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Defining the wake decay constant for onshore wind farms

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Abstract

Modelling the wake effect generated by wind turbines is an essential part for calculating a wind farm's expected energy production. Operating wind turbines disturb the flow of the wind, which results in decreased production of downwind turbines.

The N. O. Jensen model is an industry standard wake model that assumes a linear expansion of the downstream wake. The only adjustable parameter in the model is the wake decay constant (WDC), which has traditionally been derived semi empirically from terrain surface roughness[1]. However, the WDC defines the expansion rate of the generated wake, and therefore can be linked to the ambient turbulence intensity (TI): high ambient turbulence leads to a faster decay of the generated wake (i.e. high WDC), and therefore to lower wake losses, and vice-versa. Since the influence of the roughness on the ambient turbulence intensity is expected to be less significant at higher heights, the traditional roughness-based WDC values are rather uncertain for the currently used hub heights [2,3,4].

This poster presents the results of a comparison between measured and modelled wake losses based on different WDC values.

Objectives

The main objective is to provide practitioners with insights on how the choice of WDC influences the estimated wake loss when using the N. O. Jensen model in windPRO for sites located in forested and hilly terrain.

Methodology

Three years of operational data from two wind turbines located at a distance of 7.8D in hilly and densely forested terrain have been analysed. The turbines have a hub height of 90 m, a rotor diameter of 45 m and a rated power of 2 MW. The operational data was filtered for icing events, turbine standstill and out of range measurements. The wake sector 265° - 315° has been selected by investigating the relative power deficit of Turbine 2 and Turbine 1 (Figure 2). The predominant wind direction at the site is southwest.

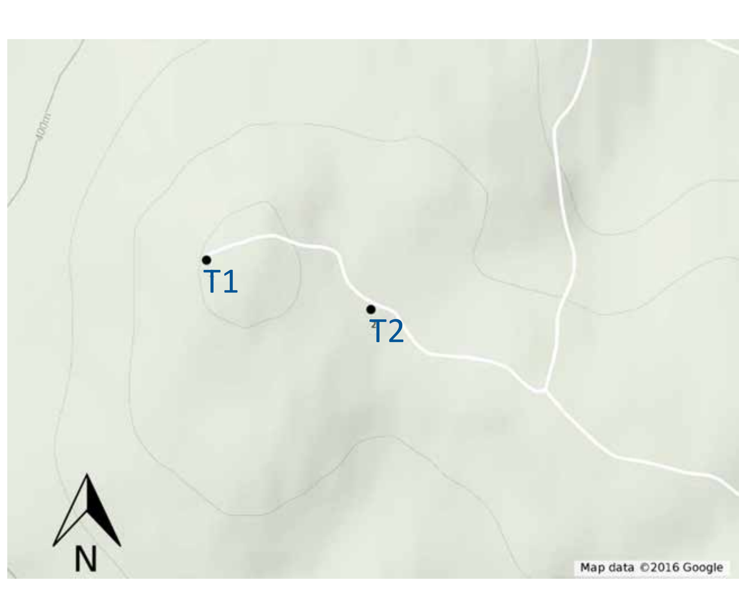


Figure 1: Partial Farm Layout

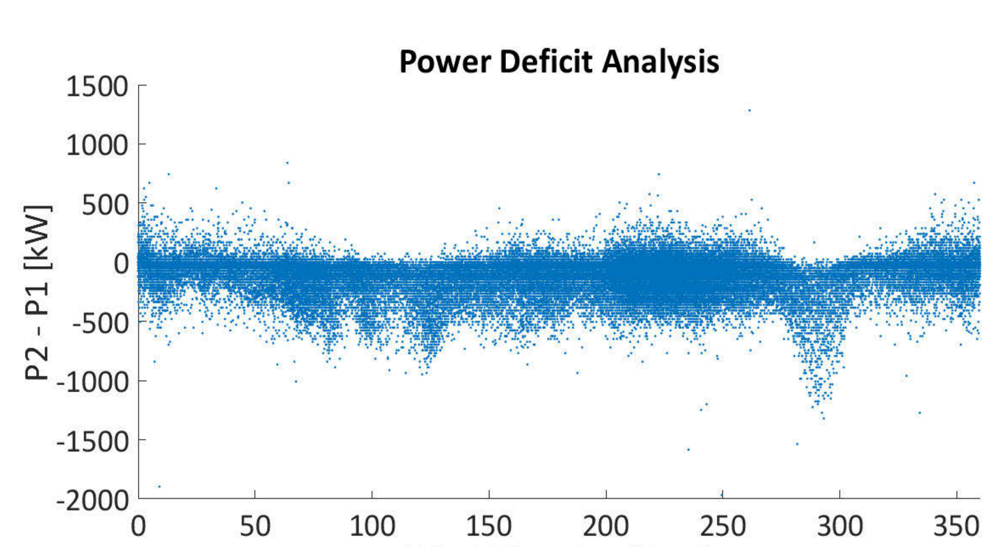


Figure 2: Observed Power Deficit of Turbine 2 relative to Turbine 1

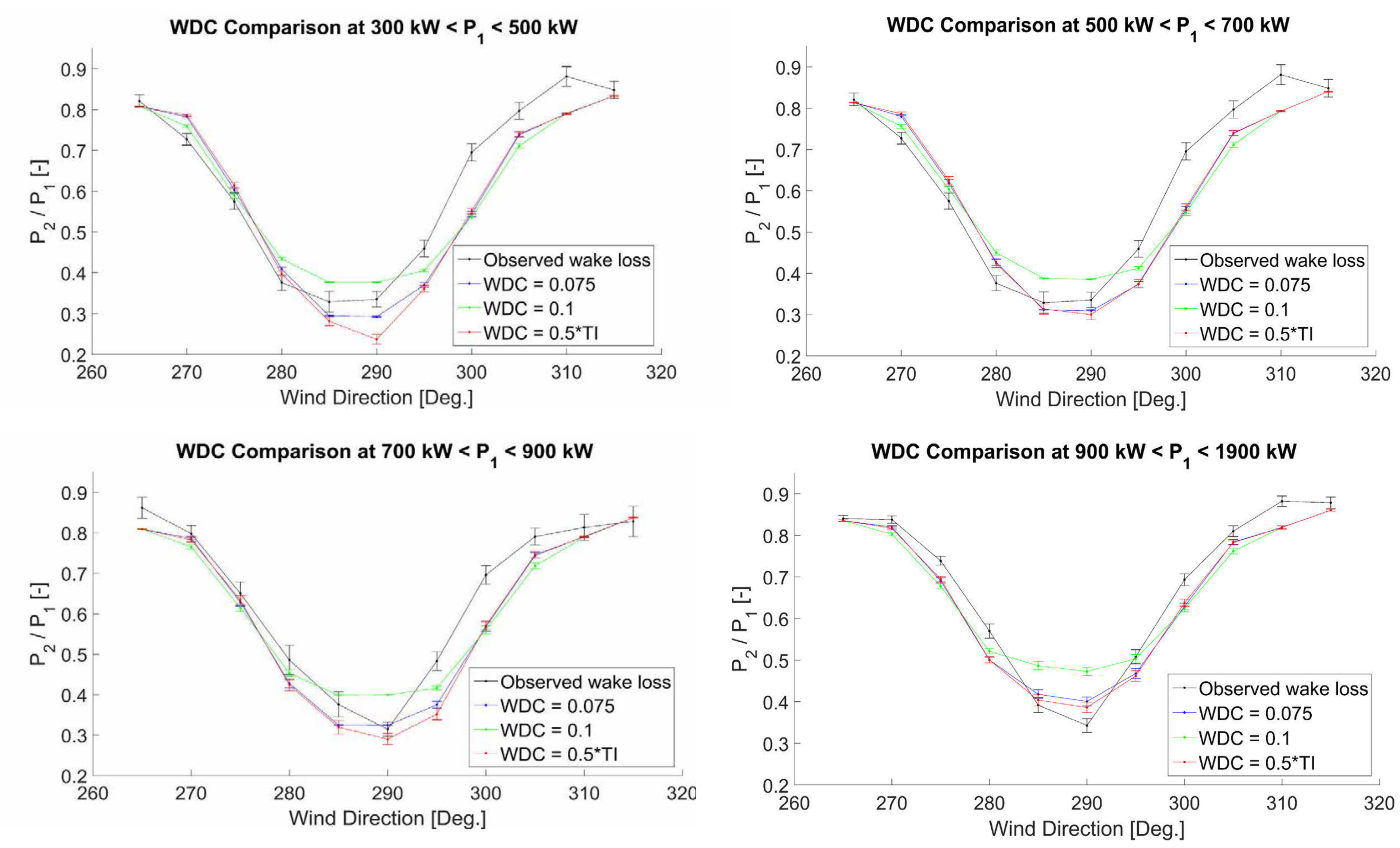
windPRO simulations have been conducted in the time domain with the EMD 2005 Jensen model implemented in the Time series based PARK module. Nacelle anemometer data of Turbine 1 was used as input data for the simulations.

The following three cases were simulated:

- WDC = 0.075
- WDC = 0.1
- WDC = 0.5 * TI

The power deficit was binned with 5° resolution between 265° and 315°. Furthermore, only the time periods when the wake of T1 significantly impacts the production of T2 have been considered. These time periods were defined as the periods when T1 is > 300 kW and the power at T2 is < 1900 kW.

Results



Figures 3 – 6: Observed and Modeled Power Deficit for different Power Intervals

Figures 3-6 show the ratio between P2 and P1 for the wake sector 265° - 315° for different power intervals. The corresponding wind speeds are shown in Table 1.

At the first interval, T1 produces between 300 and 500 kW. The observed maximum power deficit is best matched with the simulations using a WDC = 0.075. This is also the case for the intervals 500 – 700 kW and 700 – 900 kW. For the last interval, the WDC = 0.5*TI shows the best fit. Furthermore, the wake asymmetry is less pronounced for this interval.

Table 1: Wind Speed at Power Bin

Power [kW]	Wind Speed [m/s]
300	5.8
500	6.5
700	7,8
900	8,8
1900	< 11

Conclusions

The obtained results show the following:

- When P1 is set to be 300 – 500 kW, the best agreement between modelled and measured wake is obtained for WDC = 0.075.
- Considering the cases when P1 ranges between 500 – 700 kW and 700 – 900 kW, the best agreement can be obtained for WDC = 0.075. The deviation obtained using WDC = 0.5*TI is just slightly higher. Setting WDC to 0.1 still gives the largest deviation between modelled and measured wake loss (17 – 25 %).
- For the interval 900 < P1 < 1900 kW, the best fit is achieved for WDC = 0.5*TI.

Finally, the goodness of fit for the different WDC cases appears to depend on the wind speed regime. For high wind speeds, WDC = 0.5*TI seems to be more suitable, while for low wind speeds WDC = 0.075 matches the observed maximum power deficit better.

The WDC value (WDC = 0.1) derived from the site's roughness class (class 3.0) according to the standard values defined in windPRO, gives the largest deviation for this specific case.

References

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