Loss} and VD which can be written as follows:

$$F = F_1 + F_2 = P_{Loss} + VD$$

2.1 Minimization of system power losses:

The optimal power flow problem aims at minimizing the real power loss in a power system while satisfying the unit and system constraints. This goal is achieved by proper adjustment [12] of reactive power variables like generator voltage magnitudes (VGi), reactive power generation of capacitor banks (Qci) and transformer tap settings (tk).

This is mathematically stated as:

$$F_1 = P_{Loss} = \sum_{k=1}^{nl} g_k\left[V_i^2 + V_j^2 - 2V_iV_j\cos\boldsymbol{\theta}_{ij}\right]$$

Where nl is the number of transmission lines, gk is the conductance of the kth line, Vi and Vj are the voltage magnitude at the end buses i and j of kth line respectively and $\boldsymbol{\theta}_{ij}$ is the voltage phase angle at the end buses i and j.

2.2 Voltage profile improvement:

Bus voltage is one of the most important security and service quality indices. Improving voltage profile can be obtained by minimizing the load bus voltage deviations from 1.0 per unit. The objective function can be expressed as:

$$F_2 = VD = \sum_{i \in NL} |V_i - 1.0|$$

Where NL is the number of load buses.

The minimization problem is subjected to the following equality and inequality constraints.

2.2.1 Equality Constraints:

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{N_B} V_j \left(G_{ij} \mathrm{Cos}\theta_{ij} + B_{ij} \mathrm{Sin}\theta_{ij} \right) = 0,$$

$$Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{N_B} V_j \left(G_{ij} \mathrm{Cos}\theta_{ij} - B_{ij} \mathrm{Sin}\theta_{ij} \right) = 0,$$

$$i \;= 1,2 \ldots \ldots . . N_B$$

where NB is the number of buses, PG is the active power generated, QG is the reactive power generated, PD is the load active power , QG is the load reactive power, Gij and Bij are the transfer conductance and susceptance between bus i and bus j respectively.

2.2.2 Inequality constraints:

Voltage constraints:

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max} \quad ; \quad i = 1, \ldots \ldots \ldots N_G$$

Generator reactive power capability limit:

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \quad ; \quad i = 1, \ldots \ldots \ldots N_G$$

Reactive power generation limit of capacitor banks:

$$Q_{ci}^{min} \leq Q_{ci} \leq Q_{ci}^{max} \quad ; \quad i = 1, \ldots \ldots \ldots N_c$$

Transformer tap setting limit:

$$t_k^{min} \leq t_k \leq t_k^{max} \quad ; \quad i = 1, \ldots \ldots \ldots N_T$$

Security constraints: these include the constraints of voltages at load buses and transmission line loading as follows:

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max} \quad ; \quad i = 1, \ldots \ldots \ldots N_L$$

$$S_{li} \leq S_{li}^{max} \quad ; \quad i = 1, \ldots \ldots \ldots nl$$

3. ABC ALGORITHM

In computer science and operations research, the Artificial Bee Colony algorithm is a population based search algorithm first developed in 2005. It mimics the food foraging behavior of swarms of honey bees. In its basic version, the algorithm performs a kind of neighborhood search combined with random search and can be used for both combinatorial optimization and functional optimization. ABC is developed based on inspecting the behaviors of real bees on finding nectar and sharing the information of food sources to the bees in the hive.

In ABC algorithm, the colony of artificial bees consists of three groups of bees: employed bees, onlooker bees and scouts. The employed bees stay on a food source and provide the neighborhood of the source in its memory. Onlooker bees get the information of food sources from the employed bees in the hive and select one of the food sources to gather the nectar. Scouts are responsible to find new food source depending on an internal motivation or possible external clues or randomly [9].

Main steps of the algorithm are given below:

1. Initialize the food source position.
2. Each employed bee produces a new food source in her food source site and exploits the better source.
3. Each onlooker bee selects a source depending on the quality of her solution, produces a new food source site and exploits the better source.
4. Determine the source to be abandoned and allocate its employed bee as scout for searching new food sources.
5. Memorize the best food source found so far.
6. Repeat steps 2-5 until the stopping criterion is met.

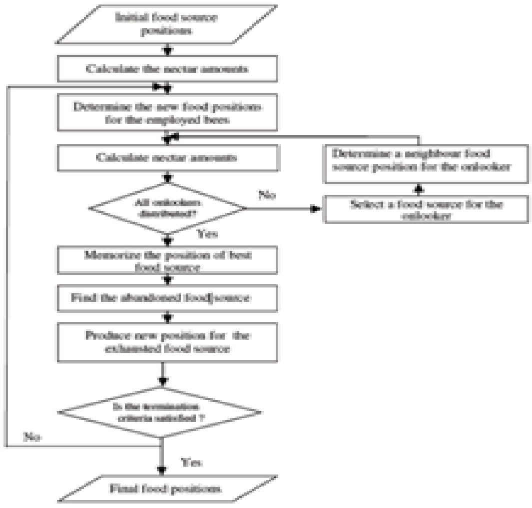

Figure1.Flow chart of ABC algorithm (Karaboga and Basturk, 2007) [11]

4. CALCULATION OF THE NEW POSITION

In the first step of algorithm, random solutions are produced in the specified range of variables θi (i = 1, 2………..S), where S is the number of food sources. Secondly, for each employed bee, whose total amounts are equal to the half of the total food sources, a new source is produced by the equation (1):

$$x_{ij}(t+1) = \theta_{ij}(t) + \emptyset \left(\theta_{ij}(t) - \theta_{kj}(t) \right) \ldots \ldots \ldots (1)$$

where

xi= The position of the onlooker bee, t =The iteration number, θk= The randomly chosen employed bee [k = int(rand*S)+1], j =1……D (D is the dimension of the solution) and ϕ(·)=A series of random variable in the range [-1,1].

5. PROBABILITY OF SELECTING A NECTAR SOURCE

After creating xi, this new solution is compared with θi solution and best one is used as the source. In the third step of the algorithm onlooker bees choose a food source whose probability is given by the equation (2):

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{s} F(\theta_k)} \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

where

Pi= The probability of selecting the ith employed bee, S= The number of employed bees, θi= The position of the ith employed bee and F (θi) = The fitness value

6. THE MOVEMENT OF THE SCOUT BEES

The employed bee whose food source has been abandoned becomes a scout and is responsible for random searches in each colony. The selection of scout among the employed bees is realized with respect to the limit parameter. A new source of scout can be determined by the equation (3):

$$\theta_{ij} = \theta_{j\,min} + r.\left(\theta_{j\,max} - \theta_{j\,min}\right) \dots\dots\dots (3)$$

where

r is a random number and r € [0, 1]

7. TEST RESULTS AND ANALYSIS

The process described above was implemented using the FORTRAN language and the residential software Program was executed on a CORE I3 PC. The ABC algorithm based reactive power optimization problem was implemented using MATLAB code was executed on a PC. The proposed algorithm was run minimization of real power loss as the objective function [3].

Table 1. Comparison of Power Loss in IEEE 6-bus System

Loss (in MW) With NLP Method	Loss (in MW) With Simplex linear method	Loss (in MW) With Genetic Algorithm	Loss (in MW) With PSO Algorithm	Loss (in MW) With ABC algorithm
8.830	8.847	8.760	8.730	8.678

Hence from simulation results shown, ABC algorithm technique proves well with reduced losses for optimal power flow.

8. CONCLUSIONS

In this review paper, ABC algorithm has been effectively applied to solve optimal power flow (loss reduction) problem. The main objective is to minimize the active power loss in the network, while satisfying all the power system operation variable constraints (equality and inequality). The ABC algorithm has been coded using MATLAB software. The simulation results show that ABC algorithm always leads to a better result.

9. REFERENCES

[1] J.A. Momoh, S. X. Guo, E. C. Ogbuobiri, and R. Adapa, "The quadratic interior point method Solving power system optimization problems,"IEEE Trans. Power Systems, vol. 9, pp. 1327-1336, Aug. 1994.

[2] Z. L. Gaing, "Particle swarm optimization to solving the economic dispatch considering the generator constraints," IEEE Trans. Power Systems, vol. 18, pp. 1187-1195, Mar. 2003

[3] K. Y. Lee, Y. M. Park, and J. L. Ortiz, "A united approach to optimal real and reactive power Dispatch," IEEE Trans. Power Systems, vol. 104, pp. 1147-1153, May 1985.

[4] J. Liu, Y. Y. Tang, and Y. C. Cao, "An evolutionary autonomous agents approach to image feature extraction," IEEE Trans. Evolutionary Computation, vol. 1, pp.141-158, Feb. 1997.

[5] Y. C. Wu, A. S. Debs, and R. E. Marsten, "A direct nonlinear predictor-corrector primal-dual interior point algorithm for optimal power flows," IEEETrans. Power Systems, vol. 9, pp. 876-883, May1994.

[6] Abdul Rahman, K.H. and Shahidehpour, S.M. 1993 A fuzzy based optimal reactive power control IEEE Transactions on Power Systems, 8 (1993) 662-670.

[7] K. Iba, "Reactive power optimization by genetic algorithm", IEEE Trans. Power Systems, Vol. 9, No. 2, pp. 685-692, May 1994.

[8] B. Bhattacharyya and S.K. Goswami, "SA based genetic algorithm for reactive power optimization", The Journal of CPRI, Vol. 3, No. 1, pp. 59-64, Sept. 2006

[9] Bhagat Singh Prajapati, Laxmi Srivastava, "Multi-Objective Reactive Power Optimization Using Artificial Bee Colony Algorithm", International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 1, July 2012.

[10] Ali Ozturk, Serkan Cobanli, Pakize Erdogmus and salih Tosun (2010) "Reactive power optimization with ABC algorithm" Scientific Research and Essays Vol.5 (19) pp.2852

[11] A.A. Abou El Ela, M.A. Abido, S.R. Spea , "Differential Evolution algorithm for optimal reactive power dispatch ", Electric Power Systems Research 81 (2011) 458–464.

[12] M. Varadarajan, K.S. Swarup, "Network loss minimization with voltage security using differential evolution", Electric Power Systems Research 78 (2008) 815–823.

[13] M.A. Abido, J.M. Bakhashwain , " Optimal VAR dispatch using a multi objective evolutionary algorithm", Electrical Power Energy Systems 27 (2005) 13–20.

[14] M.A. Abido, "Optimal power flow using particle swarm optimization", Electrical Power Energy Systems 24(7) (2002) 563–571.