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Wave-Age Influence on Aerodynamic Loads and Wake Recovery in Offshore Wind Farms

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ABSTRACT

The accurate simulation of offshore wind turbine dynamics is essential for optimizing energy production and understanding complex wake and wave interactions. This study focuses on high-fidelity modeling of a 3x3 offshore wind farm under various wave-age ratio conditions.

The setup involves nine NREL 5-MW reference wind turbines following the definition presented by Jonkman (2009), and modeled using a Rotating Actuator Disk Model (RADM) by Martinez et al. (2012) to simulate rotor-induced flow dynamics. The turbulent Atmospheric Boundary Layer (ABL) is considered in neutral stratification conditions. Sea surface dynamics are incorporated through a dynamic Immersed Boundary Method (IBM), enabling a one-way coupling between the sea surface and the flow field. The investigation spans multiple wave-age ratios to examine their influence on turbine wake characteristics, aerodynamic loads, and power production.

Results are analyzed to assess velocity deficits, turbulence characteristics, and the interplay between wave dynamics and wake recovery. The joint use of LES and RADM on high-performance computing (HPC) resources offers an efficient yet detailed resolution of turbine wakes, capturing the impact of wave conditions on turbulence structures affecting the wake recovery process.

References

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