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WAKE MODELING WITH ANALYTICAL MODELS AND ACTUATOR DISCS

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Abstract

Inside the activities of the IEA-WIND TASK 31, called Wakebench, the WindSim AS and the University of Perugia are carrying out a series of CFD simulations. Different working groups are set in the task, in particular for the wake modeling of large offshore wind farms the case of Horns Rev is analyzed. Horns Rev is a wind farm counting 80 Vestas V80 deployed on a slightly skewed array of 8 times 10.

Large arrays of wind turbines are important test-cases for the wake models and offshore wind farms need accurate wake models. The approaches in estimating the wake losses goes from simple theoretical or empirical laws to full rotor aerodynamic calculations; in between there is a range of possibilities.

In this work it is presented a comparison between power production estimates and real production at Horns Rev. The estimates are carried out with so called analytical models and actuator disc technique. The analytical models used are in particular using the approaches proposed by Katic *et al.* [1], Larsen [2] and Ishihara *et al.* [3] while the actuator disc technique is the one described in Crasto & Gravdahl [4].

Two methodologies to post-process the numerical database generated by the actuator disc simulations have been developed, reported in Crasto *et al.* [5], one is based on the use of the power curve of the machine while a second one is based on an integral over the swept area. Results from both the methodologies are presented and discussed.

References

[1] I. Katic, J. Højstrup, N.O. Jensen. *A Simple Model for Cluster Efficiency.* EWEC Proceedings, 7-9 October 1986, Rome, Italy.

[2] C.G. Larsen. *A Simple Wake Calculation Procedure.* Risø-M-2760, 1988.

[3] T. Ishihara, A. Yamaguchi, Y. Fujino. *Development of a New Wake Model Based on a Wind Tunnel Experiment.* Global Wind Power 2004.

[4] G. Crasto, A. R. Gravdahl. *CFD wake modeling using a porous disc.* EWEC2008 Proceedings, 30 March – 3 April 2008, Brussels, Belgium

[5] G. Crasto, F. Castellani, A. R. Gravdahl, E. Piccioni. *Offshore wind power prediction through CFD simulation and the actuator disc model.* EWEA Annual Event 2011 Proceedings, 14-17 March 2011, Brussels, Belgium.

The actuator disc

In an actuator disc the forces exchanged by rotor and flow are distributed over a disc on the swept area. The axial forces, causing a pressure-drop across the swept area are computed directly from the thrust coefficient of the turbine.

The Reynolds Averaged Navier-Stokes (RANS) equations are solved with a finite volume technique; the turbulence is closed by the standard k-ε model.

Some computational cells are used to exchange forces between swept area and wind. A wake is generated, including estimation of turbulence level.

*Fig. 2. aerial view of Horns Rev (*Photographer Christian Steiness).

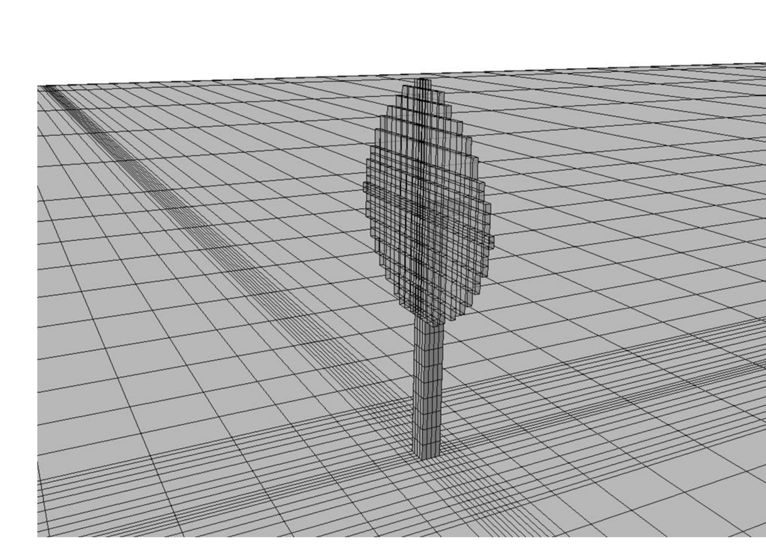
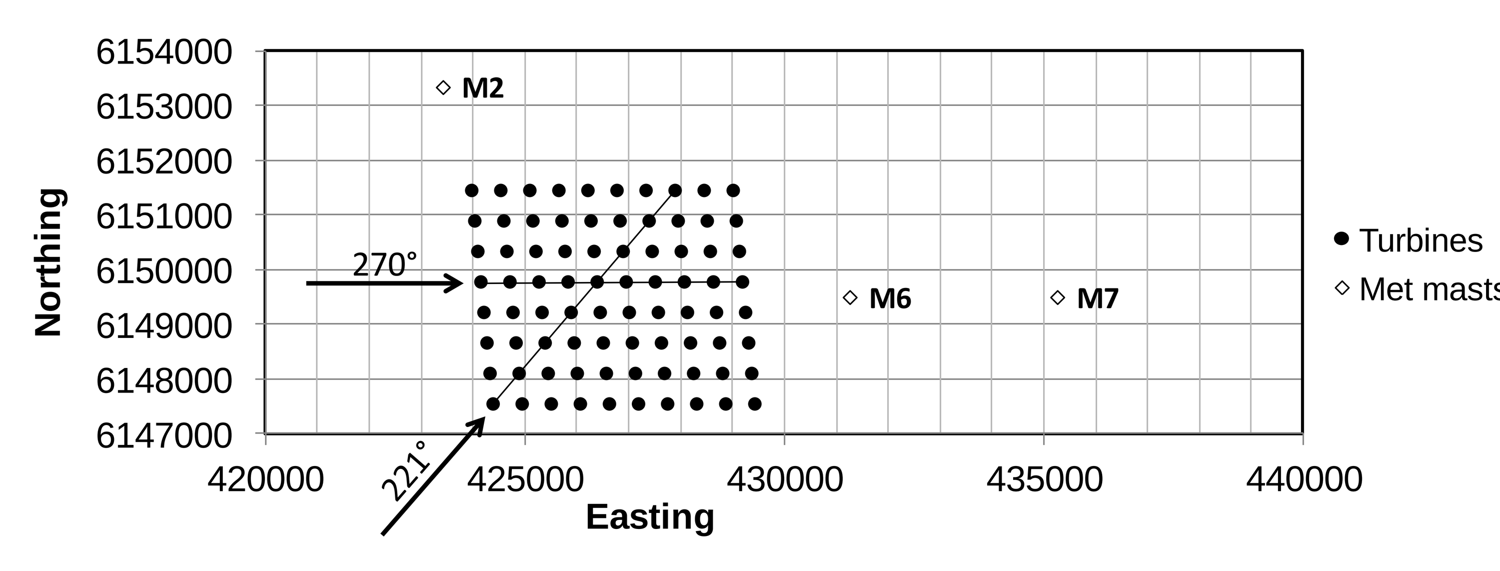
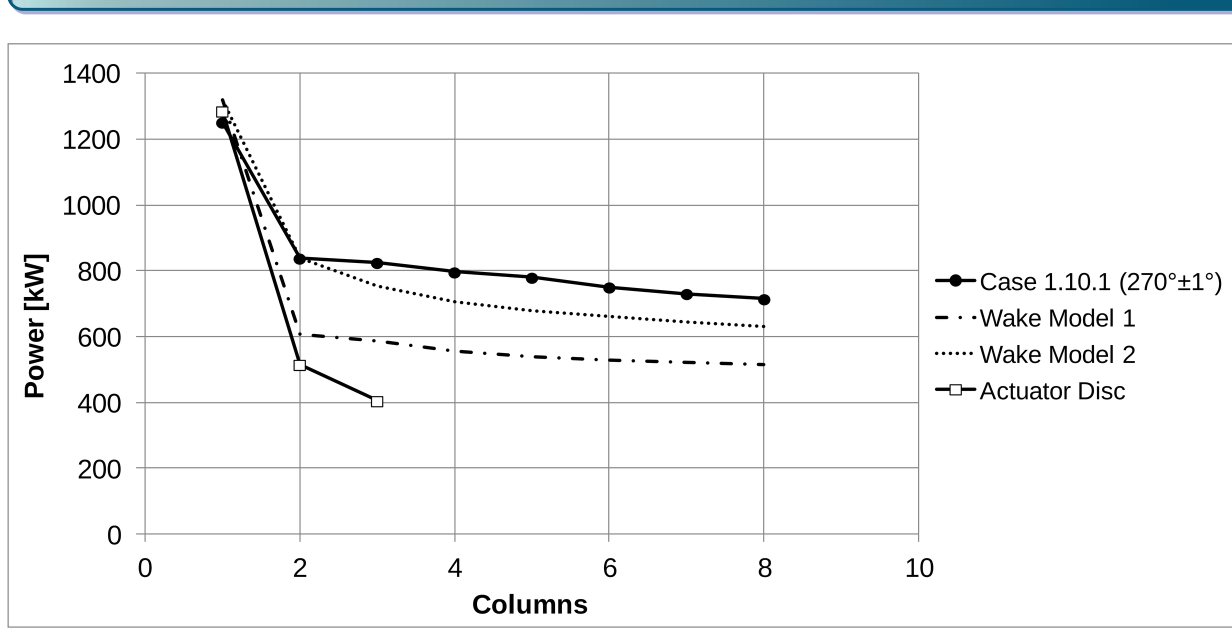


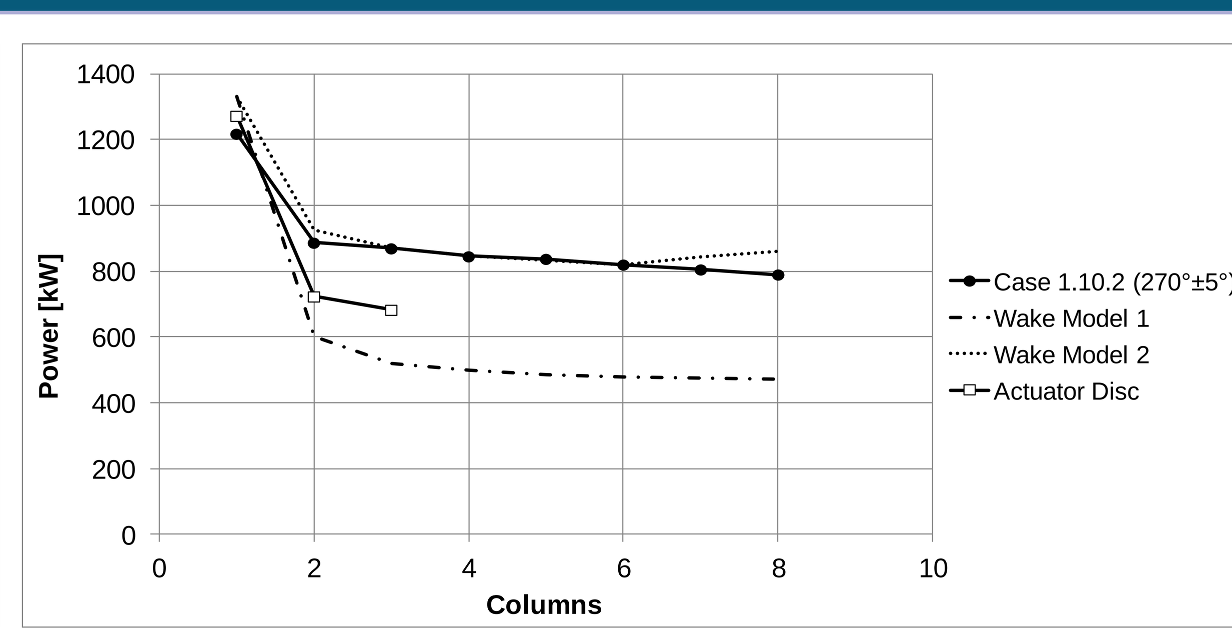
Fig. 3. a part of the computational mesh for an actuator disc.

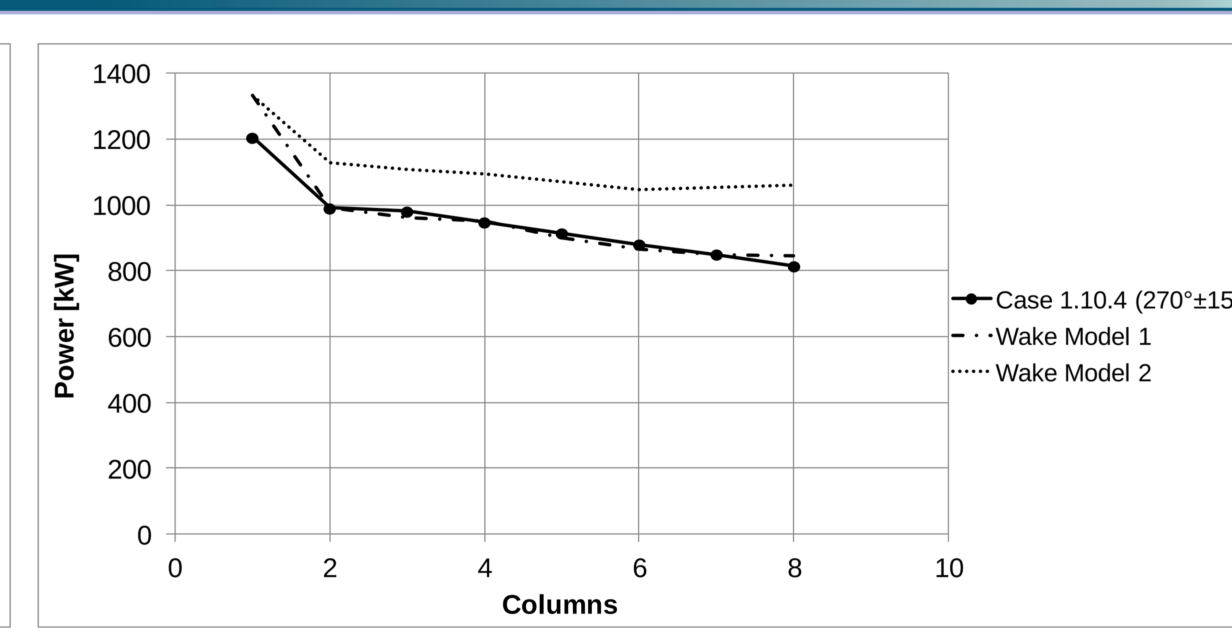
Comparison against production at Horns Rev



Cases at 10 m/s at Horns Rev







The Sexbierum test-case

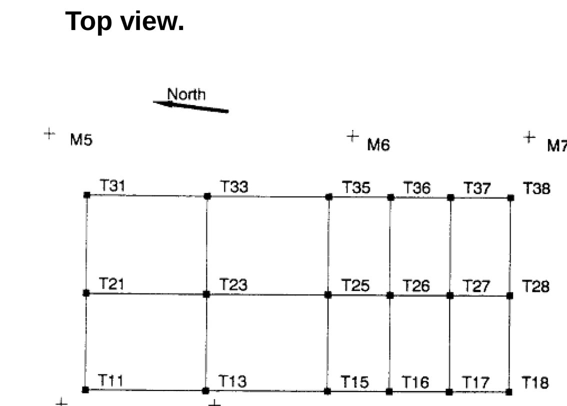
18 turbines HOLEC three-bladed machines, hub height 35 m, power of 310 kW, for a total power of 5.4 MW.

The wind farm layout is a semi-rectangular grid of 3 × 6 turbines.

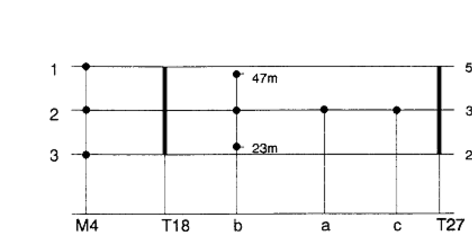
Seven fixed met-masts M1-M7 and a mobile met-mast used to measure the wake along the main wind direction T18-T27.

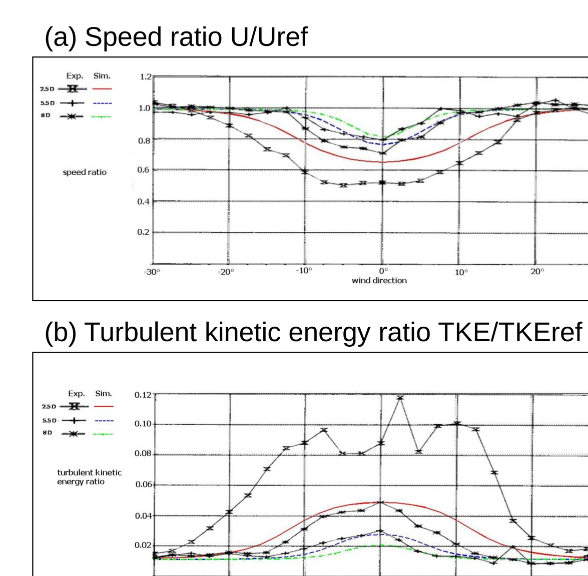
Experimental data at Sexbierum

Top view.



Side view. Mobile met-mast locations along th emain wind direction T18-T27

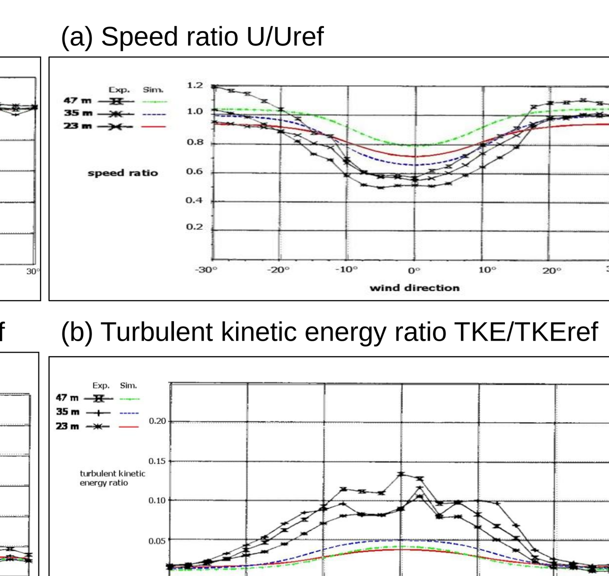




(a) Speed ratio U/Uref

(b) Turbulent kinetic energy ratio TKE/TKEref

Figure: speed (a) and turbulent kinetic energy (b) ratio profiles at hub height observed 2.5, 5.5 and 8 diameters downstream.



(a) Speed ratio U/Uref

(b) Turbulent kinetic energy ratio TKE/TKEref

Figure: speed (a) and turbulent kinetic energy (b) ratio profiles at different level observed 2.5 diameters downstream – position b, 75 m downstream of T18.

Conclusions

- Two different methods are applied:
  1. Analytical models [1,2,3] AND Actuator discs
- Testing on Horns Rev reveals a big sensitivity to sector width;
- A relevant difference in power production is observed also at first column of turbines;
- Sector width is the one showing a higher mismatch between real production and actuator disc predictions, probably the mismatch is due to a missing modeling for unsteady flows as meandering;
- Another probable source of uncertainty in the implemented actuator disc is the missing exchange of torque between rotor and wind.