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On the Accuracy of Wind Turbine Actuator Models

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ABSTRACT

In this study, large-eddy simulations of an isolated NREL-5MW wind turbine are carried out using different wind turbine models. Results from the actuator line model and actuator disk model with non-uniform and uniform blade loading are compared to a simulation in which the wind turbine is fully resolved using a sharp interface immersed boundary method. Actuator line and disk models with non-uniform blade loading require geometric and dynamic information about the wind turbine and are equipped with the NREL five-region rotor speed controller. Pitch controller is deactivated since simulations are performed below the rated wind speed. Different types of velocity sampling to make the thrust coefficient of the uniform actuator disk model dimensional are also described. To prescribe the inlet boundary condition, the precursor-successor method is used. In the latter, the sole atmospheric boundary layer is firstly solved, and flow snapshots are saved at each time step. The resulting database is used as inlet boundary condition for the simulations with the wind turbine, so that all relevant turbulent scales, the logarithmic profile, and the non-deterministic nature of turbulence are correctly represented. Average hub-height velocity is maintained at the desired value by a proportional-integral uniform pressure gradient controller, which drives the boundary layer. Velocity and pressure evolutions upstream and past the wind turbine, as well as kinetic energy budgets in the wake are compared to the high-fidelity immersed boundary solution for the three actuator models. The results provide guidance for balancing the computational cost and numerical accuracy of modelling wind turbines within numerical simulations of large wind farms.