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Artificial Bee Colony Algorithm Based Optimal Power Flow

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ABSTRACT: This paper presents a solution to Optimal Power Flow (OPF) using Artificial Bee Colony Algorithm. The aim of Optimal Power Flow (OPF) is to minimize or maximize an objective function of our own while satisfying the system design and operational requirements. Here minimization of the total cost of generation is the objective. This paper describes the use of Artificial Bee Colony algorithm (ABC), which is one of the latest computational intelligence to solve the OPF problem. The proposed method is applied to IEEE-9 Bus system and verified for its robustness and effectiveness.

KEYWORDS: Optimal Power Flow (OPF), Artificial Bee Colony (ABC), Interior Point Programming,

I. INTRODUCTION

Optimal power flow (OPF) has been widely used in the power system operation and planning. The optimal power flow module is an intelligent load flow that employs techniques to automatically adjust the power system control settings while simultaneously solving the load flows and optimizing operating conditions with specific constraints.

Optimal power flow (OPF) is a static nonlinear programming problem which optimizes a certain objective function while satisfying a set of physical and operational constraints imposed by equipment limitations and security constraints. In general, OPF problem is a large dimension nonlinear and highly constrained optimization problem. So, the objective is to minimize the fuel cost and keep the power outputs of generators, bus voltages, shunt capacitors/reactors and transformer tap settings in their secure limits. The OPF has been usually considered as the minimization of an objective function representing the generation cost and/or the transmission loss. The optimal power flow has been frequently solved using classical optimization methods. A comprehensive review of various optimization techniques available in the literature is reported in Refs. [1, 2]. A new method of soft computing known as Artificial Bee Colony algorithm is used here to solve the optimal power flow problem.

II. PROBLEM FORMULATION

The OPF can be considered as a combination of economic dispatch problem and power flow equations, in which the latter are expressed as a set of equality constraints. Typically, the OPF problem is formulated to minimize the total generation cost and satisfy power system constraints. The OPF problem can be stated mathematically as:

$$Minimize\,\{ f(P_G) = \sum_{i=1}^{N} f(P_{Gi})\} \qquad (1)$$

From eq. (1), the total generation cost is normally expressed by a quadratic function

$$f_i(G_i) = a_i P_{Gi}^2 + b_i P_{Gi} + c_i \qquad (2)$$

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Where,

$f_i(G_i)$ is the value of total generation cost

$f_i(G_i)$ is the generation cost of the i^{th} generator

P_{Gi} is the real power output of generator i in MW

a_i, b_i, c_i are cost coefficients of i^{th} generator

In minimizing the generation cost, equality constraints (power-flow) and inequality constraints (MW and MVA Limits) should be satisfied as shown in the following equations.

A. Equality Constraints

$$\sum_{i=1}^{N} P_{Gi} - \sum_{j=1}^{N} P_{Dj} - P_L = 0 \quad (3)$$

$$\sum_{i=1}^{N} Q_{Gi} - \sum_{j=1}^{N} Q_{Dj} - Q_L = 0 \quad (4)$$

Where

$\sum_{i=1}^{N} P_{Gi}$ and $\sum_{i=1}^{N} Q_{Gi}$ are respectively the total values of real power and reactive power generation at bus i.

$\sum_{j=1}^{N} P_{Dj}$ and $\sum_{j=1}^{N} Q_{Dj}$ are respectively the total values of real power demand and reactive power demand at bus j.

P_L and Q_L are real and reactive power losses.

B. Inequality Constraints

A set of inequality constraint equations, which is the flow of MW, MVA, voltage angle, transmission line currents or voltage at particular buses, can be expressed as

$$P_{Gi}^{Min} \le P_{Gi} \le P_{Gi}^{Max} \quad (5)$$

$$Q_{Gi}^{Min} \le Q_{Gi} \le Q_{Gi}^{Max} \quad (6)$$

$$V_{Gi}^{Min} \le V_{Gi} \le V_{Gi}^{Max} \quad (7)$$

$$\theta_{Gi}^{Min} \le \theta_{Gi} \le \theta_{Gi}^{Max} \quad (8)$$

Where,

P_{Gi}^{Min} and P_{Gi}^{Max} are respectively minimum and maximum values of real power generation at bus i.

Q_{Gi}^{Min} and Q_{Gi}^{Max} are respectively minimum and maximum values of reactive power generation at bus i.

V_{Gi}^{Min} and V_{Gi}^{Max} are respectively minimum and maximum values of voltage at bus i.

θ_{Gi}^{Min} and θ_{Gi}^{Max} are respectively minimum and maximum values of voltage angle at bus i.

The optimal power flow (OPF) problem is solved not only when the power system is operating in a normal state but also when it is in a contingency condition. This kind of OPF problem is referred to as a security-constrained OPF, which makes the OPF far more useful as it guarantees that all contingencies are not going to cause any limit violations.

III. ARTIFICIAL BEE COLONY ALGORITHM

Swarm intelligence is a form of Artificial Intelligence (AI) based on the collective behaviors of animals or certain phenomenon of natural systems such as ants, fish and birds. Some of its techniques such as Ant Colony

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Optimization (ACO) and Particle Swarm Optimization (PSO) have been successfully implemented to a wide range of optimization problems including those in power system operation and control. Recently, a novel swarm-based intelligence called the Bees algorithm which mimics the food foraging behavior of honey bees colony, has been developed by D.T Pham in 2006, and is considered to be as an efficient as other swarm intelligence approach. Some basic concept of Honey Bees Colony, its application to swarm intelligence and the proposed Bee Colony algorithm for solving OPF problem will be explained briefly in this section.

A. THE NATURE OF BEES

In order to search for food sources, a honey bee colony can expand in multiple directions and over a distance of 10 kilometers. The process of food foraging starts from sending out a group of scout bees to search for flower patches that contain a large amount of nectar and pollen. After returning to their hive, those scout bees would perform a special movement, which is known as the 'waggle dance' to communicate with other bees and report three kind of information regarding the flower patches, which are the direction of food sources, their quality and distances. This information helps the bees travelling towards flower patches more rapidly and precisely without using guides or maps. After the waggle dance, scout bees will fly back to the flower patch again with follower bees or workers.

More follower bees are sent to more promising patches and allow the colony to collect food during the short amount of time. Additionally, the bees evaluate the food level from the flower patch to decide how to perform the next waggle dance and recruit more workers to the remaining food sources. The food foraging process will repeat as long as there is enough food sources in the search space, and more bees will be recruited to collect food more effectively.

B. PROPOSED ARTIFICIAL BEE COLONY ALGORITHM

In order to applying the Bees Algorithm properly, a number of parameters are required to be set such as number of iterations (g), initial patch size (ngh) number of bees in the population (n), number of sites selected for neighborhood search (m), number of bees recruited for the selected sites (nep), and the stopping criterion. A simple flowchart of Bee Colony Algorithm corresponding to the food foraging behavior of a honey bee colony is demonstrated in Fig. 2. After all parameters are initialized, the Bees Algorithm starts with placing scout bees randomly in the search space, the fitness values of those sites where the scout bees visited will be calculated. A number of sites that have high fitness values, along with a number of bees for these sites, will then be chosen for neighborhood search and fitness evaluation. Additionally, the remaining bees are assigned to search randomly in the search space in order to find more promising solutions.

C. PSEUDO CODE OF ABC ALGORITHM

Generate the initial population size as n, set the best patch size as *m*, set the elite patch size as e, set the number of forager bees recruited to the of elite sites as nep, set the number of forager bees around the non-elite best patches as nsp, set the neighborhood size as ngh, set the maximum iteration number as *MaxIter*, and set the error limit as *Error*.

i = 0
Generate initial population.
Evaluate Fitness Value of initial population.
Sort the initial population based on the fitness result.
While $i \leq MaxIter$ *or* $FitnessValue_i - FitnessValue_{i-1} \leq Error$

1. i = i + l;
2. Select the elite patches and non-elite best patches for neighborhood search.
3. Recruit the forager bees to the elite patches and non-elite best patches.
4. Evaluate the fitness value of each patch.
5. Sort the results based on their fitness.
6. Allocate the rest of the bees for global search to the non-best locations.
7. Evaluate the fitness value of non-best patches.
8. Sort the overall results based on their fitness.
9. Run the algorithm until termination criteria met.

End

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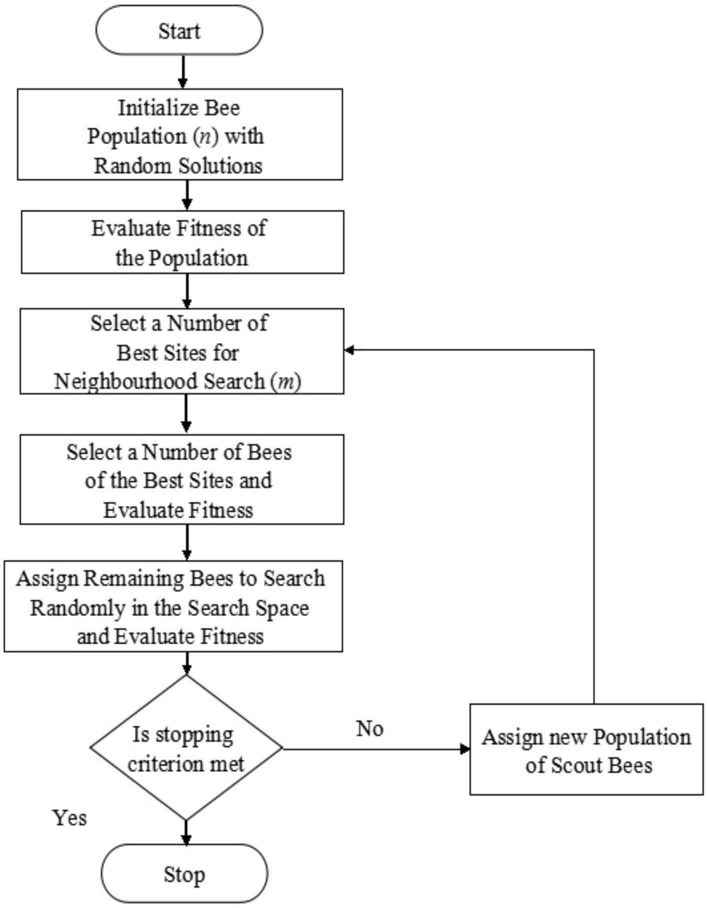

Figure 1. Flowchart of the Bees algorithm

The working of Artificial Bee Colony Algorithm for Optimal Power Flow can be summarized as follows:
Step 1: Start the program and Set the iteration count as NC
Step 2: Initialize the system data which denotes the generator and load data of the specified bus system.
Step 3: Generate randomly the initial populations of scout bees. This initial population must be feasible candidate solutions that satisfy the constraints.
Step 4: Run power flow by using Newton method and evaluate the fitness value of the initial populations.
Step 5: Check for limit violations and select best solutions.
Step 6: Separate the best solutions to two groups, the first group have e best solutions and another group have m-e best solutions.
Step 7: Determine the size of neighborhood search of each best solution.
Step 8: Generate solutions by using Newton method around the selected solutions within neighborhood size.
Step 9: Select the fittest solution from each patch.
Step 10: Check the stopping criterion. If satisfied, terminate the search, else NC=NC+1.
Step 11: Update all bee parameters and go to Step 4.

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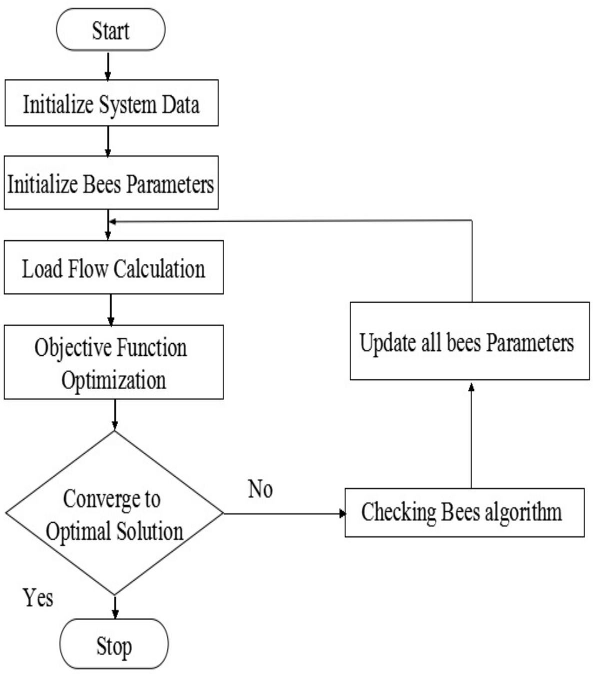

Figure 2. Bees Algorithm – OPF Flowchart

IV. SIMULATION RESULTS

Applying the Artificial Bee Colony Algorithm to solve OPF problem was carried out on the IEEE-9 bus system and compared its simulation results with those of conventional Interior point programming method. The coding were developed and implemented in MATLAB and run on the Intel Pentium B950 Processor with 2GB of RAM.

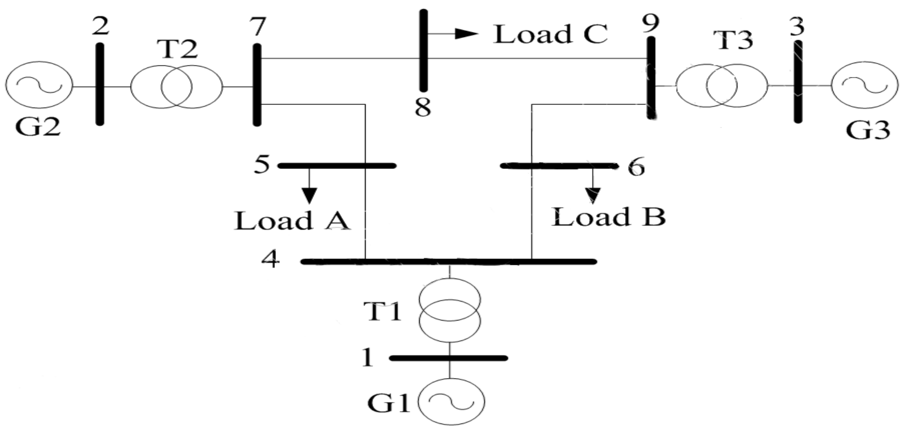

Figure 3. Single Line Diagram of IEEE-9 Bus System

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Table I. Generating Unit capacity and Cost coefficients of IEEE-9 Bus System

Unit No	Bus No	Pmin (MW)	Pmax (MW)	Qmin (MVar)	Qmax (MVar)	Cost Coefficients		
						A	B	C
1	1	10	250	-300	300	0.11	5	50
2	2	10	300	-300	300	0.085	1.2	600
3	3	10	270	-300	300	0.1225	1	335

Table II. ABC Parameter Setting

No. of Scout Bees	100
No. of sites selected for neighborhood search	60
No. of bees recruited for best sites	30
No. of the remaining bees	15
No. of iterations	100
No. of Scout Bees	100
No. of sites selected for neighborhood search	60
No. of bees recruited for best sites	30
No. of the remaining bees	15
No. of iterations	100

Table III. Generator Allocation

Method	Generating Power (MW)			Cost ($/h)
	P1	P2	P3	
Interior Point Programming	89.80	134.32	94.19	5296.69
ABC	89.88	135.26	93.19	5295.82

V. CONCLUSION

In this paper, the implementation of Artificial Bee Colony Algorithm for solving Optimal Power Flow problem was established. The effectiveness of the Bee Colony Algorithm was verified by testing with IEEE-9 bus system and compared with Linear Programming method. The results obtained are shows that it can be considered as a promising alternative that is suitable for solving the OPF problem. In future, efforts will be made to incorporate with many objective functions to the problem structure. Practical large sized problems will be attempted by the proposed methodology.

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