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Application of neural networks to the management of voltage constraints in the Spanish market

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ABSTRACT

The security criteria of a power system require that branch power flows and bus voltages are within their limits, not only in normal operating conditions but also when any credible contingency occurs. In the Spanish electricity market, voltage constraints are solved by connecting a set of off-line generators located in the areas where they occur. Thus, for a market participant it is necessary to predict approximately when its generating units are connected in order to prepare the annual budget and/or decide the time and location of new plants. The authors have presented in a former paper a methodology based on decision trees to estimate the daily load pattern of units, which have not been cleared in the daily energy market and can be connected to alleviate voltage constraints. In this paper, considering a set of potential explanatory variables, a different methodology based on neural networks is proposed to forecast if a non-connected unit will be committed by the System Operator to remove voltage violations. The performance of neural networks is illustrated with a study case. In addition, a thorough comparison with the methodology based on decision trees is carried out.

1. Introduction

The solution of power system constraints is an important issue to be addressed in deregulated power markets. The Spanish electricity market [1], as it started on January 1st, 1998, is organized and operated by two separate entities: the Market Operator and the System Operator. The Market Operator receives the offers of generation and demand for each hour of the following day and clears the market according to economic criteria. The System Operator is responsible for the secure operation of the power system and owns the transmission system [2]. One of the main tasks of the System Operator consists of solving the power system constraints that arise after the daily energy market has been cleared.

Power system constraints are addressed in Spain by increasing and decreasing the generation of connected units, and by connecting off-line ones. Both generation re-dispatch and adjustment of the demand–generation imbalance is computed according to the generation offers submitted by the agents into the market [3].

Power system constraints are classified in the Spanish system in [4–7]: (a) branch overloads and (b) bus voltage violations.

Branch overloads occur occasionally in the Spanish power system. They are solved by increasing and decreasing power in connected units and in some cases, connecting off-line ones. The Spanish transmission system is a highly meshed one. Under the transmission planning criteria applied when the Spanish transmission power system was developed, most of the lines carry less than 50% of their thermal rate under normal operating condition, and therefore, overloads are not frequent.

However, voltage violations are more frequent than overloads in the Spanish system, due to the lack of reactive power in the areas where they occur and the existence of a big generation imbalance between exporting and importing areas. The generation demand imbalance of an electrical area is computed subtracting from the total area demand the total area generation, and thus, it indicates the magnitude of the energy transport entering the area from the rest of the system. Voltage constraints are solved by connecting a set of off-line generators, and reducing an equal amount of power in the most expensive connected ones. The new connected generators provide reactive support in the importing areas and also inject active power in the system, thus reducing the power transfers between exporting and importing areas (the effect of injecting active power to increase the voltage profile is significant when a power system is close to the critical loading condition of the nose curve [8,9]). This type of constraints has a local effect: they can only be solved by the connection of generators located in the importing areas where they occur. Fig. 1 shows a map of the Spanish power system and the locations where voltage constraints may occur.

Spanish regulation imposes that generators that increase their output in the congestion management procedure are paid at their offer price. In this context, the annual income that a unit located in

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