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Assessment of nacelle-mounted LIDAR for onshore power performance testing

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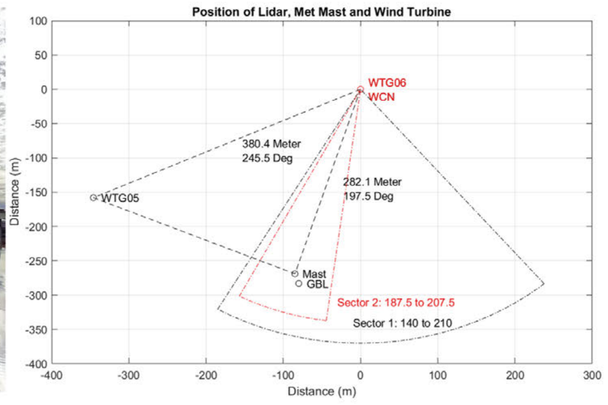
Introduction

ENGIE North America, GE Renewable Energy, DNV and Leosphere, a Vaisala Company, have deployed a WindCube Nacelle Lidar (WCN) in a 250 MW wind farm, in the U.S. to gain experience with the technology and accelerate the acceptance and commercial application of nacelle-mounted lidars for power performance testing (PPT).

The objective of the project is to prove the suitability of the system for contractual wind turbine power performance tests using a nacelle mounted lidar remote sensor according to the IEC 61400-50-3 procedures in anticipation of the release of this new IEC standard in 2021.



Methodology

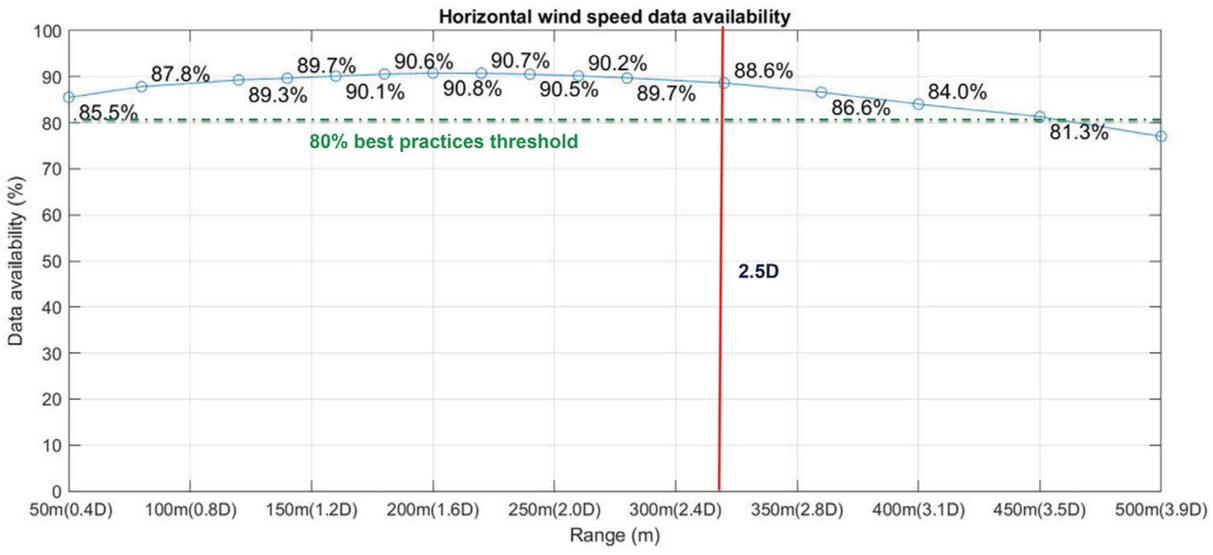
Measurements were taken at ENGIE's operational wind farm (U.S.) in flat onshore terrain for a 3-month duration. A Leosphere WindCube Nacelle Lidar, previously known as Wind Iris, installed on a wind turbine. One IEC met mast and a WindCube vertical profiler lidar, are located respectively at 282 m (2.2D) and 290m (2.3D) in front of wind turbine. Wind speed at hub height is compared in the two wind sectors: 140°-210° and 187 °-207 °.

The nacelle lidar was installed in its standard 4-beams configuration (horizontal set-up: 2 beams with elevation angle of +5°, 2 beams with -5°). The nacelle lidar was positioned and mounted following the recommendations provided by GE Renewables Energy. This campaign was used to gain operational experience and define installation guidelines now available for future projects on GE 2MW turbines.

Instrumentation	Type	Measurement Height [m]	Distance from WTG [m]	Distance from WTG in [D]
Nacelle-mounted Lidar	WindCube Nacelle	89m	50m-700m	0.4D-5.5D
Met Mast	IEC compliant	32m-89m	282m	2.2D
Ground-based Lidar	WindCube	40m-200m	290m	2.3D

Data availability

Lidar data availability is one of key indicators for accurate power performance testing. IEC standards and industry best practices recommend to measure the wind between 2D and 4D. Below figure shows that the averaged data availability during the 3 months is very good and the data availability at the distance of 2.5D reaches at 88.6%, well above 80% which enables the accurate measurement for PPT.



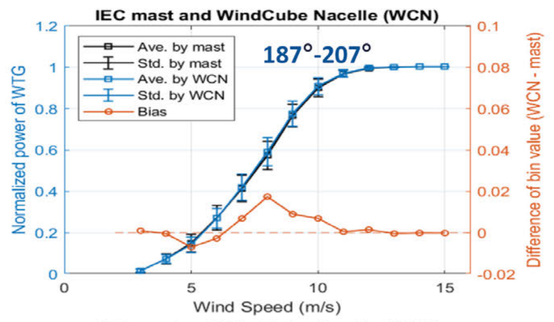
Results

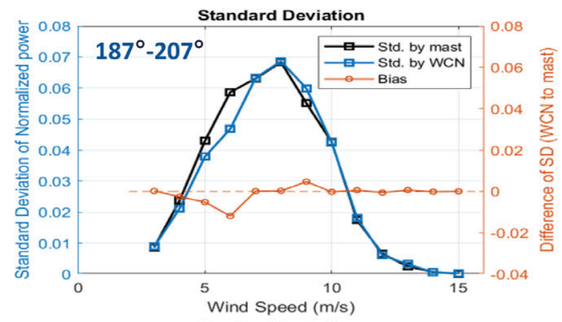
The below figures show the power curves measured by IEC met mast and WCN. Data filtering criteria: 1) WCN data availability >80%; 2) WCN wind direction : +/- 10° from rotor axis. Two different wind sectors are selected:

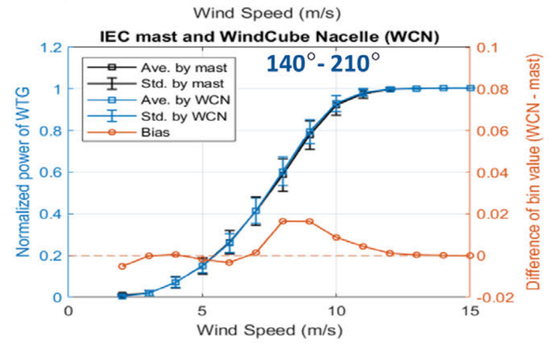
- 187 °-207 ° : met mast centered wind sector
- 140 °-210 ° : IEC valid wind sector

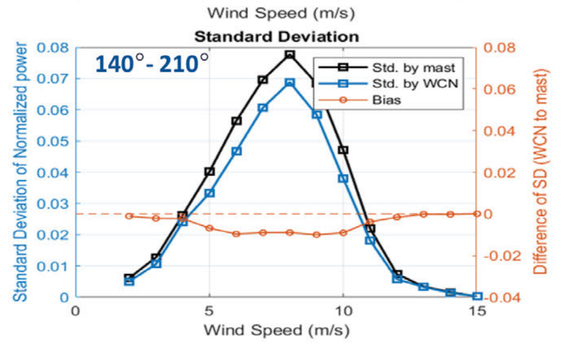
The left figures bellow show the match between the IEC met mast and nacelle lidar power curves for both sectors. Difference between the two devices is <2%.

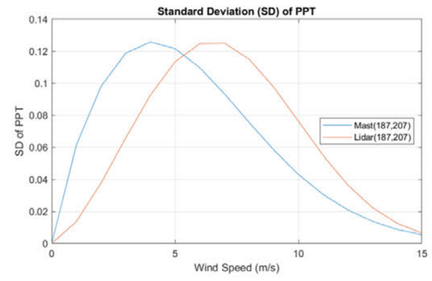
The right figures shows that Standard Deviation (SD) is smaller for WCN, especially when comparing the results for the wider wind sector [140°-210°] This can be explained by the poorer spatial coherence of the met mast measurements. This highlights the advantage of nacelle-mounted lidars which are constantly measuring in front of the turbine.

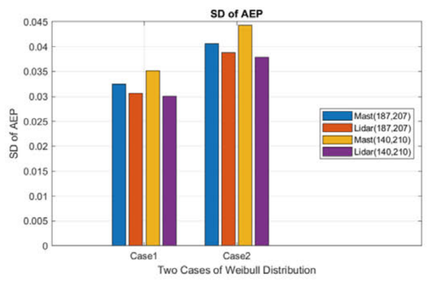












The difference of standard uncertainty in AEP is analyzed using two Weibull distributions, simulating different wind conditions at the test site. The left graphs show the standard deviation in AEP of the power curve measurements.

1) SD in AEP measured with the met mast is bigger than when measuring with the nacelle lidar;
2) SD in AEP measured by the nacelle lidar is smaller when using the larger wind sector.

This also highlights the better spatial coherence of nacelle lidar measurements.

SD in AEP	Mast 187 °-207 °	Lidar 187 °-207 °	Mast 140 °-210 °	Lidar 140 °-210 °
Distribution 1	0.032	0.031	0.035	0.030
Distribution 2	0.041	0.039	0.044	0.038

Conclusion

The campaign results show that the WindCube nacelle Long-Range provided accurate wind measurements relative to concurrent IEC-compliant measurement instruments.

This joint industry campaign brings compelling evidence of the technical suitability and market readiness for power performance testing using nacelle mounted lidars for power performance testing in flat onshore terrain as per upcoming IEC-61400-50-3 standard.

In order to further evaluate the added value of nacelle-mounted lidar, more parameters such as uncertainties, turbulence intensity, shear, veer and REWS will be analyzed.

References

1. IEC 61400-12-1 Wind Turbines Part 12-1: Power Performance Measurements of Electricity Producing Wind Turbines
2. Borraccino, Antoine, David Schlipf, Florian Haizmann, and Rozenn Wagner. 2017. "Wind Field Reconstruction from Nacelle-Mounted Lidars Short Range Measurements." Wind Energy Science Discussions.