Chapter 4
Quantum-Behaved Bat Algorithm for Solving the Economic Load Dispatch Problem Considering a Valve-Point Effect

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ABSTRACT

Quantum computing-inspired metaheuristic algorithms have emerged as a powerful computational tool to solve nonlinear optimization problems. In this paper, a quantum-behaved bat algorithm (QBA) is implemented to solve a nonlinear economic load dispatch (ELD) problem. The objective of ELD is to find an optimal combination of power generating units in order to minimize total fuel cost of the system, while satisfying all other constraints. To make the system more applicable to the real-world problem, a valve-point effect is considered here with the ELD problem. QBA is applied in 3-unit, 10-unit, and 40-unit power generation systems for different load demands. The obtained result is then presented and compared with some well-known methods from the literature such as different versions of evolutionary

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programming (EP) and particle swarm optimization (PSO), genetic algorithm (GA), differential evolution (DE), simulated annealing (SA) and hybrid ABC_PSO. The comparison of results shows that QBA performs better than the above-mentioned methods in terms of solution quality, convergence characteristics and computational efficiency. Thus, QBA proves to be an effective and a robust technique to solve such nonlinear optimization problem.

INTRODUCTION

Thermal plants mainly utilize fossil fuels like coal, gas and oil to generate electricity. Capacity to deliver fossil fuels as per their growing demand is very much limited due to the shortage of fossil fuel supply and lack of adequate infrastructures (Mahdi, Vasant, Kallimani, & Abdullah-Al-Wadud, 2016). Moreover, fossil fuels are not always easily accessible to all as the reserves of the fossil fuels are concentrating into a small number of countries. Furthermore, the reserves of the fossil fuels are declining and it will be distinct and too expensive in near future. Thus, economic load dispatch (ELD) plays one of the most crucial parts in electrical power generation system. ELD deals with the minimization of fuel cost, while satisfying all other constraints (Wood & Wollenberg, 2012). The simplification of traditional ELD problem fails to offer satisfactory results in real-world system as they consider that the efficiency of power plant increases linearly or quadratically. However, in real-world system separate nozzle groups help the valves to control the steam entering the turbine. The system tries to achieve its highest efficiency by activating the valves in a sequential way and thus resulting a rippled efficiency curve. This phenomenon is known as valve-point effect. In this research, valve-point effect is considered as a practical operation constraint of generator. Considering valve-point effect helps to model ELD problem more accurately and closer to actual power generation system at the cost of adding extra complexities in the system.

Traditional methods like Newton-Raphson (Lin, Chen, & Huang, 1992), linear and nonlinear programming techniques (Momoh, El-Hawary, & Adapa, 1999) were used to solve ELD problem, where the ELD problem is represented using linear quadratic function. They proved to be fast and reliable against linear ELD problem. But, when considering the nonlinear characteristics of power system like consideration of valve-point effect, the traditional methods were proved to be ineffective and inefficient (Chen & Wang, 1993). They are prone to trap into the local optima and have sensitivity to the initial point (Mahdi, Vasant, Kallimani, Watada, et al., 2017).

Different heuristic and metaheuristic techniques have later used to overcome the shortcomings of the traditional methods to solve nonlinear ELD problem. Genetic algorithm (GA) (Walters & Sheble, 1993), simulated annealing (SA) (Wong & Fung, 1993), evolutionary programming (EP) (Yang, Yang, & Huang, 1996), tabu search (TS) (Lin, Cheng, & Tsay, 2002), enhanced Lagrangian artificial neural network (ELANN) (S. C. Lee & Kim, 2002), generalized ant colony optimization (GACO) (Hou, Wu, Lu, & Xiong, 2002), improved fast evolutionary program (IFEP) (Chakrabati, Choudhury, Chattopadhyay, Sinha, & Ravi, 2003), particle swarm optimization (PSO) (Park, Lee, Shin, & Lee, 2005), pattern search (PS) method (Al-Sumait, Al-Othman, & Sykulski, 2007), Biogeography based optimization (BBO) (Roy, Ghoshal, & Thakur, 2009), improved harmony search (IHS) (Coelho & Mariani, 2009b), chaotic artificial immune network (CAIN) (Coelho & Mariani, 2009a), bat algorithm (BA) (Sakthivel, Natarajan, & Gurusamy, 2013), chaotic teaching-learning-based optimization with Lévy flight (CTLBO) (X. He, Rao, & Huang, 2016) and swarm based mean-variance mapping optimization ($MVMO^S$) (Khoa,