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# A novel approach for economic dispatch of hydrothermal system via gravitational search algorithm

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A B S T R A C T

The daily economic dispatching of hydrothermal system (DHS), which is a large-scale dynamic nonlinear constrained optimization problem, plays an important role in economic operation of electric power systems. This paper proposes a novel enhanced gravitational search algorithm (EGSA) to solve DHS problem. In the proposed method, the improvements mainly include three aspects. Firstly, particle swarm optimization (PSO) that acts complementary is integrated into gravitational search algorithm for update of agent's velocity. Secondly, heuristic search strategies based random selected dependent discharge of hydro plants and average full-load cost priority list of thermal units are adopted to deal with equality constraints of DHS problem. Thirdly, feasibility-based selection comparison techniques are devised to effectively handle inequality constraints in EGSA, which do not require penalty factors or extra parameters and can guide the agent to the feasible region quickly. The feasibility and effectiveness of the proposed EGSA method is verified by a hydrothermal test system and the simulation results are compared with those of differential evolution, PSO, genetic algorithm, classical evolutionary programming, fast evolutionary programming, and improved fast evolutionary programming algorithm. From the results, it clearly shows that the proposed method gives better quality solutions than other methods.



## 1. Introduction

The short-term daily optimal dispatching of hydrothermal system (DHS) problem is one of important and difficult optimization problems in economic operation of power systems. In hydrothermal system, the water resources available for electrical generation are represented by the inflows to hydropower plants and the water stored in reservoirs. Thus, the available resources at each stage of dispatching horizon depend on the previous use of water, which establishes a dynamic relationship among the operation decisions along the whole horizon. By utilizing the limited water resource, the main objective of daily economic dispatch of hydrothermal system is to determine the optimal amount of water release for hydro generation power in cascade reservoirs such that the total fuel cost of thermal plants over the dispatching period can be minimized while satisfying various constraints. Mathematically, the DHS problem is categorized as a class of large-scale, dynamic, nonlinear constrained optimization problem.

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The importance of daily economic operation of hydrothermal system is well recognized. An efficient economic dispatch not only reduces the production cost of hydrothermal system but also maximizes the energy capability of the reservoirs. Therefore, many methods have been developed to solve this problem in the past decades. The major methods include progressive optimality algorithm [1], Lagrangian relaxation method [2], network flow algorithm [3], mixed-integer linear & nonlinear programming [4–6], dynamic programming [7] and modern heuristics algorithms, such as artificial immune system [8], particle swarm optimization [9–11], artificial neural networks [12,13], evolutionary strategy [14], evolutionary programming [15], genetic algorithm [16], ant colony [17], differential evolution [18–20], Tabu search [21] and cultural algorithm [22]. But these methods have one or another drawback such as dimensionality difficulties, large memory requirement or an inability to handle nonlinear characteristics, premature phenomena and trapping into local optimum, taking too much computation time. Thus, improving current optimization techniques and exploring new methods to solve DHS problem has great significance so as to efficiently utilize water resources, which can be regarded as a renewable source of energy.

In recent years, a new optimization method known as Gravitational Search Algorithm (GSA) [23] proposed by Rashedi et al. in 2009 has become a candidate for optimization application due to its flexibility and efficiency, which is based on the Newton's law of gravity and law of motion. GSA has been verified high quality performance in solving optimization problems in the literature, such as optimal power flow and optimal reactive power dispatch [24,25] in power system, control of servo system [26] and future oil demand forecasting [27]. The most substantial feature of GSA is that gravitational constant adjusts the accuracy of the search, so it is to speed up solution process. Furthermore, GSA is memory-less, it works efficiently like the algorithms with memory, and it can be considered as an adaptive learning algorithm, respectively. As the GSA has many advantages, an enhanced GSA method is proposed to solve DHS problem in this paper. The proposed GSA method is enhanced over by feasibility-based selection comparison techniques and heuristic search strategies to handling complex constraints of DHS problem effectively. This assures that the EGSA does not require penalty factors or extra parameters and can guide the agents to feasible region quickly, which reduces the computation time as well as improves the quality of the solution. At the same time, particle swarm optimization is introduced into gravitational search algorithm for update of agent's velocity, which makes GSA has a moving strategy in the search space, obeying the law of gravity and receiving guide of memory and social information. In order to verify the feasibility and effectiveness of the proposed EGSA method, a hydrothermal test system of multi-chain cascaded reservoirs with thermal plant is solved by using the EGSA method. Simulation results obtained by EGSA are compared with those of other optimization methods reported in literatures [15,16], such as genetic algorithm, classical Evolutionary Programming, fast evolutionary programming and improved fast evolutionary programming algorithm. It is found that the proposed EGSA is more powerful and effective than other optimization algorithms for solving DHS problem.

This paper is organized as follows. Section 2 provides the mathematical formulation of the DHS problem. Section 3 briefly introduces the basics of GSA. Section 4 presents the EGSA for solving DHS problem. Section 5 gives the numerical example. Section 6 outlines the conclusions. Acknowledgment is given in Section 7.

## 2. Formulation of the DHS problem

### 2.1. Objective function and constraints

The daily optimal hydrothermal generation dispatching problem is aimed to minimize the total thermal cost while making use of the availability of hydro resource as much as possible. The thermal cost is generally assumed to be a quadratic function of thermal generation power. The objective function and associated constraints of the problem are formulated as follows.

Objective function:

$$\min \quad F = \sum_{t=1}^{T}\sum_{i=1}^{N_s} f_i(P_{si}^t) = \sum_{t=1}^{T}\sum_{i=1}^{N_s}\left\{a_i + b_i P_{si}^t + c_i (P_{si}^t)^2\right\} \tag{1}$$

where $F$ is the composite fuel cost function, $f_i(P_{si}^t)$ is fuel cost of $i$th thermal unit at time interval $t$, $N_s$ is number of thermal unit, $T$ is the total time horizon, $a_i$, $b_i$, $c_i$ are thermal generation coefficients of $i$th unit, $P_{si}^t$ is power generation of thermal unit $i$ at time interval $t$.

Subject to the following constraints:

- System load balance

$$\sum_{i=1}^{N_h} P_{hi}^t + \sum_{j=1}^{N_s} P_{sj}^t = P_D^t \quad t = 1,2\ldots T \tag{2}$$

where $P_D^t$ is system load demand at time interval $t$, $N_h$ is number of hydro plants, $P_{hi}^t$ is power generation of hydro plant $i$ at time interval $t$.