Electrical Power and Energy Systems 73 (2015) 830–842

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

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

Backtracking search optimization based economic environmental power dispatch problems

Kuntal Bhattacharjee [a], Aniruddha Bhattacharya [b,*], Sunita Halder nee Dey [c]

[a] B.C. Roy Engineering College, Durgapur, West Bengal 713206, India
[b] The Department of Electrical Engineering, National Institute of Technology-Agartala, Tripura 799055, India
[c] The Department of Electrical Engineering, Jadavpur University, Kolkata, West Bengal 700 032, India

ARTICLE INFO

Article history:
Received 15 February 2014
Received in revised form 24 February 2015
Accepted 10 June 2015
Available online 24 June 2015

Keywords:
Backtracking search optimization
Best compromise solution
Economic emission load dispatch
Valve-point loading

ABSTRACT

This paper presents the solution for a nonlinear constrained multi objective of the economic and emission load dispatch (EELD) problem of thermal generators of power systems by means of the backtracking search optimization technique. Emission substance like $NO_{X,}$ power demand equality constraint and operating limit constraint are considered here. The aim of backtracking search optimization (BSA) is to find a global solution under the influence of two new crossover and mutation operations. BSA has capability to deal with multimodal problems due to its powerful exploration and exploitation capability. BSA is out of excessive sensitivity to control parameters as it has single control parameter. The performance of BSA is compared with existing newly developed optimization techniques in terms quality of solution obtained, computational efficiency and robustness for multi objective problems.

Introduction

The traditional economic load dispatch (ELD) problem is an optimization problem looks for the best available generation units in order to provide the most efficient, reliable and low cost of generation while satisfying several equality and inequality constraints. To minimize the fuel cost of economic dispatch is inadequate when environmental emissions are also to be included in the operation of different power plants. Due to increasing awareness of environmental protection since 1970s with implementation of several pollution control acts, power plant are bounded to considered emissions like NO_X, SO_X, CO_X, etc. in the ELD of power system studies to achieve minimum levels of pollution with the cheapest energy. The Economic emission dispatch (EED) problem plays an important role in the optimal amount of the generated power for the fossil-based generating units in the system by minimizing the emission level. However, EED problems cannot be handled by conventional single objective optimization techniques. Thus, the concept of economic emission load dispatch (EELD) has been implemented to figure out into a nonlinear multi objective optimization problem by considering both the objective of minimum cost of generation and as well as minimum emission level at the same time with heavy equality and inequality constraints.

In 1986 the first influence of power pools to solve the EED problem by considering emission as a single-objective optimization was described in [1]. Several approaches have been proposed as a multiple-objective optimization problem to minimize the total cost of generation and pollution control simultaneously in [2,3]. EL-Keib et al. applied air pollution act in economic dispatch problem in [4]. Nanda et al. used classical based techniques in EELD as a multiple-objective optimization problem to minimize the total cost of generation and pollution control simultaneously [5]. Economy, security and environment protection had been discussed in [6]. A linear programming technique was also applied in multi-objective economic load dispatch problem in [7] where single-objective is considered one at a time. Dhillon et al. and Chang et al. both used the cost of generation and emission accordingly as a single objective in [8,9].

Real-world power system optimization problems are often very complicated because of their high complexity and fuzziness. The conventional methods were applied to solve EELD problems. In case of conventional method, the essential assumption is that, the incremental cost of the generating units are monotonically increasing or piece-wise linear. As the effect of valve point loading is included in the mathematical problem formulation of practical EELD problem with a sinusoidal term along with normal quadratic fuel cost function or quadratic emission function, therefore modified fuel cost function or quadratic emission function become purely non linear and the resulting EELD problems become totally non-convex optimization problem. Therefore, classical optimization techniques

* Corresponding author.
E-mail addresses: kunti_10@yahoo.com (K. Bhattacharjee), ani_bhatta2004@rediffmail.com (A. Bhattacharya), sunitaju@yahoo.com (S. Halder nee Dey).

http://dx.doi.org/10.1016/j.ijepes.2015.06.018
0142-0615/

which solves this type of EELD problems, can give only approximate solution.

Therefore, presently soft computing techniques are applied to solve practical EELD problems and it outperforms other previously developed techniques due to following reasons:

1. It can use the previous knowledge for the solution of a problem and its behavior under various circumstances while finding new solutions.
2. It utilizes a population of points (potential solutions) in their search leading to parallel processing.
3. It uses direct fitness information instead of function derivatives or other related knowledge.
4. It mainly uses probabilistic rather than deterministic transition rules.

Abido [10–12] solved the multi-objective environmental and economic dispatch using non-dominated sorting genetic algorithm (NSGA) and evolutionary programming. The quadratic programming solution had been implemented in emission and economic dispatch problems in [13]. Srinivasan et al. solved the Multi-objective generation scheduling [14] by using a fuzzy optimal search technique. However, due to some disadvantages for using these methods the global optimum solution could not be achieved properly. Huang et al. proposed a new technique fuzzy satisfaction-maximizing decision approach [15] in Bi-objective power dispatch to overcome the problems observed in [14]. Yalcinoz et al. proposed a genetic algorithm with arithmetic crossover technique and multi-objective optimization method is used for EELD problem in [16,17]. Srinivasan et al. applied an evolutionary algorithm [18] based method to solve EELD problems. Multi-objective stochastic search technique was integrated in [19] to evaluate economic load dispatch problems. The weakness of this approach is enormous time-consuming. Fonseca et al. applied evolutionary algorithm in [20] to solve economic and emission load dispatch by considering either emissions as constraints for first objective function or cost of generation as a second objective function of a multi-objective optimization problem. In [21], Wei et al. discussed minimization of carbon oxide as an emission dispatch for better solution. AlRashidi et al. and Thakur et al. both tried to provide better solution by applying population based algorithm called particle swarm optimization (PSO) technique [22,23] in EELD problem. Perez-Guerrero RE et al. [24] applied another new population based technique differential evolution method to evaluate economic and emission load dispatch by considering either emissions as constraints or cost of generation as a second objective function of a multi-objective optimization problem. Wu et al. [25] used a multi-objective differential evolution (MODE) algorithm to solve EELD problem taking three multi-objectives of fuel cost, emission and system loss. Abou El Ela et al. [26] applied also the differential evolution algorithm to solve emission constrained economic power dispatch problem. A new hybrid bacterial foraging with PSO-DE algorithm was implemented to solve dynamic economic dispatch problem with security constraints in [27]. Hota et al. [28] incorporated also a new fuzzy based bacterial foraging algorithm (MBFA) to solve both single and multi-objective EELD problems. In 2008, Biogeography-Based Optimization (BBO) algorithm developed by Dan Simon, proved it's advantage to solve different optimization problems. In 2010, A. Bhattacharya et al. applied BBO successfully to incorporate it to various multi-objective EELD problems in [29]. The above-mentioned technique has comparatively fast, reasonable nearly global optimal solution with other soft computing techniques. Hybrid technique of differential evolution and biogeography-based optimization (DE/BBO) [30] has been employed to solve different EELD problem in search for much improved and fast output, compared to those of individual techniques. Recently Rajasomashekar et al. proposed BBO algorithm to find out a new approach to find out the best compromising solution between fuel cost and NO_X emission in EELD problems [31].

Niknam et al. used two different efficient evolutionary techniques known as new adaptive particle swarm optimization [32] and Modified Shuffle Frog Leaping Algorithm with Chaotic Local Search [33] to solve Non-smooth economic dispatch problem. Celal Yasar et al. [34] applied genetic algorithm integrated with conic scalarization method to convert multi-objective problem into single objective problem and solved the emission dispatch problem of power system. Again the authors applied combined modified subgradient technique integrated with harmony search [35] to solve economic dispatch problems. Chatterjee et al. [36] and Shaw et al. [37] initiated an opposition based learning scheme within basic Harmony Search Algorithm and gravitational search algorithm to solve combined economic and emission load dispatch problems.

The major drawbacks of Evolutionary algorithms, swarm intelligence and many others population based and bio-inspired algorithm are complicated computation, using lots of parameters. For that reason these algorithms are not user-friendly for beginners. Moreover, the optimization methodologies which have been developed to solve EELD problem, the complexity of the task reveals the necessity for development of efficient algorithms to locate the optimum solution accurately and computationally efficient way.

In recent times, a new optimization technique based on the concept of three new operators- selection, mutation and crossover, called backtracking search optimization algorithm (BSA) has been proposed by Pinar Civicioglu [38]. BSA has a random mutation strategy that uses only one direction individual for each target individual. In mutation operation the algorithm can control the amplitude of the search direction in a very balanced and efficient manner. During mutation it can generate numerically large amplitude values which in turn help to find solutions far way from its present state and make the algorithm suitable for a global search. At the same time it can generate small amplitude values which in turn help to find solutions in neighborhood of its present state and make the algorithm suitable for a local search. Apart from this, BSA possesses a memory in which it stores a population from a randomly chosen previous generation for use in generating the search- direction matrix for next iteration. Thus, BSA's memory allows it to take advantage of experiences gained from previous generations when it generates a trial preparation. The historical population used in selection operation helps for the calculation of the search-direction values for a randomly selected solution of previous generation, to generate more efficient trial individual. Crossover strategy uses non-uniform and complex structure that ensures creation of new trial individuals in each generation. Boundary control mechanism is effectively used for achieving population diversity. Due to the attractive and versatile qualities of BSA, it has been observed that the performance of the algorithm is quite satisfactory when applied to solve continuous benchmark optimization problems [38].

The all-around qualities and improved performance of BSA to solve different optimization problems has motivated the present authors to implement this newly developed algorithm to solve a basic but complex power system optimization problem e.g. ELD, to realize its future scope in the field of power system optimization.

Section 'Mathematical formulation of EELD problems' of the paper provides a brief mathematical formulation of different types of EELD problems. The concept of Backtracking Search algorithm is described in Section 'Backtracking search optimization (BSA)' short description of the BSA algorithm and it used in EELD problems. Simulation studies are discussed in Section 'Numerical examples