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Enhanced cross-entropy method for dynamic economic dispatch with valve-point effects

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A B S T R A C T

This paper proposes an enhanced cross-entropy (ECE) method to solve dynamic economic dispatch (DED) problem with valve-point effects. The cross-entropy (CE) method, originated from an adaptive variance minimization algorithm for estimating probabilities of rare events, is a generic approach to combinatorial and multi-extremal optimization. Exploration capability of CE algorithm is enhanced in this paper by using chaotic sequence and the resultant ECE is applied to DED with valve-point effects. The performance of the proposed ECE method is rigorously tested for optimality, convergence, robustness and computational efficiency on a 10-unit test system. Additional test cases with different load patterns and increased number of generators are also solved by ECE. Numerical results show that the proposed ECE approach finds high-quality solutions reliably with faster convergence. It outperforms CE and all the previous approaches.

1. Introduction

Power utilities are expected to generate electrical power at minimum cost within the generator and system limits. Economic dispatch (ED) plays a major role in this aspect [1]. Plant operators, to avoid life- shortening of the turbines and boilers, try to keep thermal stress on the equipments within the safe limits. This mechanical constraint is usually transformed into a limit on the rate of change of the electrical output of generators. Such ramp-rate constraints link the generator operation in two consecutive time intervals. ED which includes such inter-temporal dynamic connection is termed as dynamic ED (DED) [2]. The DED has been recognized as not only a more accurate formulation of ED, but also a most challenging optimization problem in power system operation. The DED solution provides the optimal operating trajectories based on the forecasts of system load demand profile. Generating units are then driven along these trajectories by plant controllers to have the lowest operating costs.

Accurate modeling with the inclusion of valve-point loading effects makes the solution space of DED nonconvex with many local minima. Therefore, DED becomes a highly nonlinear and nonconvex optimization problem, which cannot be solved by traditional techniques [3]. Dynamic programming (DP) can solve such type of problems [4], but it suffers from the curse of dimensionality. In recent years, many purebred and hybrid metaheuristic algorithms have been proposed to solve DED with valve-point effects. Mathematical properties such as differentiability, convexity, and linearity are of no concern for these algorithms. Modified differential evolution (MDE) [5] and improved particle swarm optimization (IPSO) [6] are the purebred algorithms that have been applied to DED.

Hybrid algorithms (combination of metaheuristic algorithms and local search procedures i.e. combination of exploration and fine-tuning) have provided significant results for DED with valve-point effects. The constituent algorithms of hybrid methods optimize the problem during different phases of optimization and they are integrated either sequentially or cyclically. Hybrid algorithms like evolutionary programming–sequential quadratic programming (EP–SQP) [7] and improved differential evolution (IDE)-Shor's r-algorithm [8] are examples for sequentially integrated hybrid algorithms, which have been applied to solve DED with valve-point effects. In these algorithms, EP/IDE is used as a base level search; then the fine-tuning is carried out by SQP/Shor's r-algorithm. Even though sequential integration provides better results, it has some drawbacks. First, deciding the point of integration of two algorithms, which has to be specified by the user, is very difficult. At the integration point, there is no guarantee of the favorable state i.e. fine-tuning may be invoked closer to a local-optimum. Secondly, the base algorithm may allow the better regions which are encountered in the earlier iteration stages without fine-tuning.

To ensure fine-tuning at all the stages of optimization, the cyclical hybrid algorithms invoke a deterministic local search procedure whenever the primary heuristic algorithm finds a better solution. Examples of such hybrids are modified hybrid EP–SQP (MHEP–SQP) [9] and deterministically guided PSO (DGPSO-A

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