Actuator Disc Wake Modelling in RANS

N. Simisiroglou[1,2], M. Karatsioris[2], K. Nilsson[2], S.P. Breton[2], S. Ivanell[2]

[1]WindSim AS, Fjordgaten 15, N-3125 Tønsberg, Norway
[2]Department of Earth Sciences, Wind Energy section, Uppsala University Campus Gotland, Sweden

Background

Accurate modelling of wind turbine wakes is essential for the design and optimization of modern wind farms. This study presents two approaches to simulate a wind turbine. This is done by employing the 1D momentum actuator disc theory (ACD) in the general purpose computational fluid dynamics software PHOENICS, developed by CHAM.

Methodology

Two ACD implementations

- Undistributed method: $$F_i = C_T\left(U_{1,i}\right)\frac{1}{2}\rho\left(\frac{U_{1,i}}{1-a_i}\right)^2 A_i$$
- Polynomial method: $$F_{pol,i} = 6\frac{F_{tot}}{A_{tot}}\left(\frac{r}{R}\right)^2\left(1-\left(\frac{r}{R}\right)^2\right)$$

Rotor sensitivity study

- The simulations are performed by imposing sheared inflow with hub height wind speeds ranging from 3 m/s up to 25 m/s.
- The computational parameters investigated are; the resolution of the domain, the thickness of the actuator disc and the iterative convergence criteria.
- The main output of the simulations studied are namely the wind turbine power and thrust.

Wake validation study

- It is performed by comparing comparison study between the developed methods and the state of the art Large-Eddy Simulations employing an actuator disc using airfoil data in EllipSys3D.

Conclusions

The main conclusions of this study may be summarized as follows:

- The present results show that the RANS ACD methods are able to provide reasonable estimations of the conventional wind turbine power and thrust output with low computational effort.
- Changing the disc thickness had negligible effect on the estimation mentioned above.
- A grid resolution of 10 cells per rotor diameter gives sufficiently accurate results, although a grid resolution of 20 cells per rotor diameter should be preferred.
- A convergence criteria of 0.1 % is found to be sufficient.
- Lastly, the wake resulting from the RNG k-ε turbulence model with the polynomial method compares well to the LES simulations. On the other hand the standard k-ε turbulence model seems to over predict the wake recovery relatively to the other two models.

Contact

Nikolaos Simisiroglou
Uppsala University,Campus Gotland
621 67 Visby, Cramérgatan 3
Email: nikolaos.simisiroglou@windsim.com
Phone: +46 72 903 88 21

Aims

- To create an approach in RANS that will simulate a wind turbine and its wake development in an accurate and time efficient manner.
- Test the general applicability of the method for different wind turbines i.e. rated power, hub height, rotor diameter and manufacturing companies.

Results

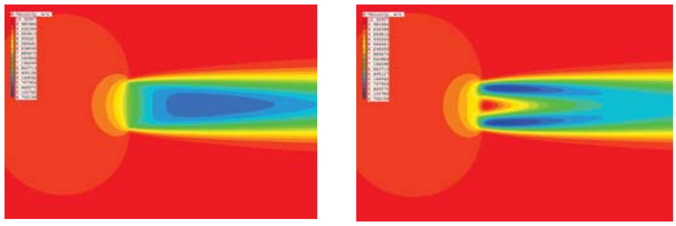

Figure 1. *Streamwise velocity contours for undistributed and polynomial method.*

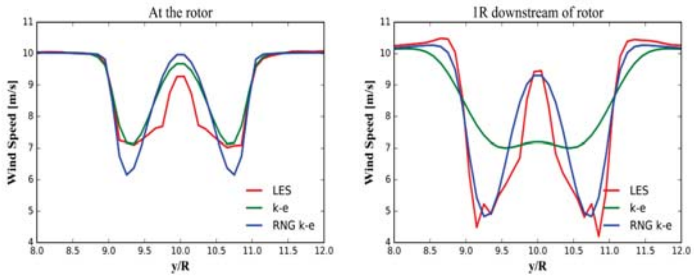

Figure 2. *Stream wise velocity at hub height along the transversal direction produced by the polynomial method using two different closure models and state of the art LES simulation, at the rotor position and 1R downstream of the rotor position.*

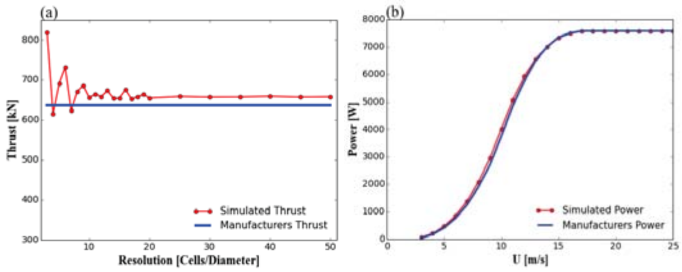

Figure 3. *Results for Enercon E-126 using the undistributed method (a) Total simulated wind turbine thrust for different grid resolutions versus the manufacturers thrust for a wind speed of 10 m/s. (b) Power production versus the manufacturers power curve for different wind speeds.*

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