Turbine mounted pulsed LiDAR for performance verification in complex terrain

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Introduction

- The accurate information on the local wind field and its temporal and spatial variations is a crucial parameter in wind energy business.
- Operational use of Doppler Wind LiDAR (Light Detection And Ranging) systems in simple terrain has been extensively proven and are well accepted.
- Accurate assessment of wind turbine performance in complex terrain is recognized to be a costly and technically challenging task.
- In this context, a turbine mounted pulsed multi range LiDAR is increasingly seen as a promising cost effective yet accurate alternative [1] compared to traditional meteo masts.
- The objective of the present work is to explore and validate the use of a turbine mounted pulsed multi range LiDAR to better understand power performance for a large rotor onshore wind turbine installed in complex and forested terrain.
- High resolution wind data from multiple measurement sources leading to a high quality, synchronized data set for further analysis.

Campaign overview

Fig.1: WINDCUBE® v2 ground based LiDAR Equipped with FCR™ (Flow Complexity Recognition)

Specially adapted to wind energy requirements remote sensing systems as the Doppler Wind LiDAR Systems (WINDCUBE® v2 and WIND IRIS) are capable of measuring the wind field with high frequency, high accuracy (~ 1%) and good data availability.
The turbine mounted LiDAR (WIND IRIS) was installed on a turbine within a wind park (Ellern, Hunsrück) located in a complex terrain and forested area [5]. 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 ground based LiDAR (WINDCUBE v2) installed 2.3D (290m) away from the turbine. Using simultaneous measurements in all sectors at short and long ranges, several topics are investigated such as the effect of wind sector and turbulence intensity on wind turbine power curve, yaw and nacelle transfer function. It is shown that the WIND IRIS allows for faster evaluation as more wind sectors become available.

Fig.2: WIND IRIS, turbine mounted pulsed multi range LiDAR installed on turbine roof

SETUP, EXPERIMENTAL DATA, and RESULTS

The accuracy of the turbine mounted LiDAR was validated against a ground-based WINDCUBE v2 LiDAR located ~290m away. A high quality correlation between the two units is obtained in common measurement volume, which corresponds to the wind sector where the turbine is facing the location of the ground based LiDAR. Forward facing pulsed LiDAR are also now well proven to measure accurately longitudinal turbulence [2,3].

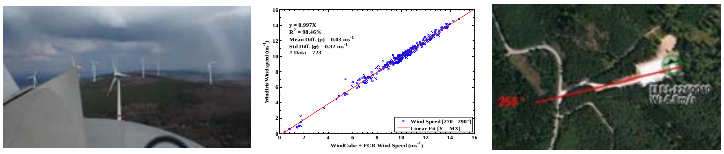

Fig.3: Windpark Ellern, Correlation WINDCUBE v2 and WIND IRIS, Location WINDCUBE v2 and WIND IRIS

The main goal of the project was to measure wind speed, wind speed variation, wind direction and power output of a 7.5 MW turbine in complex terrain in the wind park Ellern with state-of-the-art and innovative measurement techniques [4,5]. In order to support the analysis of the data derived from multiple measurement sources, a procedure was developed for automated data preprocessing.

1. Pre-process Turbine Data (1Hz → 10-min reduction)
2. Import Turbine 10-min Data
3. Import WIND IRIS 10-min data (for specific horizontal location)
4. Compare time stamps and reject inconsistencies
5. Filter WIND IRIS data according to defined criteria
6. Filter Turbine data according to defined criteria
7. Produce dataset for comparisons (both filters combined)
8. Generate results (power curve, turbulence, yaw offset, NTF)

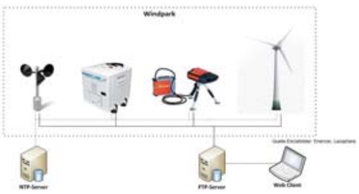

Fig.4 Multiple data sources to be combined and synchronized

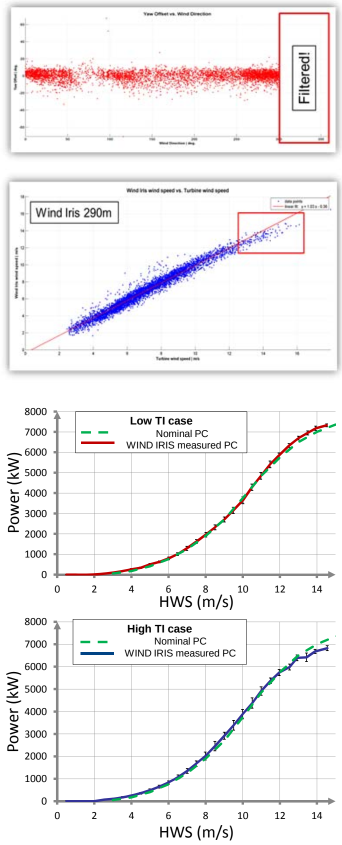

Fig.5: Graphics for YAW Offset, NTF, Low and High TI case

YAW Offset

Within a few days, it was identified that the turbine did not suffer from significant yaw misalignment.

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. Above 12 m/s, a stronger nonlinear deviation is observed.

Effects of Turbulence

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

To investigate the effects of TI on the Power Curve (PC), low TI (TI<12%) , and high 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.

CONCLUSIONS

- The WIND IRIS was validated in complex and forested terrain on a large rotor turbine against a ground-based LiDAR 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

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