Improvement of aerodynamic blade design tools by means of advanced CFD

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Summary
At Fraunhofer IWES, aero-elastic high-fidelity simulation tools based on Computational Fluid Dynamics (CFD) are used to investigate complex flow phenomena, relevant for the design of state-of-the-art offshore wind turbines blades. This work gives insight into the validity of BEM based tools for the simulation of the large, flexible rotor blades subjected to complex inflow conditions. The results illustrate, that the current standard BEM approaches show clear deviations compared to the highly complex CFD simulations.

1. Introduction

The traditional approach for the aerodynamic design of wind turbine blades is based on the Blade Element Momentum (BEM) method. The low computational costs of BEM simulations make it affordable to numerically simulate many thousands of time steps. However, currently, major concerns exist regarding the applicability of the engineering models of BEM in the design process of large and very flexible wind turbine blades [1].

Recent studies demonstrated that the modeling of large rotors is falling increasingly outside the validated range of current state-of-the-art aerodynamic and aero-elastic tools in various aspects [2]. Larger rotors come with thick(er) airfoils, high(e)r flexibility and high(er) Reynolds and Mach numbers which lead to more unknown and non-linear behaviors. These uncertainties make it very difficult to design cost-effective and reliable wind turbines.

2. Results

In this work, several complex load situations, which are relevant for large offshore turbines, have been simulated using a standard BEM tool and a fluid-structure coupled CFD solver. As an example, Fig. 1 illustrates the resolved wake computed by a CFD solver behind a large wind turbine rotor subjected to yawed inflow. The complexity of the flow results in significant deviations between both numerical approach. Fig. 2 illustrates the normalized flapwise tip deflection for the BEM and CFD based results and different yaw angles. It can be observed, that clearly different variations amplitudes of the structural deformations are predicted.

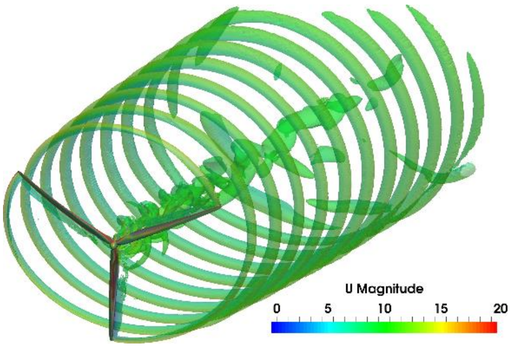

Fig. 1: Rotor wake structure

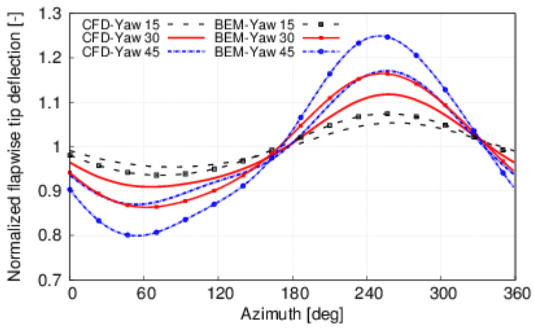

Fig. 2: Wind

In the final work, the presented results will shed light into the question if and how future load calculations of large offshore rotors can be improved.

3. References

[1] Rahimi H, Dose B, Stoevesandt B, Peinke J. Investigation of the Validity of Bem for Simulation of Wind Turbines in Complex Load Cases and Comparison with Experiment and CFD, Vol. 749; IOP Publishing; 2016.

[2] Schepers G. J, Ceyhan O, Boorsma K, et al. Latest Results from the Eu Project Avatar: Aerodynamic Modelling of 10 mw Wind Turbines, Vol. 753.