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Spatio-temporal modeling of wind power prediction errors

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Short Abstract

Forecasts of wind power production are increasingly used in various management tasks for an optimal integration of wind generation into power systems. Forecast quality is paramount, while a reliable estimation of forecast uncertainty is known to be essential. Today, wind power forecasts do no properly account for the spatio-temporal dependencies observed in the wind generation field. The paper focuses on analyzing the spatio-temporal propagation of WPPT (Wind Power Prediction Tool) errors over western Denmark. The crucial role of predicted wind direction is demonstrated, while it is shown that nonlinear statistical models can explain significant part of short-term prediction errors.

Extended Description

The optimal integration of wind energy into power systems requires high-quality wind power forecasts, accompanied with reliable estimates of the forecast uncertainty. So far, state-of-the-art prediction systems typically provide forecasts for a single wind turbine, for a wind farm, or over a region with significant installed wind power capacities. However, the spatio-temporal interdependencies in the wind generation field are not adequately considered. The aim of the paper is to examine the possibility of improving forecasts produced with WPPT (Wind Power Prediction Tool), which is one of the leading systems, by analysing the spatio-temporal propagation of its errors. Such analysis is based on the hourly wind power prediction errors and corresponding meteorological forecasts (wind direction and wind speed) for the region of western Denmark over the year 2004.

The new models and methods proposed in the paper, along with the results examined, reveal a non-linear behavior of forecast errors. The relation is shown to be dependent on

both the weather forecast information and the geographical layout of the wind farms. Wind direction plays a crucial role, while the influence of wind speed is more subtle. Different types of statistical models are fitted to the data, ranging from simple linear models to more advanced threshold or conditional parametric models. The results obtained are carefully examined in order to fully understand the spatio-temporal characteristics of prediction errors. It is shown that the nonlinear behavior of prediction errors can be described best by fitting a threshold model with regime-switching according to the forecast wind direction. For the case-study considered, such model allows to explain 47% of the errors variation for one-hour ahead predictions.

The promising results presented in the paper show a great potential in improving WPPT forecasts over Denmark by modeling the spatio-temporal dependencies of the errors. Better understanding of such spatio-temporal dependencies may also be beneficial at the planning stage, for the optimal dispatching of wind farms with the aim of improving predictability of wind generation at the regional level. Some possible directions for future research are presented and discussed in the paper. More complex statistical models and methods are suggested based on the results from the performed structural analysis of the data and the output of the fitted models.