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Prediction of the hub vortex instability within wind turbine wakes and effects of the incoming wind and turbine aerodynamic characteristics GIACOMO VALERIO IUNGO, University of Texas at Dallas, FRANCESCO VIOLA, Ecole Polytechnique Fédérale de Lausanne (EPFL), SIMONE CAMARRI, University of Pisa, FERNANDO PORTÉ-AGEL, FRANCOIS GALLAIRE, Ecole Polytechnique Fédérale de Lausanne (EPFL) — Instability of the hub vortex, which is a vorticity structure present in wind turbine near-wake and mainly oriented along the streamwise direction, is predicted from wake velocity measurements. In this work, stability analysis is performed on wind tunnel velocity measurements acquired in the wake produced from a wind turbine model immersed in a uniform flow. Turbulence effects on wake dynamics are taken into account by modeling the Reynolds stresses through eddy-viscosity models, which are calibrated on the wind tunnel data. This formulation leads to the identification of one dominant mode associated with the hub vortex instability, which is characterized by a counter-winding single-helix mode. Moreover, this analysis also predicts accurately the frequency of the hub vortex instability observed experimentally. The hub vortex instability is also investigated by considering incoming wind fields with different turbulence characteristics, different turbine aerodynamic designs and operational regimes, which affect the morphology of the wake vorticity structures and their dynamics. The ultimate goal of this work consists in providing useful information for predicting wind turbine wake dynamics and their effects on downstream wake recovery, thus to maximize wind power harvesting.

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