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A Memetic Computing Approach for Unit Commitment with Energy Storage Systems

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Abstract

The intermittency and unpredictability of renewable energy source availability cause relevant problems in terms of grid balance and stability. Such problems can be partially solved by introducing energy storage systems (ESS), although capital costs required could be prohibitive. To explore the potential achievable benefits, a generalized unit commitment algorithm has been developed. The adopted approach integrates original memetic operators into a genetic algorithm. To evaluate the optimal amount of energy storage, the memetic computing approach has been coupled with a recursive quadratic programming optimizer. The computational code has been applied to a test case available in literature. Results show a good capability of the proposed algorithm to find really satisfactory solutions in reduced computational time.

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Keywords: Unit commitment; memetic computing; energy storage.

1. Introduction

The use of new technologies has introduced significant changes in generation, transport and electricity distribution systems. As an example, the introduction of large gas/steam combined plants characterized by fast startups and improved load following capabilities has reduced the utilization of hydro pumping storage plants.

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Moreover, the increasing penetration of renewable (in particular wind and solar) has introduced relevant problems in managing in a safe and reliable way the electric networks. Such problems are related to the inherently intermittent nature of the renewable sources and to the difficulty of making precise predictions of their availability.

As a result, relevant costs have been incurred in the last years and will be borne in the future to improve the reliability of the electric grids.

Such improvements call for the adoption of smart grid technologies at low, mean and high voltage level.

Electric Energy Storage (EES) systems can greatly contribute to solve the above problems. However, the traditional hydro pumping stations are usually located very far from areas favorable for electricity production from RES, e. g. lowlands and off shore sites appropriate for large wind farms. The adoption of alternative ESS, such as batteries and compressed air energy storage systems, that are the most suitable ones to be integrated in a distributed generation system, is encountering many difficulties. Such difficulties are connected to the insufficient maturity level of some solutions or to the high plant costs. Therefore, the evaluation of benefits achievable by installing EES systems is of paramount importance. In this view, a computer code capable of solving the unit commitment problem of thermal plants in the presence of a storage system has been developed. The code has been realized on the basis of memetic computing approach and integrated with a quadratic programming algorithm for the evaluation of the best operating set and of the relative operational costs.

2. Unit Commitment

The cost based Unit Commitment Problem (UCP) refers to the scheduling of power production plants over a given planning time horizon to satisfy load minimizing costs [1]) Such a problem encompasses the simultaneous solution of two sub-problems: 1) the definition of generating unit on/off statuses for each time interval in which the planning horizon is subdivided (usually 1 hour); 2) the optimization of loads allocated on the committed units. Recently, the UCP has gained a renewed interest as a tool for the analysis of ancillary services and electric storage in systems with high penetration of renewables [2,3,4,5].

2.1. UCP problem formulation

The objective is to minimize the total operation cost f_c which is expressed as the sum of fuel, start-up and shutdown costs over the entire time horizon T:

$$f_c = \sum_{t=1}^{T}\sum_{i=1}^{N}\left[u_i^t Fc_i^t + u_i^t\left(1-u_i^{t-1}\right)SU_i^t + u_i^{t-1}(1-u_i^t)SD_i\right] \tag{1}$$

being N the total number of generation units, u_i^t the binary commitment status of the unit i at time t (=1 if unit is on, =0 if unit is off), Fc_i^t the fuel cost of unit *i* at time t, SU_i^t the startup cost of unit *i* at time t. The hourly fuel cost of unit *i* is expressed as:

$$Fc_i^t = a + bP_i^t + c(P_i^t)^2 \tag{2}$$

being a, b, c coefficients and P_i^t the power output from the j-th unit at time t. Startup costs are evaluated as follows:

$$SU_i^t = \begin{cases} SU_{i\,h}^t & if down - time \le coldstarthours \\ & SU_{i\,c}^t\ otherwise \end{cases} \tag{3}$$

being $SU_{i\,h}^t$ and $SU_{i\,c}^t$ hot and cold startup costs respectively. Shutdown costs are usually charged as a fixed amount for each unit per shutdown.

The problem involves a set of system and generator constraints.

- *System constraints*:

- *Power demand* Pd^t must be meet at each time interval *t*: