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Committing electrical power units taking into account wind sources

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Abstract

The large integration of wind energy into electrical systems poses important challenges to the power operators in the scheduling of the production and in the management of the network. This leads to the necessity to modify the current industry procedures, such as the Unit Commitment (UC) and the Economic Dispatch (ED), to take into account large amounts of wind power production. Even if an exhaustive literature exists on the general Unit Commitment problem, devoted on how to improve its mathematical formulation and its solution algorithm, the research that considers the Unit Commitment problem with wind generators is limited. In this work, a new Unit commitment model in presence of wind energy resources has been defined and analyzed, in order to formulate and solve the problem of determining the best configuration (optimal mix) of available thermal, hydro and wind power plants, taking into account proper emission considerations and the risk associated with the use of wind turbines.

Keywords: energy generation systems, Unit Commitment Problem, wind energy sources, emission constraints, risk control.

1. Introduction

The integration of wind energy sources into conventional electrical system is growing in importance, and particular attention must be devoted to the related practical operational aspects. In order to perform this integration, Gardiner *et al.* [3] presented a simpler approach to operate a power system with wind generation, called '*fuel-saver*' approach. According to this approach, the utilities vary the output of their conventional power plants in order to compensate the uncertain output of the wind power plants, resulting in greater fuel and operational costs. This simple approach presents few drawbacks. In fact, it assumes that wind generation has a capacity equal to zero and it is available at real time. Furthermore, it ignores forecasting and reliability issues of wind production and it results in an over commitment of conventional units, making these units running at much lower levels of efficiency than under the approach adopting wind power forecasts. For this reason, the fuel-saver approach results in large amounts of wind energy curtailment, of up to 30% of the annual output at high levels of installed wind power [4]. The large integration of wind energy resources into electrical systems leads to the necessity to modify the current industry procedures, such as the Unit Commitment (UC) and the Economic Dispatch (ED), to take into account large amounts of wind power production. Researchers have focused their attention on the improvement of the Security-Constrained Unit Commitment (SCUC) formulation, taking into account wind energy resources, while others have developed novel methods for solving the UC problem. Bart *et al.* presented the first stage of the WILMAR model

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(Wind Power Integration in the Liberalised Electricity Markets) [7]; later, a more refined UC algorithm based on MILP approaches has been introduced in WILMAR. Tuohy *et al.* [8] studied the effects of stochastic wind on UC using the WILMAR model and extending their previous studies. Ummels *et al.* analyzed the impacts of wind on the UC in the Dutch system, utilizing an ARMA model to consider the forecasting error [9]. Bouffard and Galiana [10] developed a stochastic UC model to take into account wind power generation and system security. Ruiz *et al.* [11] used a stochastic framework, already presented in [12], to consider the uncertainty and the variability of wind power in the UC problem. Wang *et al.* [13] presented a SCUC algorithm that considers also wind generation, capturing the uncertainty of wind in a number of scenarios. Building on the previous results, we propose a new Unit commitment model in presence of wind energy sources, that formulates and solves the problem of determining the best configuration (optimal mix) of available thermal, hydro and wind power plants. The proposed model is a generalized form of the Unit Commitment problem, which takes into account conventional generating units (like thermal and hydro power plants) and wind turbines; we call this model *Generalized Wind Unit Commitment Problem* - (GWUCP).

2. Objectives of the Generalized Wind Unit Commitment Problem

The *Generalized Wind Unit Commitment* - (GWUC) model is based on the concept of subsets of units: it is possible to choose only a part of the available generators, making a dynamic modification of the given set of generating units, in order to determine the best configuration of generators (optimal mix), minimizing the total production cost and satisfying the energy demand. The main difference between this novel model and a classical UC one is that in the classical UC *all* the available units (conventional and not) are considered committable for each time interval, satisfying the constraints of the model. On the other hand, additional constraints are introduced in the GWUC model; these constraints are taken into account during all the optimization scenario and individuate a *subset* of units that can be committed: the units that the solution of the model chooses to not belong to these subsets will be never committed. In this way, subset constraints can be used as external requirements, for instance related to regulatory laws, such as limited number of units of a particular type; risk limits associated with not programmable sources; emissions constraints; geographical distribution; reliability and security constraints; transmission constraints. In all these cases we do not know *a priori* which is the single unit that is not committed, hence the classical UC model is not applicable, while the GWUC model could represent a valid approach because the additional constraints are sufficiently general: here we have specialized them to geographical distribution, emission control, and risk limit.

The GWUC model is defined as follows. Consider a set of thermal generating units $\mathcal{P}$, a set of hydro generating units $\mathcal{H}$ and a set of wind turbines $\mathcal{W}$. Thermal generating units belonging to the set $\mathcal{P}$ can be grouped into subsets called S_s, with respect to similar technical and operating characteristics. The same idea can be applied to the case of wind turbines belonging to the set $\mathcal{W}$. These units can be grouped into subsets called E_e, with respect to similar technical and operating characteristics. On the other hand, we assume that hydro generating units belonging to the set $\mathcal{H}$ are not grouped into subsets. In fact, the optimal mix depends on the status of the units, as we will describe in the following sections, and no binary variables are necessary to model the status of hydro units, since these power plants are not subjected to on/off constraints. For this reason, we assume that hydro units are always available in the set $\mathcal{H}$. Thermal units and wind turbines could be grouped into subsets as depicted in the example of Fig. 1.

Assigned this data structure for thermal units and wind turbines, the objective of the GWUC model is to analyze all the given subsets S_s and E_e and to determine the optimal mix of thermal, hydro and wind generating units, in order to satisfy the energy demand, minimizing the total production cost and respecting the operating and technical constraints of the generating units. The optimal mix of generating units M_{OPT} has the following properties: i) it is a subset of the available thermal and wind generating units set, this means that all the available units could be chosen in the optimal mix. In other words, we have $M_{OPT} \subseteq \mathcal{P} \cup \mathcal{W}$; ii) generating units which constitutes the optimal mix M_{OPT} belong to subsets S_s and E_e which satisfy certain relationship criteria; this concept is better described in the sections 3.5 and 3.6. An example of optimal mix of thermal and wind units is shown in Fig. 1. M_T represents the optimal mix of thermal units, while M_E is