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Abstract title

Verified available power estimation of offshore wind farms

Introduction

The wind power plants have remarkably increasing curtailed (down-regulated) hours in recent years, making reliable available (or possible) power estimation crucial. Currently, there is no clear way to determine the available power of a down-regulated wind farm, even though the modern wind turbines have a corresponding SCADA signal. The sum of those individual signals gives a clear overestimation for down-regulated wind farm because the wind speed is higher at the downstream turbine location(s) due to the decrease in wake losses under curtailment. Here we describe an industrially applicable, verified method for the estimation of the available power of a wind farm.

Approach

To develop the high frequency (1 Hz) wind farm scale available power signal, the free wind speed at the upstream turbine locations has to be estimated and input to a novel real-time wake model which is calibrated for the same resolution, to obtain the corrected downstream wind. In this paper, the available power algorithm is presented together with the validation cases prepared using a set of wind farm scale experiments in Horns-Rev offshore wind farm.

Main body of abstract -

To estimate the wind speed at turbine locations, a new approach which takes power, pitch angle, and rotational speed as inputs is developed and validated during both down-regulation and normal operation. This rotor equivalent wind speed was tested using 1 Hz met-mast and SCADA data from the Horns-Rev, Lillgrund and Thanet offshore wind farms, together with NREL 5MW simulations.

The wind speeds of the upstream turbines should be read by the wake model to estimate the velocity deficit as if the turbines are operating ideally and calculate the possible power of the wind farm. However, most of the robust wake models are tuned for 10-min averaged data. Therefore, the GCLarsen wake model is re-parameterized and re-calibrated for a single wake case and then implemented to the wind farm extent considering the time delay and the local turbulence. The preliminary results on Thanet indicate that the wake velocity inside the wind farm can be estimated with a maximum 10-min average error of 12% using the re-calibrated model on 1-sec dataset. When applied during the nominal operation, the algorithm clearly provides a real-time wind farm power curve which can be fed into the control system.

The test and validation of the algorithm is rather challenging since there is no actual measure of the available power for wind farm scale. However, we can benefit from the similarity in power production between the neighboring rows in a simple layout. Therefore, a set of experiments were designed and initiated in Horns Rev wind farm where two of the upstream turbines are down-regulated according to certain inflow criteria. The first results of the experiment indicate a significant improvement in the available active power signal calculated by the algorithm compared to the SCADA data. The preliminary verification studies and uncertainty analysis of both approaches is performed based on the experimental results.

Conclusion - Word count: 84

The verified and validated algorithm could be employed by manufacturers, operators and grid operators world-wide, both for the determination of compensation payments during mandated down-regulation as well as for the exact determination of reserve power for use in ancillary services markets.

Learning objectives - Word count: 26

Re-parameterization and re-calibration of analytical real-time wake model(s)
Experiments with downregulated turbines at Horns Rev
Validation and uncertainty quantification of a multi-layered model

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Brief biography

Dr. Gregor Giebel is Senior Scientist at DTU Wind Energy in Risø. His main topic is short-term prediction of wind energy and integration in the grid. He is the Operating Agent of the newly built IEA Wind Forecasiting Task, and collaborates on standardisation within IEC and SGIP. During his 19 years in wind power, he also looked into wind resource estimation, the use of drones for atmospheric measurements, and condition monitoring for the drive train.

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General
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Abstract content

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Abstract title
Design tool for offshore wind farm cluster planning

Introduction - Word count: 82
The novel software 'Wind & Economy' is useful for offshore wind farm cluster planning. It is spin-off from the FP7 project EERA DTOC acronym for European Energy Research Alliance: Design Tool for Offshore wind farm Cluster. The software enables planning of offshore wind farms using a suite of integrated 'state of the art' software including WAsP, Fuga, WRF, NetOp, LCoE model, CorWind, FarmFlow, Eefarm and grid code compliance calculation. The development is done by members from EERA and guided by several industrial partners.

Approach - Word count: 53

The project aim of the EERA DTOC project was to develop 'A robust, efficient, easy to use and flexible tool created to facilitate the optimised design of individual and clusters of offshore wind farms'. This was successfully achieved during the 3.5 year long project coordinated by DTU Wind Energy and in collaboration with 21 partners.

Main body of abstract - Word count: 282

The integrated software 'Wind & Economy' is based on software that has been compared and validated to wide extent. Within the EERA DTOC project one major task completed was comparison of around 10 wake models to SCADA data from Horns Rev 1 offshore wind farm in the North Sea, Lillgrund wind farm in the Baltic Sea and Rødsand-2 wind farm in the Baltic Sea. The Rødsand-2 is located nearby the Nysted-1 wind farm, thus the wake influence between dual operation twin farms was possible. Furthermore both micro- and mesoscale wake models have been compared to satellite-based wind farm wake data in the North Sea. The WRF model is operated at three institutes (CENER, CIEMAT and DTU) and comparison of WRF model results to satellite winds has also been performed. WRF is generally used to provide the wind climate, with and without wind farm clusters, or alternatively if meteorological observations are available, these data may be used for wind climate. Another part of the work was on uncertainty analysis for estimation of annual energy yield. FINO-1 meteorological data were used as basis. Ship-based wind lidar data observed near FINO-1 and Alpha ventus wind farm in the North Sea and scanning lidar data were collected and compared to wake models. Also planning of the electrical grid both inter-array and long-distance cables were done by the software and several tests were made. The calculations include the smoothing effect on produced energy between wind farms located in different regional wind zones and the short time scales relevant for assessing balancing power. The grid code compliance was tested for several cases and the results are useful for wind farm planning of the grid and necessary components and controls.

Conclusion - Word count: 83

The 'Wind & Economy' software provide a new frame for planning offshore wind farm clusters. The software includes state of the art software from the scientific development by the European Energy Research Alliance members. The software has to wide extent been compared and validated. The rapid development of offshore wind farms in the Northern European Seas with major clusters planned in several countries including the UK, Germany, the Netherlands, Belgium, Denmark and France makes the release of this novel tool available with due diligence.

Learning objectives - Word count: 26

One learning objective is on integration of very diverse models. Another learning objective is on practical offshore wind farm planning needs and novel methodologies for developers.

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