Outcomes of the DeepWind conceptual design

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\[ P = \frac{1}{2} \rho A v^3 C_p \]

\[ \sqrt{17} \]

\[ \sum \]
Contents

• DeepWind Concept

• Advances
  – Rotor
  – Floater
  – Power module
  – Mooring system

• Deepwind Simulations

• Upscaling

• Cost of technology

• Conclusions

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DeepWind Concept

FP7 project (2010-2014)

- A radical new design- aiming for better COE and a more reliable wind turbine
  - Few components-less failures at less cost
  - Pultrusion-less failures; cost approximately 30% of conventional blade
  - Operation not influenced by wind direction
  - New airfoil profiles available for better efficiency
  - Simple stall control with overspeed protection

- Rotating spar with high Aspect ratio-Less displacement than existing concepts

- No nacelle-low center of gravity - high stability

- Upscaling potential

- Paulsen et al. The 5 MW Deepwind Floating Offshore Vertical Wind Turbine Concept Design - Status And Perspective Proceedings of EWEA 2014, Barcelona
Modified Troposkien shape; analyses with NACA 0018/25 airfoils

Advances

Rotor

\[ C_p \] aerodynamic simulation with DU12W262 for a Reynolds number of \( 1 \times 10^7 \) with free transition on 2-bladed 5 MW DW rotor (without stall)

Advances
Floater

- Draught 108 m, redundancy with 6 mooring lines
Advances

Power transmission
Advances

Power transmission

- Map of NESSIE design tool GUI

Advances

Deepwind Simulations

1) code development and validation including different type of measurement campaigns on model rotors
2) contribution to turbine design of 1kW demonstrator, 5MW Deepwind final design and initial simulations on a 20MW turbine

- Structural core based on a multibody formulation
- Joints modeled by geometric constraints

Use for VAWT

- Arbitrary geometry √
- Hydrodynamic loads √
- Wave loads √
- Mooring lines √
- Turbulent inflow model √
- Aerodynamic blade loads √
- Dynamic stall √
- BEM induction model √
- Magnus forces on floater √

Upscaling
Deepwind 1 kW-5 MW 20 MW

5 MW conceptual design
1 kW upscaled to 5 MW
### Cost of Technology

**Deepwind  5 MW**

<table>
<thead>
<tr>
<th>Operational and Performance Data</th>
<th>Geometry</th>
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<tbody>
<tr>
<td><strong>Rated power</strong> [MW] 5</td>
<td>Rotor radius (R) [m] 60.49</td>
</tr>
<tr>
<td><strong>Rated rotational speed</strong> [rpm] 5.95</td>
<td>Rotor height (H) [m] 143</td>
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<tr>
<td><strong>Rated wind speed</strong> [m/s] 15</td>
<td>Chord (c) [m] 5</td>
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<tr>
<td><strong>Cut in wind speed</strong> [m/s] 4</td>
<td>Solidity (σ =Nc/R) [%] 16.53</td>
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<tr>
<td><strong>Cut out wind speed</strong> [m/s] 25</td>
<td>Swept Area [m²] 11996</td>
</tr>
</tbody>
</table>

**Base line .. 2nd DeepWind 5MW**

**1st DeepWind 5 MW**

51 kg/m²
DeepWind conceptual Design
Installation, Operation and Maintenance

• INSTALLATION
  ✓ Using a two bladed rotor, the turbine and the rotor can be towed to the site by a ship. The structure, without counterweight, can float horizontally in the water. Ballast can be gradually added to tilt up the turbine.

• O&M
  ✓ Moving the counterweight in the bottom of the foundation is possible to tilt up the submerged part for service.
  ✓ It is possible to place a lift inside the tubular structure.
Cost of Technology

Deepwind  5 MW

Left: Floater with steel material. Right: Floater made of reinforced concrete

<table>
<thead>
<tr>
<th></th>
<th>k€</th>
<th>Cost [k€]</th>
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<tbody>
<tr>
<td>rotor</td>
<td>2123</td>
<td>2,123</td>
</tr>
<tr>
<td>floater</td>
<td>3591</td>
<td>859</td>
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<tr>
<td>generator</td>
<td>2173</td>
<td>2173</td>
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<tr>
<td>mooring system</td>
<td>1062</td>
<td>862</td>
</tr>
<tr>
<td>total</td>
<td>8,949</td>
<td>6,017</td>
</tr>
</tbody>
</table>

100 MW Wind Farm project economy

- Energy production MWh/year: 19,953
- Net production MWh/year: 19,306
- Windfarm production 98% MWh/year: 378,399
- Wind farm hexagonal mooring* k€: 175,083

specific cost €/kWh*: 0.46

Cost of Technology

Deepwind 5 MW

LEVELIZED COST OF ENERGY

$$\text{COE} = \frac{(\text{FCR} \times \text{ICC}) + \text{LRC} + \text{AOM}}{\text{AEP}}$$

- 101 c€/kWh
- 10%
- 450,000 €/yr
- 9 M€
- 19 GWh/yr
- 30 c€/kWh

\text{LCOE approach following:}
Simplified model based on utility approach: 500 MW 100-110 €/MWh OPEX 30 €/MWh

- 100 MW: 65 €/MWh, 500 MW 62 €/MWh
- with high/low rates: between 59 and 75 €/MWh

Floating market potential

America
- Maine leading U.S. efforts to develop floating offshore wind solutions
- Market watch status

Europe
- Pilot programs in process in Portugal and Norway
- Main priorities: Deep UK Rd 3 projects suitable for floating turbines and France

Asia
- Japan in need of deepwater solutions to scale offshore wind industry effectively
- Tariff secured

<table>
<thead>
<tr>
<th>Location</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (GW)</td>
<td>2</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
</tr>
<tr>
<td>Rest of EU (GW)</td>
<td>1</td>
</tr>
<tr>
<td>(Med. &amp; Scand.)</td>
<td></td>
</tr>
<tr>
<td>Japan (GW)</td>
<td>6</td>
</tr>
<tr>
<td>US (GW)</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL (GW)</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

Deepwind closure meeting – Roskilde – 29/09/2014 – p.8
Conclusions

- Simulation tools are provided—they are working to details
- 5 MW Conceptual made ready
  - Challenges in rotor and yaw stability
- Cost analysis
  - Simple analysis promising but rudimentary; to be improved
  - Floater materials for cost of floater important
  - Mooring system
  - Variability of cost for resources (e.g. steel prize)
  - Wind turbine around 1800 €/kW, with new floater material 30% less
  - COE around 100€/MWh
  - OPEX mostly unknown due to unknown procedures (30€/MWh)
  - Differences in Development and consenting for industrial model
- Concept to be looked further into towards higher TRL.
Acknowledgements

The work is a result of the contributions within the DeepWind project which is supported by the European Commission, Grant 256769 FP7 Energy 2010- Future emerging technologies, and by the DeepWind beneficiaries: DTU(DK), AAU(DK), TUDELFT(NL), TUTRENTO(I), DHI(DK), SINTEF(N), MARINTEK(N), MARIN(NL), NREL(USA), STATOIL(N), VESTAS(DK) and NENUPHAR(F).

Dr Birgitte R. Furevik, Norwegian Meteorological Institute Bergen(NO)

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement No 256769
Thank You for your Attention