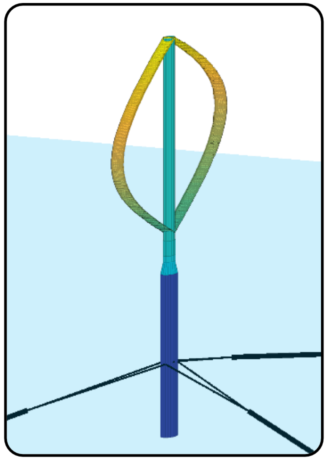
Floating vertical-axis wind turbines

Comparison of two numerical tools for integrated dynamic analysis



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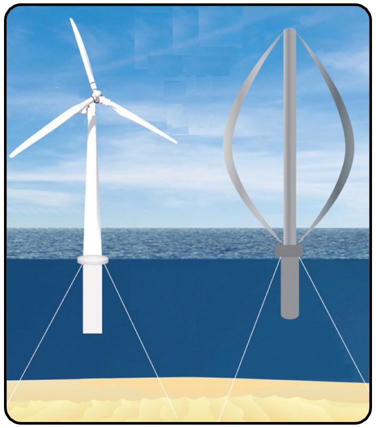
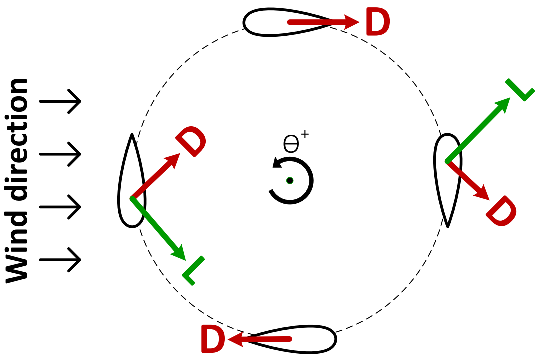
1. Introduction: **Floating VAWTs**

- **Floating wind turbines**
- **Vertical-axis wind turbines**
  - Simple design
  - Insensitive to wind direction
  - Low machinery position
- **VAWT characteristics**
  - Dynamic inflow conditions
  - Blade meets flow twice
  - Encounters own wake





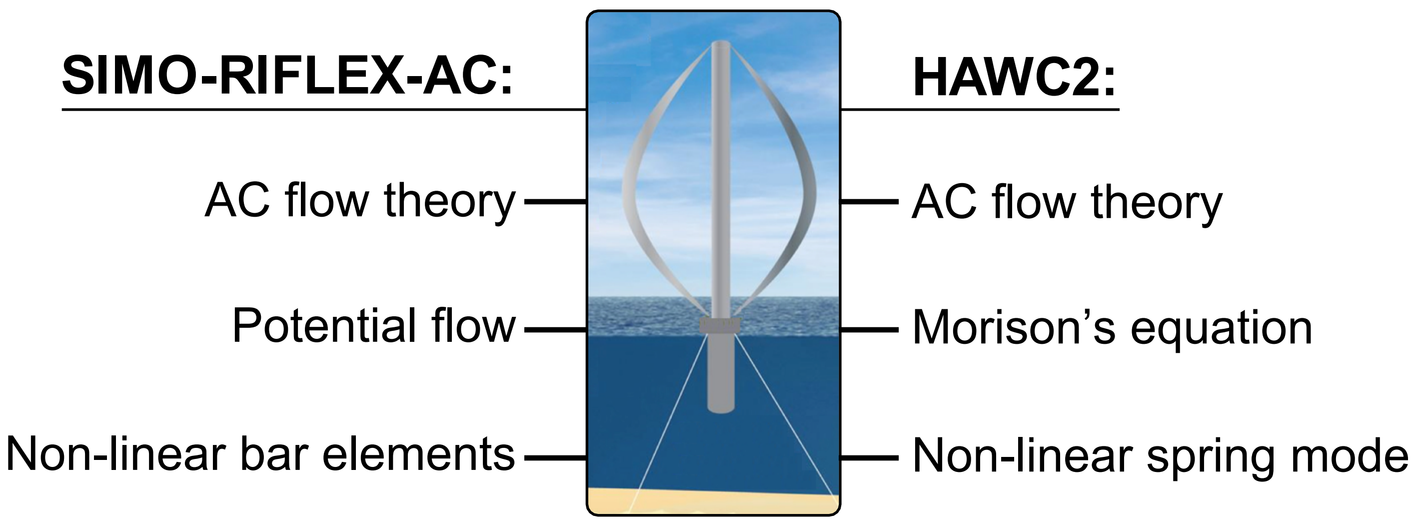
1. Introduction: **Aim / Scope**

- **VAWTs are different**
  - Aerodynamics
  - Load transfer to support structure
  - New simulation tools
- **Code-to-code comparison**
  - Modeling differences
  - Focus on implementation aerodynamics
  - Coupled analyses using a floating spar VAWT

2. Numerical tools: **Overview**

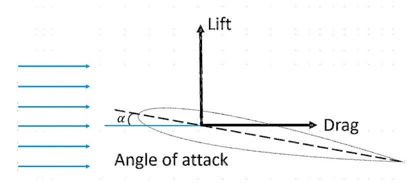
Current publicly available tools

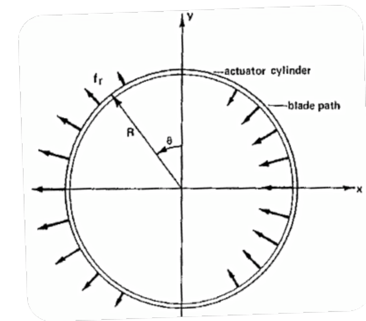
1. FloVAWT — *Cranfield University*
2. CALHYPSO — *EDF R&D*
3. OWENS toolkit — *Sandia National Laboratories*
4. **HAWC2** — ***DTU Wind Energy***
5. SIMO-RIFLEX-DMS — *NTNU/Marintek*
6. **SIMO-RIFLEX-AC** — ***NTNU/Marintek***



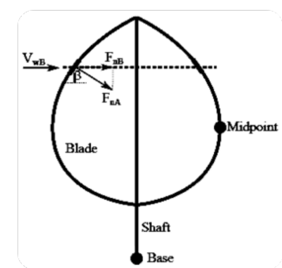
2. Numerical tools: **Aerodynamics**

- **Based on AC flow theory**
  1. Section rotor in ACs
  2. Loads from blade element theory
  3. Blade loads as body forces on the AC
  4. Solve pressure field for velocities





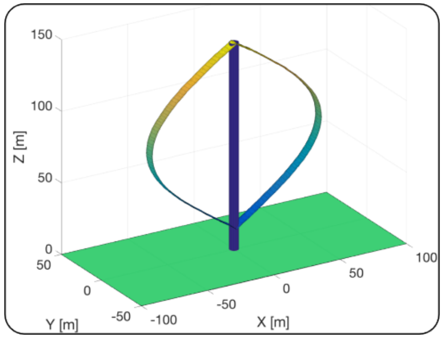
- **Additions in SIMO-RIFLEX-AC**
  - ✓ Local blade inclination
  - ✓ Tangential terms
  - ✓ Correction factor



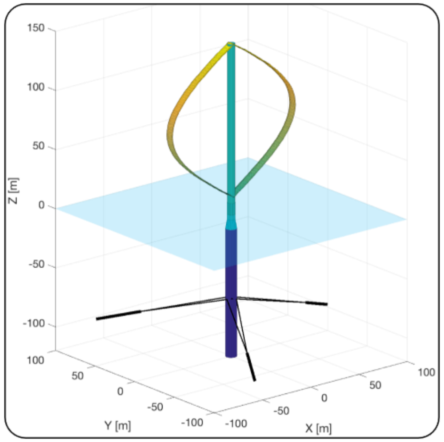
$$w_{x,j} = \boldsymbol{k_a} \left(\sum_{i=1}^{i=N} Q_{n,i} R_{w_x,i,j} + \sum_{i=1}^{i=N} Q_{t,i} R_{w_y,i,j} - \left(Q_{n,N+1-j}\right)^* - \left(Q_{t,N+1-j} \frac{y_j}{\sqrt{1-y_j^2}}\right)^* \right)$$

3. Methodology: **Two cases**

1. **Aerodynamic modeling**
   - Rigid land-based VAWT
   - 5MW DeepWind rotor
   - Steady wind-only at 8, 14 and 20 m/s

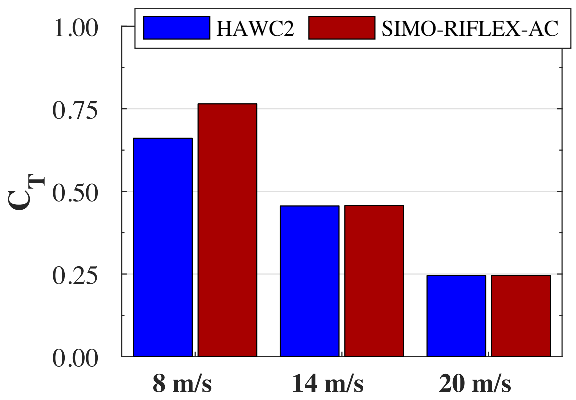


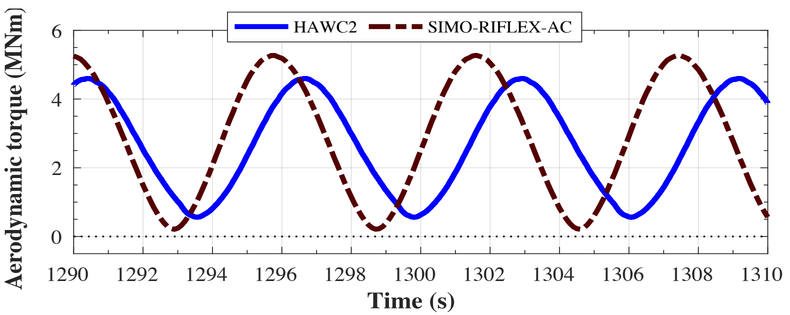
2. **Fully coupled analyses**
   - Spar VAWT
   - Platform from OC3-Hywind
   - Turbulent wind and irregular waves



4. Results: **Aerodynamic modeling**

- **Rotor-averaged thrust**
  - Similar at high wind speeds
  - C_T different at 8 m/s
- **Aerodynamic torque 8 m/s**
  - 2P effect, troughs and peaks
  - Tangential terms
  - Induced velocity





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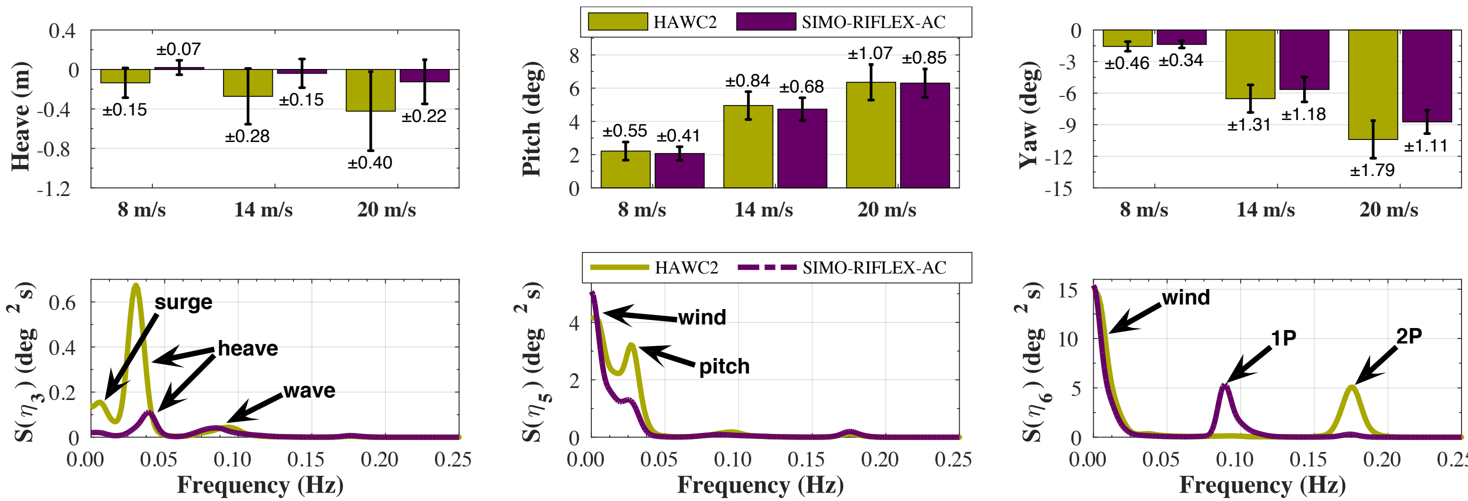
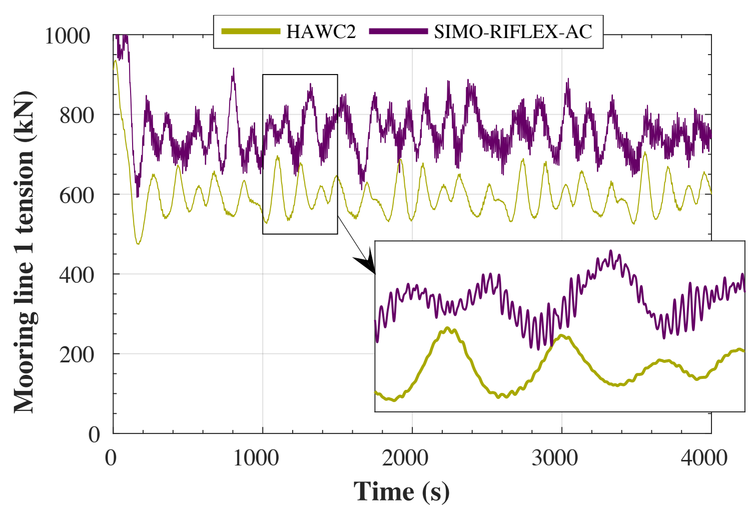
4. Results: **Coupled analyses**

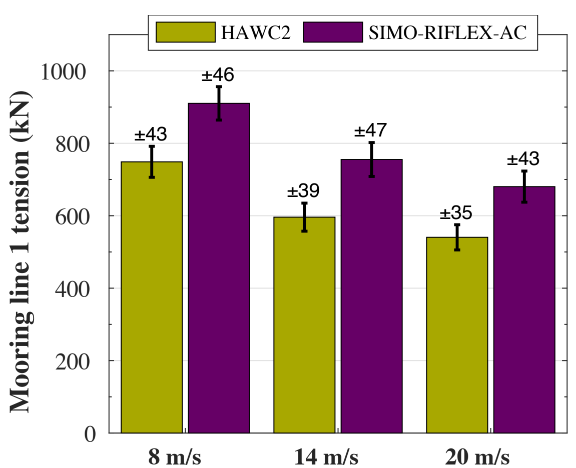
- **Platform response**
  - Larger offsets in HAWC2
  - Surge-heave coupling
  - Yaw in 1P and 2P



4. Results: **Coupled analyses**

- **Mooring line tension**
  - 1P yaw in SIMO-RIFLEX-AC
  - Mooring line (hydro)dynamics





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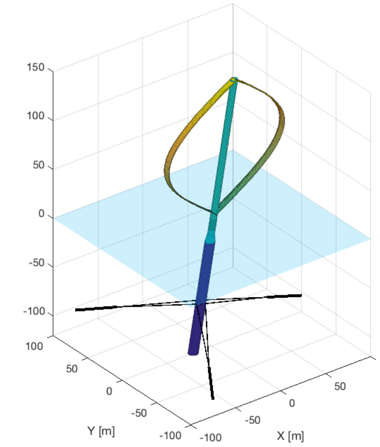
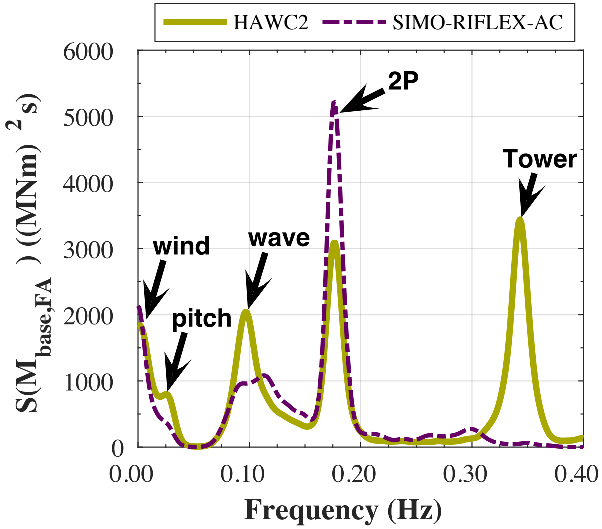
4. Results: **Coupled analyses**

- **Tower base bending**
  - Dominated by 2P excitation
  - Pitch response
  - Wave contribution
  - Tower mode (0.35 Hz)





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5. Summary

- **Vertical axis wind turbines**
  - Benefits for floating applications
  - Complex aerodynamics
- **Aerodynamic modeling**
  - AC flow theory
  - Implementation important at low wind speeds
- **Fully coupled analyses**
  - Mooring line dynamics
  - Wave contribution
  - Tower mode

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