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Short-term hydrothermal generation scheduling by a modified dynamic neighborhood learning based particle swarm optimization

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ABSTRACT

The main objective of the short-term hydrothermal generation scheduling (SHGS) problem is to determine the optimal strategy for hydro and thermal generation in order to minimize the fuel cost of thermal plants while satisfying various operational and physical constraints. Usually, SHGS is assumed for a 1 day or a 1 week planing time horizon. It is viewed as a complex non-linear, non-convex and non-smooth optimization problem considering valve point loading (VPL) effect related to the thermal power plants, transmission loss and other constraints. In this paper, a modified dynamic neighborhood learning based particle swarm optimization (MDNLPSO) is proposed to solve the SHGS problem. In the proposed approach, the particles in swarm are grouped in a number of neighborhoods and every particle learns from any particle which exists in current neighborhood. The neighborhood memberships are changed with a refreshing operation which occurs at refreshing periods. It causes the information exchange to be made with all particles in the swarm. It is found that mentioned improvement increases both of the exploration and exploitation abilities in comparison with the conventional PSO. The presented approach is applied to three different multi-reservoir cascaded hydrothermal test systems. The results are compared with other recently proposed methods. Simulation results clearly show that the MDNLPSO method is capable of obtaining a better solution.

Introduction

Motivation

Due to the concerns regard to increasing the atmospheric pollutions and also decreasing fossil resources, using hydro power plant can attenuate the intensity of the current dilemma. The inclusion of hydro power plant interposes the coordination of hydrothermal operation in electric utility system. One of the most important aspect of hydrothermal coordination is to adopt the optimal strategy in order to utilize hydro and thermal power plants economically. This subject is known as short-term hydrothermal generation scheduling (SHGS) problem which is of great importance in power system operation. The SHGS problem determines optimum operation strategy for output power of whole units for specified scheduling time horizon. It aims to minimize the total operational cost subject to a variety of constraints. In fact, the discharged water of hydro units, for all time intervals, is chosen such that the total fuel cost related to thermal units, is minimized considering the hydro and thermal units constraints. The major constraints of the SHGS problem include the limits of output power for units, the initial and final water volume, the discharge rate limits, the dynamic balance for the water flow and electrical active power; moreover the limits of reservoir storage volume must be considered due to the some technical and environmental conditions. In hydrothermal system, cascaded hydro power plants have hydraulically connections as parallel or series which forces the operation of downstream reservoir to be dependent to the upstream units. With these constraints and transmission loss and valve point loading effect for thermal units, SHGS problem will be non-linear, non-convex and non-smooth optimization problem that is difficult to solve.

Literature review

In the technical literature, several works are available, which have studied the SHGS problem. Traditionally, some of those studies deal with the SHGS problem using mathematical methods. These methods such as dynamic programming (DP) [1–3], mathematical decomposition (MD) [4], mixed integer linear programming (MILP) [5], Lagrangian relaxation (LR) [6,7], linear programming

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(LP) [8,9], progressive optimality algorithm (POA) [10], gradient search (GS) [11,12], truncated dynamic programming (TDP) [13], mixed integer programming (MIP) [14] and network flow method (NFM) [15] have been proposed to solve SHGS problem during recent decades. These methods have some drawbacks in various aspects. Furthermore, these traditional methods have major problems in finding optimal solution and suboptimal ones are often obtained. This condition is deteriorated when the problem is being large-scale or more constraints are considered [16]. In order to deal successfully with nonlinear optimization problems, it is required to use linearized models of objective function and constraints. Sometimes the optimal solution of problem is avoided due to the inaccuracy of linearization process [17]. Large dimensionality is the main drawback of DP methods. In addition, increasing in the system size and planning horizon exponentially increases the computational burden of DP [18]. The efficiency of LR is affected by the size of the duality gap. In addition, selection of method to update Lagrange multipliers is a highly controversial subject that its influences on the quality of solution was reported [19].

Recently, many meta heuristic methods have been successfully applied to solve the SHGS problem. Simulated annealing was employed for solving the SHGS problem in [20]. However, choosing the control parameter and high computational burden were two major challenges in application of SA in solving the SHGS problem. Artificial neural network (ANN) based SHGS problem was demonstrated in [21,22]. Evolutionary algorithms (EAs) have been widely used in solving the SHGS problem. Application of evolutionary programming (EP) with Gaussian mutation in solving the SHGS problem have been discussed in [23]. In order to enhance applicability of EP, Sinha et al. [24] proposed fast evolutionary programming (FEP) with Cauchy mutation and showed the better performance of FEP achieving lower fuel cost. Also, they simultaneously applied both Gaussian and Cauchy mutation to EP and proposed new variant of EP namely improved fast evolutionary programming (IFEP). Capability of IFEP in solving SHGS problem was tested and the results presented that (IFEP) outperforms other variants of EPs. Genetic algorithm (GA) have been used to solve the SHGS problem in [25]. Differential evolution (DE) is implemented in [26] for solving the SHGS problem. Compared by other evolutionary techniques such as EP and GA, the one-to-one competitions between the fittest of an off-spring and corresponding parent have improved the convergence rate of DE [27]. So, the quality of obtained results from DE and its computational burden were better than GA as reported in this paper. Lakshminarasimman and Subramanian [28] proposed modified DE (MDE) in order to handle the equality constraints avoiding penalty functions. In [27] they reported a modified hybrid DE (MHDE) which developed for equality constraints handling and also proposed the acceleration and migration operators added to the original DE. Furthermore, an adaptive dynamic control mechanism for adjusting crossover parameter of DE algorithm was proposed in [29]. In this approach, called adaptive chaotic DE (ACDE), the performance of DE was also influenced by integration of the logistic equation based chaotic local search which helped DE to avoid premature convergence. Improved differential evolution [30] is the other variant of DE which its application have been investigated in solving SHGS problem. IDE used Gaussian random variable instead of scaling factor. It may be difficult to recognize that IDE is the best among other DEs or not. The reason is related to some infeasibility which is found in IDE solutions reported in the literature [31]. A recent developments in DE variants which its capability in solving the SHGS problem have been investigated, was the modified chaotic differential evolution (MCDE) [32]. The solutions obtained by MCDE were better than DE, MDE and MHDE when they were implemented for solving some common hydrothermal test systems. In addition to above mentioned EAs, new EA based methods have been proposed to solve SHGS problem. Wang et al. [16,33] solved the SHGS problem using quantum-inspired evolutionary algorithm (QEA). First, they applied QEA for solving the SHGS problem and represented that QEA had some drawbacks in solution accuracy and computation time for large optimization problems. Hence, a differential real-coded quantum-inspired evolutionary algorithm (DRQEA) was suggested [16] to improve the performance of QEA. Furthermore, a clonal real-coded quantum-inspired evolutionary algorithm (CRQEA) was proposed in [33]. The comparison results of QEA and its variants i.e. DRQEA and CRQEA in solving the SHGS problem can demonstrate that CRQEA had the best performances. The SHGS problem was resolved by a real-coded version of chemical reaction optimization algorithm (RCCRO) [31] and the results were compared with other approaches. Also, the oppositional based learning method was added to RCCRO. Consequently, oppositional based RCCRO (ORCCRO) was applied to resolve the SHGS problem in [34]. The obtained results clearly showed that ORCCRO was more capable obtaining better solution especially for more complex test systems. An adaptive chaotic artificial bee colony (ACABC) [17] was applied to solve a hydrothermal test system considering valve point effects and transmission loss. In this study, the performance of original artificial bee colony (ABC) was improved by applying chaotic local search and some modifications on the main procedures of ABC. Clonal selection algorithm (CSA) [18] was the other approach that successfully applied on the SHGS problem. Teaching–learning based optimization (TLBO) is a relatively new optimization algorithm that its application has been recently tested for solving the SHGS problem [35]. In fact, TLBO simulates the teaching–learning process which is occurred between the teacher and the students in a class. The performance of TLBO is improved in [36] using the concept of quasi-oppositional learning led to proposal of quasi-oppositional teaching–learning based optimization (QOTLBO) algorithm. In this paper, solving QOTLBO based SHGS problem and comparing with TLBO clearly showed the better performance of QOTLBO. An enhanced gravitational search algorithm (EGSA) was used to solve the SHGS problem in [37]. The combination of real coded genetic algorithm (RCGA) and artificial fish swarm algorithm (AFSA) for solving the SHGS have been reported in [38]. This paper simultaneously made profit of potential of RCGA global search and also potential of AFSA local search to solve the SHGS problem efficiently.

Each of the above mentioned intelligent algorithms has some advantages over the others, but two attributes are common for all of them; the first is that the none of them guarantee obtaining global solution of the SHGS problem, the other is related to their dependency on the own control parameters that affect solution quality. In order to overcome these issues, several modified and also improved versions of algorithms, as briefly discussed before, have been developed. The main purpose of heuristic algorithm contribution is obtaining better solution and improving the convergence characteristics. It should be noted that the very fast convergences reduces the population diversity rapidly and hence the probability of obtaining local optimum is increased [29].

The classical version of PSO have been used to solve SHGS problem in [39]. PSO has similar problems especially premature convergence and trapping into local optimum. So, similar to the other algorithms, many ameliorated versions of PSO have been proposed to acquire better performances. Some of this approaches are put forward. In [40] improved PSO (IPSO) extended by dynamic search-space squeezing strategy readjusting dynamically of the control variables ranges. The results showed that using this strategy, the convergence speed of PSO and solution quality had been improved. Wang et al. [41] proposed an improved self-adaptive PSO (ISAPSO) with an emphasis on accuracy constraint handling. This method was implemented on one test system. [19,41] proposed a modified adaptive PSO (MOPSO) and suggested a new