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Aero-hydro-servo-elastic simulations of a floating spar-buoy wind turbine using multi-body vortex method

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Abstract

This work describes advanced numerical aero-hydro-servo-elastic simulations of a floating offshore wind turbine using a multi-body vortex-particle based solver. The floating offshore substructure considered in this study is the spar-buoy as described in Phase IV of the Offshore Code Comparison Collaboration (OC3) project [1]. The wind turbine blades and rotor-wake aerodynamics are modeled using the lifting-line theory and particle-mesh approaches, respectively. The wind turbine structure and foundation are modeled using a finite-element and muti-body system approach. Last, hydrodynamics are modeled using Airy wave theory. To calculate the forces acting on the structure, Morison's equation is used for the floating spar-buoy. The developed aero-hydro-servo-elastic tool represents a more advanced approach to traditional tools used in industry based on blade-element momentum (BEM) for simulating floating offshore wind turbine performance.

Learning Objectives

- Describe the aerodynamic, hydrodynamic, controller and structural-dynamics models implemented in traditional tools used in industry for simulating floating offshore wind turbine performance and loads
- Identify the limitations of the aerodynamic modeling in traditional tools used in industry for simulating floating offshore wind turbine performance and loads
- Describe the higher-fidelity modeling methods currently being developed at Universities and research institutions and their advantages and disadvantages compared with traditional tools currently being used in industry for simulating floating offshore wind turbine performance and loads

Methods

The advanced numerical aero-hydro-servo-elastic simulation tool developed in this work is based on the in-house aero-elastic vortex code called MIRAS [2], i.e., Method for Interactive Rotor Aero-elastic Simulations. MIRAS is a multi-fidelity aero-elastic tool for wind turbine performance analyses. In the present study, the lifting-line aerodynamic module is used, which relies on airfoil polar data for lift and drag. The elastic and dynamic behavior of the wind turbine, e.g., blades, tower and shaft, and floating offshore structures, i.e., spar-buoy, is taken into account by coupling the aerodynamic module of MIRAS with the multi-body finite-element structural model of HAWC2 [3]. A loose-coupling approach is used, where the aerodynamic and structural information is exchanged once per time step for every time step.

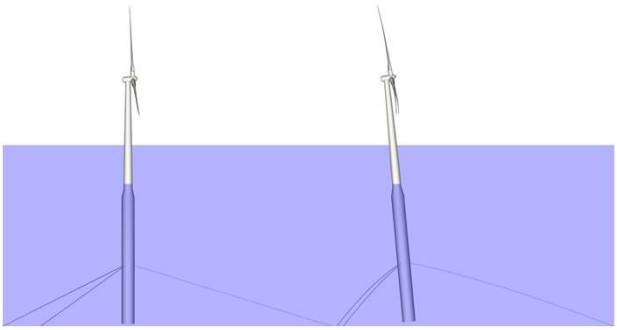

Fig.1 NREL5MW floating spar-buoy initial position (left) and in motion (right)

References

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Results

Figure 2 depicts the flow field from MIRAS for a 11.4 m/s turbulent inflow simulation of the NREL5MW on a floating spar-buoy. For this simulation, Figure 3 depicts the time series from six signals from HAWC2-BEM and MIRAS.

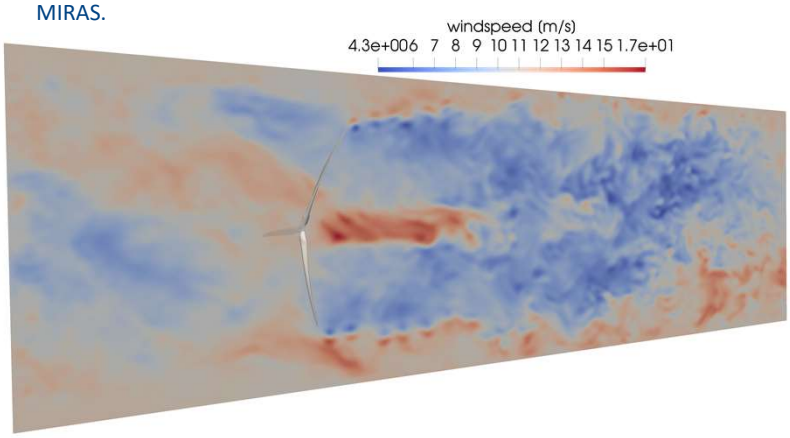

Fig.2 Flow field from MIRAS for NREL5MW floating spar-buoy in motion

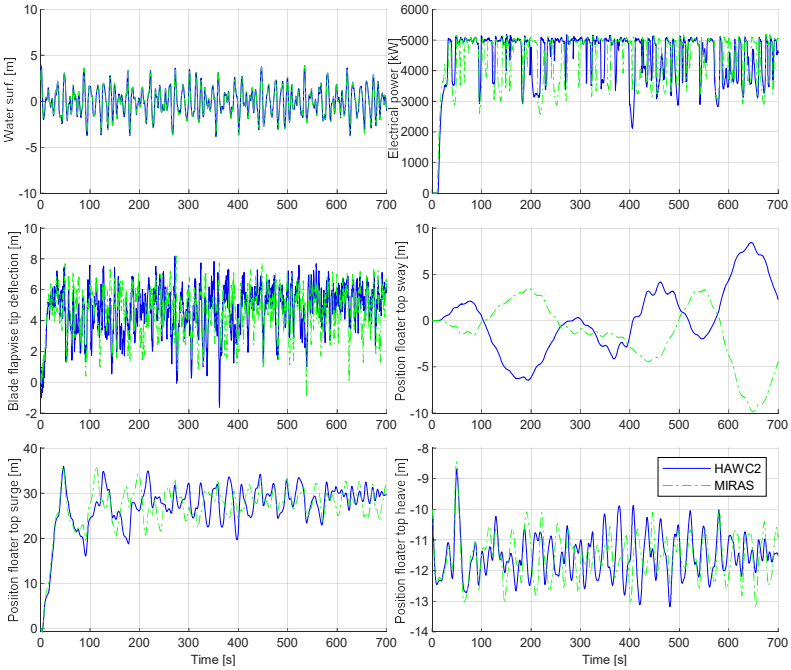

Fig.3 Time series of NREL5MW on floating spar-buoy from HAWC2 and MIRAS

Conclusions

This work described aero-hydro-servo-elastic simulations of a floating offshore wind turbine using a multi-body vortex based solver. The floating offshore substructure considered in this study is the spar-buoy as described in Phase IV of the Offshore Code Comparison Collaboration (OC3) project. This study showed the capabilities of a novel aero-hydro-servo-elastic tool for predicting floating offshore wind turbine response with a higher aerodynamic fidelity compared to traditional tools used in industry that are based on the simpler blade-element momentum method. The novel tool provides industry the ability to investigate higher aerodynamic effects and how they affect floating offshore wind turbine response.

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