Wave tank testing of floating wind turbine:

Influence of wind turbine thrust modeling methodology on global motions.

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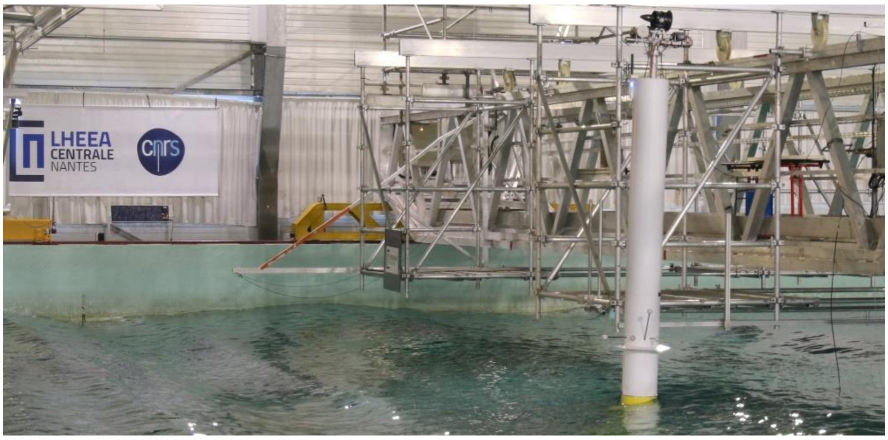
Summary

Wave tank model testing is an important step into the engineering design process of floating wind turbines. While Froude scaling insures that most of the hydrodynamic loads are correctly scaled, representing simultaneously and with a good accuracy the aerodynamic loads acting on the wind turbine requires additional complexity than what has been done for O&G platforms in the previous decades. In this context, the SOFTWIND project aims at developing an innovative experimental test bench dedicated to the wave tank testing of floating wind turbines using a hybrid -"software-in-the-loop" – methodology [1,2].

The objective of this paper is to present the results of a wave tank test campaign which was performed on a 1/40 scale 10 MW SPAR floating wind turbine between November 2019 and March 2020 in the Ecole Centrale de Nantes facilities. The objectives of these tests was primarily the validation of the experimental setup developed with a single actuator. A SPAR platform, its mooring system and a flexible tower in modal similitude were built and characterized for this test campaign purpose. The setup is depicted in Picture 1.



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Picture 1: Illustration of the setup

In order to provide guidelines about suitable methodologies for modeling rotor loads during wave tank testing, comparisons between simplified methodologies and a real-time integration of a state-of-the-art aerodynamic model were conducted. Ranked in an increasing order of complexity, the different methodologies tested were:

- Equivalent of a "drag disc" or "porous disc", with a constant thrust coefficient. That corresponds to a case where the operating point of the wind turbine is arbitrary fixed.
- The steady-state thrust curve of the wind turbine, using the total velocity at the hub (incident wind velocity + measured hub motions).
- Time series of rotor thrust computed with the OpenFAST numerical model running in open-loop, without any influence of the global motions. It is denoted "Fixed" in the following figures.
- The "software-in-the-loop" methodology, with the OpenFAST numerical model running in closed-loop. The motions of the floater, measured in the wave tank, are sent as inputs to the numerical model. It is denoted "SIL" in the following figures.

- Different control strategies of the actuator, when using the software-in-the-loop methodology, by a voluntary deterioration of the actuator bandwidth and real-time delay, to analyze the sensitivity. It is denoted “SIL + XX” in the following figures, XX being the type of deterioration.

This paper compares the global motions characteristics, for different kinds of tests, using the different above-mentioned methodologies. This includes decay tests but mostly turbulent wind and irregular wave tests to highlight the involved physical phenomena.

Preliminary results

Different turbulent winds and irregular waves cases have been selected from the design load cases of the Gulf of Maine representative site of the North East coast of the USA [3].

On a case defined by full-scale wave and wind properties of $H_s = 4.5m;\ T_p = 12s; U_w = 11.4m.s^{-1}$ $and\ TI = 15\%$, the different methodologies are compared for 10 min-long tests. The power spectral density of the platform Surge and Pitch motions as well as the tower deflection are represented in Figure 1 for the different methodologies. The main differences occur around 0.2 Hz, which is the natural platform pitch frequency, and also around 2.4 Hz, which is the natural tower frequency. For the wave frequencies, centered around 0.5 Hz, the differences are very limited. Using a software-in-the-loop methodology doesn’t have a significant contribution on the wave frequencies motions but increases the fidelity of the tower mode and the low frequency motions.

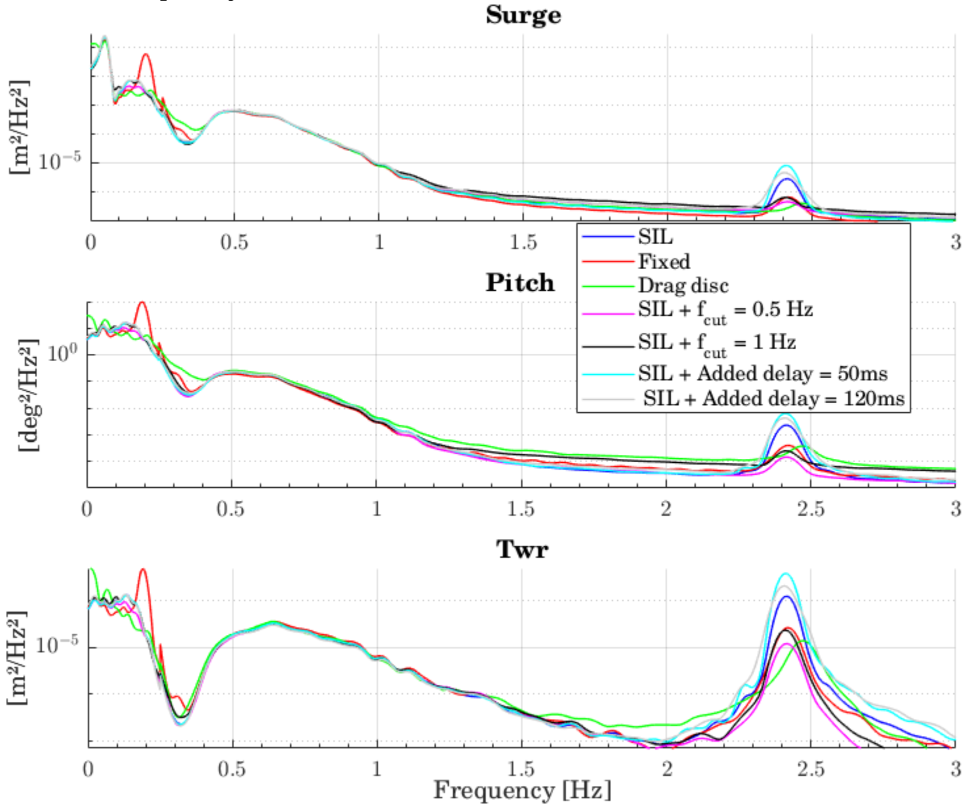

Figure 1: PSD of platform Surge, Pitch and tower deflection for different rotor load methodology

Acknowledgments

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References

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