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Wall-resolved LES simulation of vortex-induced vibration of wind turbine blades

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Modern wind turbines feature very large blades to increase the power output. However, this increase comes with the cost of the increase in flexibility and aeroelastic effects. At extreme conditions which feature high wind speeds, the blades are prone to experience high angle of incidents, large separation and are susceptible to developing dangerous vortex-induced vibrations (VIV). Those conditions cannot be accurately predicted with existing analysis tools and require a high-fidelity numerical method to estimate the fluid forces on the highly deformable slender blade. A high-fidelity fluid-structure interaction solver has developed for simulation of such conditions and implemented in the high-order spectral/hp element Nektar++[1]. Implicit large eddy simulation (LES) is used to resolve the flow turbulence. The thick-strip method[2, 3] is adopted where the full fluid 3D domain is represented with smaller 3D domains, each of them has a finite spanwise thickness which enables capturing the local 3D turbulent wake while reducing the computational costs of wall-resolved LES by avoiding solving the full fluid domain. The geometrically-exact composite beam model is used for non-linear high-deformation blade dynamics. Using the FSI solver, vortex-induced vibration of the NREL5MW reference wind turbine blade is investigated under extreme conditions. Simulations are conducted to investigate the dynamics of the blade at several above-design wind speeds. Further, the effect of the incoming wind's angles of incident on the VIV response of the blade is studied. All computations has been carried out on the UK supercomputing facility ARCHER2 and the high-performance computing aspect of such simulations is explored and discussed.

References

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