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Wind field re-construction of 3D Wake measurements from a turbine-installed scanning lidar

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Abstract

High-resolution wake flow measurements obtained from a turbine-mounted scanning lidar have been obtained from 1D to 5D behind a V27 test turbine. The measured line-of-sight projected wind speeds have, in connection with a fast CFD wind field reconstruction model, been used to generate 3D wind fields in the scan planes consisting of all three wind components. The combination of a fast-scanning wind lidar and a corresponding fast wind field reconstruction model is shown to be able to provide detailed wind data useful for proactive steering of wakes in real time and also for advanced feed-forward turbine control.

Keywords: *Wake measurements, Scanning Lidar, 3D wind field reconstruction*

DTU SpinnerLidar wake measurements and wind field reconstruction

High-resolution lidar wake measurements are part of an ongoing field campaign being conducted at the Scaled Wind Farm Technology (SWiFT) facility [1–4] by Sandia National Laboratories and the National Renewable Energy Laboratory using a customized scanning "DTU SpinnerLidar," developed for research by the Technical University of Denmark [5]. The purpose of the SpinnerLidar measurements at SWIFT is to measure the response of a V27 turbine wake to varying inflow conditions and turbine operating states.
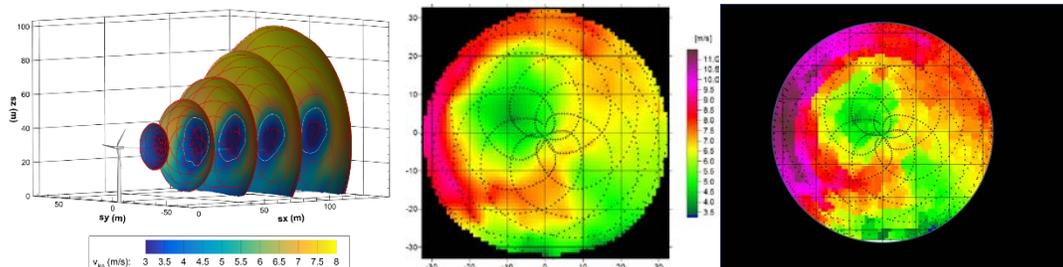

Fig.1. [Left]: SpinnerLidar scanning pattern in the wake of the V27 test turbine at the SWiFT site, overlaid on interpolated line-of-sight speed measurements; [Middle]: Line-of-sight wind speeds measured by the SpinnerLidar on Dec 15th 2016 20:31:00 to 20:31:02 at 66.2 m downwind distance, interpolated on a 1×1 m grid facing the turbine, i.e. the turbine is behind the frame. [Right]: The corresponding Lincom reconstructed axial wind component, *u(y, z)*.

Although the fast-scanning SpinnerLidar is able to measure the line-of-sight projected wind speed at up to 400 points per second, a single lidar is in principle never able to measure all three wind components (u, v, w) in the scan plane at the same time. This limitation is often referred to as the "lidar cyclops syndrome". However, by applying the measured line-of-sight wind speed data as boundary conditions to a fast linearized Navier-Stokes CFD code referred to as LINCOM the corresponding 3D wind vector field (u, v, w) can be reconstructed very fast under the mass and momentum conservation constraint in the 3D wind field. In this way, the LINCOM model calculated line-of-sight projections of the 3D wind velocity vectors become consistent with the line-of-sight wind speed measurements of the SpinnerLidar.

The SpinnerLidar measured line-of-sight wake data from the SWiFT site were used to calculate the three wind components *u(y, z), v(y, z)* and *w(y, z)* of the turbine wake in a number of downwind

crosswinds scan planes from 1D to 5D downstream. Fig.1 shows [Left] the SpinnerLidar scans of the wake of the V27 test turbine at the SWiFT site from 1D to 5D as well as [Middle] an example of the line-of-sight measurements of the wake wind field in a single downwind crosswind plane at 66.2 m (2.5D), together with [Right] the corresponding axial wind component, *u(y,z)*, of the three-dimensional reconstructed wind field using the LINCOM model.

Using the fast LINCOM model [6], the SpinnerLidar's 400 real-time measurements per second of line-of-sight speed can in this way be reconstructed on-line to yield all three wind components of the wake or inflow in less than one second on a standard PC [7]. The described wind field reconstruction methodology can be used to determine the 3D wind components in the inflow as well as in the wake using a single scanning lidar mounted on the turbine
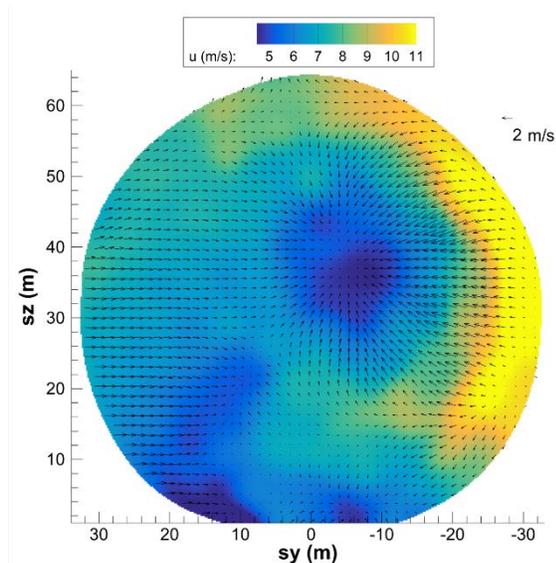

Fig. 2: Example of a 3D reconstructed wind field in the wake of a SWiFT site V27 turbine at 2.5 D downwind. The 3D wind field is reconstructed in less than one second on a PC from 800 sequential line-of-sight radial wind speed measurements scanned by the lidar during a 2 second sampling period. The axial wind component *u(y, z)* is color coded while the two transverse wind components are represented by black arrows.

The results in Fig.2 compare qualitatively well with the scaled model measurements of 3D wake flow obtained by Medici and Alfredsson (2006). In addition, full-scale validation measurements of 3D inflow were obtained during the IRPWind Joint Experiment ScanFlow 2017, i.e. a field study of 3D wind turbine inflow using a SpinnerLidar and three ground-based WindScanners, cf. http://www.irpwind-scanflow.eu/fileadmin/irpwind-scanflow/user/Data/IRPWIND-ScanFlow-final-report.pdf

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