Correlation between Acceleration and Drivetrain Load Effects for Monopile Offshore Wind Turbines

Amir R. Nejad
Erin E. Bachynski, Lin Li, Torgeir Moan
NTNU
EERA DeepWind'2016,
Trondheim
Objectives

• There is a common practice in the wind industry to set a limit for the maximum axial acceleration on the tower-top in the range of 0.2g-0.3g (in particular for the floating wind turbines)

• Is this limit rational?
• What is the correlation between axial acceleration and responses in drivetrain?
Method & Model

- Effect of tower-top maximum axial acceleration on the drivetrain installed on a monopile offshore wind turbine was investigated.

- Wind/wave data from an actual shallow water site “North Sea Centre” site from the MARINA platform project with water depth of 29 m is selected. This is similar to the Dogger Bank wind farm.
Method & Model

Models:

• NREL 5 MW reference turbine, supported by the monopile foundation from the OC3 study.
• Nowitech/NREL 5 MW reference gearbox.

INP-A,B : Main Shaft Bearings
PLC-A,B : Planet Carrier Bearings
PL-A,B : Planet Bearings
IMS-A,B,C : Intermediate Shaft Bearings
HS-A,B,C : High Speed Shaft Bearings
Method & Model

• De-coupled modelling approach:

(a) 5MW wind turbine model in SIMO-RIFLEX-AeroDyn

(b) MBS model of 5 MW reference drivetrain [11]
Method & Model

- 24 EC were considered, from cut-in to cut-out:

<table>
<thead>
<tr>
<th>EC</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_w$ (m/s)</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>11.4</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>$H_s$ (m)</td>
<td>0.59</td>
<td>0.72</td>
<td>0.85</td>
<td>1</td>
<td>1.17</td>
<td>1.34</td>
<td>1.52</td>
<td>1.72</td>
<td>1.92</td>
<td>2</td>
<td>2.13</td>
<td>2.35</td>
</tr>
<tr>
<td>$T_p$ (s)</td>
<td>6.38</td>
<td>6.32</td>
<td>6.28</td>
<td>6.27</td>
<td>6.31</td>
<td>6.35</td>
<td>6.41</td>
<td>6.5</td>
<td>6.59</td>
<td>6.62</td>
<td>6.69</td>
<td>6.81</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>used in MBS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EC</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_w$ (m/s)</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>$H_s$ (m)</td>
<td>2.57</td>
<td>2.81</td>
<td>3.05</td>
<td>3.3</td>
<td>3.55</td>
<td>3.81</td>
<td>4.08</td>
<td>4.35</td>
<td>4.63</td>
<td>4.92</td>
<td>5.21</td>
<td>5.5</td>
</tr>
<tr>
<td>$T_p$ (s)</td>
<td>6.92</td>
<td>7.06</td>
<td>7.19</td>
<td>7.33</td>
<td>7.47</td>
<td>7.62</td>
<td>7.78</td>
<td>7.93</td>
<td>8.09</td>
<td>8.27</td>
<td>8.43</td>
<td>8.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>used in MBS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

- 10 min. simulation, 6 seeds
- Results from all EC were used for evaluating main shaft responses
- Results from selected EC were used for MBS analysis and calculating forces on bearings and gears
Results

Max. axial acceleration vs. wind speed
Spectrum of axial acceleration in different environmental conditions
Results

Axial force:

Max. Axial force on tower-top vs. max. axial acceleration

Thrust force vs. wind speed
Results

Bending moment:

Max. bending moment vs. wind speed

Max. bending moment on tower-top vs. max. axial acceleration
Results

Drivetrain components:

INP-A, B : Main Shaft Bearings
PLC-A, B : Planet Carrier Bearings
PL-A, B : Planet Bearings
IMS-A, B, C : Intermediate Shaft Bearings
HS-A, B, C : High Speed Shaft Bearings

Nowitech/NREL 5 MW Reference Drivetrain
Results

Drivetrain components:

Main bearing: INP-A

Main bearing: INP-B
Results

Drivetrain components:

High speed stage bearing: HS-C

1st stage gear mesh force
Discussion & Conclusion

• The results showed that the maximum tower-top acceleration is about 0.1g for this case study monopile.
• The axial acceleration increases with the wind speed.
• **No correlation** was found between the maximum axial force on the tower-top and the maximum axial acceleration. The axial force follows the thrust force mainly. (In a 4-point support configuration, the axial force on the main shaft is the design driver for the second main bearing).
Discussion & Conclusion

• The tower-top bending moment was found to increase as the wind increase. (The bending moment is a design driver for the main shaft and the main bearing).

• The load effect of the components, gears and bearings, inside the gearbox were found to be **not correlated** with the axial acceleration. They mainly follow the torque and are influenced by the power control system.
References

• 5 MW reference offshore gearbox:

• Environmental data:
Thank you