Geophysical Research Abstracts
Vol. 15, EGU2013-10710, 2013
EGU General Assembly 2013

Comparing model-based predictions of a wind turbine wake to LiDAR measurements in complex terrain

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The application of remote sensing techniques to the measurement of wind characteristics offers great potential to accurately predict the atmospheric boundary layer flow (ABL) and its interactions with wind turbines. An understanding of these interactions is important for optimizing turbine siting in wind farms and improving the power performance and lifetime of individual machines. In particular, Doppler wind Light Detection and Ranging (LiDAR) can be used to remotely measure the wind characteristics (speed, direction and turbulence intensity) approaching a rotor. This information can be utilised to improve turbine lifetime (advanced detection of incoming wind shear, wind veer and extreme wind conditions, such as gusts) and optimise power production (improved yaw, pitch and speed control). LiDAR can also make detailed measurements of the disturbed wind profile in the wake, which can damage surrounding turbines and reduce efficiency. These observational techniques can help engineers better understand and model wakes to optimize turbine spacing in large wind farms, improving efficiency and reducing the cost of energy.

NEL is currently undertaking research to measure the disturbed wind profile in the wake of a 950 kW wind turbine using a ZephIR Dual Mode LiDAR at its Myres Hill wind turbine test site located near Glasgow, Scotland. Myres Hill is moderately complex terrain comprising deep peat, low lying grass and heathers, localised slopes and nearby forest, approximately 2 km away. Measurements have been obtained by vertically scanning at 10 recorded heights across and above the rotor plane to determine the wind speed, wind direction and turbulence intensity profiles. Measurement stations located at various rotor diameters downstream of the turbine were selected in an attempt to capture the development of the wake and its recovery towards free stream conditions. Results of the measurement campaign will also highlight how the wake behaves as a result of sudden gusts or rapid changes in wind direction.

NEL has carried out simulations to model the wake of the turbine using Computational Fluid Dynamics (CFD) software provided by ANSYS Inc. The model incorporates a simple actuator disk concept to model the turbine and its wake, typical of that used in many commercial wind farm optimization tools. The surrounding terrain, including the forestry is modelled allowing an investigation of the wake-terrain interactions occurring across the site. The overall aim is to compare the LiDAR measurements with simulated data to assess the quality of the model and its sensitivity to variables such as mesh size and turbulence/forestry modelling techniques. Knowledge acquired from the study will help to define techniques for combining LiDAR measurements with CFD modelling to improve predictions of wake losses in large wind farms and hence, energy production. In addition, the impact of transient wind conditions on the results of predictions based on idealised, steady state models has been examined.