Large-eddy simulation of floating wind turbines under offshore wind and wave conditions

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ABSTRACT

We developed a high fidelity numerical framework for simulating floating wind turbines and its interaction with the large-scale wind and wave conditions representative of offshore environments. We adopted a domain decomposition approach consisting of two regions. A first region of large dimensions, referred to as the far-field region, where the two-fluid approach of Yang and Shen [1] is used to efficiently develop realistic ocean wind and wave conditions. The simulated far-field conditions are fed as input into a one way coupling simulation of a second region of reduced dimensions, referred to as the near-field region, where the high resolution fluid-structure interaction (FSI) model of Calderer, Kang, and Sotiropoulos [2] is applied.

The far-field solver of [1] uses a potential-flow based wave solver for the water side, and a large-eddy simulation (LES) model with undulatory boundaries for the air flow. The near-field method of [2] is a two-phase flow solver based on the level set method incorporating a curvilinear immersed boundary method (CURVIB) for tracking the motion of moving structures.

The wind field is directly transferred from the far-field region to the near-field by feeding at the inlet plane of the latter simulation instantaneous velocity fields from the former simulation. The transfer process of the wave field is based on the method of Guo and Shen [3], adapted to the level set method, and consists of applying an oscillatory pressure normal to the free surface.

A key aspect of the present work is in the treatment of the boundary layer formed on the air flow due to the presence of the free surface. When dealing with high Reynolds number flows, which are typically encountered in offshore environments, the resolution required to resolve the thin viscous sub-layer is computationally prohibitive. We propose in this work a novel wall model technique, which is adapted to work with the level set approach and is based on adding eddy viscosity on the nodes above the free surface.

The wave transfer method has been validated for several cases involving simple wave trains, 3D directional waves, and a JONSWAP wave spectrum. The free surface wall model has been tested for simplified cases and is shown to improve the velocity profile and turbulence statistics of the wind field. Finally, the framework has been applied to simulate a realistic 13.3MW offshore wind turbine under the operational offshore conditions that are typical of the US east coast.

REFERENCES

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