S4VAWT
Floating vertical axis wind turbines with pitched blades

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Cost reduction of offshore wind

This project focusses on the optimization of a semi-submersible floating support for VAWTs and aims to have most impact on the CAPEX of offshore wind energy.
Motivation

Why floating?
- Large wind resource in deep (>50m) water areas
- Ease of installation (in harbor, towed to site) and major O&M activities potential cost saver

Why vertical axis wind turbines (VAWT)?
- Aerodynamic loads scale less severe than gravity loads when upscaling
- Aerodynamic efficiency can match HAWT, when using pitched blades
- Insensitive to wind direction changes

Why floating VAWT?
- Despite slightly larger rotor mass, the center of gravity will be lower
- Large platform motions are less intrusive for VAWT

-> smaller, lighter and cheaper support structure!
S4VAWT:
Content

• Background
  – VAWT
  – Floating wind

• S4VAWT
  – Overview
  – Objectives & Approach
  – Deliverables

• First results
  – Basis of design
  – Model development and validation

• Conclusion and outlook
Background (1)

Early days of VAWTs (1970-1990):
- Small scale
- Various configurations
- Sandia NL research and test bed (17m, 34m) [1]

Recent attention to VAWTs:
- Focus on CoE, instead of aerodynamic efficiency
- Application on floating support structures

Status of floating wind turbine development:
- Several prototypes operational
- Many different concepts, not converged yet
- DNV-GL JIP on floating wind (guidelines)

Consortium joint R&D work on floating wind:
- 2003: feasibility study DRIJFWIND (MSC, MARIN, TUD, ECN oa)
- 2013: MIP R&D project (GustoMSC, MARIN & ECN) [2]
- 2015: TO2 project on floating wind (MARIN, ECN oa)

Background (3)

Aero-hydro coupling including control, investigated with:

- Numerical simulations
- Model test campaign

Understanding this interaction is essential for integral design!

Floating wind turbine model test results of a stepwise increasing wind speed with two different controllers; clear limit cycling (for C2) above rated (~700s), due to the aero-hydro coupling including control.
S4VAWT (1)

Overview:
- TKI-WoZ Innovation R&D project
- Consortium: GustoMSC, EOLFI, TUDelft, WMC, MARIN, ECN (coordinator)
- Period: 2015/09/01 - 2018/02/28
S4VAWT (2)

Objectives:
- Develop the required methods and models
- Identify the design driving load cases
- Optimize the semisubmersible support structure
- Evaluate the CoE of floating VAWT

- WP1 rotor modelling
- WP2 wind turbine modelling
- WP3 coupling of tools
- WP4 optimization of the support structure: floater and mooring system
- WP5 requirement for wave basin model test
- WP6 project coordination, dissemination and exploitation
The project delivers:

- Optimized blade design and control strategy for a VAWT with pitched blades
- A model for integral design and analysis of floating VAWTs
- Overview of design driving load cases for floating VAWTs
- Optimized semi-submersible support structure (floater and mooring) for VAWT
Summary of the basis of design:

- Design according to the last DNV guideline [3]
- Design life of 20 years
- Site conditions as in Mediterranean Sea region
  - ~100m water depth
  - 8.5m/s mean wind speed
  - offshore: moderate turbulence intensity and shear
  - sheltered: moderate waves
- Load cases considered:
  - survival
  - extreme operation
  - normal operation

First results - aero model (1)

Aerodynamic model development and validation:
- Definition of a new coordinate system for VAWTs
- Extension of the capabilities of ECN AeroModule to simulate VAWTs
- Validation with:
  - Numerical benchmark
  - Experiment
First results - aero model (2)

Validation of the AeroModule with Torque2014 test cases [4]

- 2D
- 2 blades
- NACA 0015
- $C_l = 2\pi*1.11*\sin(AoA)$ and $C_d = 0$
- TSR 4.5
- rotor solidity 0.1
- blade pitch 0 degrees

First results - aero model (3)

Validation of the AeroModule loads:
First results - aero model (4)

Aerodynamic loads for turbulent wind case:

- aerodynamic rotor load in turbulent wind
- psd of aero torque
Conclusion and outlook

Floating support structures and Vertical Axis Wind Turbines seem to be a good combination, which deserves further investigation.

The S4VAWT project focusses on the optimization of a semi-submersible floating support for VAWTs.

Ongoing/future work:
- Development of methods & models
  - a dedicated control strategy
  - structural modelling of VAWT
  - validation with experimental data
- Coupled aero-hydro simulation
- Optimization of the support structure
Thank you for your attention

EUROMECH conference on Vertical Axis Wind Turbines
TU Delft, September 2016 (C.J.SimaoFerreira@tudelft.nl)

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Floating wind: HAWT or VAWT?
Thank you & questions please

Special thanks to: