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Impact of Ground Clearance on Wind Farm Performance

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Abstract

When designing a wind farm, a minimum ground clearance for the lower tip of a rotor is required, to lessen the turbulent impact of obstacles and vegetation. Beyond this, the hub height of a wind turbine becomes a trade-off between increased wind speed and increased cost for the tower. Reasons for choosing a low hub height may include planning restrictions or a wind profile with low shear.

In recent decades, the industry has kept the requirement for minimum ground clearance of the lower rotor tip constant, whilst the typical rotor diameter of modern wind turbines increased significantly. Little consideration has been given to interaction between the wake of a wind turbine and the ground. One reason for this is that such interaction is not often included in wind farm models and a hub height dependency of the wake effects sometimes even actively discouraged.

Objectives

A parameter study is presented, which verifies dependency on rotor ground clearance by several of the current state of the art industrial wake models and their implementations. The study verifies how wake losses are modelled for a realistic, but artificial, scenario. What are the differences in wake losses between the models? What hub height and ground clearance dependency is predicted?

Scenario investigated

We compare, for different models, the predicted wake loss on the downstream turbine of a single pair of turbines (Figure 1).

The scenario:

- Diameter: 1 D
- Spacing: 6 D
- Wind speed: 8 m/s
- Turbulence: 10%
- Hub height: 0.6-1.5D

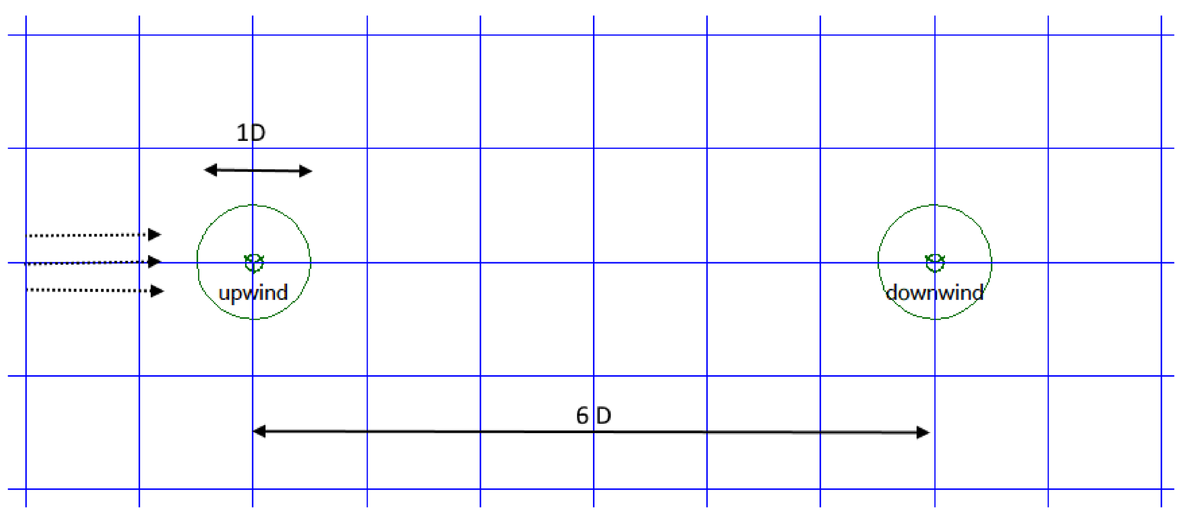

Figure 1: Scenario with two turbines. The downwind turbine is fully immersed in the wake of the upwind turbine. Spacing between turbines is 6 D.

With hub heights varying from 0.6 D to 1.5 D, the resulting ground clearance is between 0.1 D and 1 D. For example with D=100 m the ground clearance of the rotor would vary from 10 m to 100 m.

Software	Version	Model	Producer
WindFarmer	5.3.38	EV	DNV-GL
OpenWind	01.08.00.2886c	DAWEV	UL
WindPro	3.3.247	Park	EMD
WindPro	3.3.247	Park-2	EMD
WakeBlaster	1.10.10	WakeBlaster	ProPlanEn

Table 1: Details of the commercial wind farm simulation models used

Most models used in the industry today, are conceptually from the 1980's and assume an axisymmetric wake. Hub height dependency can only be added through empirical corrections.

WakeBlaster stands out, in the field of competitors, as the only representative of a new generation of 3D CFD wake models.

We verify for all models the relative wake loss and hub height dependency, or lack thereof, and compare the results for a fixed wind speed of 8 m/s (C_t =0.796).

Results

Figure 2 shows the results of the WakeBlaster 3D CFD simulation and the wake losses predicted by all models. The predictions show a spread of 35% to 58% wake loss in power for this (extreme) scenario. The hub height dependency modelled by the WB model offers a possible explanation.

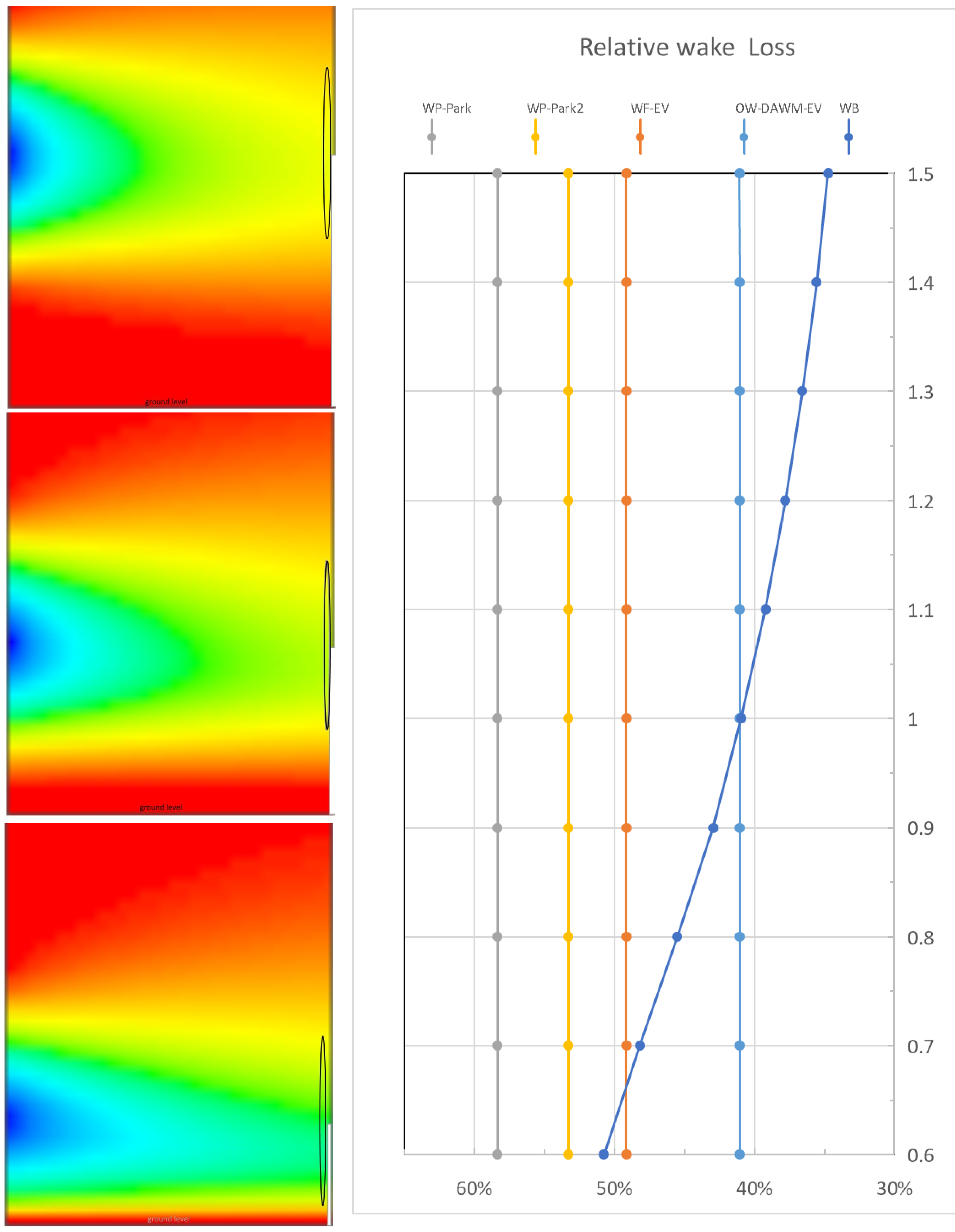

Figure 2 Hub height dependency of wake losses. Left: Simulation of the recovery of relative wind speed deficits between 2.1 and 6.0 D downstream. For a hub height of 1.5 D an axisymmetric is a valid approximation, for lower hub heights the ground interference becomes important. Right: Wake model predictions of power losses for a wind turbine at 6D, directly downstream.

Conclusions

This publication compares results obtained from different wake models. We have verified that a modern 3D CFD model like WakeBlaster has the potential to reduce the need for empirical approximations, optimise the performance and reduce the uncertainty associated with the selection of hub heights in wind farms.

A validation against wind farm SCADA data is planned and will be reported at a later opportunity.

References and Acknowledgements

1. Wind Farm Simulation – A Closer Look at the WakeBlaster Project, WindTech International, 13(6),2017
2. Operational Data Analysis with a Cloud Based Wake Model, WindTech International, 14(4), 2018

WakeBlaster is a 3D RANS solver developed by ProPlanEn. See www.wakeblaster.net for details.
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