Energy Conversion and Management 79 (2014) 344–354

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

A modified artificial bee colony based on chaos theory for solving non-convex emission/economic dispatch

H. Shayeghi *, A. Ghasemi

Technical Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran

ARTICLE INFO

Article history:
Received 23 July 2013
Accepted 12 December 2013
Available online 10 January 2014

Keywords:
Multi objective optimization
Pareto fronts
Chaos theory
Fuzzy decision
EED problem
CIABC technique

ABSTRACT

In this paper, a modified ABC based on chaos theory namely CIABC is comprehensively enhanced and effectively applied for solving a multi-objective EED problem to minimize three conflicting objective functions with non-smooth and non-convex generator fuel cost characteristics while satisfying the operation constraints. The proposed method uses a Chaotic Local Search (CLS) to enhance the self searching ability of the original ABC algorithm for finding feasible optimal solutions of the EED problem. Also, many linear and nonlinear constraints, such as generation limits, transmission line loss, security constraints and non-smooth cost functions are considered as dynamic operational constraints. Moreover, a method based on fuzzy set theory is employed to extract one of the Pareto-optimal solutions as the best compromise one. The proposed multi objective evolutionary method has been applied to the standard IEEE 30 bus six generators, fourteen generators and 40 thermal generating units, respectively, as small, medium and large test power system. The numerical results obtained with the proposed method based on tables and figures compared with other evolutionary algorithm of scientific literatures. The results regards that the proposed CIABC algorithm surpasses the other available methods in terms of computational efficiency and solution quality.

1. Introduction

In the recent years, in view of the increasing public understanding of the environmental protection and approval of the US clean air amendments of 1990, the governments have obliged the manufacturing units and power utilities to modify their strategies to decrease environmental pollutions and atmospheric emissions in the thermal plants [1,2]. A host of traditional economic dispatch is in vogue to decrease environmental pollutions like installing switching to low emission fuels, post-combustion cleaning equipment, and replacement of the aged fuel burners or dispatching with emission considerations [3]. The latter decision is preferred in many cases due to economical reasons and its immediate availability for short term operation [4,5].

The aim of EcD problem is provide best generation schedule for the generating plants to provide the required demand plus transmission losses with the minimum production cost [6,7]. The EmD problem is similar to EcD problem except that it extends to minimize the net emissions instead of fuel cost [8]. The multi objective generation dispatch in electric power systems is combining of EED that focuses to simultaneously minimize both the fuel cost and emission levels by fulfilling all unit and nonlinear systems constraints. There is no solitary best result to the bi-objective EED problem unless exact preference or weight of both the objectives is known [9]. Thus, it gives rise to finding a set of compromise solutions known as Pareto optimal solutions, which explain the trade-off between the two conflicting objectives [10].

Recently, conventional mathematical programming methods such as lambda iteration, gradient search, linear programming and Lagrangian relaxation [11] and evolutionary optimization algorithms such as TS [12], GA [13,14], multi objective PSO [15], NSGA [16], MDE [17], EMODE [18], cultural self-organizing migrating strategy [19], quantum-inspired evolutionary algorithm [20], clonal algorithm [21], Tribe-MDE [22] and biogeography based optimization [23] are applied to deal with EED problem.

Unfortunately, the above-mentioned methods lost numerous non-dominated solutions (dominated and non-dominated solutions explain in Fig. 3) to be in the search process which some of dominated solutions may be misclassified as non-dominated ones due to the selection process. Thus, they do not offer a outline for directing the search toward Pareto-optimal front that has lost its diversity and converged to local optimum of the objective function and the searching methods do not enhance toward more appropriate solutions and as a result it might not be possible for the this technique to proceed toward the global optimum (hasty convergence). In other words, when the system has a highly epistatic

* Corresponding author. Address: Daneshgah Street, P.O. Box: 179, Ardabil, Iran. Tel.: +98 451 5517374; fax: +98 451 5512904.
E-mail address: hshayeghi@gmail.com (H. Shayeghi).

0196-8904/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enconman.2013.12.028

Nomenclature

ABC	Artificial Bee Colony
CIABC	Chaotic Interactive Artificial Bee Colony
CLS	Chaotic Local Search
EED	Environmental/Economic Dispatch
US	United States
EcD	Economic Dispatch
EmD	Emission Dispatch
TS	Tabu Search
GA	Genetic Algorithm
PSO	Particle Swarm Optimization
NSGA	Non-dominated Sorting Genetic Algorithm
MDE	Modified Differential Evolution
EMODE	Enhanced Multi-Objective Differential Evolution Algorithm
Tribe-MDE	Tribe-Modified Differential Evolution
ELD	Economic Load Dispatch (ELD)
IABC	Interactive Artificial Bee Colony
NDS	Non-Dominated Sort
IHBMO	Interactive Honey Bee Mating Optimization
HBMO	Honey Bee Mating Optimization
MODE	Multi-Objective Differential Evolution Algorithm
IABC	Incremental Artificial Bee Colony
CPSO–SQP	Chaotic PSO algorithm and Sequential Quadratic Programming
EP	Evolutionary Programming
MGSO	Modified Group Search Optimizer
SOMA	Self Organizing Migrating Strategy
IABC-LS	Incremental Artificial Bee Colony algorithm with Local Search
ABCDP	Artificial Bee Colony with Dynamic Population size

objective function and number of variables to be optimized is large, then they have degraded efficiency to obtain global optimum solution.

To capture these shortages, a multi objective CIABC algorithm based on fuzzy decision making is introduced in this paper. In other words, modifications in local rule based on CLS are proposed to the original ABC method that explores the searching space with a random localization, enhancing its rate of convergence for a better solution quality. By combining CLS mechanism with ABC, it can be ensured that the solutions are not trapped in local optima, based on the characteristics of periodicity and regularity of chaos. By applying the proposed technique to the standard IEEE 30-bus six-generator, medium power system with 14-generator, and a large scale system with 40 generators, its efficiency has been studied. The simulations results are compared with the recent algorithms of existing literatures. The results evaluation shows that the proposed algorithm achieves good performance in finding optimal solution for EED problem.

2. Problem formulation

The EcD problem is one of the main issues of modern power system, which determines the optimal real power settings of generating units so minimized two opposing objective functions, fuel cost and environmental emission while satisfying numerous equality and inequality practical constrains of generators [24]. This problem can be summarized in below subsections:

2.1. Problem objectives

2.1.1. Minimization of fuel cost

The EcD can be defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically [22]. The objective of EcD is to minimize the overall cost of generation. This function can be defined by:

$$F(P_G) = \sum_{i=1}^{N} F_i(P_{G_i}) \tag{1}$$

where N is number of generator and $F_i(P_{Gi})$ is the total fuel cost of ith generator (in \$/h). P_{Gi} denote the output of ith generator (in MW). The cost of generating unit $F_i(P_{Gi})$ is represented by the following quadratic functions:

$$F_i(P_{G_i}) = a_i + b_i P_{G_i} + c_i P_{G_i}^2 (\$/\text{h}) \tag{2}$$

where a_i, b_i, c_i are the fuel cost coefficients of ith generator. To take into account for the valve-point effect, sinusoidal functions are added to the quadratic constant functions that the graphical structure is shown in Fig. 1. Thus, it can be written as:

$$F_i(P_{G_i}) = a_i + b_i P_{G_i} + c_i P_{G_i}^2 + |e_i \sin(f_i(P_{G_i}^{\min} - P_{G_i}))| \tag{3}$$

where e_i and f_i are the fuel cost-coefficients of the ith unit with valve-point effects.

2.1.2. Minimization of emission

The production of electricity from fossil fuel releases some contaminants, such as Sulfur oxides, Nitrogen oxides and Carbon dioxide, into the atmosphere. The total ton/h pollution of these pollutants can be defined as [24].

$$E(P_G) = \sum_{i=1}^{N} 10^{-2}(\alpha_i + \beta_i P_{G_i} + \gamma_i P_{G_i}^2) + \xi_i \exp(\lambda_i P_{G_i}) \tag{4}$$

where ζ_i, λ_i, γ_i, α_i and β_i are the emission coefficients of the ith generator.

2.1.3. Minimization of power loss

To obtain network power loss the Newton Raphson method is used that can be expressed as:

$$P_L(P_G) = \sum_{k=1}^{N_L} g_k [V_i^2 + V_j^2 - 2V_i V_j \cos(\theta_i - \theta_j)] \tag{5}$$

where the subscript k shows kth branches between bus ith and jth, i = 1, 2, ..., N_D, j = 1, 2, ..., N_j. ND shows the set of numbers of power demand bus; N_j is the set of numbers of buses adjacent to bus j,

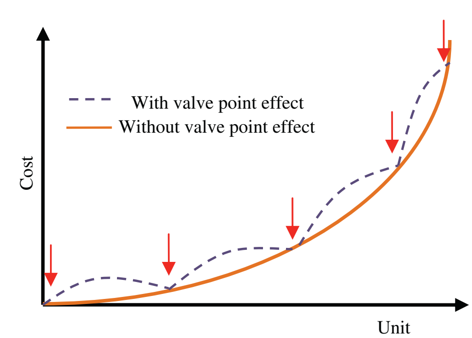

Fig. 1. Variation of cost with valve point effect.