The GICON®-TLP for wind turbines

Experimental Studies and numerical Modelling of structural Behavior of a Scaled Modular TLP Structure for Offshore Wind turbines

J. Großmann, F. Dahlhaus, F. Adam, B. Schuldt

Main partners:
Motivation

- Globally found wind resources present a great and ecological opportunity for power generation.
- Floating foundations are economical for water depths > 60 m [Musial et al, 2006].
- Founding depths for the GICON®-TLP are:

Source: ORECCA
Outline

GICON® Group
- Revenue
- Partners

GICON®-TLP
- Path of development
- Design (2.0 MW, 6.0 MW, comparison)

Scaled tests (2.0 MW)
- HSVA (Feb. 2012), MARIN (June 2013), VWS (Sep. 2013)

Conclusion and Outlook
GICON® Group

An independent engineering and consulting group
1994: GICON – Grossmann Ingenieur Consult GmbH established in Dresden, Germany, as a privately held engineering company with 20 employees by CEO Prof. Jochen Grossmann

Today: The GICON Group’s 300 full-time employees across 12 companies Average revenue growth 10% p.a.; 23.4 Mio €. 

On average 30 ongoing applied R+D projects in all departments

Over 80 German and international patent applications for processes or technology have arisen from research conducted by GICON engineers

Sample of national and international cooperation partners:
GICON®-TLP

A development of private industry in cooperation with academic institutions
→ the development comprises: 10 Patent families in 22 countries

First concept HSVA tank model high redundancy principle tests ~ 1500 t

MARIN tank model optimized design high redundancy test of dynamic behavior of the pilot plant ~ 1200 t

pilot plant modified design adequate redundancy economical solution ~ 670 t
Advantages of the GICON®-TLP:

- Deployable from 20 meters to 300 meters
- Portside assembly and transport of the entire structure to the deployment location
- Modular construction resulting in more flexibility in the supply chain
- Depending on the geology - anchoring via piles, micro piles or gravity foundations

<table>
<thead>
<tr>
<th>Wind Turbine</th>
<th>Weight/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 MW</td>
<td>≈ 291 t /MW</td>
</tr>
<tr>
<td>4.0 MW</td>
<td>≈ 248 t /MW</td>
</tr>
<tr>
<td>6.0 MW</td>
<td>≈ 214 t /MW</td>
</tr>
</tbody>
</table>
Concept for prototype (2.0 MW)

Components of the platform:

- cylindrical buoyancy bodies (BB)
- horizontal pipes (HP) for structural base
- vertical pipes (VP)
- cantilever beam (CB)
- transition piece (TP)

<table>
<thead>
<tr>
<th>Dimensions (L x B x H)</th>
<th>32m x 32m x 28m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>2070 m³</td>
</tr>
<tr>
<td>TLP Weight incl. sec. Steel</td>
<td>≈ 670 t (590t + 80t)</td>
</tr>
<tr>
<td>Total weight incl. WT</td>
<td>≈ 972 t</td>
</tr>
<tr>
<td>min. # of Anchor points</td>
<td>4</td>
</tr>
</tbody>
</table>
Characteristics:

- Modular construction
- Structure width < PanMax
- Also usable for 4.0 MW
- Fabrication: 2 TLP per week (one shipyard)
Comparison of both concepts (2.0 and 6.0 MW)
Scaled tests

HSVA Hamburg, MARIN Wageningen, TU Berlin
Scaling after Froude

Scaling factor $\lambda = 25$

Incoming flow angle 0.0°, 22.5° and 45.0°

Only wave loads

Depth of water 30 m

Testing conditions:

<table>
<thead>
<tr>
<th>$h_s$ in m</th>
<th>$T_p$ in s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>5.9</td>
</tr>
<tr>
<td>3</td>
<td>6.9</td>
</tr>
<tr>
<td>4</td>
<td>8.0</td>
</tr>
<tr>
<td>6</td>
<td>9.8</td>
</tr>
</tbody>
</table>

- good agreement
- added mass coefficients differ from those stated by [Clauss, 1988]
  - $c_{\text{tube}} = 0.6$
  - $c_{\text{bb}} = 0.2$
- Scaling after Froude
- Scaling factor $\lambda = 37$
- Incoming flow angle $0^\circ$, $22.5^\circ$ and $45^\circ$
- Exposure to wind, wave and coupled wind/wave loads
- Fixed ($\alpha = 35\,^\circ$; $\theta = 90\,^\circ$) and towing states
- Water depth 20 m

- Testing conditions:

<table>
<thead>
<tr>
<th>$v_w$ in m/s</th>
<th>$h_s$ in m</th>
<th>$T_p$ in s</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.0</td>
<td>2.30</td>
<td>0.83</td>
</tr>
<tr>
<td>25.0</td>
<td>4.72</td>
<td>1.00</td>
</tr>
<tr>
<td>36.5</td>
<td>5.30</td>
<td>1.44</td>
</tr>
</tbody>
</table>
Comparison eigenfrequencies for $h_s = 4.72$ m

<table>
<thead>
<tr>
<th>Comment</th>
<th>#</th>
<th>$f_m$ in Hz</th>
<th>$f_c$ in Hz</th>
<th>$f_m/f_c$ in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surge</td>
<td>$f_1$</td>
<td>0.637</td>
<td>0.625</td>
<td>1.9</td>
</tr>
<tr>
<td>Sway</td>
<td>$f_2$</td>
<td>0.637</td>
<td>0.625</td>
<td>1.9</td>
</tr>
<tr>
<td>Heave</td>
<td>$f_3$</td>
<td>2.111</td>
<td>1.955</td>
<td>8.0</td>
</tr>
<tr>
<td>Roll</td>
<td>$f_4$</td>
<td>1.150</td>
<td>1.160</td>
<td>0.9</td>
</tr>
<tr>
<td>Pitch</td>
<td>$f_5$</td>
<td>1.150</td>
<td>1.160</td>
<td>0.9</td>
</tr>
<tr>
<td>Yaw</td>
<td>$f_6$</td>
<td>1.308</td>
<td>1.304</td>
<td>0.3</td>
</tr>
</tbody>
</table>

- good agreement
- added mass coefficients differ from those stated by [Clauss, 1988]
- $c_{tube} = 0.6$
- $c_{bb} = 0.2$
- Scaling after Froude
- Scaling factor $\lambda = 37$
- Incoming flow angle 0° and 45°
- Water depth 20 m
- Regular waves
- Towing velocities 3.5, 5.3 and 7.0 kn

- Testing conditions:

<table>
<thead>
<tr>
<th>$h_s$ in m</th>
<th>$T_p$ in s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2.3</td>
<td>6.5</td>
</tr>
<tr>
<td>3.8</td>
<td>7.2</td>
</tr>
</tbody>
</table>
Towing power for 5.3 kn and different sea states
Conclusion and next steps
Outlook and next steps

- 2009 First concept
- 2012 First tank tests (HSVA)
- 2013 Tank tests with modified design (MARIN/VWS)
- 2013 Optimizing design for pilot plant (optional: additional tests 2014)
- 2014/15 Prototype (2.0 MW) in the German Baltic Sea
- 2015/16 Prototype (6.0 MW) in the German North Sea
- 2017/18 Serial production (6.0 MW)
Further literature


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