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Effects of nacelle and tower on the wake recovery of a hydrokinetic turbine

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ABSTRACT

Detached eddy simulation is adopted to investigate the wake development downstream of an axial-flow turbine. Both the isolated rotor and the complete configuration (i.e., including nacelle and tower) are analysed in depth for a range of tip speed ratios. For the isolated rotor we found (see Posa et al., 2024) that the trend of the momentum deficit as a function of the rotational speed changes between the near wake and further downstream. While the momentum deficit in the near wake is a growing function of the rotational speed, it becomes a decreasing function further downstream. This behaviour is due to the acceleration of the instability of the tip vortices, triggering the process of wake recovery through both radial advection and turbulent mixing (Lignarolo et al. 2014, 2015 and Posa & Broglia, 2021). In the present study, the computations including tower and nacelle demonstrate that they strongly influence the wake dynamics, with a clear anticipation of the mutual inductance between tip vortices, their pairing and eventual break-up into turbulence. As a result, wake recovery occurs more upstream when the presence of the nacelle and supporting tower is included in the computational model. The results of the present computations demonstrate indeed that mutual inductance phenomena between tip vortices develop at shorter downstream distances. This result has important implications, since axial-flow turbines are usually deployed in array configurations, where the downstream devices ingest the wake coming from the upstream ones. The flow structures they shed, especially the tip and hub vortices, are sources of fatigue loads on the downstream turbines, while the speed of the wake recovery affects the momentum actually available to them. Therefore, faster instability of the wake structures and wake recovery enable closer streamwise distances between devices. The results of this study highlight the importance of taking into account the effects of both the typical tip speed ratios of operation and the supporting structures of the rotor for an accurate assessment of the speed of their wake recovery and the optimal distance between turbines in farms of multiple devices.

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