LES-based evaluation and improvement of wind power forecasts

Supporting the development of observer-based very short-range wind power forecasts by virtual lidar measurememts in atmospheric large-eddy simulations

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In Short

- Wind resources are fluctuation in space and time.
- With increasing amount of wind power in the grid the need for accurate wind power forecasts increaes to keep the stability of the grid.
- In WindRamp II observer-based wind power forecasts are further developed.
- The LES model PALM will provide a numerical testing environment for the evaluation of observer-based wind power forecasts.
- The accuracy of forecasts in cases of low-level jets and horizontal homogeneous wind direction fields will be improved.

This project comprises the atmospheric modelling activities that are part of the BMWK funded project WindRamp II. In order to guarantee the stability of the electricity grid, the amount of electricity fed into the grid must always be equal to the electricity consumption. Wind power is characterized by great temporal variability. As the proportion of wind power in the energy system increases, it is becoming increasingly important to accurately predict the supply of electricity from wind energy so that sufficient balancing power is available at all times to compensate for fluctuations in wind power. Within the previous BMWK project WindRamp a lidar-based wind and wind power forecasting approach has been developed by ForWind. That forecasting approach allowed for forecasts up to 15 minutes and was especially evaluated for its performance at wind ramp events. WindRamp II aims at increasing the forecast horizon to 30 minutes and investigating the performance of the lidar-based forecasting approach also for other potentially difficult to measure and therefore also to predict atmospheric phenomena such as low-level jets or situations with a horizontally heterogeneous wind direction. The objective of this NHR project is to create and apply a numerical testing environment consisting out of the large-eddy simulation model PALM and a lidar simulator implemented into it that allows for testing the lidar-based forecasting approach in a virtual atmosphere of which the development in space and time is well-known.

Very short-term forecasts refer to forecasts with predictions up to an hour. They are usually derived using statistical models (e.g. persistence), i.e. derived from observations in the past. While statistical models can predict many situations with sufficient accuracy, they provide no or only very inaccurate forecasts, especially for so-called ramp events, i.e. rapid and strong changes in wind speed or direction. In recent years, very short-term forecasts based on remote sensing methods have therefore become increasingly important as an alternative to the commonly used statistical models [1]. The incoming wind field is then measured over a large area and with high spatial and temporal resolution several kilometers upstream of the wind farm. An advection method can be used to infer wind speeds downstream at a point in the future and generate a wind speed and power forecast accordingly.

[2] used dual-Doppler radar measurements to predict the performance of individual wind turbines and extended this approach to predict wind farm performance and detect wind ramps[3]. The high measurement range and scanning speed of the devices also worked in favor of the prediction quality. Lidar devices are significantly cheaper and have a higher availability than radar devices and can also be used offshore due to their compactness [1]. Disadvantages that have made further methodological development of lidar-based forecasting necessary are the comparatively low scanning speeds and ranges and, when using a single device, the one-dimensional wind field information.

While studies have demonstrated the potential of lidar-based methods (e.g. [1], [4]), these have so far been limited to forecasting horizons of up to five minutes. For use in grid operation management or electricity trading, these horizons must be significantly increased. In WindRamp, the forecast horizon could be extended to 15 minutes. At the same time, a demonstrator of an XXL lidar with ranges of up to 25 km has been developed in WindRamp. A prototype of that device will be applied in Windramp II in order to extend the forecast horizon to 30 minutes.

WindRamp focused mainly on ramp events. Other complex meteorological situations, such as strong wind shear and changes in wind direction with height or low level jets, are also attracting great interest by the wind energy industry. While some results are already available for the prediction of ramp events ([3], [5], the prediction of other kinds of complex situations using remote sensing methods is largely unexplored. WindRamp II therefore aims to define possible relevant situations and develop methods for predicting them. Closely related to this is the development of a height-resolved wind speed and wind direction forecast as a supplement to forecasts only at hub height.

Windramp II aims at expanding the observer-based very short-term forecast for wind farms through application-oriented collaborative research. The overarching project objectives include the extension of the observer-based forecast to heterogeneous wind farm clusters with very large turbines (rotor diameter over 220 m), the development of new methods for increased forecast accuracy, extended forecast horizon and improved reliability in unfavorable meteorological conditions. WindRamp II continues the scientific work done in WindRamp. The requirements of the wind energy industry show that there is a need to further develop the observer-based very short-term forecast in terms of forecast accuracy, forecast horizon, forecasted phenomena and methodology for application to larger wind farms.

In order to achieve the objectives of the jiunt research project, the sub-project of FW-OL pursues a number of scientific and technical work objectives. The following objectives are related to the simulation activities for which computing time is applied through this proposal.

- Implementation of a lidar simulator in the large-eddy simulation model PALM and simulation of complex atmospheric conditions;

- Research into prediction methods for particularly challenging atmospheric conditions (e.g. low-level jets, situations with horizontally heterogeneous wind direction field)

  The aim of WP 3 "Forecasting methods" of WindRamp II is to further develop the observer-based forecasting method developed in WindRamp. FW-OL will develop a height-resolved wind speed and wind direction forecast based on lidar scans with different elevations, from which a rotor-equivalent wind speed and ultimately a power forecast can be derived. This further development is particularly relevant for future turbine classes with very large rotor diameters and heterogeneous wind farm clusters and will therefore become increasingly important in the future. Other focal points of WP 3 are the analysis of uncertainties, particularly in connection with wind vector advection, as well as research into hybrid methods, which will also include machine learning approaches. In addition, FW-OL tests the developed forecasting methods for complex atmospheric situations, such as ramp events, situations with low-level jets (i.e. situation with strong shear and veer) as well as situations in which the wind direction shows a horizontally heterogeneous field. Such situations are expected to be challenging for existing wind and wind power forecasting tools. This investigation will be carried out using a lidar simulator integrated into the LES model PALM on the one hand and based on the data from the measurement campaigns provided in WP 1 of WindRamp II on the other. The requirements defined by a wind farm operator for height-resolved forecasts and complex situations will be taken into account.

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https://uol.de/we-sys

More Information

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Project Partners

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