An optimized probabilistic forecasting approach for hybridized wind power plants

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Abstract

Accurate forecasts are essential for efficiently integrate variable renewable power plants into power systems and electricity markets. Since hybrid power plants are a new area of research, several key challenges need to be addressed. This work presents a probabilistic power forecast approach to hybridised wind power plants with solar power. The forecasting methodology uses a sequential forward feature selection algorithm, employing distinct objective functions and an artificial neural network approach. The probabilistic power forecasts are obtained using a quantile spline regression technique. The approach supports the identification of the: i) optimal quantile and ii) exogenous features (e.g., meteorological input features from numerical weather prediction – NWP models) to increase the profitability of the hybrid power plants in an electricity market environment. As expected, hybridization increases the remuneration of the producer when compared to existing wind plants, regardless of complementarity levels. This increase in remuneration of hybrid plants is superior for the highest generation complementarity case. The use of quantiles to calibrate the forecast approach proves to be crucial for increasing the remuneration compared to the traditional deterministic approach based on the power forecast expected value.

1 Introduction

One of the key challenges in the power system sector relies on integrating variable renewable energy sources (vRES), particularly wind and solar photovoltaic (PV) technologies, in a cost-effective sustainable manner. Currently, to support the transmission system operators (TSOs) in constantly ensuring a balance between electricity production and consumption, accurate vRES and consumption forecasts are crucial [1]. These forecasts minimize the need for costly balancing measures in reserve markets [2]. As a transition to nearly 100% power systems become a reality, the importance of accurate forecasting systems will be even more noticeable [3].

Forecasts also play a crucial role in electricity markets. Market participants rely on forecast systems to establish their bidding strategies for various market products. In existing market structures, deviations from scheduled bids by power producers result in penalties and substantial profit reductions. For instance, the day-ahead markets (DAM), typically require forecasts with a time horizon of 12 to 36 hours, which can lead to significant power forecast errors [4]. For this time horizon, forecast methods based on numerical weather prediction (NWP) models outperform other techniques, such as autoregressive models, which are more suitable for shorter time horizons [2].

NWP models simulate atmospheric circulation and provide weather parameters such as wind speed, cloud cover, temperature, and pressure and they have advanced significantly in recent years due to, e.g., improved understanding of atmospheric dynamics and enhanced computational capacity. Nevertheless, these models still exhibit errors due to, for instance, the uncertainty in the initial and boundary conditions [5]. Post-processing approaches applied to the output from these models can enable to mitigate some of these issues by establishing relationships between local (e.g., solar power PV) and large-scale (e.g., cloud cover) variables to provide location-specific forecasts.

In the post-processing approaches, most of the available literature explores advanced forecast methods like machine learning, ensemble, and hybrid models to improve the power forecast, e.g., [6]. While promising, these models, are complex and need extensive tuning, making challenging to interpret and adopt them, and most only showing minor performance improvements. On the other hand, recent studies indicate that an optimal selection of the meteorological input parameters from NWP data can have a superior impact in the accuracy of vRES power forecasts [7].

Historically, power forecast research has predominantly focused on individual analysis of wind or solar PV power, neglecting the potential benefits of their combination in reducing the combined forecast errors. This potential can be explored in concepts such as hybrid power plants (HPPs). HPPs incorporate two or more renewable sources (and it can include storage) sharing the same point of common coupling (Pcc) [8], [9]. This concept can contribute to the fulfilment of European decarbonisation objectives, due to their multiple benefits. Some of these benefits are: i) no need to reinforce transmission grid, ii) synergetic use of grid assets, iii) increased dispatch capability, and iv) reduced balancing needs [10], [11].

The literature regarding power forecast HPPs is still limited. For instance, Lindberg et al. [8] using probabilistic forecasts examined how aggregation affects forecasting accuracy in a HPP with wind and solar technology. They found that a ratio of 50-60% wind power, along with solar PV, is the one that enables to obtain the most accurate forecasts. Couto and