UniTTe –Turbine performance assessment with nacelle lidars

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Innovation Fund Denmark
RESEARCH,TECHNOLOGY & GROWTH

Abstract

Instead of using mast mounted instruments measuring the free-stream wind speed far upstream, we propose to use modern, nacelle-mounted wind lidars, measuring the wind field a short distance ahead of the rotor. With these measurements, the correlation between the wind and the turbine response (loads and power) will be increased and the influence of the terrain on the measurements will be minimized, allowing the same procedures to be used both offshore and in mountainous terrain. UniTTe, performed by a consortium of 11 partners, covering a broad spectrum of international players in the wind industry, aims at delivering the future industrial procedures for loads and power verification that will also form the basis of new international standards.

This poster presents the results obtained in the first phase of the UniTTe project: wind turbine performance assessment using profiling nacelle lidars measurements taken in the rotor inflow in flat terrain.

WP1: Turbine rotor blockage

Computational modelling of the turbine inflow was necessary to better understand the induction. CFD simulations using an actuator disc have been validated against 3-dimensional measurements of the inflow to a 500kW turbine obtained with the Short Range WindScanner (a system based on three synchronized lidars) [1].

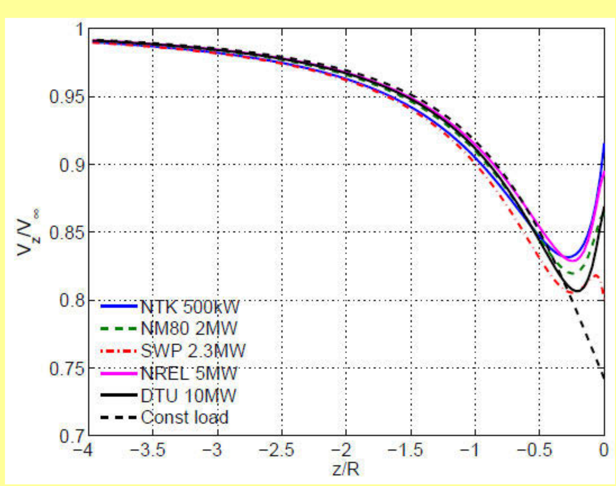

Fig.1. Simulated wind velocity as function of distance upstream of the rotor for 5 different turbines

Then, simulations for 4 different rotor designs ranging from 500kW to 5MW turbines showed that the mean velocity profile up to 1 rotor radius upstream is independent of the rotor design and wind speed (to within 0.6% of the free-stream).

WP2: Uncertainty of nacelle lidar measurement

A methodology for calibrating profiling nacelle lidar has been developed. The basic principle is that the radial wind speed measured by a lidar is compared to collocated and simultaneous measurements taken with a reference cup anemometer [2].

Lidar	LOS	Calibration [m/s]	Uncertainty (k=2)
5B	0	$y = 1.0058\ x$	1.94% to 2.72%
	1	$y = 1.0072\ x$	1.84% to 2.73%
	2	$y = 1.0084\ x$	1.85% to 2.73%
	3	$y = 1.0090\ x$	1.82% to 2.73%
	4	$y = 1.0056\ x$	1.84% to 2.68%
ZDM	179°-181° azimuth	$y = 1.0050\ x$	1.89% to 2.75%

Table1. Results of V_{LOS} calibration for each beam for the Avent 5 Beam and the bottom sector of the circular scan for the ZephIR DM

An Avent 5 beam lidar and a ZephIR Dual Mode have been calibrated with this methodology. The uncertainty results are very similar for the two lidars.

Measurement campaign in flat terrain (WP3)

Fig.2. Picture of Avent 5 beam and ZephIR ZDM lidars mounted on the nacelle of a Siemens 2.3MW in Nørrekær Enge.

Both calibrated nacelle lidars have been installed on a Siemens 2.3MW wind turbine in the Nørrekær Enge wind farm, surrounded by flat terrain, in Denmark. A met mast, compliant to the IEC 61400-12-1:2005 requirements, has been used as reference wind speed measurement. Moreover the turbine has been instrumented for a full load assessment including strain gauges on the blade roots and the top and bottom of the tower.

WP4: Power curve measurement

An algorithm to derive the wind parameters (horizontal wind speed, direction, shear, veer) from the lidars radial wind speed measurements has been developed. This algorithm is based on a fit of the lidar line of sight velocity to a wind model which can include a variable number of parameters (e.g. shear, veer, induction) [3].

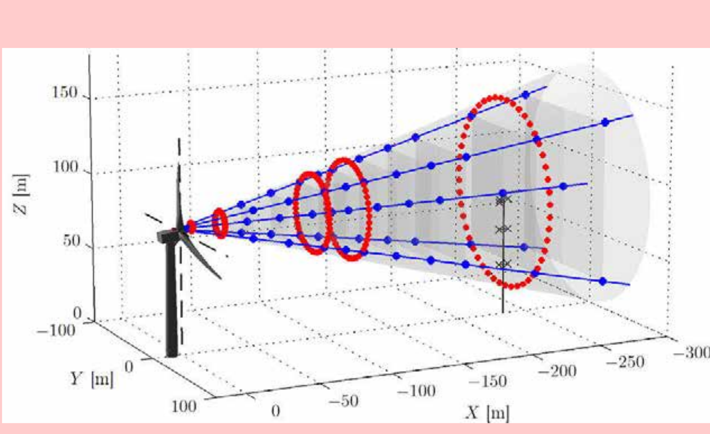

Fig.3. Scanning pattern for each lidar at Nørrekær Enge (Avent 5 beam : blue; ZephIR DM: red)

The reconstruction has been applied to from Nørrekær Enge, considering various measurement ranges, e.g. 2.5D, or 1D upstream of the rotor, in which case the rotor induction was integrated in the wind model to retrieve free stream wind characteristics, to be used as input for the power curve.

See presentation by A Borraccino, "Nacelle lidars near flow measurements: the future of power performance?" (Lidars Session: 27 Sept 16, 14:30, Hall F)

WP5: Loads assessment

A method for incorporating wind velocity measurements from multiple-points scanning lidars into three dimensional wind turbulence time series serving as input to wind turbine load simulations was developed [4]. The next step is to apply this method with turbulence parameters extracted from the lidar high frequency data.

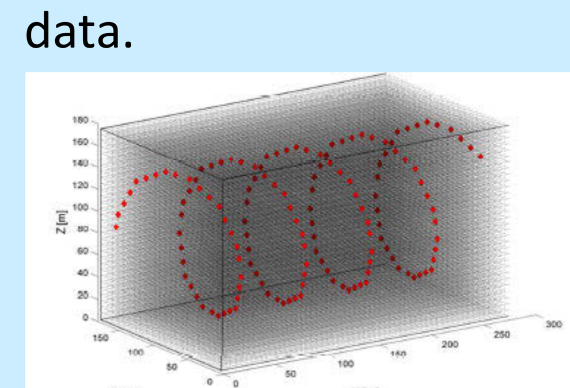

Fig.4. Simulated lidar scanning patterns were implemented by imposing constraints on randomly generated Gaussian turbulence fields.)

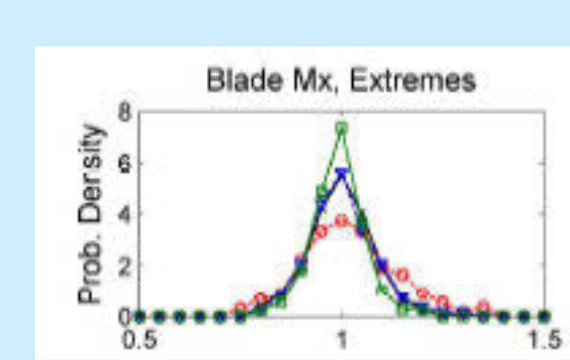

Fig.5. Probability density of uncertainty in blade root out of plane extreme loads. (Red: unconstrained; Blue: constrained with ZephIR DM pattern; Black: cinstrained with Avent 5 Beam pattern)

Lidar measurements as turbulence constraints in load simulations may bring significant reduction in load and energy production uncertainty.

References

1. Forsting A et al. *Validation of a CFD model with a lidar-based wind scanner upstream of a wind turbine*, submitted to Wind Energy
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3. Borraccino A et al. , *Wind Field Reconstruction from Nacelle-Mounted Profiling LiDARs integrating Induction Model*, ISARS 2016 proceedings
4. Dimitrov N and Natarajan A. *Application of simulated Lidar scanning patterns to constrained Gaussian turbulence fields for loads validation*, Wind Energy 2016

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The UniTTe project is funded by Innovation Fund Denmark (Grant No: 1305-00024A)