MODELING MEDIUM TERM HYDROELECTRIC SYSTEM OPERATION WITH LARGE-SCALE PENETRATION OF INTERMITTENT GENERATION

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1 INTRODUCTION

Electricity production from renewable energy sources (RES) is being promoted worldwide as a way to decrease CO_2 and pollutant emissions. Nowadays special regime generation in Spain corresponds to cogeneration, renewable and biomass (photovoltaic solar power, wind power, geothermal, small hydro plants, and biomass and waste power plants) and urban and mining waste. Some of these RES are highly intermittent with sharp changes in power production and difficult predictability. When the ratio of electricity generated by this intermittent generation (IG) to its installed power is small the system operation is not substantially modified, it may be easily considered as a variation in the demand. However, when the penetration of IG is high enough then they may cause problems in the operation and should be taken expressly into account in the operation models that need to be revisited for including it. This paper presents a new medium-term planning model for evaluating a large-scale penetration of IG. In particular, nowadays wind power generation is the most important IG. Other potential IGs are solar or tidal power generation and will be modeled in the same fashion.

2 CASE STUDIES

In Spain, for example, there are three paradigmatic systems where wind generation may become relevant for the system operation. The first one is mainland Spain where wind generation was 10 % of the yearly energy demand in 2007, and the installed power represents a 16 % of the total capacity, see [1]. The wind power produced in the windiest day so far (March 4, 2008) covered a 28 % of the peak demand and a wind generation curtailment was ordered by the System Operator (SO) (http://www.ree.es/sistema_electrico/detalle_curva_eolica.asp?grafico=eolica20080304&hoy=0). European Union policy is aiming at having 20 % of the energy supplied by RES in 2020, see [2]. The second system are the Canary Islands with two main systems and where there are plans to substantially increment the energy produced by RES in the medium term and are relative small isolated systems. The third one is the Hierro Island that will become the first island in the world to produce all the electricity from RES combining wind and pumped storage hydro power plants. The paper deals with the first case, mainland Spain, in a distant future like year 2030.

3 INTERMITTENT GENERATION CHARACTERISTICS

There are special characteristics of the wind generation that affect the way they are incorporated into the operation models, mainly:

- High hourly ramp rates
  Sudden changes in power production of ±600 MW have been frequently observed in the past.
- Windy and calm days in the same season
  For example in two close winter days, in December 8, 2006 the power produced oscillated between 4999 and 8142 MW and in February 2, 2007 the wind power produced varied between

25 and 309 MW.

4 MODEL SPECIFICATION

Two main studies are addressed in the ***medium term operation planning***, with a typical scope of one year. One is ***resource management*** that estimates the production of each generation unit and all the operating parameters of the system under uncertainty in the IG. From this point of view it is important to know in advance if the system operation pattern may change due to the large-scale penetration of IG. For example, pumped storage and storage hydro plants may be more heavily used as a complement to the wind generation, minimum-load of thermal units may be tripped in windy off-peak hours, and frequent startups of gas turbines may be needed if no enough energy storage is available. In the distant future plug-in hybrid cars or active demand technologies can also play a role. The other is ***reliability assessment*** that evaluates the contribution of each generation unit to the reliability of the system, in particular the IG contribution (called capacity credit). It is important to know how much IG can be integrated into the system with a reliable operation.

Some risks associated with IG are very important. On one hand, the operational risks of the SO related to the integration of this power into the system. On the other hand, the market risks derived from the uncertainty in revenues coming from the electricity market.

The model objective is to determine technical and economic impact of IG into the medium-term system operation including reliability assessment. Results include generation output including wind waste, pumped storage hydro usage, and adequacy reliability measures. The benefits of improving wind predictions can also be determined by changing forecasting error distributions and re-running the model.

Given those characteristics it seems that an hourly time unit is required to address the time variation of IG. Chronology in wind generation must be kept. In mainland Spain electric system it can be supposed that balancing markets and spinning reserves deal with variations shorter than the hourly interval. No regulating reserve problems below one hour are foreseen due to enough hydroelectric production availability.

Wind generation forecast is a very difficult task even for short term periods. Although strong efforts have been made to improve the results there are still large variations between estimations and real productions. With high penetration of IG the unit commitment of thermal units may dramatically change with the estimation of IG. Additional tertiary reserves must be provided to support system reliability while minimizing operation cost. A daily time frame with an hourly time unit will be a suitable basis for determining the unit dispatch.

Stochasticity of IG may be incorporated in medium term planning models by analytical simulation [3] or by Monte Carlo simulation [4] where many scenarios will be needed if adequacy reliability measures are to be estimated within a certain confidence interval.

In this paper a novel approach based in these three issues is presented:

- Unit commitment and economic dispatch are vital to obtain short-term system operation and evaluate IG integration, as seen in [6]. We propose a combined approach to model the IG integration: a previous daily optimization model followed by a sequential hourly simulation. Detailed operation constraints such as minimum load, ramp-rate, minimum up-time and down-time of thermal units and tertiary reserve provision are included into the daily optimization model. The hourly simulation is run for the same day to account for wind production errors and therefore revising the previous schedule. In [6] this is alternatively done by “frequent revisions of conventional generation unit schedules”, every 6 hour interval. Differences among optimization and simulation decisions are due to prediction errors and represent the value of the perfect IG forecast.
- A chronological approach to sequentially evaluate every day of a year, as was done in [5] for weeks within a year. As the unit commitment is daily based the resource management besides this time frame is decided by another high-level model, for example, hydrothermal coordination and weekly or seasonal pumped storage hydro scheduling.
- Monte Carlo simulation of many yearly scenarios that deal with IG stochasticity.

So far no transmission system is included into the optimization problem and, given that the target year is far distant, a perfect market framework is considered. Interconnections aren't taken into account to assess the effect of IG on the system itself.

5 CONCLUSIONS

A medium term hydrothermal planning model is proposed to evaluate the unit operation and reliability measures obtained for a large-scale hydroelectric system with high penetration of IG generation. A daily unit commitment followed by a sequential hourly simulation is made for every day of a year and the process is repeated for many scenarios for taking into account IG stochasticity.

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