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Nacelle LiDAR for turbine performance analysis in complex terrain

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Introduction

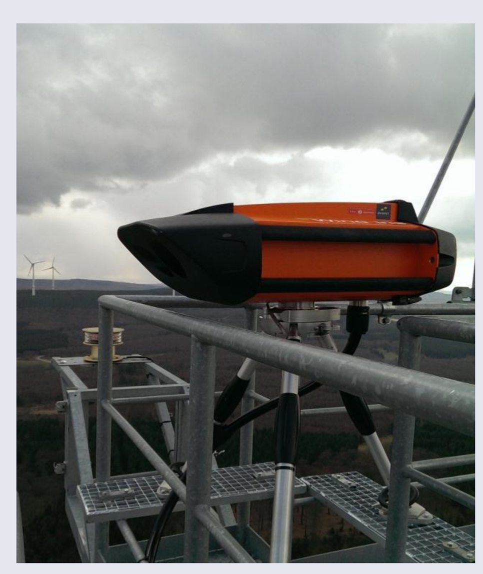
Accurate assessment of wind turbine performance in complex terrain is recognized to be a costly and technically challenging task. Using turbine mounted anemometry usually results in 8 to 15% AEP uncertainty, while using site calibrated meteorological masts is expensive, but still results in 4 to 8% AEP uncertainty.

In this context, nacelle LiDAR is increasingly seen as a promising cost effective yet accurate alternative [1]. By always measuring in the turbine inflow, sector by sector analysis can be performed, and campaign time can be reduced. Forward facing pulsed LiDAR are also now well proven to measure accurately longitudinal turbulence [2,3].

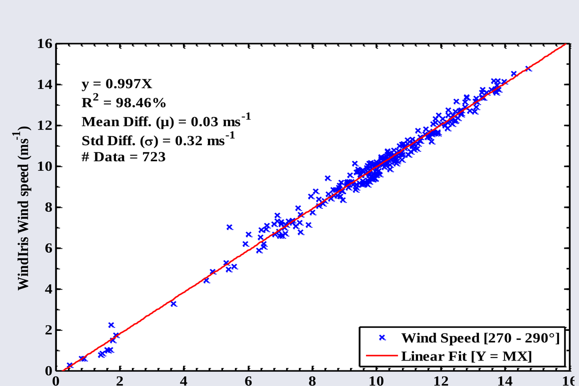
The objective of the present work is to explore and validate the use of Wind Iris nacelle LiDAR to understand finely power performance for a large rotor onshore wind turbine installed in complex and forested terrain. Yaw misalignment and nacelle transfer function are first investigated. Finally the effects of turbulence intensity on the wind turbine's performance are analyzed.

Campaign overview

A Wind Iris nacelle based LiDAR was installed on an Enercon E-126 turbine located in a complex terrain and forested area. The installation took 6 hours to complete. The three month campaign started in April and ended in June 2014.



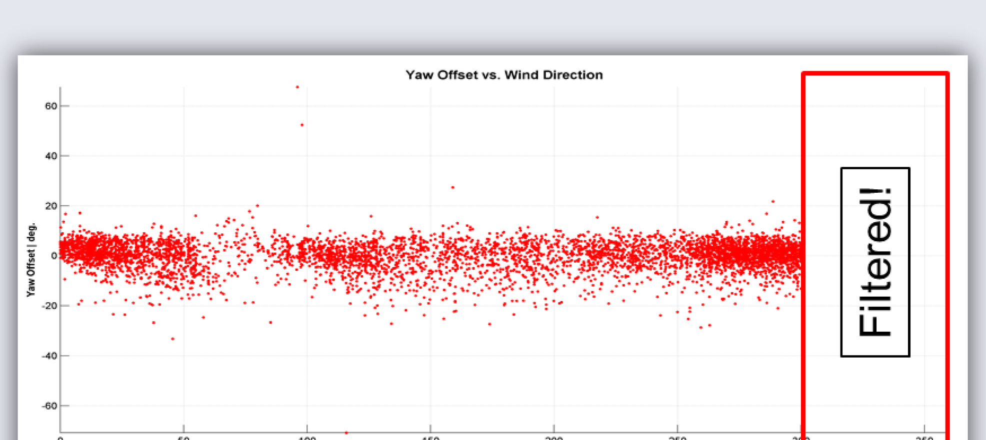
During this campaign, the Wind Iris was also validated against a WINDCUBE v2 installed 2.3D (290m) away from the turbine. The validation showed good results with slope near to 1 and R² close to 0.99 (to be presented in a later publication).

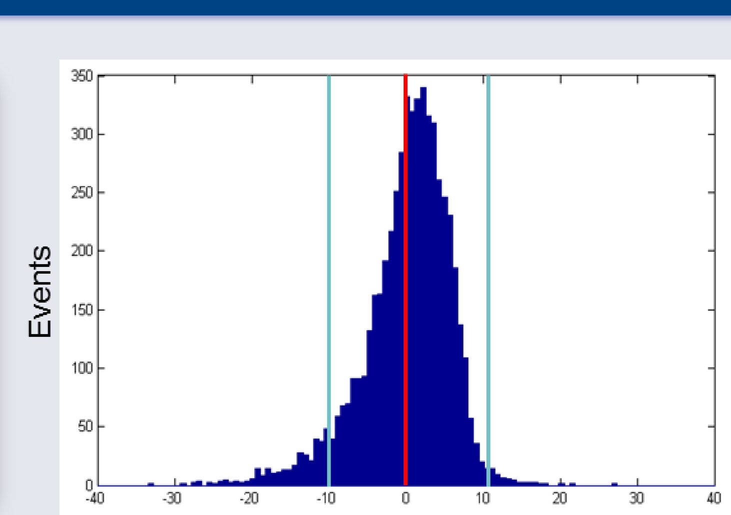


In order to support the analysis of the data derived from multiple measurement sources, a procedure was developed for automated data preprocessing. The result provided a high quality, properly synchronized dataset for further analysis.

- Pre-process Turbine Data (1Hz → 10-min reduction)
- Import Turbine 10-min Data
- Import Wind Iris 10-min data (for specific horizontal location)
- Compare time stamps and reject inconsistencies
- Filter Wind Iris data according to defined criteria
- Filter Turbine data according to defined criteria
- Produce dataset for comparisons (both filters combined)
- Generate results (power curve, turbulence, yaw offset, NTF)

Yaw error



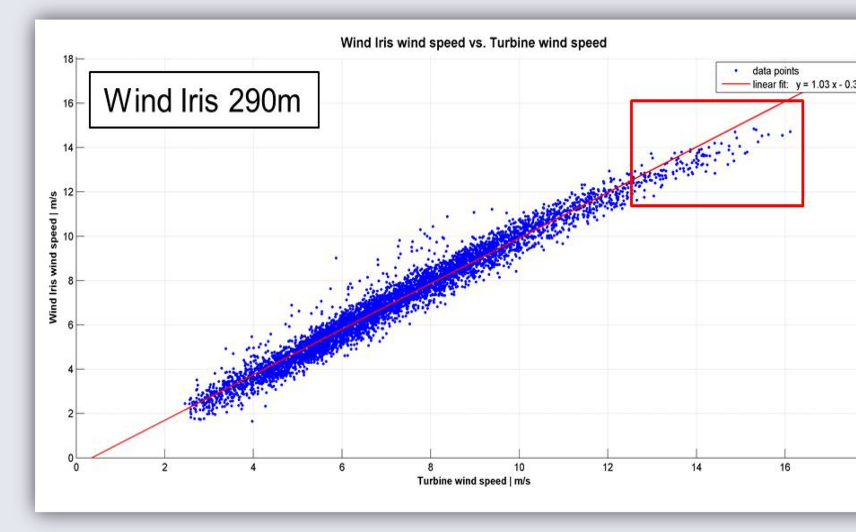


Within a few days, it was identified that the turbine did not suffer from significant yaw misalignment. The yaw offset distribution was found to be skewed, which in the present case is reflected by a higher number of large negative offsets than large positive offsets were observed.

Nacelle Transfer Function (NTF)

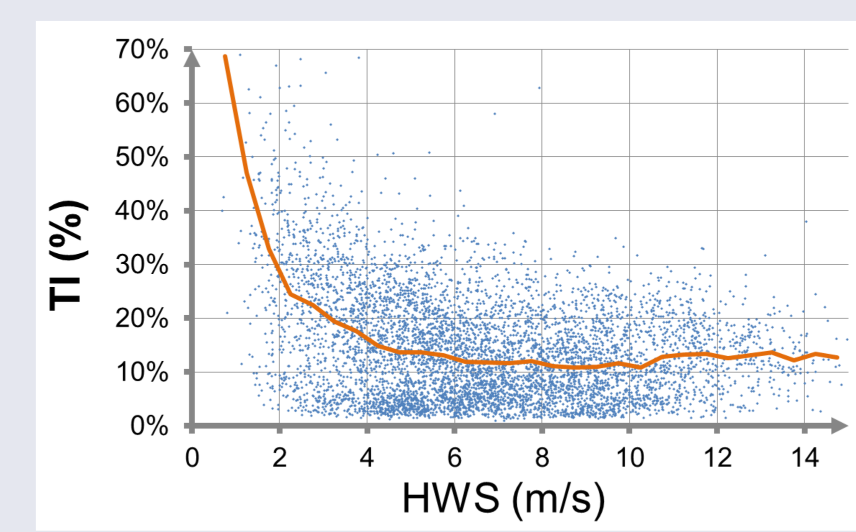
The validity of nacelle anemometer (NA) power curves were investigated by building the NTF between the free stream wind speed measured at 2.3D with the Wind Iris and that measured locally by the nacelle anemometer

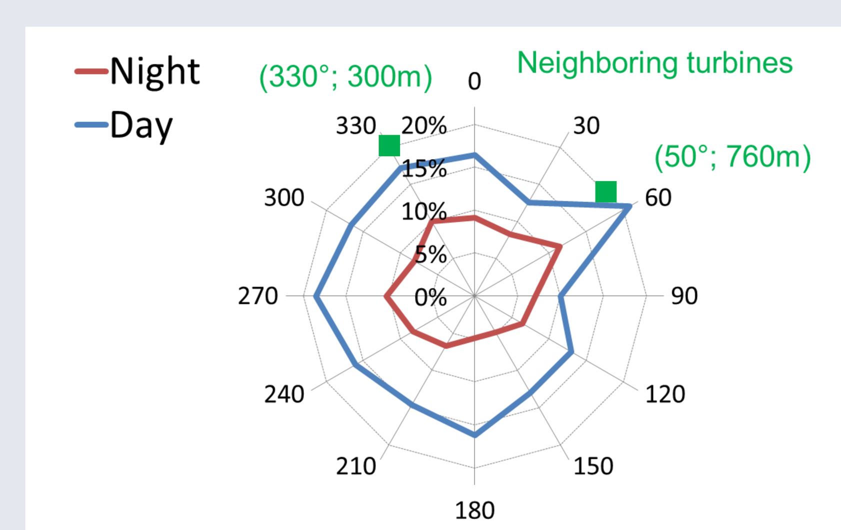
Below 10m/s, the NA is observed to slightly underestimate the wind speed (up to -0.2 m/s). Above 12 m/s, a stronger nonlinear deviation is observed. More data points would be required at higher wind speed to confirm the magnitude of this effect.



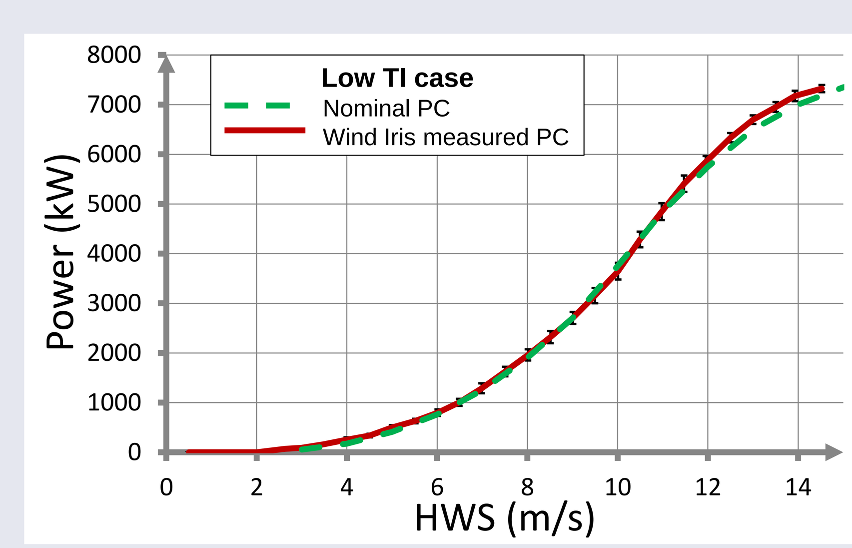
Effects of Turbulence on the Power Curve

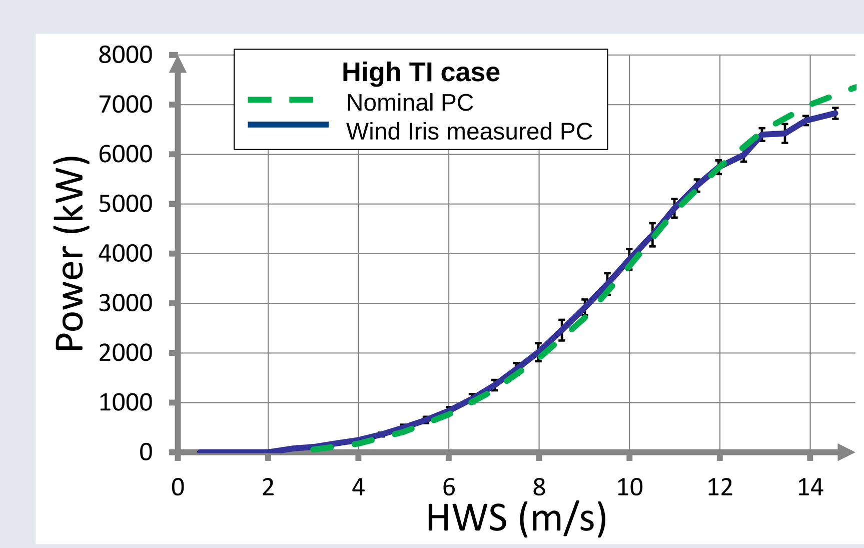
During the campaign, measured turbulence intensity (TI) distribution was in line with what was obtained during the Wind Resource Assessment. The average TI is was found to be 12.4%.





As could be expected from thermal effects during the spring season, TI is on average higher during the day (13.4%) than the night (8.6%). A day/night TI rose was built to analyze this for each sectors. It allows to visualize a wake effect for a similar size turbine located 760m away but not for a smaller one closer, at 300m.





To investigate the effects of TI on the Power Curve (PC), high TI (TI>12%) and low TI (TI<12%) categories were created. For low TI, the measured PC was slightly above the nominal PC at high wind speed. However, for high TI, although the PC is slightly above the nominal PC from 6 to 11m/s, the turbine is underperforming at high wind speeds.

Conclusion

- The Wind Iris was validated in complex and forested terrain on a large rotor turbine against a ground-based WINDCUBE v2
- Yaw analysis showed that the turbine did not suffer from misalignment
- NTF investigation showed that the nacelle anemometer power curves would tend to overestimate the power curve, especially above 12 m/s
- The Wind Iris allowed the project team to understand finely wind turbine performance as a function of Turbulence Intensity.

References

[1] A Case Study on Using a Nacelle LiDAR for Power Performance Testing in Complex Terrain. M. Quick. DNV-GL, 2013.
[2] Nacelle LiDAR for power curve measurement: Avedøre campaign. R. Wagner. DTU Wind, 2013.
[3] Procedure for Nacelle-Mounted LIDAR validation: Conclusions on 1Hz sampling rate analysis. J. Armet. Alstom Wind, 2013.

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