Evaluation of wind turbine performance using WINDCUBE with FCR™ and Wind Iris nacelle-mounted LiDARs in complex terrain

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Abstract

Based on IEC 61400-12-Ed.2 standard requirements, remote sensing devices have been proven to be used as a standard for power curve measurements in simple terrain. Large rotor diameter, multi MW turbines in complex terrain face completely new challenges in measuring the inhomogeneous incoming wind field across the rotor swept area using remote sensing devices. To this effect a measurement campaign was carried out using both, a ground based WINDCUBE with Flow Complexity Recognition (FCR™) software, and nacelle mounted Wind Iris on top of a 7.5 MW turbine. During the three month measurement campaign ten minute average data and one hertz real-time data were recorded with both LiDARs and the turbine SCADA as well. The effect of rotor equivalent wind speed measured by WINDCUBE FCR™ and hub-height winds as measured by both WINDCUBE FCR™ and Wind Iris will be presented. A detailed variance analysis of the power curve with respect to wind speed, shear, turbulence intensity and wake effects of neighboring turbines is performed. The effect of nacelle transfer function is observed to be significant on performance of turbines at higher wind speed. This study would provide new insights into the flow around turbines using one hertz real-time data of remote sensing instruments.

Complex Terrain Campaign Setup

Motivation:
The purpose of the campaign was to accurately estimate the power curve performance of a 7.5 MW wind turbine by Enercon. The measurements were directed towards capturing various wind regimes, in particular Turbulence Intensity (TI) estimates and their effect on the performance of the turbine. To this effect, two remote sensing devices were deployed. A nacelle-mounted Lidar (Wind Iris) and a vertical profiler (WINDCUBE V2) 2.5 D away from the turbine location (maintaining the IEC 61400-12-1 guidelines). Due to the complexity of the terrain, the WINDCUBE V2 was equipped with Flow Complexity Recognition (FCR) software. This allowed accurate estimates of wind speed and direction from WINDCUBE V2 device.

Power Curve Assessment with Wind Iris & WINDCUBE FCR

The measurements from all the three devices were used for calculating the power curve of the Enercon 7.5 MW wind turbine. The high frequency 1 second data was used to measure the Turbulence Intensity from the Wind Iris measurements and the WINDCUBE V2. The comparison between the WINDCUBE V2 with FCR and Wind Iris measurements is shown in Figure 4. The good comparison in the sector, where both the devices overlap is shown (270° – 290°). The R² between the measurements is 98.5%, which provides confidence in the measurements obtained for the campaign.

The power curve from each of the measurements is shown in Figure 5. This shows small variations in between the measurements compared to the guaranteed power curve. The difference between the measurements is shown in Table 1. The highest mean wind Speed is measured by the nacelle anemometer. The WINDCUBE + FCR shows the smallest variability compared to the WTG.

Conclusions

1. All the devices compare reasonable well amongst each other.
2. The WTG PC correlates less closely with WEC power in Complex terrain.
3. NTF investigation showed that the nacelle anemometer power curves would tend to overestimate the power curve, especially above 12m/s,
4. Day time and night time comparison show significant variability in various wind regimes.

The overall conclusion is that a multi-range turbine mounted LiDAR is a serious and competitive tool to investigate wind turbine performance in complex terrain, by providing a wide number of answers and a simplified and cheaper set-up.

References