Energy 117 (2016) 272–280

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

A priority list based approach for solving thermal unit commitment problem with novel hybrid genetic-imperialist competitive algorithm

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ARTICLE INFO

Article history:
Received 6 December 2015
Received in revised form
30 July 2016
Accepted 20 October 2016

Keywords:
Modified genetic algorithm
Hybrid genetic-imperialist competitive algorithm
Mime crossover
Economic load dispatch
Priority list
Thermal unit commitment

ABSTRACT

This paper has proposed a novel Hybrid modified Genetic – Imperialist Competitive Algorithm (HGICA) for solving thermal Unit Commitment Problem (UCP). The UCP is a mixed integer problem with many equality and inequality constraints like the minimum down and minimum up time, spinning reserve, and ramp rate so need to a complex optimization process. In this paper the constraint handling of the problem is realized without any penalizing of solutions so a wide range of feasible solutions will be available for final optimum response. The proposed modified genetic is a novel method which has better performance than its original version and helps ICA to find more optimized responses and escape for local minimum areas easily. The main advantages of HGICA are good quality of the solution and high computational speed, which make it a suitable method for solving optimization problems. This method is carried out for three case studies including 10 and 20 units systems to efficiency of it be proved. Also the obtained results is compared to other optimization methods represented in literature for different scenarios.

1. Introduction

The Unit Commitment Problem (UCP) is scheduling of on/off combination of some electrical power generating units during a time interval (e.g. 24 h or more). The object of thermal UCP is minimization of consumption fuel cost while some equality and inequality constraints such as Minimum Down time (MD), Minimum Up time (MU), Load Demand (LD), Spinning Reserve (SR) must be satisfied. Therefore UCP is a very important problem which can save big deals of expenses related to fuel while reduces environmental pollution and help to storing of the valuable fossil sources for future.

The UCP as a mixed integer nonlinear problem with a wide search space of possible solutions causes more difficult decision making about the best solution while searching through this space requires.

a big computational time to achieve good results. The various kind of methods have been developed to find more optimum results recently [1].

The older methods such as Priority List (PL) [2], mixed integer linear programming [3], Lagrange relaxation [4], dynamic programming [5] are good solution methods but they suffer from problems with high dimension and various constraints. The adjusted and combinational kind of these methods can cover their disadvantageous features and result in acceptable responses.

Lately heuristic methods such as artificial neural network [6], simulated annealing [7], Evolutionary Programming (EP) [8], Genetic Algorithms (GA) [9–11], hybrid of Genetic Algorithm and Differential Evolution (hGADE) [12], Particle Swarm Optimization (PSO) [13], Lagrange relaxation-PSO (LRPSO) [14,15], invasive weed optimization [16], Quantum-Inspired Evolutionary Algorithm (QIEA) [17], Semi Definite Programming relaxation based technique combined with Selective Pruning (SDPSP) [18], Quasi-Oppositional Teaching Learning Based Optimization (QOTLBO) [19], Imperialist Competitive Algorithm (ICA) [20], Gaussian Harmony Search and Jumping Gene Transposition algorithm (GHS-JGT) [21], and Binary/Real coded Artificial Bee Colony (BRABC) [22], which are usually randomly search approaches have been developed to find more optimum results and get better computational time than previous approaches.

The UCP presented here is a kind of generating scheduling of the thermal units implementation that their output power are constant, but the renewable energy resources due to their nature produce alternative electrical power so their scheduling is different.

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http://dx.doi.org/10.1016/j.energy.2016.10.082

Power Pinch Analysis (PoPA) is a suitable method for scheduling of the additional generated electricity power saving produced by renewable energy resources, and Electric System Cascade Analysis (ESCA) is another one for both of the saving and generation scheduling of the non-intermittent generation. The [23] has presented a developed ESCA for intermittent solar PV which is an appropriate way for this kind of generation.

In this paper a PL based method has been utilized to find on/off combination of units during scheduling time interval. Then novel Hybrid modified Genetic – Imperialist Competitive Algorithm (HGICA) solve ELD sub-problem. At the end an adjustment strategy search other convincible combination of units with lower consumption fuel cost.

The novelties of the proposed method are as follows:

- The HGICA process utilizes the advantageous of GA in discovering of global optimum area and compensate disadvantageous part of it in achieving final optimum point by a quick optimization method (ICA) to find optimum global point. The novelty details of this method is shown in Fig. 6 perspicuously.
- In HGICA a modified GA has been developed which has a new operational process.
- The GA's second novelty is a kind of crossover operator named Mime Crossover (MC). In this kind of crossover, offspring chromosomes are look like to their parent and generation elite. The proposed MC is demonstrated in Section 4.
- A novel kind of GA's selection operator is introduced that chromosomes population is divided in two section according to their fitness value then chromosomes of this groups are placed in mating pool. Section 4 reveals more details.

The presented paper has been structured as follows. The Section 2 contains formulations of the problem and different constraints related to the UCP. In Section 3 the proposed PL method and novel HGICA are exposed. Section 4 illustrates how the proposed method is carried out for solving UCP. Section 5 depicts the optimization results obtained from three different scenarios including 10, 20 generating units, and 10 units with ramp rate constraints systems then results is compared to other methods represented in literature. The final Section 6 includes conclusion.

2. Problem formulation

The problem objective is minimization of consumption fuel cost during scheduled time interval. Also some constraints have limited this problem.

2.1. The objective function

The objective function can be stated by a quadratic approximation as follows:

$$\mathrm{TFC} = \sum_{t=1}^{T}\sum_{i=1}^{N}\left\{FC_i\left(P_i^t\right)U_i^t + SC_i\left(1-U_i^{t-1}\right)U_i^t\right\} \tag{1}$$

$$FC_i(P_i) = \sum_{i=1}^{N} a_i(P_i)^2 + b_i(P_i) + c_i \tag{2}$$

In this equations, N is number of electrical power generating units. i is the index of a specific generating unit. T is number of scheduled times (hours). t is the index of specific time. U_i^t is on/off status of i_{th} generating unit during hour $t.P_i^t$ is power output of i_{th} generating unit during hour t (MW). The a_i,b_i, *and* c_i are fuel cost coefficients for i_{th} generating unit. *TFC* is total fuel cost ($) of on line generating units during scheduled time interval (T hours). FC_i is Fuel cost of i_{th} unit ($). SC_i is startup cost of i_{th} generating unit ($).

2.2. Constraints

The practical equality and inequality constraints related to problem have affected its optimization process. The some of this limitations such as load power balance, spinning reserve, minimum up time, minimum down time, ramp rate, and limited output power of units have formulated as follows.

2.2.1. Load demand

The load demand usually is changed each hour and on line generating units must feed them.

$$\sum_{i=1}^{N} U_i^t P_i^t = \mathrm{t} = 1,\ 2, \ldots,\ \mathrm{T} \tag{3}$$

In this equation, LD_t is load demand during hour t (MW).

2.2.2. Generated power limits

The generated power by a unit is confined by minimum and maximum boundaries.

$$P_{i,min}U_i^t \le P_i^t \le P_{i,max}U_i^t \tag{4}$$

2.2.3. Spinning reserve

The maximum output power of the online generating units must be able to feed load demand and required spinning reserve during hour t.

$$\sum_{i=1}^{N} U_i^t P_{i,max} \ge LD_t + SR_t \quad \mathrm{t} = 1,\ 2, \ldots,\ \mathrm{T} \tag{5}$$

In this equation, $P_{i,max}$ is the maximum output power thati_{th} unit can generate, andSR_t is spinning reserve during hour t (MW).

2.2.4. Minimum up and down time

To an online unit be capable to turn down, it must pass its Minimum Up time (MU) hour(s). Also for an offline unit be capable to turn on, it must pass its Minimum Down time (MD) hour(s).

$$HR_i^{t,on} \ge MU_i \tag{6}$$

$$HR_i^{t,off} \ge MD_i \tag{7}$$

In this equations, $HR_i^{t,off}$ is number of hours that unit i is continuously offline until t_{th} hour, $HR_i^{t,on}$ is number of hours that unit i is continuously on line until t_{th} hour.

2.2.5. Ramp-rate constraint

This constraint states this fact that generating output power of unit i cannot be elevated more than its ramp up limitation from the previous hour until the present hour. Also it cannot be reduced less than its ramp down limitation from the previous hour until the present hour.

$$\begin{cases} P_i^t - P_i^{t-1} \le RU_i \\ P_i^{t-1} - P_i^t \le RD_i \end{cases} \tag{8}$$