Impact of Turbulence on Wind Turbine Blade Loadings

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The impacts of the aerodynamic loading on wind turbines in wind farms caused by the atmospheric boundary layer turbulence and upstream turbines are investigated. Large scale structures present in the boundary layer drive the intermittent peak structural loadings on the turbine blades. These loadings contribute to fatigue which lead to premature failures. A previous experimental study [1] reported that the fatigue loading was found to increase for turbines within wind farms compared to the free flow cases. The increased fatigue in the interior of a wind farm was found to be attributed to the changes in the turbulence scales and the horizontal shear flow [2].

A large eddy simulation (LES) study by Troldborg et al. [3] found significant differences between laminar and turbulent inflow conditions in the aerodynamic interaction of two rotors. As the ambient turbulence is imposed, the wake vortices from the upstream turbine are perturbed. This causes the boundary layer to transition into a fully turbulent flow resulting in a faster recovery of the wake deficit and generally increase the average blade loads on the downstream turbines. Recently, strong spatial and temporal correlation was found [4] between the large scale unsteady motions of the turbulent wake and the peak loadings on the turbine blade, similar to the previous experimental studies in wakes [1, 2]. In addition, it was found that the stability of the boundary layer yielded different loading characteristics as the updrafts in the coherent structures reduced the loadings on the blades. However, in both numerical studies [3, 4], the aerodynamic loading calculation was based on a one-way coupled approach in that the LES computation does not take into account the forces imposed on the fluid from the wind turbine structures.

Therefore, the present study builds on these previous investigations by including aero-elastic computations using FAST/AeroDyn [5], coupled with the OpenFOAM flow solver. The predicted aerodynamic forces from AeroDyn and the new blade positions from FAST are coupled with the LES solver as body forces. To the authors knowledge, this fully coupled aero-elastic calculations with LES on a wind farm is first to be reported. The evolutions of the turbulent wake structures downstream of the wind turbines are studied, as well as its impact on

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the downstream turbine structures. Furthermore, the effects of the wind turbine relative positions are investigated.

REFERENCES


