Floating wind turbines: the future of wind energy?



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Outline

- Trends in (offshore) wind energy
- Concepts of floating wind turbines
- Some challenges
- Research in the field at LR



Trends in (offshore) wind energy





How big is 8MW?





How big is 8MW?



Samsung S7.0-171 83.5 m blade length



Cumulative wind power installations in Europe (GW)



Wind in power - 2015 European Statistics, EWEA report (Feb. 2016)



Cumulative wind power installations **offshore** in Europe (MW)



hftم

The European offshore wind industry - key trends and statistics 2015, EWEA report (Feb. 2016)

Types of foundations

Newly installed foundations in Europe in 2015

- 97% monopiles (385 structures)
- 3% jackets (12 structures)

In 2015, there were 3,313 foundations installed offshore in Europe



Monopile: <u>www.londonarray.com</u> (May, 2016) Jacket: Alpha Ventus, <u>www.offshorewind.biz</u> (May, 2016)

Limitations of current technology

Most seas are deeper than 50 metres

Existing commercial foundations are not economically viable in deep seas





Concepts of floating wind turbines



Main types of foundation



Tension leg platform

Semi-submersible

Spar buoy

Stability Assembly Installation Depth Moorings Dry dock Towing to site 50-150 m Buoyancy Dry dock Towing to site 50-150 m Ballast On/off-shore Towing or not 100m - ?



2008 - Blue H (80kW)



http://www.bluehengineering.com/historical-development.html



2009 – Hywind (2.3MW)



Photo: Trude Refsahl/Statoil

Upcoming- Hywind Scotland Pilot Park (30MW)



www.statoil.com/HywindScotland



2011 – WindFloat (2MW)



Upcoming – WindFloat Atlantic (25MW)





http://www.principlepowerinc.com/en/windfloat

2011-2016 – Fukushima Forward project (2MW, 5MW, 7MW)



http://www.fukushima-forward.jp



And much more...















And much more...

State of development of selected floating turbine concepts



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Combining wind and wave energy





http://www.floatingpowerplant.com

Floating airborne wind energy





http://www.skysails.info/english/power

Some challenges



Some challenges

- Turbine
 - Rotor-wake interactions
 - Control systems
- Support structure
 - Conservatism in the design (not cost effective)
 - Relation between size of turbine rating
- Mooring lines
 - Dynamic behaviour of moorings, esp. in shallow water
 - Anchors and soil conditions
- Electrical infrastructure
 - Dynamic power cables
- Operation and maintenance
 - Harsh environmental conditions
- Design standards
 - Lack of experience leads to conservative designs
 - Modelling of the system dynamics

Numerical modelling



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Research at LR



High-fidelity modelling of FSI

Unstructured mesh fluid/ocean model (finite elements)







High-fidelity modelling of FSI



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Applications

- Wind/tidal turbine modelling through actuator disks
 - Abolghasemi et al. "Simulating tidal turbines with multi-scale mesh optimisation techniques", Journal of Fluids and Structures 66:69-90 (2016)
 - Viré et al. "Towards the fully-coupled numerical modelling of floating wind turbines", Energy Procedia 35:43-51 (2013)
- Dynamics of a floating monopile
 - Viré et al. "Towards the fully-coupled numerical modelling of floating wind turbines", Energy Procedia 35:43-51 (2013)
- Aerodynamics of kite wings
 - Rajan et al. "Fluid-structure interaction of an inflatable kite wing", Airborne Wind Energy Conference (2015)
- Wave-structure interactions
 - Viré et al. "Application of the immersed-body method to simulate wave-structure interactions", European Journal of Mechanics B/Fluids 55:330-339 (2016)



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Wave-structure interactions

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• Regular waves of steepness ak = 0.01where $gk \tanh(kh) = (2\pi T)^2$ and T = 1

• Intermediate water depth: $h/\lambda_0 = 0.45$ ($\lambda_0 = 2\pi g/\omega^2$)



Reference: linear wave theory (MacCamy & Fuchs, 1954)

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- Irregular waves
- Amplitudes of the focused wave (k_p is the Jonswap peak) $A_{
 m sum}k_p=0.018$ $A_{
 m sum}k_p=0.09$
- The amplitude is maximum at: $x_f = 10h$ and $t_f = 7.5T$



Reference: second-order calculation (Sharma & Dean, 1981)

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Upcoming works

- CFD modelling of the TetraSpar concept (Stiesdal, 2016), with Deltares and NTNU
- Re-design of blades for model-scale testing, with MARIN
- Build synergies at TU Delft and internationally on floating wind energy



The future of wind energy?

LEVELISED COST OF ELECTRICITY (LCOE) OF MAJOR POWER GENERATION TECHNOLOGIES IN EUROPE





Subsidies and costs of EU energy, Ecofys (Nov. 2014)

The future of wind energy?



Cost comparison for a wind farm of 800 MW installed capacity

* Electrical infrastructure installation cost per MW for floating is based on demo park scale and are therefore not directly comparable to bottom fixed.

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Thank you for your attention