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Braking and propeller state for floating offshore wind turbines

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Abstract

When a floating wind turbine moves backwards quicker than the wind, it can experience propeller-like conditions with flow reversal through the rotor and negative aerodynamic forces.[1,2] This is referred to as propeller state. It was first studied with respect to helicopters in vertical descent, but needs further research in the context of floating turbines.

In an attempt to analyse the aerodynamic forces of a floating turbine during propeller state, 3D RANS simulations were run using OpenFOAM and the k-ω SST turbulence model for closure. A range of wind and wave conditions were tested that were favourable to this state, where 1D velocity predictions were used as a reference. Surge-only conditions were investigated, with an overset mesh method to prescribe rotor rotation and turbine translational motion within the domain.

The results showed that the torque is negative prior to the thrust on entry to propeller state, suggesting the existence of a previously undefined rotor state. This new state has been named the 'braking state'. It was seen to occur for all simulations, including those which did not see a negative thrust, suggesting that it will be more common than a full propeller state in practice. Both of these states were found to be due to a drop in spanwise angle of attack, where inboard regions were more susceptible. When compared with 1D velocity predictions, rotor-averaged propeller state occurred within 0.15 s of a theoretical flow reversal and braking state occurred within 0.20 s of when the surge velocity exceeded the wake velocity (a 1D turbulent wake state).

This work explains the causes of and behaviour during propeller state in the context of a floating wind turbine during surge. It forms part of a PhD studentship funded by EPSRC (award reference EP/P020267/1) with initial thesis submitted for examination.

References

[1] Sebastian, T. and Lackner, M. A., "Offshore Floating Wind Turbines - An Aerodynamic Perspective," *49th AIAA Aerospace Sciences Meeting*, AIAA, Orlando, Florida, 2011, pp. 1–27.

[2] Kyle, R., Lee, Y. C., and Früh, W.-G., "Propeller and vortex ring state for floating offshore wind turbines during surge," *Renewable Energy*, Vol. 155, 2020, pp. 645–657.