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Implementation of hybrid harmony search/random search algorithm for single area unit commitment problem

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ABSTRACT

Harmony Search (HS) is a population based metaheuristics search algorithm inspired from the musical process of searching for a perfect state of harmony and has ability to escape from local minima, does not require differential gradients and initial value setting for the variables and free from divergence and has strong ability on exploring the regions of solution space in a reasonable time. However, it has lower exploitation ability in later period and it easily trapped into local optima and converges very slowly. To improve the exploitation ability of HS algorithm in later stage and provide global optimal solution, a memetic algorithm approach considering Harmony Search and Random Search is presented in the proposed research to solve unit commitment problem of electric power system. The proposed memetic algorithm is tested for IEEE benchmarks consisting of 4, 10, 20 and 40 generating units. The effectiveness of proposed hybrid algorithm is tested for unimodal and multimodal benchmark functions and is compared with others well known evolutionary, heuristics and meta-heuristics search algorithms and it has been found that performance of proposed hybrid algorithm is much better than classical Harmony Search Algorithm and Improved Harmony Search Algorithm as well as recently developed algorithms.

Introduction

Today's power system is characterized by large proportions, high interconnections and high nonlinearities, as the size of the power system is growing exponentially due to heavy demand of power in all the sectors viz. agricultural, industrial, residential and commercial ones. Increase in the electrical energy demand and trends in privatization and deregulation result in overloading impact on electrical grids. The situation necessitates the development of electrical grid at the same pace as the demand increases, but economical commitment and scheduling has the ability to tackle the time-varying power demand, environmental constraints and led to the full exploitation of accessible grid. In the modern power system networks, there are various generating resources like thermal, hydro, nuclear, etc. Also, the load demand varies during a day and attains different peak values. Thus, it is required to decide which generating unit to turn on and at what time it is needed in the power system network and also the sequence in which the units must be shut down keeping in mind the cost effectiveness of turning on and shutting down of respective units. The entire process of computing and making these decisions is known as unit commitment (UC). The unit which is decided or scheduled to be connected to the power system network, as and when required, is known to be committed unit. Unit commitment in power systems refers to the problem of determining the on/off states of generating units to minimize the operating cost for a given time horizon [1]. Generators cannot be immediately turned on to meet up power demand. So it is required that the planning of generating units must be so prepared that there is enough generation available to fulfil the load demand along with an ample reserve generation to avoid failures and malfunctions under adverse conditions. Unit commitment knob the unit generation schedule in electric power system for minimizing operational and fuel cost and satisfying system and physical constraints such as load demand and system reserve requirements over a set of time periods [2]. Unit Commitment Problem (UCP) is basically about finding the most suitable schedule to turn-on or turn-off the generating units to meet the electric power demand and at the same time keep the cost of generation as much minimum as possible. UCP is a non-linear, large scale, mixed integer constrained optimization problem [3] and happens to belong to combinatorial optimization problems. There are many constraints involved in UCP and hence it is quite a complex and tedious task to compute or to find the optimal solution for Unit Commitment Problem (UCP).

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Unit commitment problem

The scheduling of the units together with the allocation of the generation quantities which must be scheduled to meet the demand for a specific period represents the Unit Commitment Problem (UCP). The Unit Commitment Problem is to determine a smallest cost turn-on and turn-off plan of a set of generating units to meet a power demand while satisfying system operational and physical constraints liked with various generating units. The production cost includes fuel, startup, no load costs and shutdown cost. The operational constraints that must be taken into consideration comprises, 1. The total power generated must meet the power demand plus system losses. 2. There must be an adequate amount of spinning reserve to cover any shortfalls in power generation. 3. The loading of each unit must be within its minimum and maximum permissible rating. 4. The minimum up and down times of each unit must be pragmatic. The unit commitment is aimed to formulate a proper generator commitment schedule for electric power system over a period of one day to one week. The main objective of unit commitment is to minimize the total production cost over the study period & to satisfy the system and physical constraints imposed on the system such as spinning reserve, power generation-load balance, operating constraints, and minimum up time & minimum down time. Several conventional methods are available to solve the unit commitment problem. But all these methods need the exact mathematical model of the system & there may be a chance of getting stuck at the local optimum [4]. Sriyanyong and Song [5] proposed Particle Swarm Optimization combined with Lagrange Relaxation method for solving UCP. The proposed approach employs PSO algorithm for optimal settings of Lagrange multipliers. The feasibility of the proposed method is demonstrated for 4 and 10 unit systems, respectively. Xiong et al. [6] have applied multi particle swarm to parallel arithmetic to produce particle to enhance the convergence speed and found the more efficient results than genetic algorithm. Jeong et al. [7] have discussed binary Particle Swarm optimization-based approach for solving the UC problems. Ge [8] has proposed a new approach to solve ramp rate constrained unit commitment problem by improving the method of Particle Swarm Optimization. Borghetti et al. [9] have suggested that there is no guarantee that the Tabu search will yield the global optimal result for large systems. There is a similar method named Particle Swarm Optimization proposed in [10]. Rajan et al. [11] proposed Neural based Tabu search algorithm for the unit commitment problem and developed an improved version of Neural based Tabu search approach [3]. Gaing [12] proposed binary particle swarm optimization (BPSO). The BPSO is used to solve the combinatorial unit on/off scheduling problem for operating fuel and transition costs. The ED subproblem is solved using the lambda iteration method for obtaining the total production cost. Zhao et al. [13] presented an improved particle swarm optimization algorithm (IPSO) for UC which utilizes more particles information to control the process of mutation operation. For proper selection of parameters some new rules are also proposed. The proposed method combines LR technique to 0–1 variable. Lee and Chen [14] presented a new approach for UCP named the iteration particle swarm optimization (IPSO). The proposed method improves the quality of solution in terms of total production cost and also improves the computation efficiency. A standard 48 unit system has been tested for validation. Samudi et al. [15] have presents a new approach of particle swarm optimization (PSO) algorithm for short term hydro thermal scheduling (HTS) problems. The proposed algorithm is ideally suitable for hydro-thermal co-ordination problems, hydro economic dispatch problems with unit commitment, thermal economic dispatch with unit commitment problems and scheduling of hydraulically coupled plants. Yuan et al. [16] proposed a new improved binary PSO (IBPSO). The standard PSO is improved the using the priority list and heuristic search to improve the MUT and MDT constraints. The 10–100 units have been tested to validate the proposed approach. Numerical performance shows that the proposed approach is superior in terms of low total production cost and short computational time compared with other published results. No optimization algorithm can perform general enough to solve all optimizations problems, each optimization algorithm have their own advantages and disadvantages. Particle swarm optimization (PSO) has simple concept, easy implementation, relative robustness to control parameters and computational efficiency [17,18], although it has numerous advantages, it get trapped in a local minimum, when handling heavily constrained problems due to the limited local/global searching capabilities [19,20]. The limitations of the numerical techniques [21,22] and dynamic programming method [23,24] are the size or dimensions of the problem, large computational time and complexity in programming. The mixed integer programming methods [25,26] for solving the economic load dispatch problem fails when the participation of number of units increases because they require a large memory and suffer from great computational delay. Gradient Descent method [27] is distracted for Non-Differentiable search spaces. The Lagrangian Relaxation (LR) approach [28] fails to obtain solution feasibility and solution quality of problems and becomes complex if the number of units are more. The Branch and Bound (BB) method [29] employs a linear function to represent fuel cost, start-up cost and obtains a lower and upper bounds. The difficulty of this method is the exponential growth in the execution time for systems of a large practical size. An Expert System (ES) algorithm [30] rectifies the complexity in calculations and saving in computation time. But it faces the problem if the new schedule is differing from schedule in database. The fuzzy theory method [31] using fuzzy set solves the forecasted load schedules error but it suffers from complexity. The Hopfield neural network technique [32] considers more constraints but it may suffer from numerical convergence due to its training process. The Simulated Annealing (SA) [33] and Tabu Search (TS) [34] are powerful, general-purpose stochastic optimization technique, which can theoretically converge asymptotically to a global optimum solution with probability one. But it takes much time to reach the near-global minimum. Gravitational Search algorithm has the advantages to explore better optimized results, but due to the cumulative effect of the fitness function on mass, masses get heavier and heavier over the course of iteration. This causes masses to remain in close proximity and neutralise the gravitational forces of each other in later iterations, preventing them from rapidly exploiting the optimum [35]. Therefore, increasing effect of the cost function on mass, masses get greater over the course of iteration and search process and convergence becomes slow.

Motivation for proposed hybrid harmony search algorithm

The Harmony Search (HS) algorithm proposed by Geem et al. [36] is recently developed metaheuristics search algorithm inspired from the musical process of searching for a perfect state of harmony, HS has a novel stochastic derivative [37] applied to discrete variables, which uses musician's experiences as a searching direction and is free from divergence. It can handle discrete and continuous variables and do not require initial value setting for the variables. Also, it does not require differential gradients and has the ability to escape from local optima. HS has ability to overcome the drawback of GA's building block theory and explicitly considers the relationship using ensemble operation [38]. Geem et al. [39] proposed a Multi-pitch Adjusting Rate (multiple