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Turbulence intensity comparison from lidar and spinner anemometer measurements in an offshore windfarm

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Key words

Performance Transparency Project (PTP) • Nacelle based lidar • Spinner anemometry • Spinner Transfer Function • Turbulence Intensity • Offshore wind farm • Performance Monitoring • Induction zone

Abstract

Precise wind speed measurements to calculate the turbulence intensity (TI) at the turbine location are crucial for meaningful load investigations necessary for Residual Useful Lifetime calculations (RUL)[1] and can improve wake models [2] or wind farm control strategies.

The Performance Transparency Project (PTP), funded by EUDP (project partners ROMO Wind and DTU Wind Energy) [3] has produced more than one year of data from a four-beam nacelle lidar and multiple three-sensor iSpin® systems (spinner anemometer produced by Romo Wind) in an offshore wind farm.

Previous results of TI measurements obtained from the spinner anemometer showed good correlation to mast measurements [4]. In this work, we first correlate lidar measurements to spinner anemometer measurements at the reference turbine, where the latter were obtained by applying three different calibration paths. In the next step, we select and apply the best calibration path to data sets of neighbouring turbines and compare TI measurements for free-wake condition to lidar data. Finally, directional TI roses are presented for eight turbines equipped with three-sensor iSpin® systems in the wind farm, showing effects of ambient and wake-induced turbulence effects.

Methods

We define three different calibration paths on how to obtain corrected 10-minute statistics from 10Hz data. To get calibrated inflow angle and wind speed iSpin® measurements, correction factors (k_α and k_1) are applied following [6] and rotor induction effects are accounted for by utilizing the Spinner Transfer Function (STF) that was established at the reference turbine as previously shown in [7]. The calibration steps are applied in different order as shown in Figure 01.

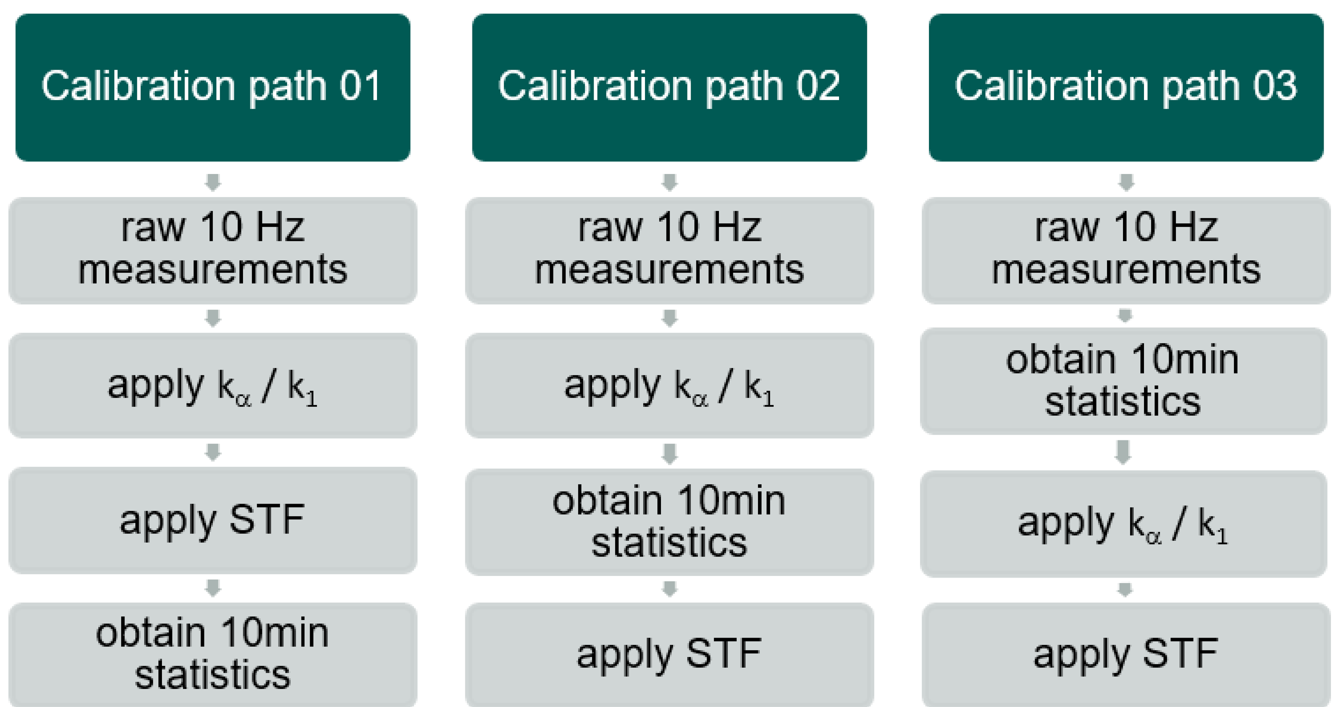

Fig 01: Different calibration paths to obtain 10-minute statistics from 10Hz measurements of the spinner anemometer applying k_α / k_1 calibration factors and the STF.

Results

Figure 02 displays correlations for wind speed and standard deviation measurements obtained at the reference turbine. The plot shows good compliance between spinner anemometer and lidar wind speed. However, the standard deviation differs depending on the selected calibration path (CP). Since the STF is obtained using 10-minute data, it seems plausible to first obtain 10-minute statistics and then apply STF, as done in CPs 02/03. This aligns well with previous results, where lidar results underestimate the standard deviation [8].

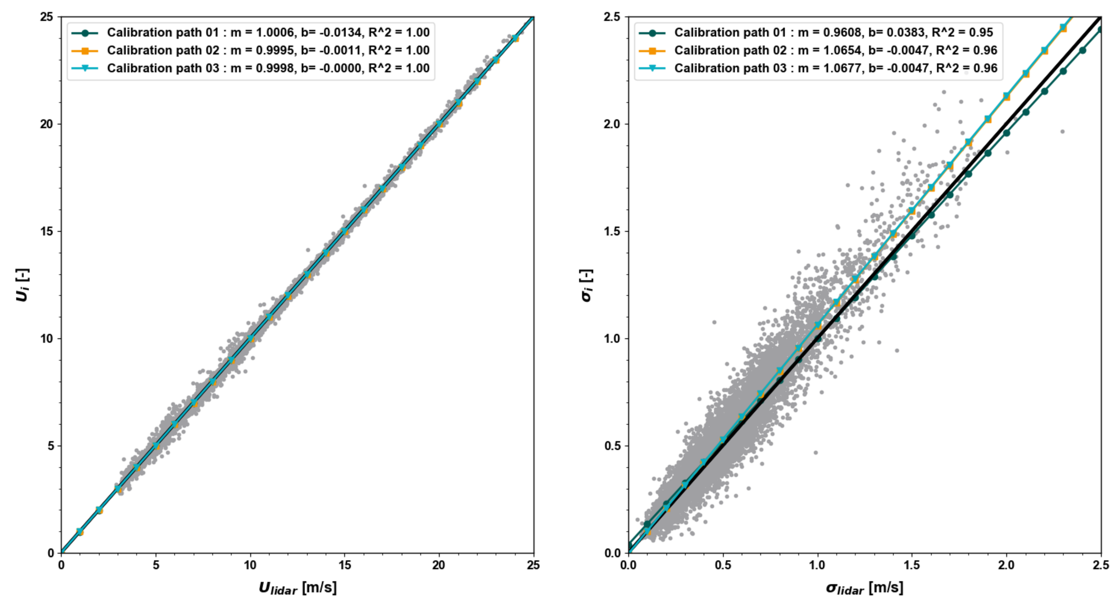

Fig. 02: Windspeed (left) and standard deviation correlation (right) obtained from lidar and spinner anemometer measurements at the reference turbine for three defined CPs. Dark grey dots represent correlation results including spinner anemometer measurements calibrated according to CP 03.

The CP 03 is applied to the data sets of neighbouring turbines of the identical turbine type. Figure 03 shows the TI comparison between the lidar and the spinner anemometer in wake-free condition. The difference between spinner anemometer and lidar TI is within ±1% for at all four turbines.

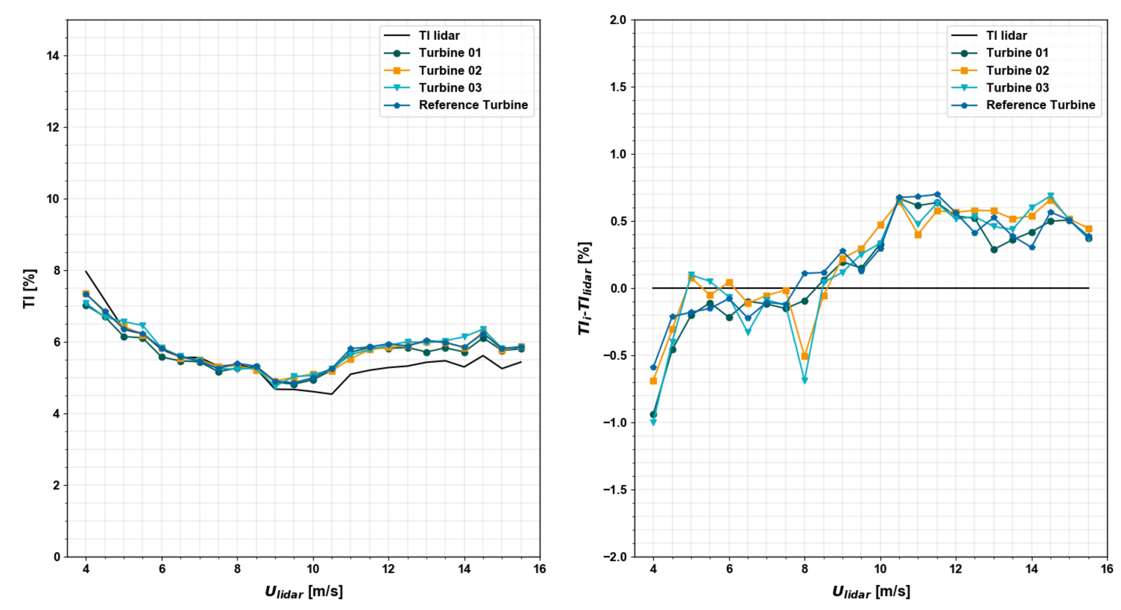

Fig. 03: TI comparison for neighbouring turbines operating in wake-free condition.

The final plot presents TI roses for eight turbines in a large wind farm. The measurements consist of ambient and wake-induced turbulence intensity, were wake-induced effects are best visualized as plots in the wind farm layout.

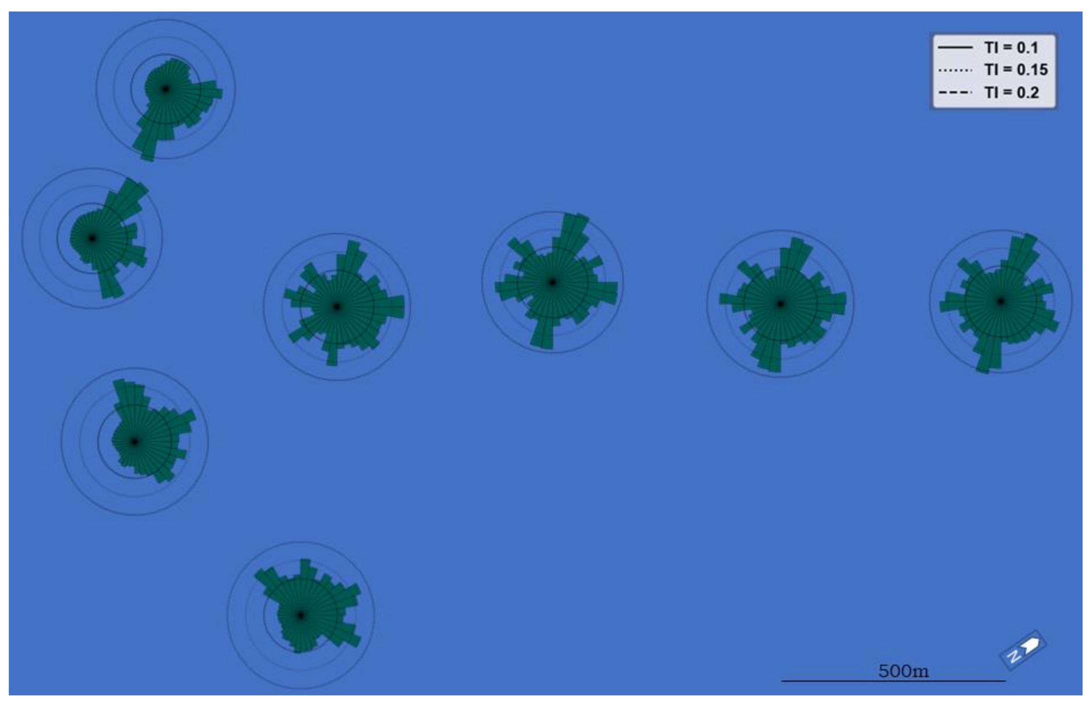

Fig. 04: Turbulence intensity roses for eight turbines with effects of ambient and wake-induced TI. Reference values of turbulence intensity are shown and defined according to the legend.

Conclusions

- Calibrated wind speed measurements from spinner anemometer align well with lidar measurements, whereas standard deviation correlation show a bias.
- Turbulence intensity measurements for wake-free wind direction show a difference of ±1% compared to lidar measurements.
- Spinner anemometer TI plotted as wind roses show local turbulence intensity of each turbine visualizing wake-induced turbulence intensity.

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