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A novel modified hybrid PSOGSA based on fuzzy logic for non-convex economic dispatch problem with valve-point effect

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ABSTRACT

Gravitational Search Algorithm (GSA) is a novel stochastic optimization method inspired by the law of gravity and interaction between masses. This paper proposes a novel modified hybrid Particle Swarm Optimization (PSO) and GSA based on fuzzy logic (FL) to control ability to search for the global optimum and increase the performance of the hybrid PSOGSA. In order to test the performance of the modified hybrid PSOGSA based on FL (FPSOGSA), it has been applied to solve the well-known 23 benchmark test functions. In order to evaluate the efficiency and performance of the proposed approach, standard power systems including IEEE 5-machines 14-bus, IEEE 6-machines 30-bus, 13 and 40 unit test systems are used. These are non-convex economic dispatch problems including the valve-point effect and are computed with and without the losses. The results obtained from the proposed FPSOGSA approach are compared with those of the other heuristic techniques in the literature. The results of the comparison demonstrate that the proposed approach can converge to the near optimal solution and improve the performance of the standard hybrid PSOGSA approach.

Introduction

Due to the limitations of the traditional optimization algorithms in solving high dimensional optimization problems various meta-heuristic optimization algorithms have been developed to solve this sort of optimization problems, lately. These algorithms can be listed as Genetic Algorithms (GA) [1], Differential Evolutionary Algorithm (DE) [2], Artificial Bee Colony (ABC) [3], Particle Swarm Optimization (PSO) algorithm [4], Ant Colony (AC) algorithm [5], Simulated Annealing (SA) [6], Harmony Search Algorithm (HSA) [7], Nondominated Sorting Genetic Algorithm II (NSGA II) [8], Charged System Search (CSS) [9], Biogeography Based Optimization (BBO) [10], Bacterial Foraging Optimization (BFO) [11] algorithm and Gravitational Search Algorithm (GSA) [35]. These algorithms have been applied to solve different optimization problems by researchers in many different scientific areas. The main objective all of the optimization algorithms is to be operated to search the best solution (global optimum) to the all optimization problems. However, these meta-heuristic algorithms should own two principal characteristics which are exploration and exploitation. Exploration is defined as the ability of the algorithm to search all parts of the specified optimization problem in search space. Exploitation is described as the convergence ability to the best outcome near the global optimum solution [12].

The economic load dispatch (ELD) of generation in modern power systems is one of the most important optimization problems. Recently, the solution of the ELD problem has become a significant task in the planning and operation of power systems. The main objective of the ELD problem is depicted as the minimization of the total fuel cost of electric power generation to meet the required load demand at minimum total fuel cost while satisfying all generating units, and system equality and inequality constraints [13]. Firstly, the ELD problem has been solved by using traditional algorithms, such as linear programming, quadratic programming and nonlinear programming techniques [14–17]. In the past decade, as an alternative to the conventional approaches, heuristic optimization techniques based on evolutionary algorithms, such as hybrid particle swarm optimization technique with the sequential quadratic programming (PSO-SQP) algorithm [18], hybrid genetic algorithm approach [19,20], anti-predatory particle swarm optimization algorithm [21], particle swarm optimization based on quantum mechanics and harmonic oscillator potential well [22], improved harmony search algorithm [23], a hybrid genetic algorithm, pattern search and sequential quadratic programming

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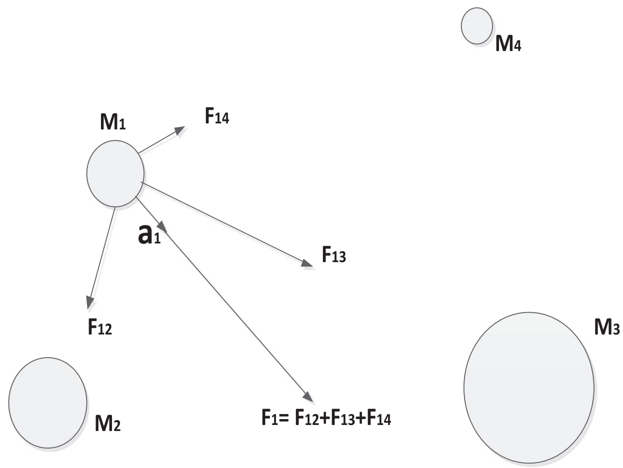

Fig. 1. Sum of the forces acting on an object.

(GA–PS–SQP) method [24], fuzzy adaptive hybrid particle swarm optimization [25], self-organizing migrating algorithm [26], parallel particle swarm optimization with modified stochastic acceleration factors (PSO-MSAF) [27], modified differential evolution algorithm (MDE) [28], biogeography-based optimization [29,30], hybrid particle swarm optimization algorithm [31], multiple tabu search algorithm (MTS) [32], hybrid algorithm chaotic particle swarm optimization (CPSO) algorithm and sequential quadratic programming (SQP) method [33], firefly algorithm [34], have been widely used to solve the ELD problem considering valve-point effects in power systems.

One of the recently improved meta-heuristic algorithms is the Gravitational Search Algorithm (GSA), which is based on Newton's law of gravity and law of motion and it is proposed by Rashedi et al. in 2009 [35]. GSA has been verified high by quality performance in solving different optimization problems in the literature [36–42]. Mirjalili and Hashim [12] have been proposed a novel hybrid particle swarm optimization and gravitational search algorithm (PSOGSA) algorithm. This algorithm is used to test 23 different benchmark functions and it is concluded that this algorithm seeks to search globally optimum solution much better than the GSA and PSO methods. Khajehzadeh et al. used to search global optimum solution of an adaptive maximum velocity constraint algorithm adjusting agent's velocity of the GSA in the search space [43]. The entire agent's velocity of the POSGSA is adjusted by the maximum velocity constraint algorithm, in which h parameter optimized a fuzzy logic is used in this paper. In this study, a novel modified hybrid PSOGSA based on fuzzy logic optimization algorithm is presented to search global optimum solution in the 23 benchmark test functions and well-known ELD problem with valve-point effects which is one of the important optimization problems in power systems.

After giving the description of the GSA approach in Section 'Gravitational search algorithm', the PSO algorithm, the hybrid PSOGSA and the modified hybrid PSOGSA based on fuzzy logic are presented in Sections 'Particle swarm optimization', 'Hybrid particle swarm optimization and gravitational search algorithm (PSOGSA) method' and 'Modified hybrid PSOGSA based on fuzzy logic', respectively. Section 'Experimental studies' presents the results of simulation and compares techniques in the literature to solve both well-known 23 benchmark test functions and non-convex economic dispatch with valve point effects. Evolution of the results obtained by the proposed approach is illustrated in Section 'Conclusion'.

Heuristic algorithms

Gravitational search algorithm

GSA is a newly improved meta-heuristic optimization algorithm based on the Newton's laws of gravity and motion. GSA was firstly improved by Rashedi et al. in 2009 [35]. GSA has many advantages which are reported in [35] by comparing it with PSO, Central Force Optimization (CFO) and Real Genetic Algorithm (RGA) using 23 different benchmark functions It is reported in the same paper that GSA is more powerful than other algorithms. According to this algorithm, agents are considered as objects and their performance is measured by their masses. Every object attracts every other object with gravitational force and this force induces the movement of all agents globally towards the agents with heavier masses. In GSA, each mass has four particulars: its position, its inertial mass (M_{ii}), its active gravitational mass (M_{ai}) and passive gravitational mass (M_{pi}). The position of the mass should it be is equated to a solution of the problem and its gravitational and inertial masses are specified using a fitness function [35]. GSA algorithm can be described following steps:

Step 1: Initialization
It is assumed that given a system with N agents, the position of the ith agent in search space represents a solution to the problem. Agent is defined as follows:

$$X_i = \left(x_i^1, \ldots, x_i^d, \ldots, x_i^n\right) \; for, \quad i = 1, 2, \ldots, N \tag{1}$$

where n is the space dimension of the problem and x_i^d describes the position of the ith agent in the dth dimension.
Step 2: Fitness Evaluation of All Agents
To execute all agents at each step, the *best* and *worst* fitnesses

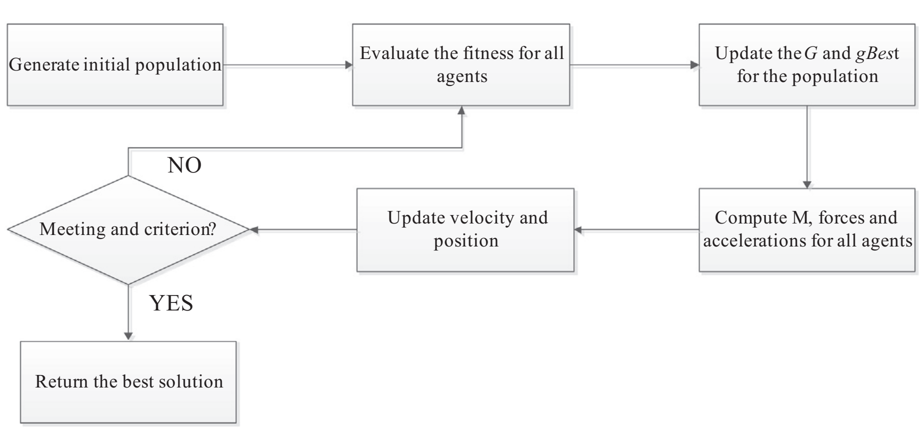

Fig. 2. The principle diagram of the PSOGSA [12].