Fluctuation-Aware Wind Power Scheduling in Day-ahead Energy and Reserve Markets

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With the development of electricity market policies and advances in wind farm control technology, Wind Power Producers (WPPs) are, more than ever, motivated to take an active role in the electricity market. Accordingly, they have incentives not only to offer energy in the energy market but also to provide balancing services in the reserve market. This thesis aims to provide wind-only portfolios with the necessary resources and visions to effectively participate in the day-ahead energy and reserve markets. To achieve this, it is important to have a day-ahead awareness of wind fluctuations at a very short timescale, e.g., minutes (which is crucial for reserve scheduling), as well as short-term variations, e.g., on an hourly timescale (for energy scheduling). Furthermore, a dedicated decision tool should be developed to leverage the obtained information on wind uncertainty at both time resolutions, thus optimally allocating the wind power share in the day-ahead energy and reserve markets. Also, the reliability of the offered reserve services, as a last resort of the system operator to balance supply and demand, should be considered in the decision framework.

In this thesis, we first present a motivational study to highlight the significant impact of wind fluctuations on WPPs' market contributions and the reliability of the submitted reserve bids. To alleviate the problem of the reliability of the offered reserve power, a new framework is proposed that contains a probabilistic constraint regarding the availability of the reserve power. In the end, when the fluctuations are low, this model allows to provide WPP and system operators with more reliable and informed decisions. However, since wind uncertainty is still modeled at an hourly resolution, this model is not very effective in the presence of large fluctuations. Therefore, an original auxiliary classifier Wasserstein generative adversarial network is proposed to generate high-temporal-resolution (minute-wise) wind speed scenarios. Afterward, the obtained minute-wise wind scenarios are incorporated into data-driven multi-resolution probabilistic energy and reserve bidding framework. It is shown that compared to the outcomes of the single-resolution model that only uses wind uncertainty on hourly resolution, the profit loss and reserve reliability are significantly improved by the proposed model. However, the proposed high-resolution scenario generation method does not directly account for time dependence between successive hourly periods. To address this issue, we propose a day-ahead wind power forecasting model that captures intra-period wind fluctuations with a second-wise resolution and considers dynamic time dependence between periods. Particularly, we formulate a day-ahead forecasting problem that provides second-wise information on intra-period wind variability by predicting the temporal distribution of wind power for day-ahead forecast horizons. Also, a differentiable loss, based on the Wasserstein distance is dedicatedly developed to compare distributions and enables the model training. Meanwhile, the developed multi-resolution bidding strategy is further modified to directly take the generated distributions as input to the decision-making framework, thus reducing the dimensionality of the problem. The effectiveness of the proposed fluctuation-aware data-driven method over its counterparts is verified regarding the minimization of the negative impact of wind fluctuations on WPPs' profit and real-time deviations of offered reserve bids using real-world market and weather data.