

## Probabilistic Forecasting and Bidding Strategy of Ancillary Services for Aggregated Renewable Power Plants

As weather-dependent renewable (RES) power plants tend to substitute dispatchable generators, they should take part in the provision of Ancillary Services (AS). Reserve volumes procured via AS are crucial for the safe operation of grids, therefore AS suppliers must supply highly reliable service bids to avoid severe penalties in case they cannot deliver the service. A validated solution to increase the reliability of renewable-based AS is to control aggregations of dispersed wind and photovoltaic (PV) plants [1], which have a higher probability to provide non-zero service capacities than individual renewable plants.

In contrast with existing AS bidding strategies which are based on a single type of energy source (e.g. wind in [2]), we propose here a forecasting and bidding strategy based on a multi-source aggregation (i.e. wind, PV plants). The model chain of the strategy, represented in Figure 1, starts with a machine learning regression that generates short-term probabilistic forecasts of the aggregated RES production, using historical production data and numerical weather predictions. A challenge for this forecast is to model correctly the uncertainty resulting from multiple energy sources. Then, the distribution of the spread price between the AS market and the energy market is forecasted using historical data and predictions of market conditions. The third step of the model chain is the stochastic decision model for the bidding that uses these forecasts as input. A copula model learns the dependence between the forecasts of production and spread price, and concentrates the offer of AS on periods when sufficient production is expected and the service price compares favorably to the energy price. The proposed strategy can be applied to different services. It is also extended to aggregations operating under a common AS market but distinct energy markets (e.g. Frequency Containment Reserve (FCR) supplied on the FCR European market by plants located in France and Germany).

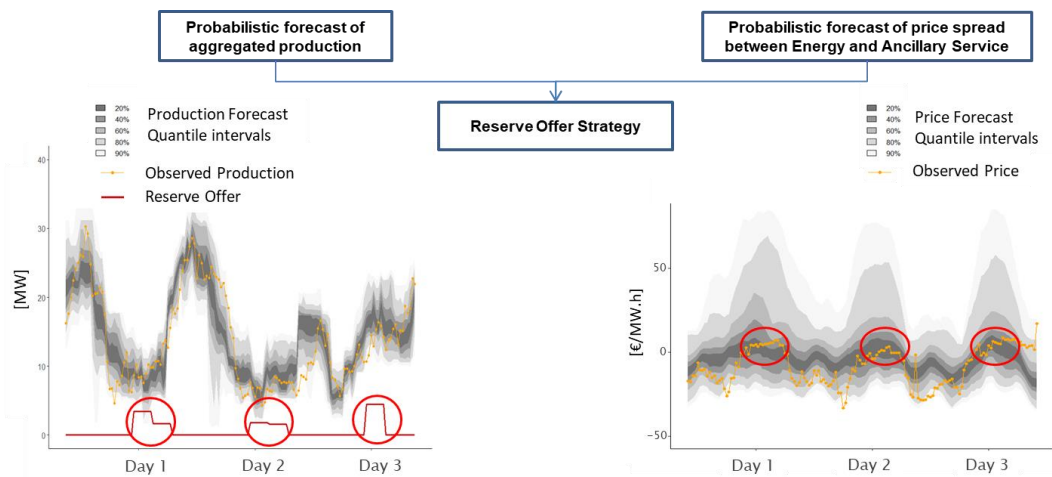


Figure 1: Overview of forecasting and bidding strategy

The strategy is evaluated on two services, FCR and automatic Frequency Restoration Reserve (aFRR), using 2 years of real measurements from a 240 MW virtual power plant composed by wind and PV plants in Germany and France. We find that by offering both energy and reserve, the average revenue can increase up to 10% compared to the offer on the energy market only. The dependence model between uncertainties in production and price ensures a high reliability of AS bids (frequency of underfulfilment below 1%). We investigate also the effect on reliability of higher diversity in RES production profiles, scaling up from regional to transnational aggregations. Finally we assess the sensitivity of results to the capacity shares of each source (wind and PV). In summary, the proposed bidding strategy is a robust decision tool for RES aggregators providing AS.

[1] Knorr et al. (2014). Kombikraftwerk 2 - Final Report.

[2] Soares et al. (2016). Optimal Offering Strategies for Wind Power in Energy and Primary Reserve Markets. *IEEE Transactions on Sustainable Energy*, 7(3), 1036–1045.