UNIT COMMITMENT UNDER IMPERFECT FORESIGHT – THE IMPACT OF STOCHASTIC PHOTOVOLTAIC GENERATION

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Overview

The German power sector has undergone a transformation process which is likely to endure the next 20 to 30 years. There has already been a shift from conventional power plants to low-carbon renewable energy systems (RES). Nevertheless, political plans envision an even higher annual share of electricity generation of at least 80% by 2050. The environmental and geopolitical costs of conventional technologies increase steadily with respect to international agreements, e.g. the Paris Accord to reduce carbon emissions. Until today, thermal power plants still dominate Germany's electricity generation. In 2016, lignite and hard coal power plants accounted for more than 43% of the overall annual electricity generation. However, the deployment of RES, mainly wind and PV, has strongly increased over the last years. These two technologies inherit an explicit dependency on weather conditions, making short-term system operations more challenging, as the final output is uncertain and volatile. If deviations in the production of RES are not comprehensively anticipated in short-term scheduling decisions of conventional power plants, this might lead to an inefficient use of the power system. Reasons for this inflexibility are technical and economic constraints as well as the possible loss of liquidity in markets with continually declining time horizons (cf. Graeber 2014). Hence, by anticipation of forecast errors, their scheduling must account for uncertainties in the system. Otherwise, high carbon and fuel costs as well as energy exports of excessive power to neighboring countries at small or even negative spot prices can arise. Thus, efficient unit commitment decisions rely on the adequate evaluation of both future wind and PV infeed.

Abrell and Kunz (2015) present a stochastic unit commitment model (stELMOD) to investigate the impact of intermittent wind generation on optimal scheduling decisions, reserve needs, and system costs. Incorporating stochastic wind power availability with a multi-period scenario-tree, they find that short-term scheduling costs can be significantly reduced by anticipating uncertainty in the optimization process. According to their results, the flexibility of the power system is achieved by either using flexible generation plants or by flexibilizing the generation pattern of mostly inert thermal power. Yet, Abrell and Kunz solely considered wind generation as a possible source of uncertainty, neglecting the impact of PV generation.

Employing stELMOD, a stochastic multi-market model, this paper investigates the impact of uncertain PV generation on unit commitment decisions for the German rolling planning procedure. An approach to simulate a time-adaptive intraday forecast is presented. Uncertainty of PV generation is incorporated by numerous multi-stage scenario trees, accounting for a decreasing forecast error over time. Three more cases of uncertainty are added to stELMOD in order to evaluate the additional effect of stochastic PV generation. By extending and updating stELMOD, it will be examined how far the gradual convergence of photovoltaic forecasts and hence, the decreasing uncertainty of photovoltaic generation over time have to be taken into account. Thereby, a comprehensive assessment of scheduling costs, redispatch costs and amounts, flexibility needs of the power system, as well as powerline usage can be carried out.

Methods

This paper uses the model stELMOD, incorporating the European multi-market regime consisting of a day-ahead (DA), an intraday (ID) and a real-time balancing (CM) market. The model iteration is based on a rolling-planning procedure similar to the WILMAR project (cf. Barth et al. 2006). It is written as a MIP in GAMS and solved with CPLEX. The multi-market regime is integrated into a rolling planning procedure that solves the DA model first, obtaining unit commitment decisions for the next 36 hours. In a subsequent rolling planning procedure, the ID and CM models are solved alternately for each hour. At 12 pm, the DA model is solved again for the following day. This procedure is integrated into a loop and is repeated for a given time horizon.

The presented paper comprises the following methodological steps (cf. Figure 1): (1) an exponential smoothing (exponentially decreasing weights over time) of previous deviations between realized and day-ahead forecast values is carried out, (2) a time-adaptive intraday forecast is constructed for each day in a quarter based on those values and (3) hourly scenario trees for the model are generated from these time series of residuals between the created intraday forecasts and the actual realization. For the handling of complex computations with redundant cases, the GAMS tool 'SCENRED' for scenario reduction in terms of clustering is applied (cf. Heitsch and Römisch 2009 and Gröwe-Kuska, Heitsch, and Römisch 2003). To comprehensively assess the impacts of fluctuating renewable generation, different cases of stochastic RES infeed are considered. Abrell and Kunz (2015) focus on three cases, namely a deterministic, changing forecast, and stochastic representation of the wind infeed. The stochastic case hereby optimizes the power plant dispatch including part-load efficiency over the whole setting of a scenario tree, taking into account different manifestations of RES forecasting errors with their assigned probabilities. For this paper three more cases have been added to the model to solely examine the impact of photovoltaic generation. By extending the scenario tree, uncertainty of both wind and PV generation is incorporated. While the scenario tree is stable for wind generation, for PV it strongly depends on the hour of day as well as on the seasonality.

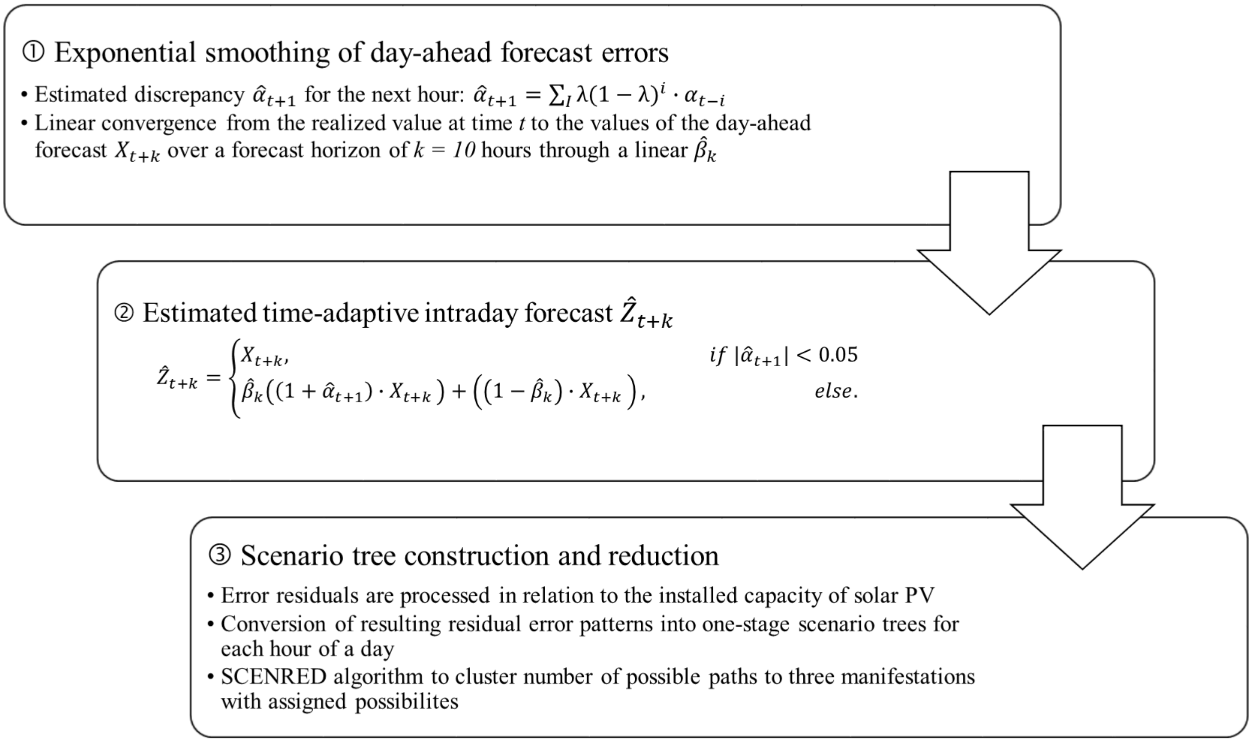

Figure 1: Flow diagram representing the methodology

Results and Conclusion

The preliminary results show an increasing need for more flexibility of the German power system in order to cover uncertain changes of both wind and PV generation. The results are consistent with the findings of Abrell and Kunz (2015) but are differently intensified by the kind of uncertainty incorporation. Updating information on both wind and PV generation with a single forecast leads to significant higher total system costs and triggers a tremendous increase in scheduling actions. The impact of capturing stochastic PV generation by different scenarios leads to a further decrease of scheduling actions, at the cost of higher balancing actions and more carbon emissions. Including improvements of both wind and PV forecasts by a scenario tree of possible manifestations, the scheduling costs could be significantly reduced in representative weeks for spring and summer. In general, the stochastic representations increase the need for congestion management as well as more frequent use of storage.

In conclusion, the impact of stochastic PV generation differs in magnitude with respect to how uncertainty is incorporated. In order to further investigate the impact of comprehensive uncertainties in power systems, future research should also include load forecasting errors into the rolling planning procedure. The influence of increased dispatch frequency is another research question in order to optimize the market design with respect to comprehensive uncertainty of RES production present in today's power systems.

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