Evolutionary Multi-objective Environmental/Economic Dispatch: Stochastic Versus Deterministic Approaches

Robert T.F. Ah King[1], Harry C.S. Rughooputh[1], and Kalyanmoy Deb[2]

[1] Department of Electrical and Electronic Engineering, Faculty of Engineering, University of Mauritius, Reduit, Mauritius
{r.ahking, r.rughooputh}@uom.ac.mu

[2] Kanpur Genetic Algorithms Laboratory, Department of Mechanical Engineering, Indian Institute of Technology, Kanpur, PIN 208 016, India
deb@iitk.ac.in

Abstract. Due to the environmental concerns that arise from the emissions produced by fossil-fueled electric power plants, the classical economic dispatch, which operates electric power systems so as to minimize only the total fuel cost, can no longer be considered alone. Thus, by environmental dispatch, emissions can be reduced by dispatch of power generation to minimize emissions. The environmental/economic dispatch problem has been most commonly solved using a deterministic approach. However, power generated, system loads, fuel cost and emission coefficients are subjected to inaccuracies and uncertainties in real-world situations. In this paper, the problem is tackled using both deterministic and stochastic approaches of different complexities. The Nondominated Sorting Genetic Algorithm – II (NSGA-II), an elitist multi-objective evolutionary algorithm capable of finding multiple Pareto-optimal solutions with good diversity in one single run is used for solving the environmental/economic dispatch problem. Simulation results are presented for the standard IEEE 30-bus system.

1 Introduction

The classical economic dispatch problem is to operate electric power systems so as to minimize the total fuel cost. This single objective can no longer be considered alone due to the environmental concerns that arise from the emissions produced by fossil-fueled electric power plants. In fact, the Clean Air Act Amendments have been applied to reduce SO_2 and NO_x emissions from such power plants. Accordingly, emissions can be reduced by dispatch of power generation to minimize emissions instead of or as a supplement to the usual cost objective of economic dispatch. Environmental/economic dispatch is a multi-objective problem with conflicting objectives because pollution is conflicting with minimum cost of generation. Various techniques have been proposed to solve this multi-objective problem whereby most researchers have concentrated on the deterministic problem.

Economic dispatch calculates the cost of generation based on data relating fuel cost and power output. This cost function is approximated by a quadratic equation with cost coefficients. In conventional economic dispatch the coefficients are assumed to be deterministic, but in real-world situations, these data are subjected to inaccuracies

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and uncertainties. These deviations are attributed to (i) inaccuracies in the process of measuring and forecasting of input data and (ii) changes of unit performance during the period between measuring and operation [1]. Thus, the operating point in practice will differ from the planned operating point and will thus affect the actual fuel cost. Similarly, emission coefficients may also be subjected to some deviations resulting in definite differences in practical systems.

There has been much research using the deterministic approach to solve the environmental/economic dispatch problem. Gent and Lamont [2] introduced the minimum-emission dispatch concept where they developed a program for on-line steam unit dispatch that results in the minimizing of NO_x emission. These authors introduced the mathematical representation of NO_x emission of steam generating units and used a Newton-Raphson convergence technique to obtain base points and participation factors. Zahavi and Eisenberg [3] proposed a dispatch procedure for power that meets the demand for energy while accounting for both cost and emission considerations. A tradeoff curve which present the decision maker with all possible courses of action (dispatch policies) for a given demand was introduced. Nanda et al. [4] presented an improved Box complex method for economic dispatch and minimum emission dispatch problems. Dhillon et al. [5] formulated the multiobjective thermal power dispatch using noncommensurable objectives such as operating costs and minimal emission. The epsilon-constraint method was used to generate non-inferior solutions to the multiobjective problem considering the operating cost as the objective and replacing emission objective as a constraint. More recently, multi-objective evolutionary algorithms have been applied to the problem at hand. Abido has pioneered this research by applying NSGA [6], NPGA [7] and SPEA [8] to the standard IEEE 30-bus system. In fact, it has been shown that NSGA-II can obtain minimum cost and minimum emission solutions comparable to Tabu search [9].

Not long after the introduction of the environmental consideration in the economic dispatch problem, researchers started considering stochastic approaches bearing in mind the uncertainties that are inherent in real-world situations. Viviani and Heydt [10] incorporated the effects of uncertain system parameters into optimal power dispatch. Their method employed the multivariate Gram-Charlier series as means of modeling the probability density function (p.d.f.) which characterizes the uncertain parameters. Parti et al. [1] extended the Lagrange multiplier solution method to solve the economic thermal power dispatch problem using an objective function consisting of the sum of the expected production costs and expected cost of deviations (a penalty term proportional to the expectation of the square of the unsatisfied load because of possible variance of the generator active power). Bunn and Paschentis [11] developed a stochastic model for the economic dispatch of the electric power. These authors used a form of stochastic linear programming method for online scheduling of power generation at 5 minute intervals taking into account the mismatch between dispatched generation and actual load demanded. Experimental results on real data demonstrated the efficiency of the approach compared to conventional deterministic linear programming model. Dhillon et al. [12] have used the weighted minimax technique to obtain trade-off relation between the conflicting objectives and fuzzy set theory is subsequently used to help the operator choose an optimal operating point. In another attempt, Dhillon et al. [13] solved the multiobjective stochastic economic dispatch problem whereby the weighted sum technique and Newton-Raphson algorithm are used to generate the non-inferior solutions considering expected operating cost and