Multi-level hydrodynamic modelling of a 10MW TLP wind turbine

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Introduction

The design of floaters for offshore wind turbines relies on aero-hydro-servo-elastic numerical models, which must be validated against tests. In these models there is a trade-off between accuracy and computational cost.

In the present work three numerical models are applied to a scaled version of the DTU 10MW wind turbine mounted on a Tension Leg Platform (TLP). The results for a set of load cases are benchmarked against test data. Finally, the advanced models are employed to enhance the performance of the simple model.

Loads acting on a TLP WT

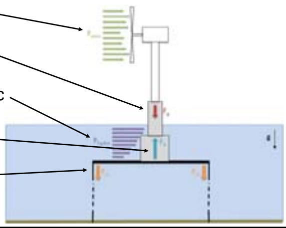
Aerodynamic

Gravitational

Hydrodynamic

Buoyancy

Mooring

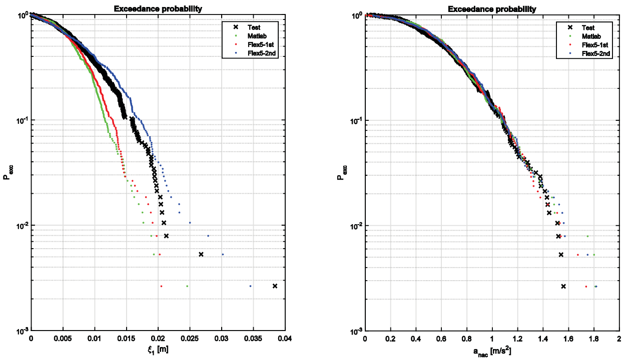


Results

Response to irregular waves

Full-size: H_s = 4.68m, T_p = 7.36s

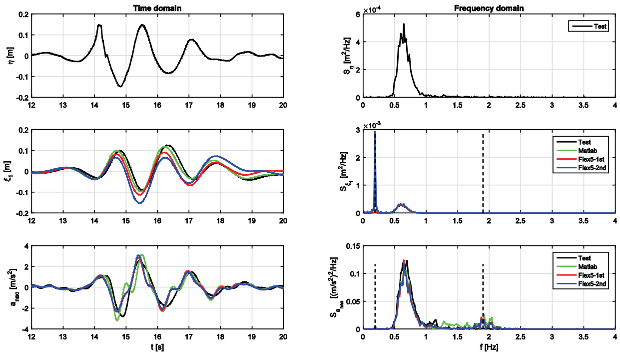
The *Matlab* model underpredicts the surge motion and predicts well the nacelle acceleration. The first-order *Flex5* model is similar to the *Matlab* model in surge, while the second-order *Flex5* model shows larger surge response. The nacelle acceleration is well predicted by both *Flex5* models.



Response to focused waves

Full-size: H_{max} = 18.84m

Surge motion is influenced by its natural frequency (0.19 Hz). The second-order wave kinematics introduce subharmonic forcing at the surge frequency, perhaps due to the difference between second-order theory and test conditions. The *Matlab* and first-order *Flex5* models agree better with the test in surge. Nacelle acceleration is well predicted by all models.



Models and load cases

The three numerical models are developed based on an experimental, Froude-scaled 1:60 TLP wind turbine:

Model	*Matlab*	*Flex5*-1st	*Flex5*-2nd
Domain	Frequency	Time	Time
DoF (total, floater)	2, 1	28, 6	28, 6
Wave kinematics	1st order	1st order	2nd order
Wave forcing	Morison	Morison	Morison
Mooring	Linear	Nonlinear	Nonlinear

A set of load cases without wind is chosen including irregular and focused waves, and corresponding to rated operation and storm condition. The wave loads are integrated by stretching up to $z=\eta$. The models are compared to the tests in terms of surge ξ_1 and nacelle fore-aft acceleration a_{nac}.

The calibration is done by comparison of the surge decay response. The nacelle damping in the *Matlab* model is further calibrated using the *Flex5* models.

The 1:60 scaled TLP WT that inspired the models

Conclusions

The *Matlab* model underpredicts surge in some cases, but often matches nacelle acceleration.

The second-order wave kinematics did not affect the nacelle acceleration significantly (due to large inertia of the TLP wind turbine). However, it induces an important subharmonic forcing at surge frequency (which leads to overprediction).

The *Matlab* model was enhanced by compensating the absent pitch motion with tower flexibility. After enhancement, its performance is comparable to that of more advanced models.

Further information

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Literature cited

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