Emulation of ReaTHM® testing

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Model scale testing of offshore wind turbines is challenging due to the incompatibility between Froude and Reynold scaling. Real-Time Hybrid Model (ReaTHM®) testing is an experimental method where numerical simulations are combined in real-time with model testing. Using this method alleviates the scaling issue since the aerodynamic loads are simulated and applied on the physical model by use of six winches and lines connected to the tower top. These loads are calculated by FAST, and include the elasticity, aerodynamics and control system. Prior to the test in the Ocean Basin, the ReaTHM® tests are emulated by simulating the physical part of the experiments. This is an important step in the design of the experiments, used to verify the complete hybrid testing loop, to ensure the quality of the tests to be performed.

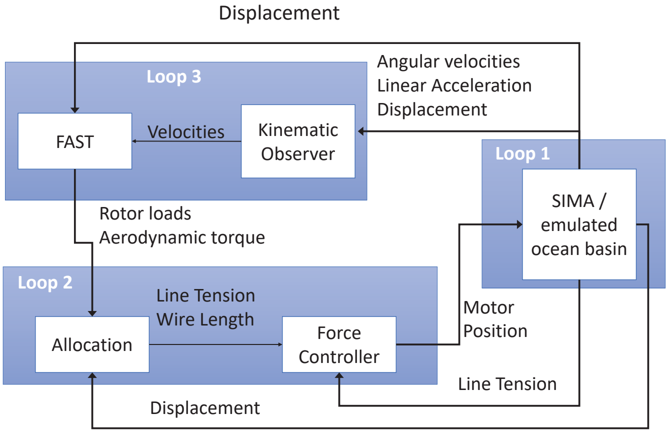

Figure 1: A schematic overview of the emulated hybrid system.

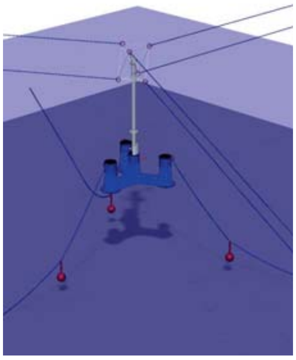

Figure 2: The OO-Star Wind Floater modelled in SIMA

DTU 10 MW RWT main properties [2]		
Rated power	10	MW
Rotor diameter	178.3	m
Hub height	119	m
Rated wind speed	11.4	m/s
Nacelle mass	446 036	kg
Rotor mass	227 962	m
Blade prebend	3.3	m

Method

An overview of the emulated hybrid system is shown in Figure 1. Loop 1 is the emulated physical experiments performed in SIMA, Loop 3 computes the aerodynamical loads based on the measured platform motions and Loop 2 is allocating the aerodynamic loads to the six different winches (see Figure 2).

From Loop 1 the displacements and velocities of the tower top are sent to Loop 3. The displacements and velocities are calculated in SIMA[4]. A Simo model is made of the OO-Star Wind Floater in SIMA. Simo is a time domain simulation program for study of motions and station-keeping of multibody system developed at SINTEF Ocean [3].

The FAST module in Loop 3 estimates the rotor loads. The FAST module contains a dll of the FAST program (v8, with AeroDyn v14) developed at NREL, which is an aero-hydro-servo-elastic software [5]. Only the first flapwise mode is included in the aeroelastic calculation in FAST, the remaining elastic modes are stiff. The weight of the rotor is included in both the Simo model and in the FAST calculation, thus, the rotor loads transferred from the FAST module in Loop 3 does therefore not contain the gravitational and inertial loads.

The rotor loads are transferred from the FAST module in Loop 3 to the Allocation module in Loop 2. The Allocation module transfers the rotor loads to commanded line tension. The Force Controller module takes the line tensions as input and controls the winches to obtain the desired tension, which is sent to the SIMA module in Loop 1.

Floating Offshore Wind Turbine Model

Hybrid testing of a semi-submersible floating wind turbine was conducted in the wave basin at SINTEF Ocean in fall 2017 as a part of the EU project Lifes50+[6]. The wind turbine tested was the OO-Star Wind Floater, which is developed by Dr Tech Olav Olsen and is a semi-sub platform for floating wind turbines [1]. The platform consists of a star shaped pontoon, which connects the central column to three outer columns. The mooring system is a catenary system with three mooring lines. The rotor used is from the DTU 10 MW reference wind turbine[2].

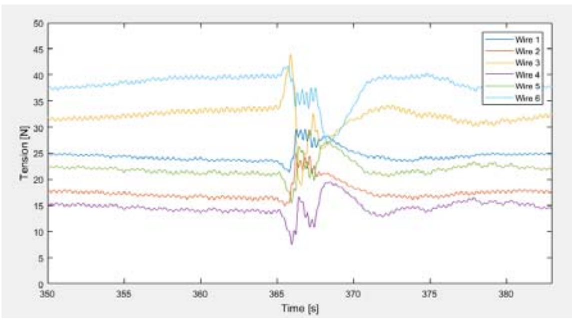

Figure 4: The commanded line tensions in the 6 wires for the ECD test

Acknowledgement

Also, we are grateful to Dr. techn. Olav Olsen AS for the permission and contribution to set up the public 10MW semi-submersible design based on their concept of the OO-Star Wind Floater (www.olavolsen.no).

Discussion

The emulated testing prior to the hybrid tests in the ocean basin is valuable both for increased quality of the tests and for the safety. It is possible to investigate the tension in the wires prior to the tests and establish that they are within the maximum and minimum levels. The tests giving the highest tension loads were the extreme wind tests; extreme operating gusts (EOG) and extreme coherent gust with direction change (ECD). The tension in the wind lines for the emulated ECD test is shown in Figure 4.

The effect of flexible blades compared to stiff blades was also investigated. In the left graph of Figure 5, the blade tip deflection of a stiff blade (no elasticity), a flexible blade (only the first flapwise mode of the blade included) and the full-flexible blade (first and second flapwise mode and the first edgewise mode are activated). The difference between the fully flexible blade and the flexible blade is small, however the difference is large for a stiff blade, around 8 m. This has an effect on the global response of the platform, which is illustrated in the right graph of Figure 5. Here the spectra of the platform pitch is shown for one turbulent wind case, and one can see that the platform pitch response is dependent on the elasticity of the blade. The flexible blade was chosen for the hybrid tests as this provided an increase in accuracy, but kept the computational time to a low level. It is important to limit the computational efforts since the hybrid tests are real-time and downscaled.

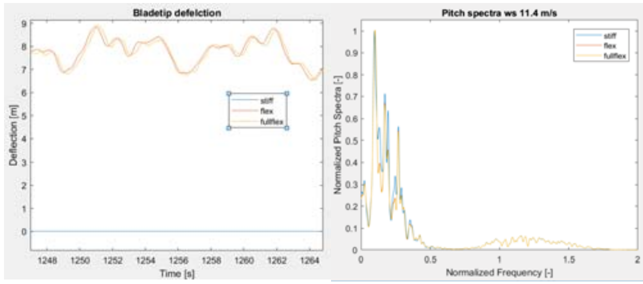

Figure 5: The blade tip deflection and the platform pitch spectra for the OO-Star wind floater. The frequencies are normalized with the wave frequency and the spectra value with the maximum value.

Referanser
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