CFD wake modelling for offshore wind farms

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Introduction

Modern offshore wind farms consist of large clusters of wind turbines in close inter row spacing. As a result, power losses due to wakes may reach up to 20% (Barthelmie 2009) of the total power production. For this reason it is crucial to take into account wake effects when predicting the power output of an offshore wind farm.

In this study, we will compare numerical simulations performed with analytical wake models and actuator disc models implemented in the CFD software WindSim for the offshore wind farm of Lillgrund to find the best performing model.

Methods

SCADA data of the wind turbine power output will be compared with results from numerical simulations. The numerical simulations are done by solving the Reynolds averaged Navier-Stokes (RANS) equations, and the effect of the wind turbines on the flow is taking into account by four different methods.

The different methods can be summarized as follows:

1. Old actuator disc implementation (ACD) (Crasto 2008): Uniform force distribution in accordance to equation:

$$T_{i,Uni.} = \frac{T_{tot.}}{A} = C_T \frac{1}{2} \rho U_\infty^2 , \quad (1)$$

where $T_{i,Uni.}$ is the trust value at each cell, $T_{tot.}$ is the total thrust over the surface area A of the disc, ρ is the air density, U_∞ is the undisturbed wind velocity.

2. New actuator disc implementation (Simisiroglou 2016): Improved way to calculate the forces on the disc and the power production. The forces are calculated directly from Eq. (2) and the power production is calculated at each cell of the disc.

$$T_i = -C_T\left(U_{1,i}\right) \frac{1}{2} \rho \left(\frac{U_{1,i}}{1-a_i}\right)^2 A_i. \quad (2)$$

Where $C_T\left(U_{1,i}\right)$ is a modified thrust coefficient curve, ρ the air density, $U_{1,i}$ the velocity at the disc at the individual cell numbered i, a_i the induction factor and A_i the surface area of the cell facing the flow.

3. Jensen wake model, velocity deficit as (Katic 1986).

4. Larsen wake model, velocity deficit as (Larsen 1988).

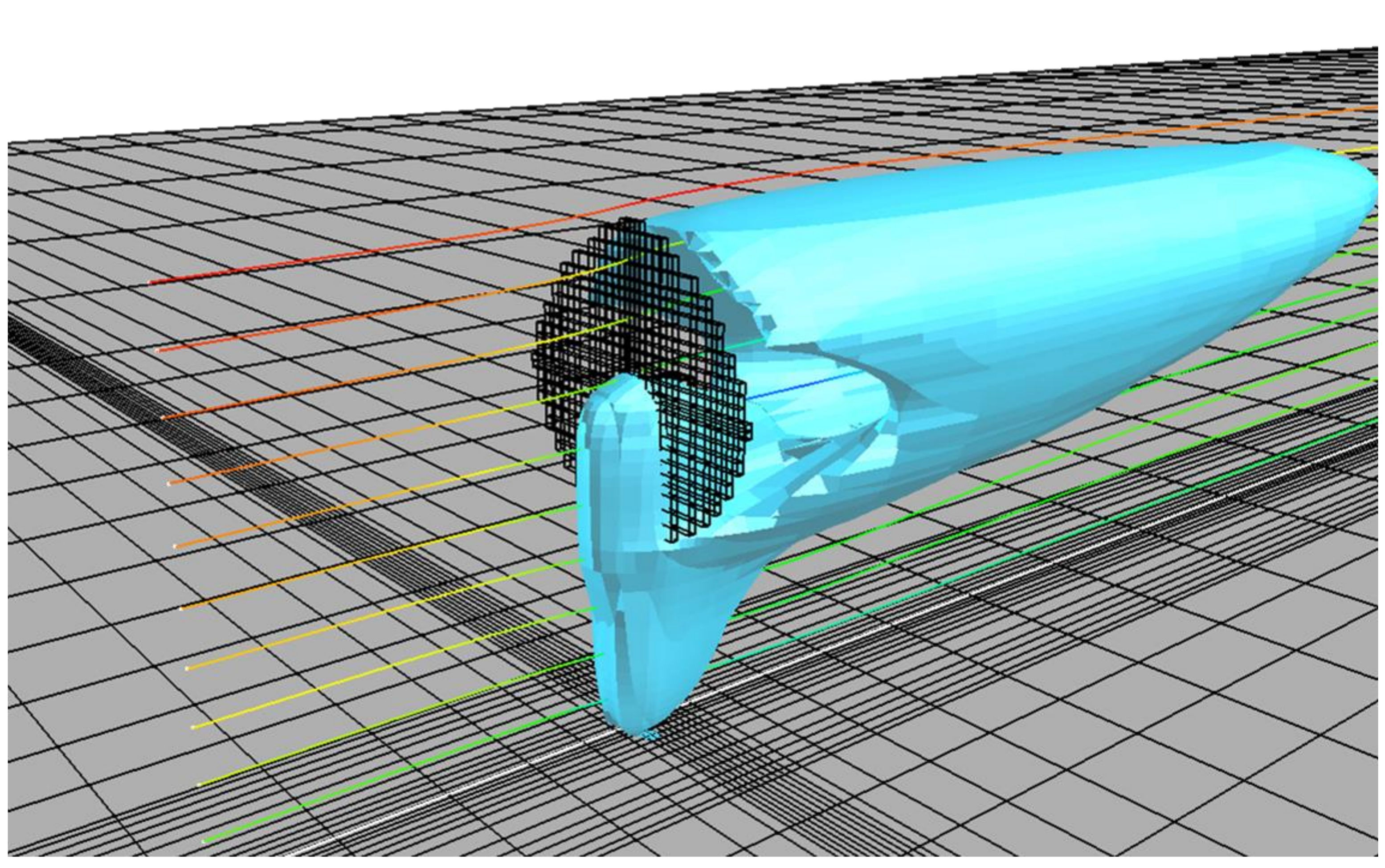

Figure 1: Actuator disc representation in the CFD code WindSim (Crasto 2008).

Results

Lillgrund is an offshore wind farm located in Öresund between Sweden and Denmark. It consists of 48 Siemens SWT-2.9-93 wind turbines with a rotor diameter of 92.6 m and a hub height of 65 m.

Figure 2 presents the wind farm layout. Records from a SCADA system of 10 min intervals are available. The directional bins are ±2.5 degrees and the velocity bin is 9.0 ± 0.5 m s^{-1}.

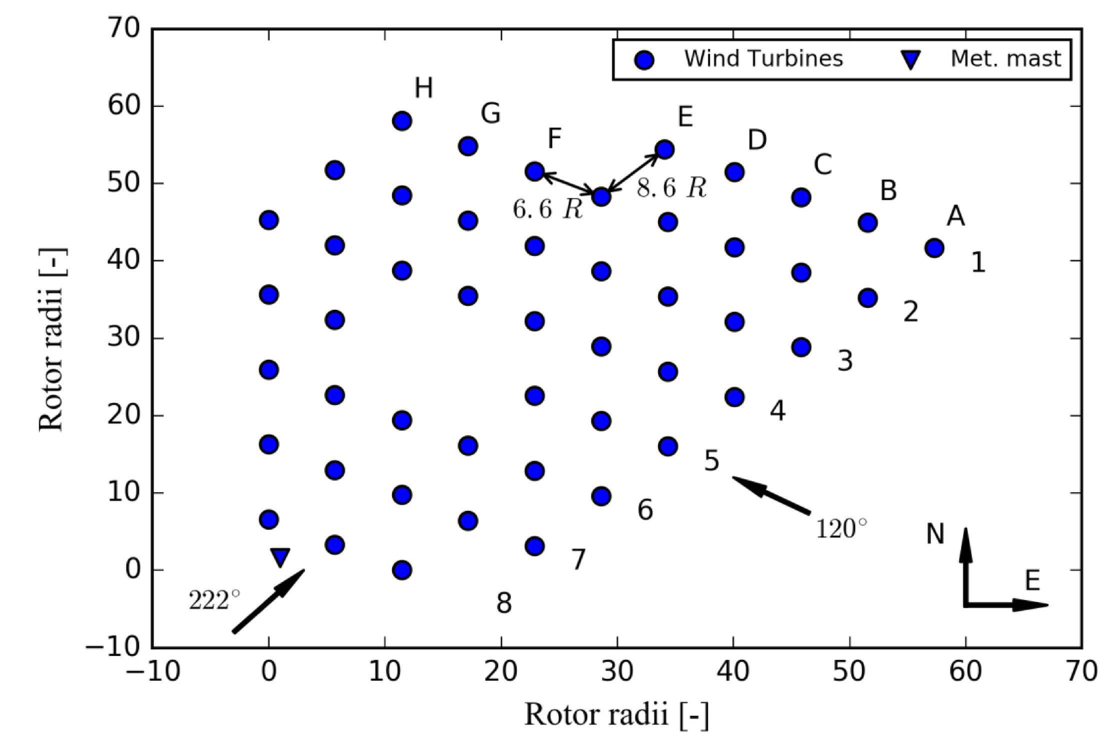

Figure 2: Lillgrund wind farm layout. R is the rotor radius.

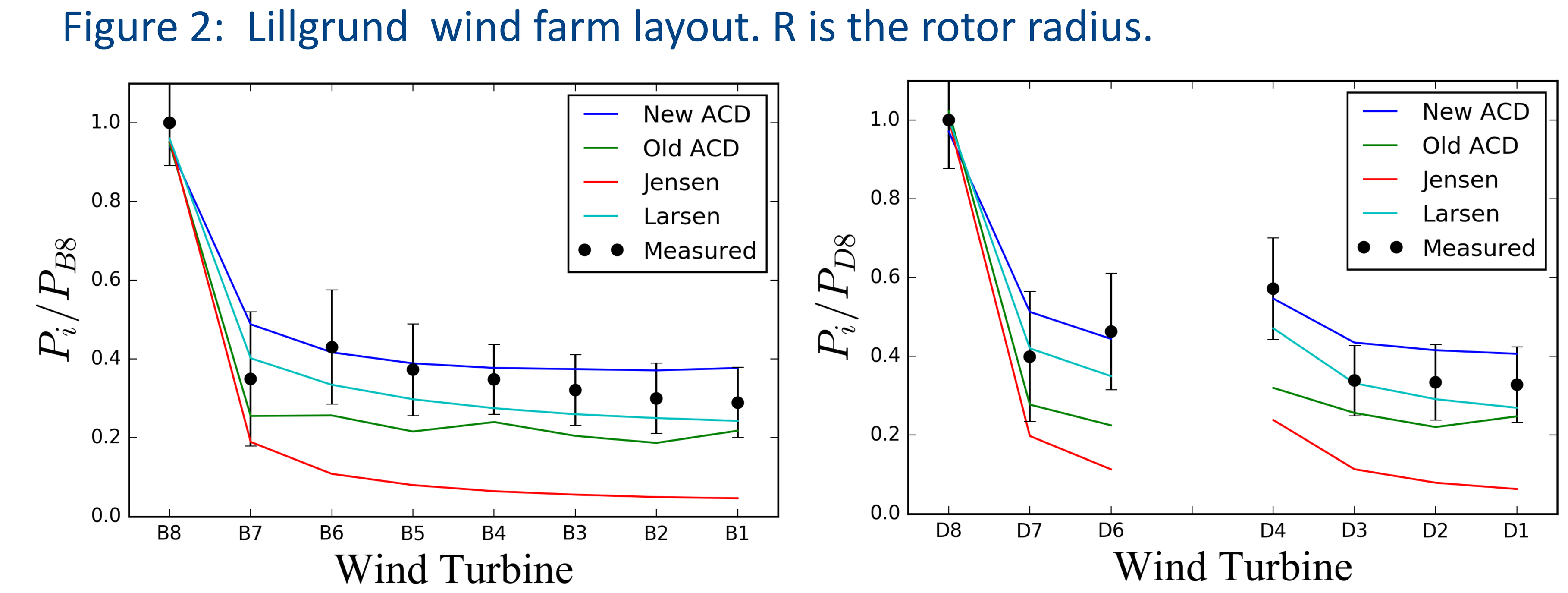

Figure 3: Normalised power production for 222 degrees direction. Left: Row B Right: Row D.

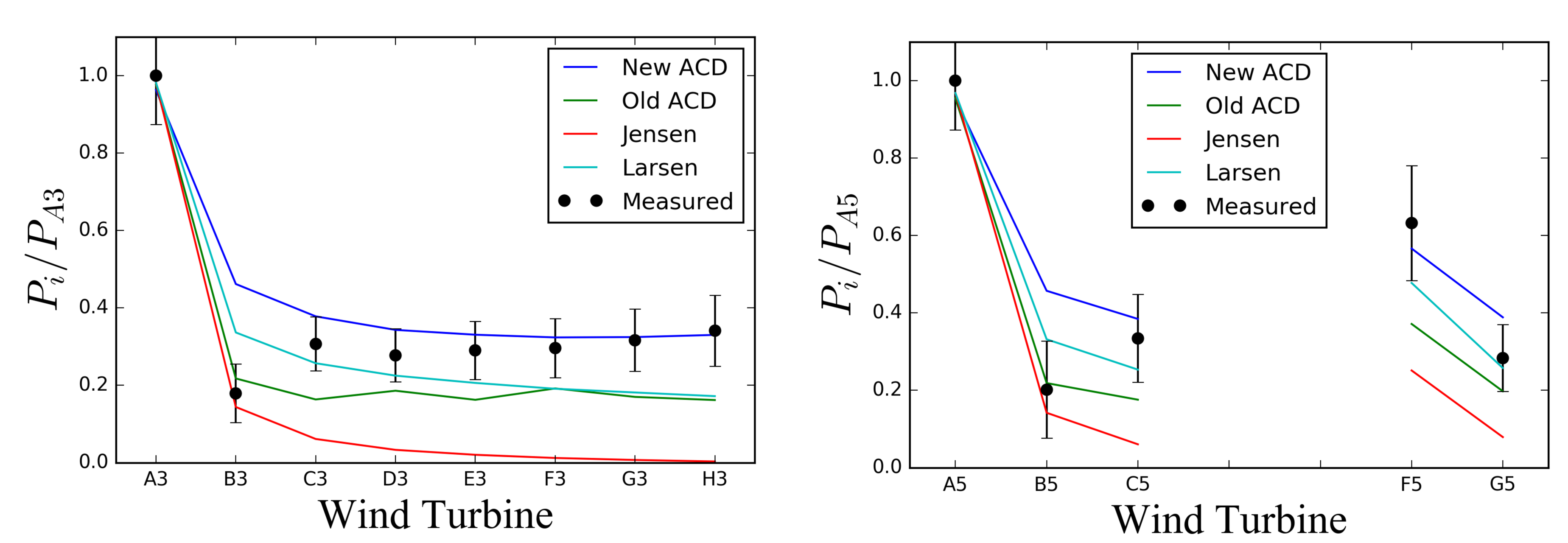

Figure 4: Normalised power production for 120 degrees direction . Left: Row 3 Right: Row 5.

Conclusions

(i) The new ACD method shows a clear improvement in the estimated power production in comparison to the old ACD method implemented into WindSim

(ii) The new ACD method considering its simplicity is capable to capture the measured power production within the error bars.

(iii) When using the ACD method the predicted power output of the row is better predicted than when using the Jensen or Larsen wake models.

References

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