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In-depth presentation of turbine after turbine performance verification and optimization campaigns with a nacelle Lidar

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Abstract

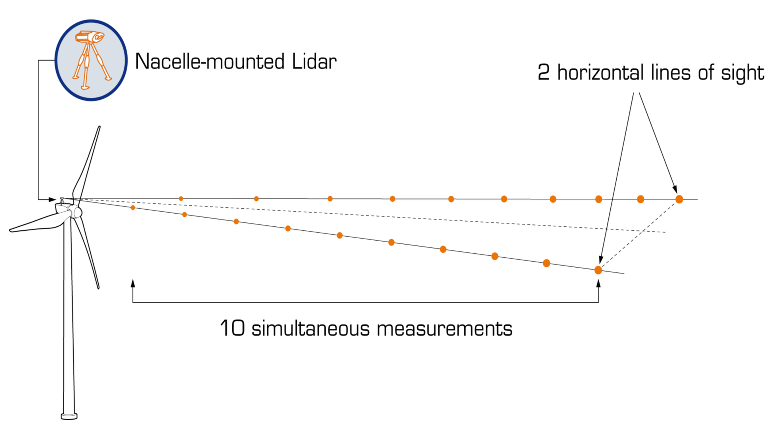
Nacelle Lidars are increasingly seen as promising tools to address turbine performance issues. Several research programs have validated their accuracy for measuring power curves [1], nacelle transfer function [2], yaw misalignment [3] or turbulence intensity in simple [1,4] and complex terrains [5, 6].

However crucial, these validations are not sufficient to enable operators to use nacelle Lidars as an efficient tool to increase performance of wind farms. In the context of an operational O&M use, emphasis is on fast and easy-to-implement campaigns in order to yield the biggest return on investment.

We here present the operational implementation and key findings of a large number of turbine after turbine performance verification and optimization projects using the Wind Iris nacelle Lidar.

Objectives

Turbine after turbine nacelle Lidar projects aim at verifying and optimising the overall performance of a wind farm by sequentially using a Lidar for a short period of time on one or several turbine. The main operational applications often include, but are not limited to:



- Evaluation of correctable static yaw misalignment to improve production
- Measurement of an operational power curve to obtain a performance reference
- Characterization of the nacelle transfer function to improve monitoring

Methods

Below are presented the main steps implemented to successfully carry out a performance optimisation project, either as a fleet-wide implementation or on a particular wind farm. Avent's teams typically follows its clients into all or parts of these steps through a pilot project.

TURBINE SELECTION
Select suspected underperformers in order to achieve the best return on investment by performing a desk study using existing O&M data

SYSTEM AND DATA TRAINING
Ensure smooth and autonomous use of the system by O&M teams: handling, communication, monitoring, analysis, ...

LIDAR INSTALLATION & MEASUREMENT
Deploy Lidar using turbine-specific procedures and service reports to ensure fast, repeatable and traceable installations

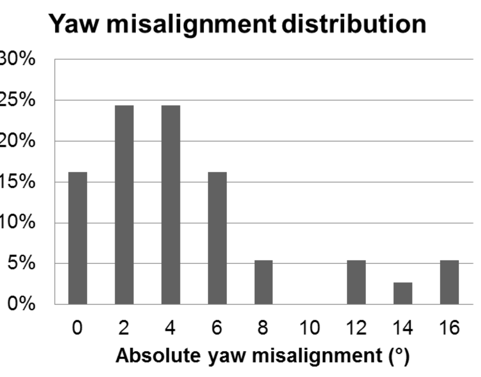
DATA ANALYSIS
Analyze data using dedicated tools, such as latest Wind Iris software module for automatic yaw misalignment calculation based on a proven algorithm [4]

RESULT IMPLEMENTATION
Depending on the results and initial goals of the campaign, take corrective actions to improve turbine operations and monitoring

LONG TERM EVALUATION
Evaluate the benefits on the long term, such as AEP gain, by using a method agreed upon, accurate and with the lowest impact on the ROI

Next sections present general results acquired following all or part of this methodology over 140 turbines with the Wind Iris covering a wide spectrum of turbines (30+ models from 15+ manufacturers, ranging from 100 kw to 7,5 MW) on all terrain types (onshore simple, onshore complex, offshore).

Yaw misalignment detection



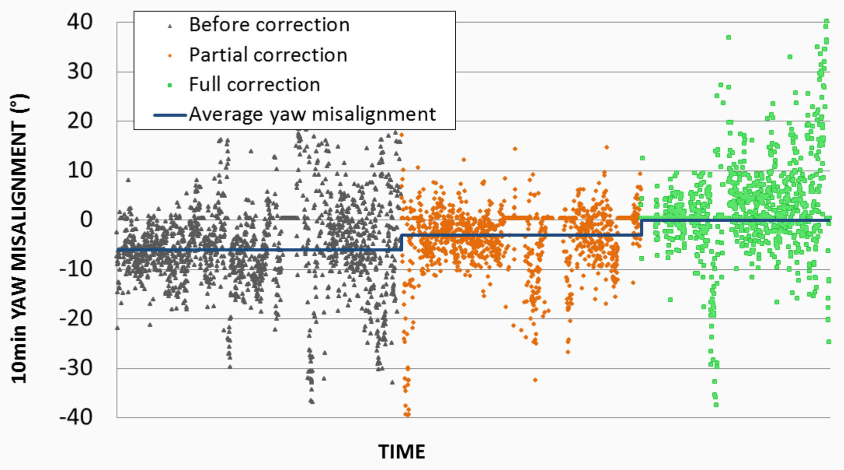
- Misalignment is determined in 1 week on average
- Average misalignment is 5,2° leading to +1,34% AEP gain after correction*
- Misalignments above 3° represent 60% of cases, with an average of 7,5° leading to +2.4% AEP after correction*

*Estimation based on model and experience.

Case study

Iberwind Natural Efficiency

As first step before a fleet-wide implementation, IBERWIND has used 3 Wind Iris over 10 turbines from 5 different farms in Portugal [7]. The graph shows yaw misalignment on one of the turbines over 4 weeks, including before and after correction down to 0°. In this project, the average misalignment of the underperforming turbines was 6.5°.



Power curve and nacelle transfer function measurements

Power curve (PC)

- Sufficient data is usually acquired in 4 to 6 weeks for an operational PC
- 30% of the PC are compliant with the reference PC, 10% are above, 60% are under

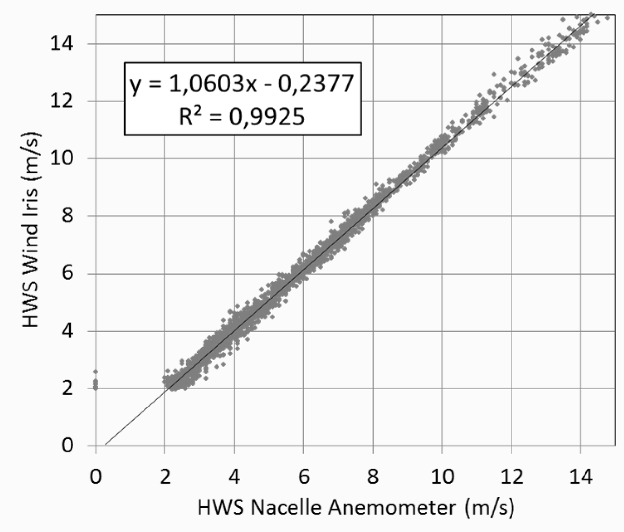
Nacelle transfer function (NTF)

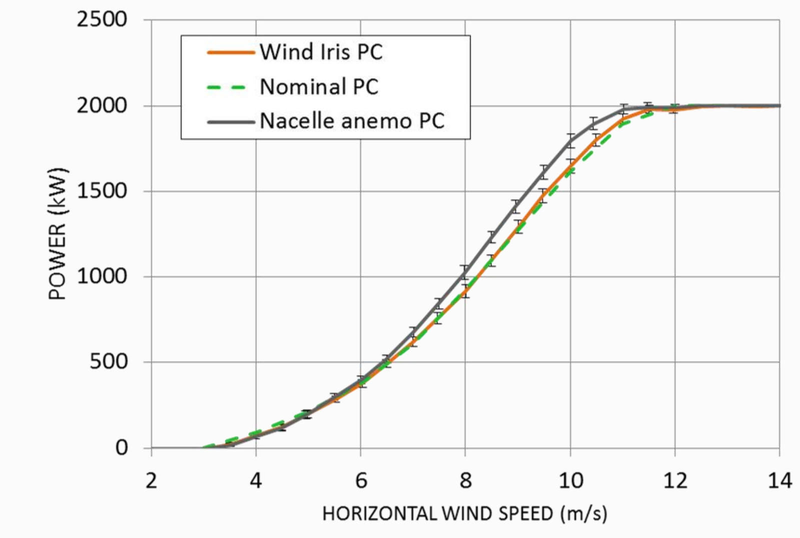
- Similar duration as for a PC
- NTF inaccuracy to free stream wind speed ranges from +8% to -13%
- Nacelle anemometers overestimate wind speed in 60% of cases

Case study

wpd windmanager

WPD uses the Wind Iris to verify and optimize wind farms. The results below are reproduced from a 6 weeks campaign [8] on a 2 MW turbine located in flat terrain in Germany. The nacelle anemometer was found to underestimate the wind speed by 6% compared to the free wind, leading to an overestimation of the performance of the turbine.





Lessons learned

- ✓ Successful nacelle Lidar projects require easy to use methods for O&M teams, and collaborative approach between involved parties
- ✓ For power production increase focused projects, a preliminary study of SCADA data is recommended to target the right turbines and yield greater benefits
- ✓ Basing the selection of underperforming turbines only on nacelle anemometer power curves increases the likelihood of encountering an NTF problematic
- ✓ Complex terrain tends to generate a higher number of under-performance problems such as sector dependent yaw misalignment
- ✓ No particular trend has been identified with respect to the behavior of different turbine models and makes

References

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