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Implementation of clustering based unit commitment employing imperialistic competition algorithm

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ABSTRACT

Saving of fuel cost can be done through proper commitment of available generating units. This paper presents a novel technique to solve the problem of unit commitment through sorting of units into different clusters based on Imperialistic Competition Algorithm (ICA). This sorting is implemented in order to decrease the overall operating cost and to assure the various constraints that involve minimum up/down. The technique of unit commitment is a significant assignment in the normal working of power systems which can actually be represented as a large scale minimization problem that involves non linear mixed integers. A new technique employing the concept of cluster algorithm called as additive and divisive hierarchical clustering has been used based on a new technique called as Imperialistic Competition Algorithm in order to carry out the technique of unit commitment. Proposed methodology involves two individual algorithms. Additive cluster algorithm has been employed while the load is increasing while divisive cluster algorithm has been used when the load is decreasing. The technique that has been developed has been tested on system with generating units in range of 10–100 and the superior performance of the technique has been reported through simulation results.

Introduction

The technique of Unit Commitment (UC) involves the calculation of levels of generation pertaining to generating units and their commitment for a certain interval of time in order to reduce the operational cost. It is actually a significant issue with very good impact on the economics. The generalized problem of UC is well known in the electric industry and definitely has the ability to save huge money each year with respect to costs of fuel and other expenses. It is basically an area that involves the scheduling of production which relates to the calculation of status of the units that are generating power for various intervals of time in order to meet the load and other requirements which are actually dependent on the environmental issues, equipment and the system. Generally the problem of UC is a process that involves making complex decisions and it is tough to design optimization techniques that are capable of solving the system in real time. The various multiple constraints also need to be considered while determining the correct commitment schedule [1].

The most talked deterministic mathematical programming techniques include: Branch-and-Bound [2], Dynamic Programming [5,6], Priority List [3,4], Lagrange Relaxation [7–9], and Mixed-Integer methods [10,22]. Generally all these mathematical techniques are quite fast and are much simple to be implemented but most of them suffer from the problem of numerical convergence and have the following limitations [1]: (i) They do not guarantee the convergence to optimum point globally for non convex problems such as UC. (ii) The results also are inconsistent due to the various approximations considered while solving the constraints and objective functions which are non linear. (iii) The difficulty in reaching the solution due to the consideration of various constraints.

As a result, more interest has been shifted to search methods which are heuristic in nature and based on evolutionary computing. The most recent advancement in the scope of evolutionary algorithms for UC problem are the usage of Genetic algorithm [11–13], Evolutionary Programming [14], Particle Swarm Optimization [15,16] and Bacterial Foraging [17]. Though the approaches have yielded attractive results, the problem of dimensionality restricts the usage of these techniques [1,19]. As a result, the increase in problem size affects the quality of the solutions. The Imperialistic Competition Algorithm (ICA) approach calculates the

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best solution in each iteration along with the updation of neighborhood values in the form of imperialists and colonies. Recently ICA has been successfully applied for solving some optimization problems [20,21].

The novel technique of employing ICA algorithm along with cluster algorithms has been demonstrated in this work. This technique employs both additive and Divisive algorithms. The method that has been proposed can be viewed in 3 stages. In the first stage, 4 groups are formed which are named as clusters namely base load, intermittent load, semi peak load and peak load. The generating units of the system are divided into the corresponding groups based on their various operating costs. The operating costs are obtained by ICA. Based on the operating costs of units, clusters are formed and also useful for calculating the priority list. In the next stage, the solution of UC is obtained by developing Additive Cluster algorithm for increasing load pattern. Finally in the third stage a Divisive Cluster algorithm is developed for decreasing load pattern.

The paper presented is organized as follows: Section 'Problem formulation' deals with the formulation of the problem. The concept of Imperialistic Competition Algorithm based cluster technique is explained in Section 'Imperialistic competition algorithm'. The new method using clustered based ICA has been explained in Section 'Proposed methodology'. Simulation results and discussions are carried out in Section 'Results and discussions' and some conclusions are drawn in Section 'Conclusions'.

Problem formulation

Based on the concept of minimization of the cost-objective function in the unit commitment problem, certain units are stated to be as 'ON' and remaining as 'OFF'. The following are the various notations considered during the implementation of the problem

N: Quantity of generating units in the system
T: Time for which the system is running in hours (h);
i: Count of Unit ($i = 1, 2, \ldots, N$);
t: Count of time ($t = 1, 2, \ldots, T$);
$I_i(t)$: status of i^{th} unit at t^{th} hour (is considered as 1, if the Unit is ON; or 0, if the unit is OFF);
$P_i(t)$: Power Generation of i^{th} unit at t^{th} hour;
$P_i^{\max}, P_i^{\min}$: Values corresponding to Maximum/Minimum power output (MW) of i^{th} unit;
$D(t)$: Load demand at t^{th} hour;
$R(t)$: Reserve capacity of the system at t^{th} hour;
T_i^{on}: Minimum up time limit of i^{th} unit;
T_i^{off}: Minimum down time limit of i^{th} unit;
$X_i^{on}(t)$: Time for which the i^{th} unit is continuously ON;
$X_i^{off}(t)$: Time for which i^{th} unit is continuously OFF;
$SC_i(t)$: Start-Up cost of i^{th} unit;
$FC_i(t)$:Cost of Fuel of i^{th} unit;
$RU_i:$ *Ramp up rate of unit i*
$RD_i:$ *Ramp down rate of unit i*
TC: Total Cost for generation;
$HC(i)$: Hot start cost of i^{th} unit;
$CC(i)$: Cold start cost of i^{th} unit;
$CS(i)$: Cold start hour of i^{th} unit;
τ: Time Step of Unit Commitment: 60 min
a_i, b_i, c_i: cost coefficients of Fuel

Objective functions

The main objective of the problem of UC is to minimize the Total cost (TC) which consists of various components of FC and SC represented by:

$$\text{Min }(TC) = \sum_{t=1}^{T}\sum_{i=1}^{N}(FC_i(t)\cdot I_i(t) + SC_i(t)) \tag{1}$$

where fuel cost of i^{th} unit:

$$FC_i(t) = a_i + b_iP_i(t) + c_iP_i(t)^2 \tag{2}$$

and Start-up cost

$$\begin{aligned} SC_i(t) &= HC(i): \text{ if } T_i^{off} \leqslant X_i^{off}(t) \leqslant H_i^{off}(t) \\ or \ &= CC(i): \text{ if } X_i^{off}(t) \geqslant H_i^{off}(t) \end{aligned} \tag{3}$$

where

$$H_i^{off}(t) = T_i^{off} + CS(i) \tag{4}$$

System constraints

The constraints, that need to be taken into view while performing the process of optimization of UC are listed below.

Demand of load

All the units that have been committed need to generate the power that is the same as load demand given by:

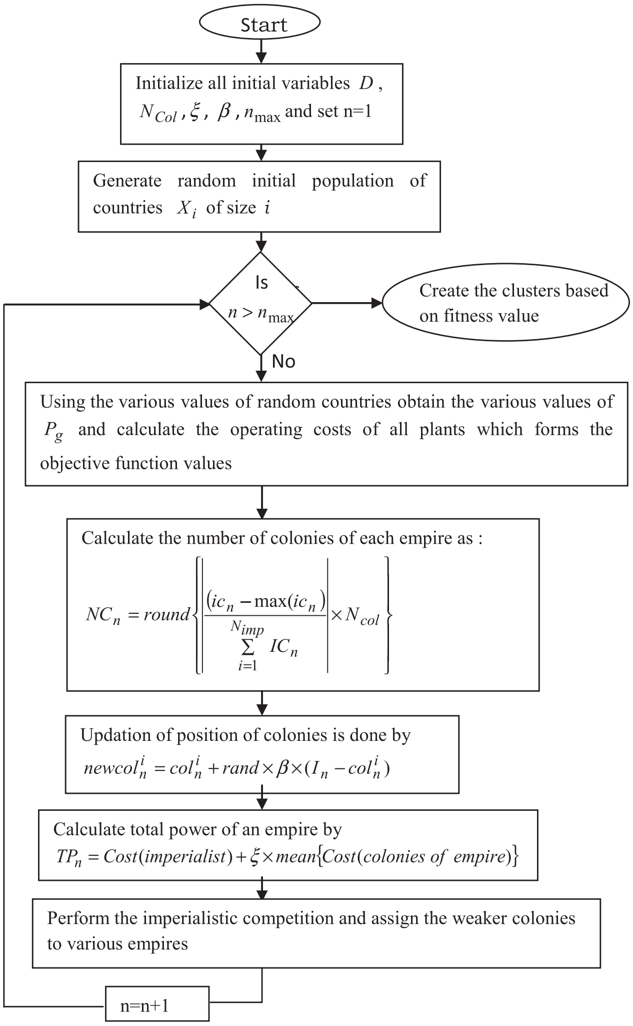

Fig. 1. Flow chart of implementation of ICA.