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.

Models and load cases

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Matlab</th>
<th>Flex5-1st</th>
<th>Flex5-2nd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain</td>
<td>Frequency</td>
<td>Time</td>
<td>Time</td>
</tr>
<tr>
<td>DoF (total, floater)</td>
<td>2, 1</td>
<td>28, 6</td>
<td>28, 6</td>
</tr>
<tr>
<td>Wave kinematics</td>
<td>1st order</td>
<td>1st order</td>
<td>2nd order</td>
</tr>
<tr>
<td>Wave forcing</td>
<td>Morison</td>
<td>Morison</td>
<td>Morison</td>
</tr>
<tr>
<td>Mooring</td>
<td>Linear</td>
<td>Nonlinear</td>
<td>Nonlinear</td>
</tr>
</tbody>
</table>

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 $z=\frac{d}{\zeta}$.

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.

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: \( H_{\text{max}} = 18.84m \)

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.

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.

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