Saudi Journal of Biological Sciences (2017) 24, 703–710

King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Dynamic population artificial bee colony algorithm for multi-objective optimal power flow

Man Ding [a], Hanning Chen [b,*], Na Lin [c], Shikai Jing [b], Fang Liu [b], Xiaodan Liang [b], Wei Liu [d]

[a] School of Architecture and Art Design, Hebei University of Technology, Tianjin 300130, China
[b] School of Computer Science and Software, Tianjin Polytechnic University, Tianjin 300387, China
[c] Beijing Shenzhou Aerospace Software Technology Co. Ltd., Beijing 110000, China
[d] College of Information and Technology, Jilin Normal University, Siping 136000, China

Received 11 October 2016; revised 25 December 2016; accepted 7 January 2017
Available online 26 January 2017

KEYWORDS

Artificial bee colony algorithm;
Life-cycle evolving model;
Optimal power flow;
Multi-objective optimization

Abstract This paper proposes a novel artificial bee colony algorithm with dynamic population (ABC-DP), which synergizes the idea of extended life-cycle evolving model to balance the exploration and exploitation tradeoff. The proposed ABC-DP is a more bee-colony-realistic model that the bee can reproduce and die dynamically throughout the foraging process and population size varies as the algorithm runs. ABC-DP is then used for solving the optimal power flow (OPF) problem in power systems that considers the cost, loss, and emission impacts as the objective functions. The 30-bus IEEE test system is presented to illustrate the application of the proposed algorithm. The simulation results, which are also compared to nondominated sorting genetic algorithm II (NSGAII) and multi-objective ABC (MOABC), are presented to illustrate the effectiveness and robustness of the proposed method.

1. Introduction

In many fields of science and engineering, there are always multiple conflicting objectives, which are formulated as multi-objective (MO) optimization problems in order to minimize or maximize these conflicting objective functions simultaneously. In MO optimization domain, the set of Pareto optimal solutions, namely several optimal solutions with different trade-offs in the objective space, is called the Pareto optimal front (Fonseca and Fleming, 1998; Cruz et al., 2014). Optimal power flow (OPF) is one of the most important MO problems in power system. The main goal of OPF is to find the optimal adjustments of the control variables to minimize the selected objective function while satisfying various physical and operational constraints imposed by equipment and network limitations (Kumari and Maheswarapu, 2010). Since the real power generation levels and voltage magnitudes are continuous variables whereas the transformer winding

* Corresponding author.
E-mail address: chenhanning@tjpu.edu.cn (H. Chen).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjbs.2017.01.045
1319-562X

ratios and shunt capacitors are discrete variables, the OPF problem is considered as a non-linear multi-modal optimization problem with a combination of the discrete and continuous variables (Abou El Ela et al., 2010).

Many mathematical models and conventional techniques, such as gradient-based optimization algorithms, linear programming, interior point method, and Newton method, have been applied to solve the OPF problem (Momoh et al., 1999a,b). However, these methods suffer from severe limitations in handling non-linear, discrete and continuous functions, and constraints. In order to overcome the limitations of classical optimization techniques, a wide variety of the heuristic methods have been proposed to solve the OPF problem, such as genetic algorithm (GA) (Lai et al., 1997), tabu search (TS) (Abido, 2002), differential evolution (DE) algorithm (Sayah and Zehar, 2008), and biogeography based optimization (BBO) (Roy et al., 2010). The reported results are promising and encouraging for further research in this field (Abou El Ela et al., 2010). However, all the mentioned heuristic mathematical techniques have some drawbacks such as being trapped in local optima or each of them is only suitable for solving a specific objective function in the OPF problem (AlRashidi and El-Hawary, 2007).

Swarm intelligence (SI) is an innovative artificial intelligence technique for solving complex optimization problems (Xu et al., 2013). Among them, artificial bee colony algorithm (ABC) is a relatively new optimization technique which simulates the intelligent foraging behavior of a honeybee swarm (Ma et al., 2013; Eberchart and Kennedy, 1995). Recently, two multi-objective approaches based on ABC model were proposed in (Passino, 2002; Gao and Liu, 2011). However, compared to the huge in-depth studies of other multi-objective evolutionary and swarm intelligence algorithms, such as nondominated sorting genetic algorithm II (NSGAII) (Deb et al., 2002), strength Pareto evolutionary algorithm (SPEA2) (Zitzler et al., 2001), and multi-objective particle swarm optimization (MOPSO) (Coello Coello and Pulido, 2004), how to improve the diversity of swarm or overcome the local convergence of multi-objective ABC (MOABC) is still a challenging to the researchers in MO optimization domain.

In this paper, a novel artificial bee colony algorithm with dynamic population (ABC-DP) is proposed to synergize the idea of extended life-cycle evolving model, which can balance the exploration and exploitation tradeoff in artificial bee colony foraging process. The proposed ABC-DP is a more bee-colony-realistic model that the bee can reproduce and die dynamically throughout the foraging process and population size varies as the algorithm runs. By incorporating this new degree of complexity, ABC-DP can accommodate a considerable potential for solving complex MO problems. Then we applied ABC-DP to solve two and three objective OPF cases considering the cost, loss, and emission impacts as the objective functions respectively on the 30-bus IEEE test system. The simulation results, on both benchmarks and OPF cases, prove that ABC-DP has better optimization performance than the NSGA-II and MOABC algorithms.

The rest of the paper is organized as follows. Section 2 first gives a review of the original ABC algorithm. Section 3 proposes the novel ABC-DP algorithm with the life-cycle model. In Section 4, the multi-objective OPF problem is formulated, and then the implementation of the ABC-DP on OPF is presented. Simulation results and comparison with other algorithms are given in Section 5. Finally, Section 6 outlines the conclusions.

2. The original artificial bee colony algorithm

From Fig. 1, we can understand the basic behavior characteristics of bee colony foraging behaviors better. Assume that there are two discovered food sources: A and B. At the very beginning, a potential bee forager will start as unemployed bee. That bee will have no knowledge about the food sources around the nest.

There are two possible options for such a bee:

i. It can be a scout and starts searching around the nest spontaneously for a food due to some internal motivation or possible external clue (‘*S*’ in Fig. 1).
ii. It can be a recruit after watching the waggle dances and starts searching for a food source (‘*R*’ in Fig. 1).

After finding the food source, the bee utilizes its own capability to memorize the location and then immediately starts exploiting it. Hence, the bee will become an ‘‘employed forager’’. The foraging bee takes a load of nectar from the source and returns to the hive, unloading the nectar to a food store. After unloading the food, the bee has the following options:

iii. It might become an uncommitted follower after abandoning the food source (*UF*).
iv. It might dance and then recruit nest mates before returning to the same food source (*EF1*).
v. It might continue to forage at the food source without recruiting after bees (*EF2*).

It is important to note that not all bees start foraging simultaneously. The experiments confirmed that new bees begin

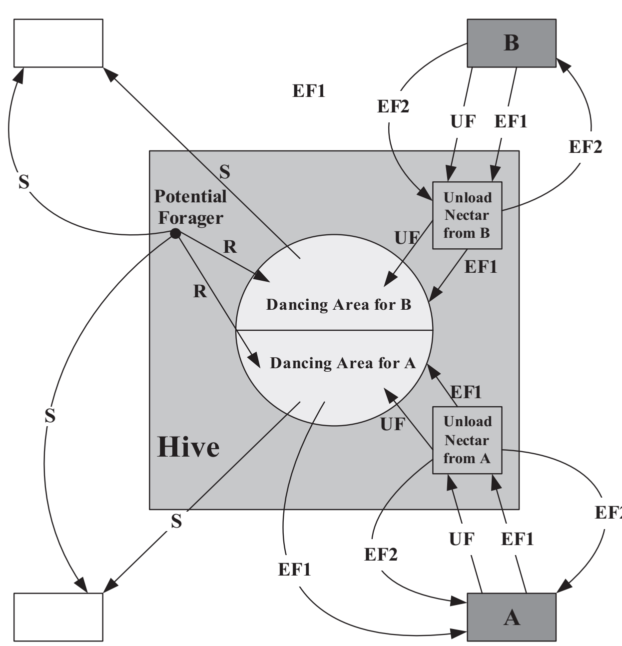

Figure 1 Behavior of honeybee foraging for nectar.