INVESTIGATING THE PREDICTION OF aFRR ACTIVATED VOLUME AND PRICE USING MACHINE LEARNING

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Background and motivation

The balanced outcome of the European and German electricity markets, where supply meets demand, does not always correspond to a physical balance between generation and consumption of electrical energy. Imbalances can result from unexpected weather conditions or consumer behavior and cause a deviation of the grid frequency from its nominal value. To compensate such short-term imbalances, transmission system operators (TSOs) procure and, if necessary, activate balancing reserves, which are divided into standard products in Europe. Automatic and manual Frequency Restoration Reserves (aFRR/ mFRR) are standard products that are used to restore the frequency to its nominal value. Different auctions for each of the standard products are organized by TSOs to secure a sufficient amount of reserves and cost-efficient activation of these reserves. For aFRR and mFRR, remuneration in these auctions consists of a capacity price for the reservation of balancing capacity and an energy price for the actual provision of energy when activated.

Balancing energy markets were introduced in Germany in November 2020 for aFRR and mFRR as a result of the Electricity Balancing Guideline (EB GL) implemented in 2017 [1]. Before the introduction of balancing energy markets, balancing capacity bids were awarded in a capacity auction based on a capacity price merit-order. Energy price bids from balancing service providers that were accepted in the capacity auction were considered for activation. With the new balancing energy markets, participation in the energy auction is also possible without having been successful in the capacity auction, enabling more short-term bidding of balancing energy products. Balancing service providers can now act at shorter notice and better align their bids in the balancing energy markets with known awards from prior electricity auctions. To couple aFRR balancing energy markets at European level and enable cross-border exchange of balancing energy, a platform called PICASSO[2] was established in June 2022 [2]. With the introduction of PICASSO, some market parameters like the remuneration rule and validity period were changed [3].

The balancing energy market provides a new opportunity for market participants like power plant and storage operators to sell their capacity. To determine the quantity and price of bids to be submitted, a forecast of aFRR activation and its market outcome could be useful for market participants. Few attempts have been made in literature to predict the activated aFRR volume or the aFRR energy price using machine learning, generally not achieving very good results. However, the new balancing energy market and the changed market parameters could affect the ability to predict activated aFRR volumes and prices. The goal of this paper is therefore to investigate the prediction of aFRR activated volumes and prices in Germany since the introduction of PICASSO.

Methodology

This paper uses supervised learning techniques to investigate the prediction of the four target variables, which are positive and negative aFRR volumes and prices. Four different tree-based machine learning methods are investigated: Gradient Boosting, Random Forest, XGBoost and LightGBM. To train the models, data such as electricity consumption, (forecasted) electricity generation by energy source and the balancing capacity market volume and price is collected from publicly available sources and prepared. Furthermore, time-related features like the hour, day of week, month and season are used. Characterized by a cyclic nature, e.g. the first day of the week follows the last day of the week, these

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features are encoded employing sine and cosine values. New features are engineered from the existing input data as well, such as generation and consumption ramps and forecast errors. Finally, some features are transformed to deal with inadequate scaling, e.g. skewness, to support the algorithms' learning ability.

For each target variable, different combinations of the input data are investigated. Varying the use of actual and/ or forecasted generation and the handling of skewness, the set of best hyperparameters for each of the target variables is used to initialize a model that is subsequently trained and evaluated. Each of these models is used to evaluate the features' importance, by ranking the features in a list from most to least important and consequently training and evaluating the model with an increasing number of features. By evaluating model performance after every increase, the optimal number of features can be found.

Model performance as well as feature importance are evaluated to compare the different methods. For every combination of the input data, the model performances are evaluated using R^2, MSE and RMSE, representing common assessment criteria for supervised learning methods.

Results

The proposed machine learning models are used to predict the German aFRR energy market for the period between May 2021 and April 2023. Input data is split into training and test sets randomly with a ratio of 80:20.

The results show that model performances for the activated volumes of positive and negative aFRR are generally not optimal, reaching R^2 values of at most 40%. The input data combinations that included actual generation lead to best model performances. Hydropower-related features appear to be most important, which, to the judgement of the authors, reflects the dominance of hydropower plants participating in the aFRR market in Germany. The prediction of negative aFRR volumes display worse results than for positive volumes.

As for the balancing energy prices, models perform better, reaching R^2 values of at most 95,8%. Balancing capacity prices and hydropower-related features are the most important features for the energy prices.

Overall, the results show that a prediction of activated aFRR volume is difficult despite the consideration of a consistent market design. This seems to be logical, since if the activated volume were predictable, the activation of aFRR could be prevented by trading on the intraday electricity market. The prediction of balancing energy prices reaches better results. If market participants were to use such a prediction to their advantage and in turn influence market outcome, however, it is not certain that predictions would stay reliable. The full version of this paper contains more extensive model descriptions and a detailed description of the results of the model comparison.

References

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