DTU Wind Energy
Department of Wind Energy

Response analysis of a 10MW floating wind turbine: flexible substructure modelling in HAWC2 & WAMIT

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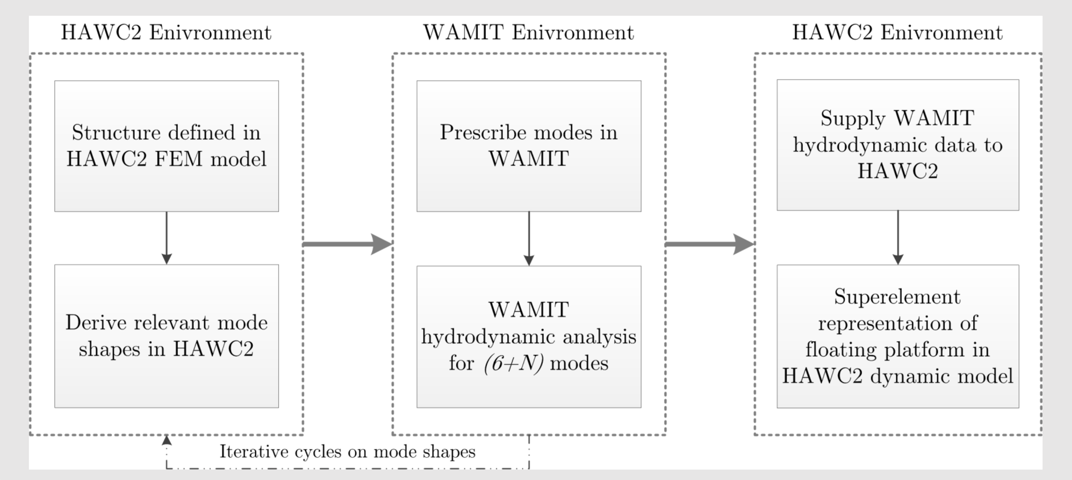
Motivation

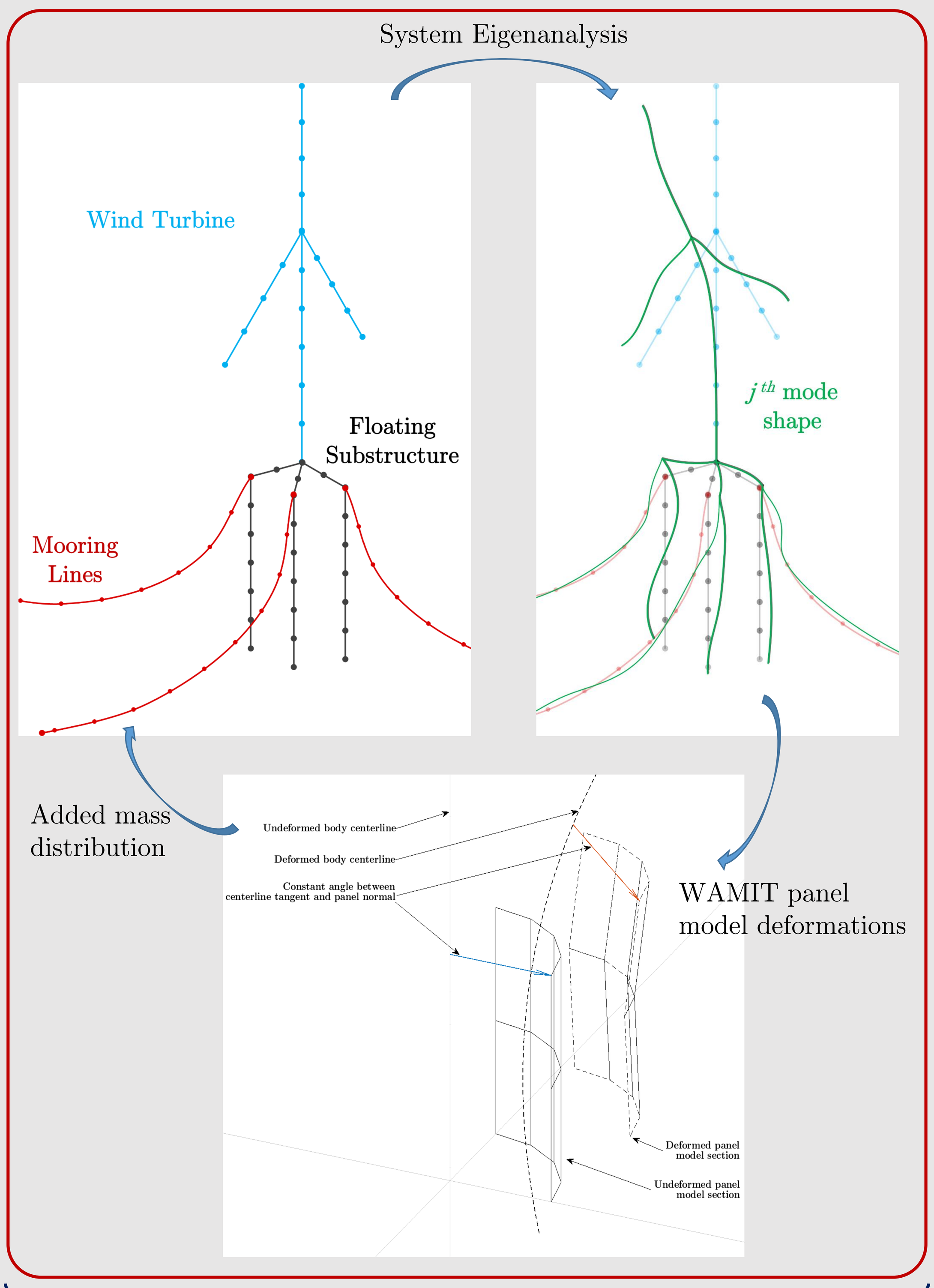
Until recently, substructure flexibility was not considered during integrated dynamic simulations of floating wind turbines due to the relative placement of substructure natural frequencies. As floater dimensions increase to support larger turbines, substructural flexibility may increase to the extent where substructure natural frequencies approach the range of wave and wind turbine excitations. Therefore it becomes relevant to include substructure flexibility within integrated dynamic calculations to capture the relevant physical and load effects on the wind turbine.

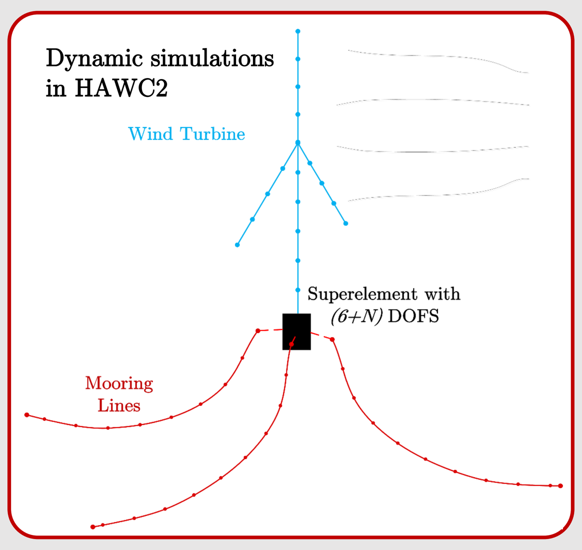
Previous work by Borg et al. [1] described a method to achieve this, implemented in HAWC2 and WAMIT, and illustrated the method for a 10MW wind turbine on a simplified spar platform. The present work applies the method to the Triple Spar concept [2], and illustrates the influence of substructure flexible modes on the response of the wind turbine and platform.

Flexibility in HAWC2 & WAMIT

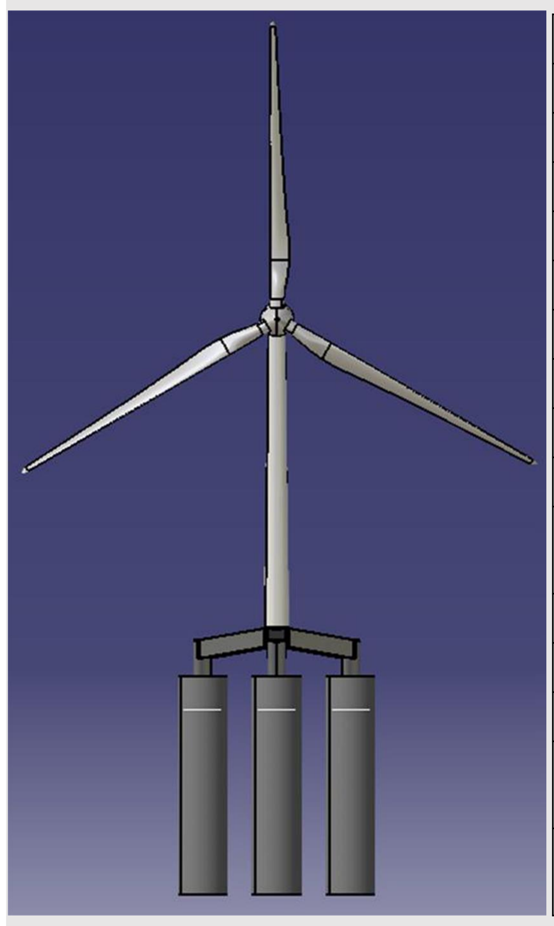
The process of setting up such a dynamic model first involves a number of pre-processing steps that establish the relevant flexible modes of the substructure, the associated hydroelastic effects and a reduced model representing the substructure, illustrated below.







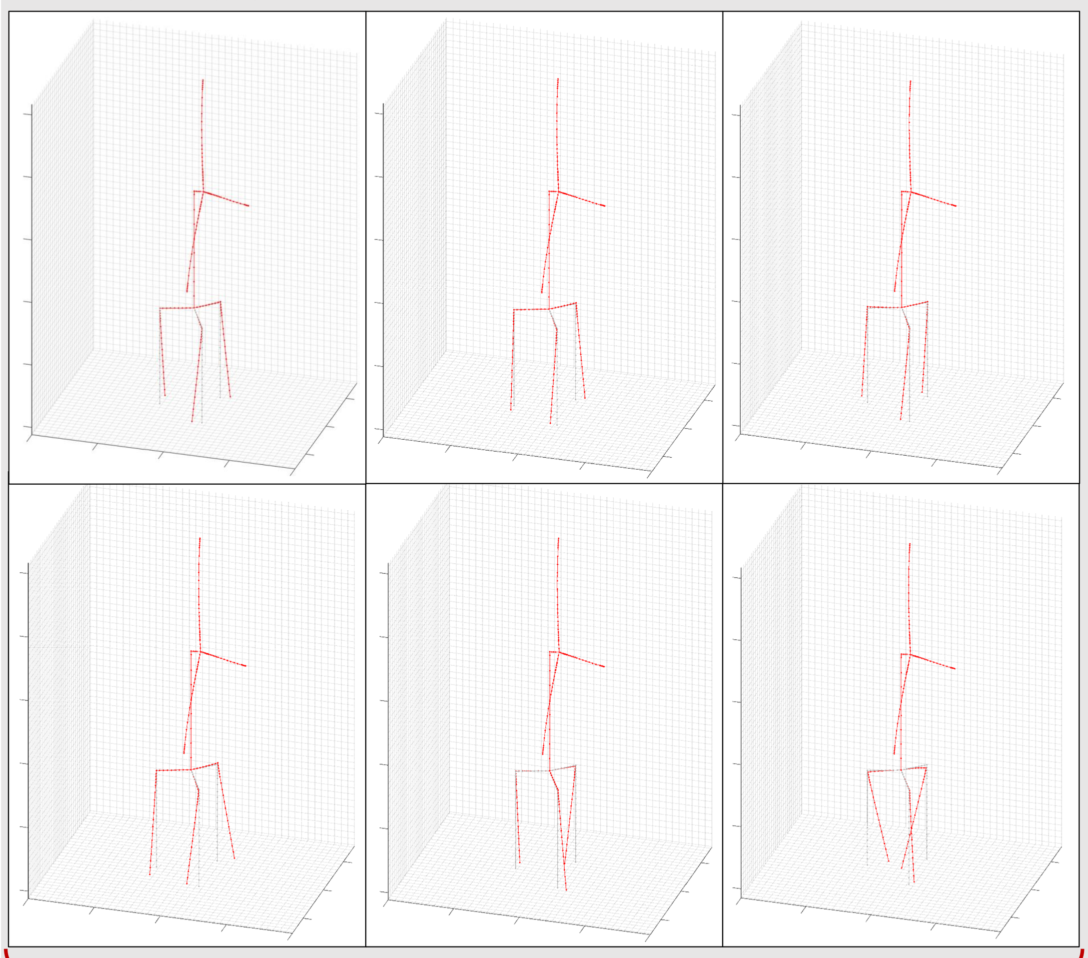
Floating Wind Turbine

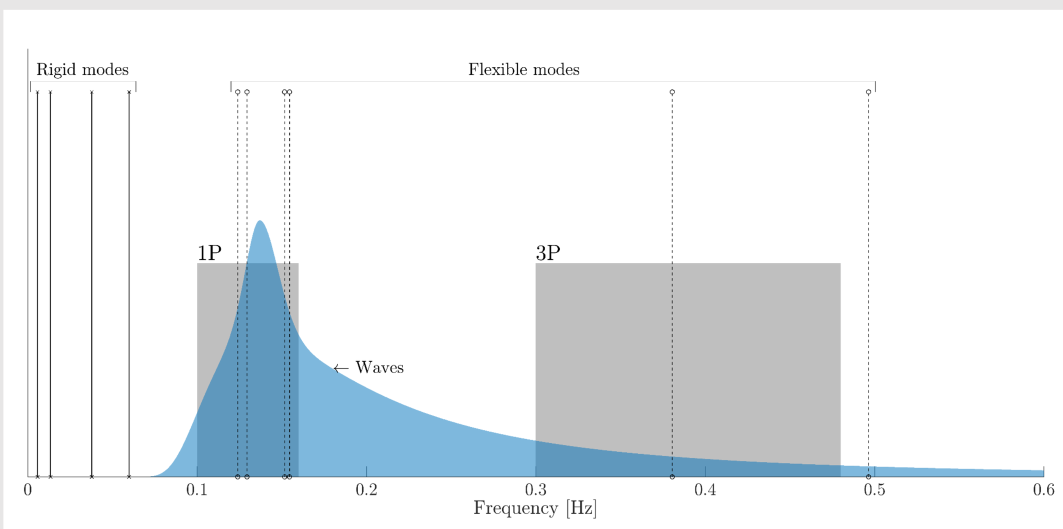


Draft [m]	54.46
Water depth [m]	180.0
System mass [t]	29278.4
Displacement [m³]	29311.1
Rated power [MW]	10.0
Rated wind speed [m/s]	11.4
Rated RPM [-]	9.6
Hub height [m]	119.0
Tower length [m]	90.63
Column diameter [m]	15.0
Column distance to centreline [m]	26.3
Heave plate diameter [m]	22.5
Catenary line length [m]	610.0
Fairlead/Anchor radius [m]	54.58/600
Fairlead height above MSL [m]	8.7
Dry/Wet mass per unit length [kg/m]	594/517

The Triple Spar concept [2], depicted above, was considered as a case study. The platform consists of 3 vertical reinforced concrete, partially ballasted cylinders connected to the tower base through a steel tripod structure. A catenary mooring system is used consisting of three lines, where each one is connected to each cylinder. The platform is oriented such that in aligned wind and wave conditions, two cylinders are located upwind of the turbine and one cylinder is located directly downwind of the turbine.

Using the HAWC2 implementation described in [3], an eigenanalysis of the system was carried out and 6 substructure flexible modes were identified to be relevant to the wave and wind turbine excitation frequency ranges. They were included in the reduced order hydroelastic model that forms the superelement within the HAWC2 dynamic calculations. The flexible modes and relative placement in the frequency spectrum are illustrated below.

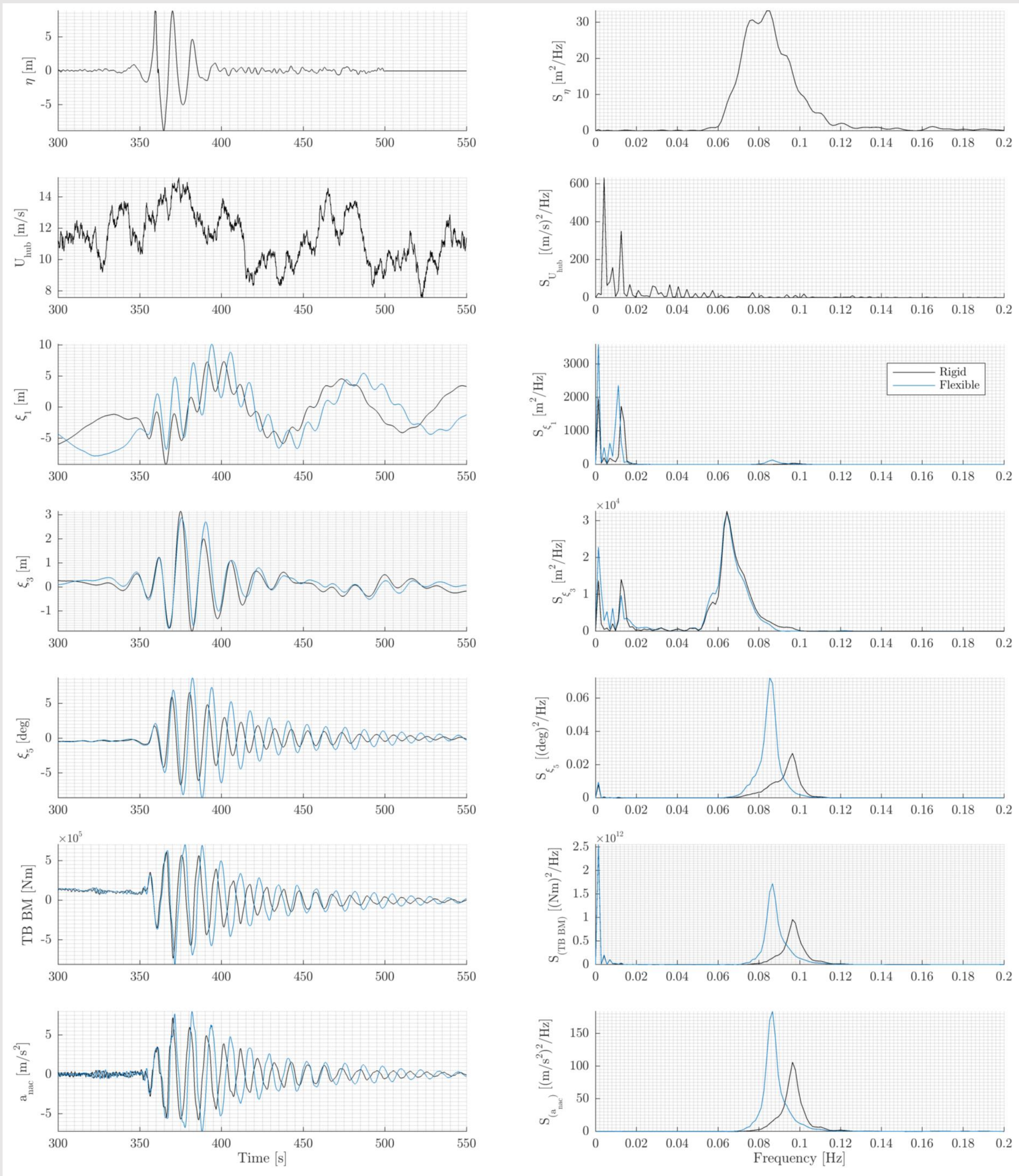




Two load cases were considered, representing rated stochastic operating conditions and an extreme event represented by a focused wave. For each load case, dynamic calculations were carried out with and without the substructure flexibility included in the model, labelled 'flexible' and 'rigid', respectively, within the following figures.

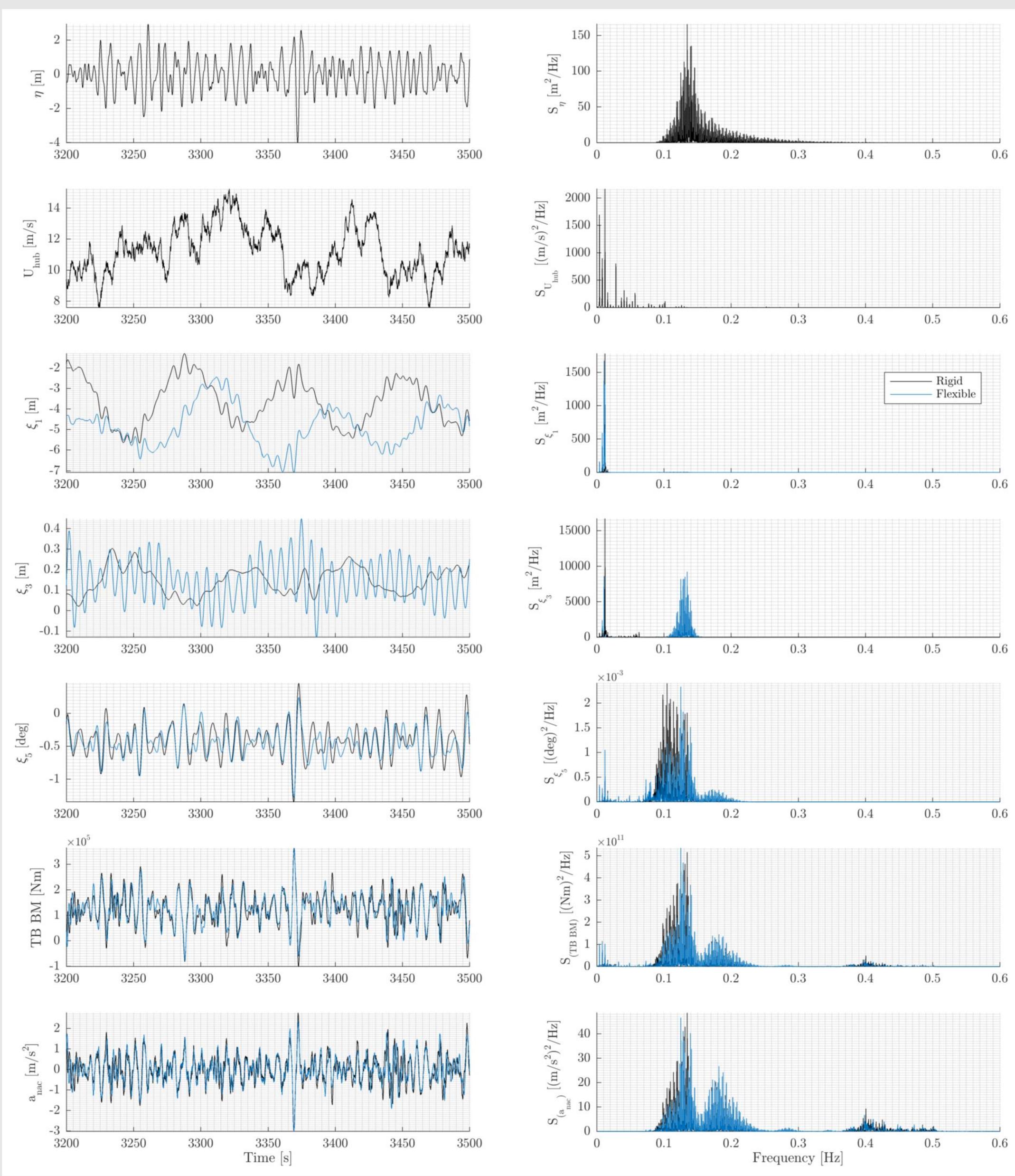
	U_{hub} [m/s]	H [m]	T_p [s]	Duration [s]
LC1	11.4	4.16	7.30	3600.0
LC2	11.4	18.84	-	700.0

Transient Response



Flexible modes significantly affect pitch, tower bending moment and nacelle accelerations. This is due to resonance of a flexible mode induced by the focused wave.

Stochastic Response



In stochastic wind and wave conditions, the substructure flexible modes augment the response around the peak wave frequency, as well as close to the tower bending mode (0.4Hz). In heave there is a significant increase in response around the peak wave frequency, but it should be noted that hydrodynamic viscous forcing was not included for flexible modes and as such these results are only qualitatively indicative of the increased motion in heave.

References

[1] Borg M, Hansen AM, Bredmose H (2016) Floating substructure flexibility of large-volume 10MW offshore wind turbine platforms in dynamic calculations. *J. Phys.: Conf. Ser.*, **753**, p. 082024.
[2] Lemmer F, Amann F, Raach S, Schlipf D (2016) Definition of the SWE-TripleSpar floating platform for the DTU 10MW reference wind turbine. *University of Stuttgart*
[3] Borg M (2016) Generic floating substructure configuration and numerical models for wind turbine controller tuning in LIFES50+. *DTU WE Report-I-0449*.

Acknowledgements

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