VAMOS

Comparison of different Modelling Approaches for the Simulation of a Wind Turbine in Surge Motion

C. W. Schulz, U. Özinan, S. Netzband
P.W. Cheng, M. Abdel-Maksoud
christian.schulz@tuhh.de

Hamburg University of Technology
Stuttgart Wind Energy at University of Stuttgart

TUHH
Hamburg
University of
Technology

Fluid Dynamics
and
Ship Theory

Maritime
Systems

Main question: Is there an impact of **transient aerodynamic phenomena on the loads of floating OWT?**

If yes: **Can we trust BEMT** methods to model these?

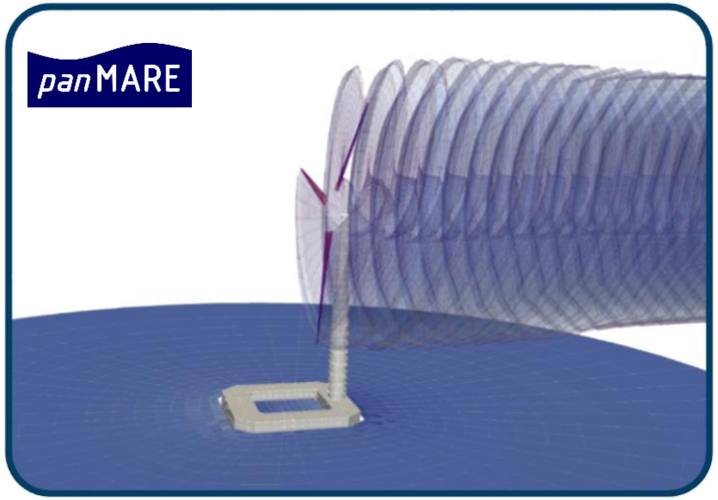
Why another investigation is needed?

- Various **conditions** (e.g. *floater type, wind speed, motion frequency and amplitude, …*)
- Absolute comparisons

Here focus on:

- **Broad motion frequency** range at moderate amplitudes
- **Transient aerodynamic phenomena**


V. Joncheray, BW Ideol



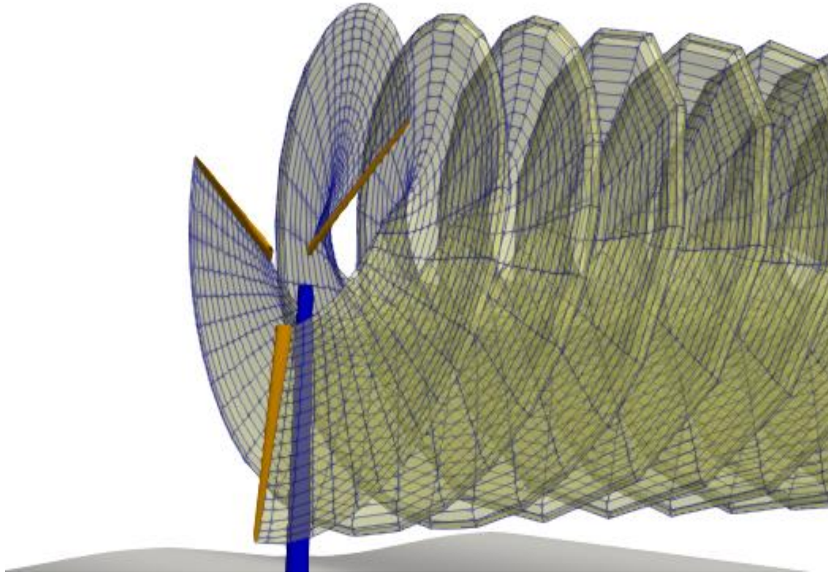
Comparison of modelling approaches for the Floatgen wind turbine in surge motion

1 Simulation models
- Blade Element Momentum Theory (BEMT) method
- BEMT with unsteady corrections
- Panel method

2 Simulation setups

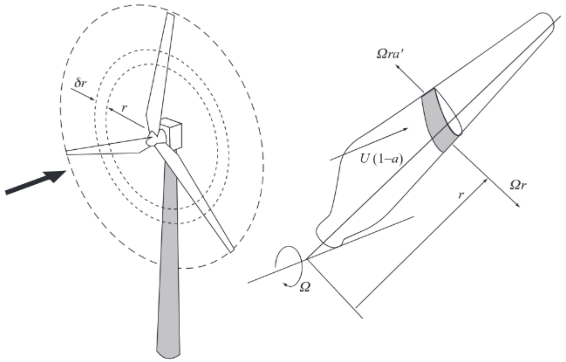
3 Results: Transient load response to
- variation of rotational speed
- surge motion

4 Conclusion and outlook



Blade Element Momentum Theory Method: AeroDyn by NREL

AeroDyn
OpenFAST



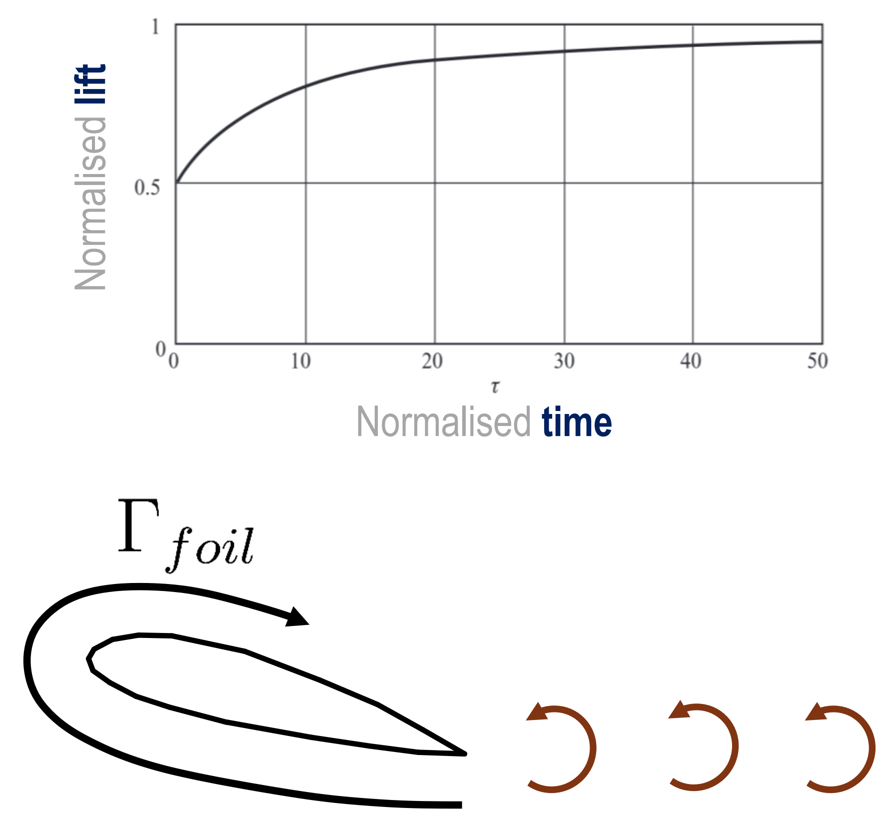
- **B**lade **E**lement **M**omentum Theory (**BEMT**)
- Based on **momentum equilibrium** on annular rings
- No flow field
- Prandtl tip and hub loss model
- **Quasi-steady**

Figure: Burton et al., 2011

BEMT + Unsteady corrections

- ***Dynamic inflow*** correction (Øye)
  - Corrects dynamic wake phenomenon
- ***Unsteady airfoil*** correction (Theodorsen)
  - **Leishman-Beddoes** model
  - (Nearly) no dynamic stall
  - **Attached flow**

Blade Element Momentum Theory Method: AeroDyn by NREL



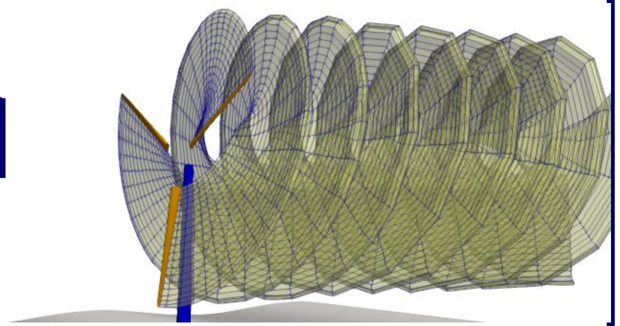
BEMT + Unsteady corrections

- ***Dynamic inflow*** correction (Øye)
  - Corrects dynamic wake phenomenon
- ***Unsteady airfoil*** correction (Theodorsen)
  - **Leishman-Beddoes** model
  - (Nearly) no dynamic stall
  - **Attached flow**
    - **2D** thin airfoil theory
    - Response to **change of circulation** / vortex shedding
    - **Delayed response of lift**

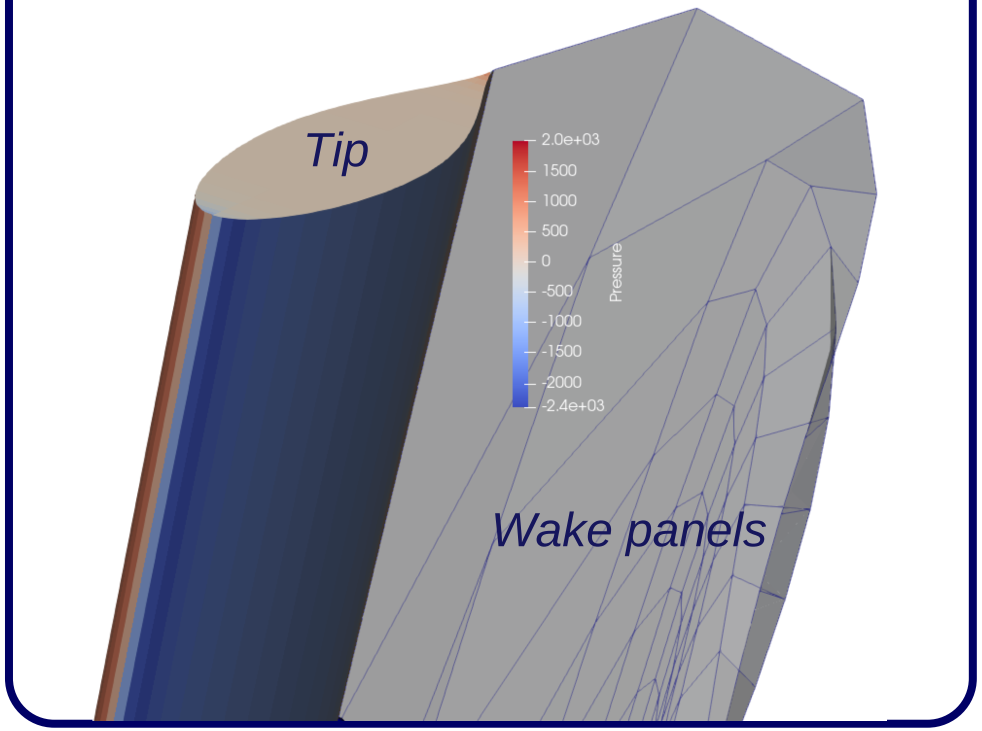
Figure: Burton et al., 2011

*Reference: panel method pan*MARE

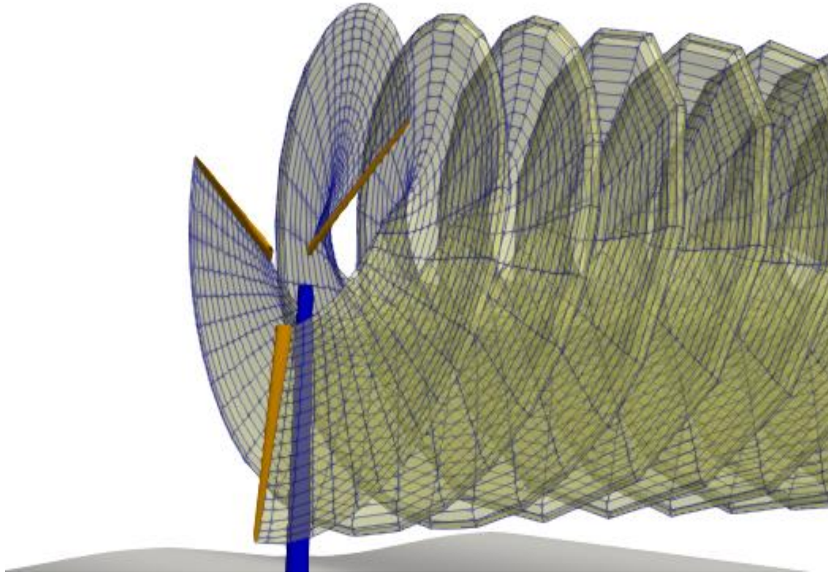
panMARE



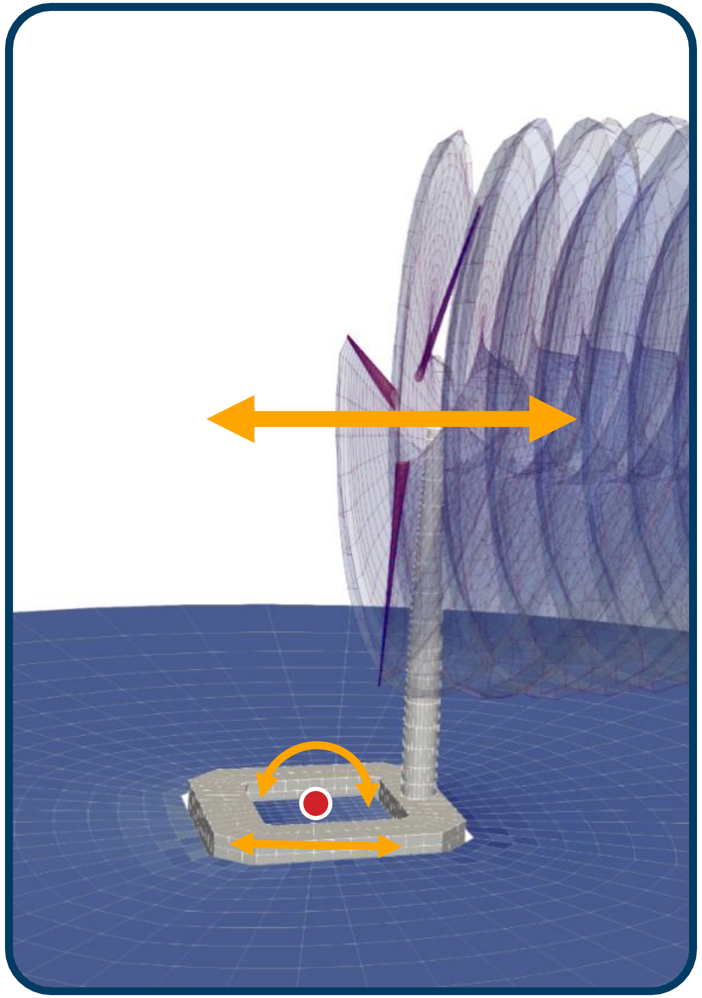
- First order **panel method**
- **3D wake**
- **Blade pressure**
- **Potential theory** – inviscid
- **2D viscous correction**
  - Drag
  - Lift for thick airfoils



Comparison of modelling approaches for the Floatgen wind turbine in surge motion



Choice of simulation scenarios: Oscillation of surge and rotor speed



Surge motion at **hub height**

↓

Variation of **inflow speed**

↓

Variation of **rotor torque**

↓

Variation of **rotor speed**

Goals:

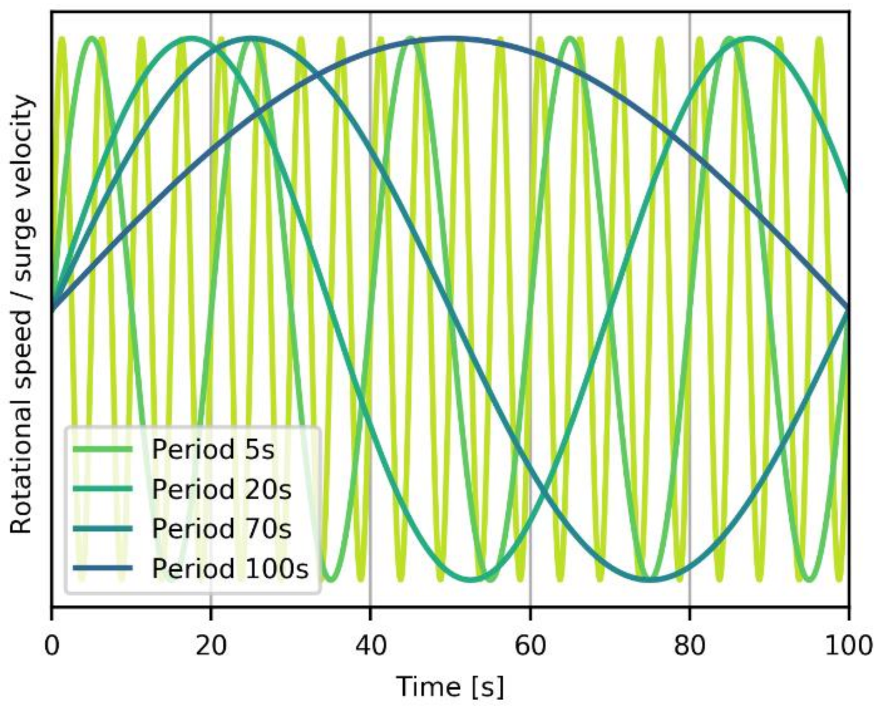
- Identification of **transient aerodynamic phenomena**
- Check **applicability of unsteady corrections** for BEMT

⇒ **Isolated** investigation of both scenarios needed

Simulation scenarios for the identification of transients in the load response

Definition of scenarios

- Basic idea:
  - Keep **quasi-steady part** of the load response **constant**
  - **Increase motion frequency**
- Rotor speed variation:
  - **Same rotor speed amplitude**, varying period
- Surge motion:
  - **Same surge velocity amplitude**, varying period



Scenario 2: Surge Velocity
Amplitude: **9%** of wind speed*

* Extracted from variable speed simulation under harmonic surge motion with 1 m amplitude and 10 s period (moderate conditions)

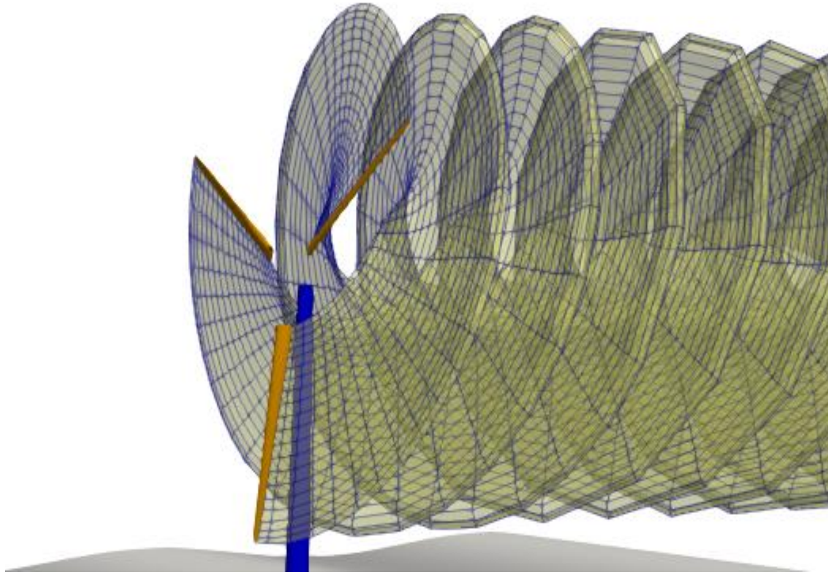
Comparison of modelling approaches for the Floatgen wind turbine in surge motion

1 Simulation models
- Blade Element Momentum Theory (BEMT) method
- BEMT with unsteady corrections
- Panel method

2 Simulation setups

3 Results: Transient load response to
- variation of rotational speed
- surge motion

4 Conclusion and outlook

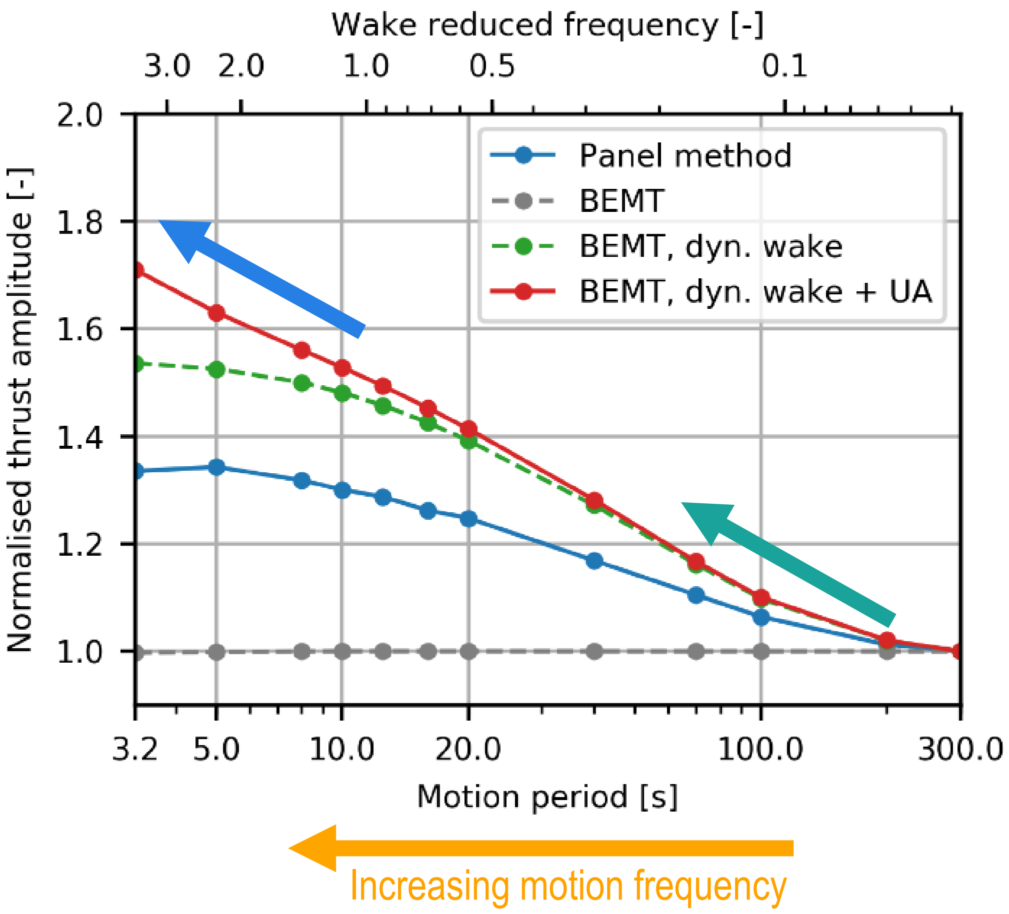


Scenario 1: Rotor Speed

Harmonic rotor speed variation

- **Normalisation** of results
  - based on **quasi-steady** response
  - **1** means **quasi-steady amplitude**
- **Quasi-steady BEMT = 1**
- **Increase of amplitude due to Dynamic wake** effect
  - At **very low frequencies**!
- Similar trends
- Considerable **absolute differences**
- **Increase** due to **unsteady airfoil correction**
- **Not** the case in ***pan*MARE**

Rotor thrust amplitude

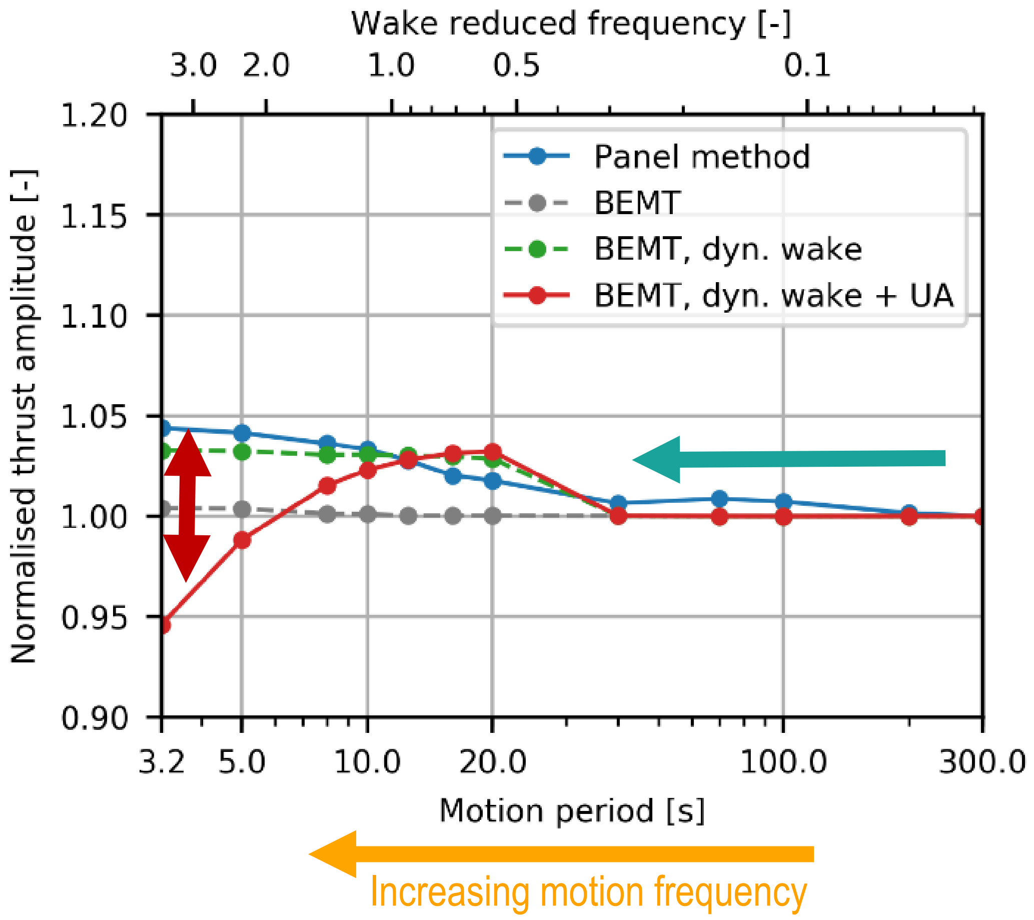


Scenario 2: Surge Velocity

Harmonic surge velocity variation

- **No transient phenomena** between 40 and 300s
- At high motion frequencies
  - **Unsteady airfoil** correction causes **decrease** of amplitude
  - Panel method shows an **increase**
  - **Contradiction!**
  - In 2D: **Decrease of amplitude** expected!
  - **Incorporated in panel method**
  - **3D wake effect superposing unsteady airfoil phenomenon?**

Rotor thrust amplitude



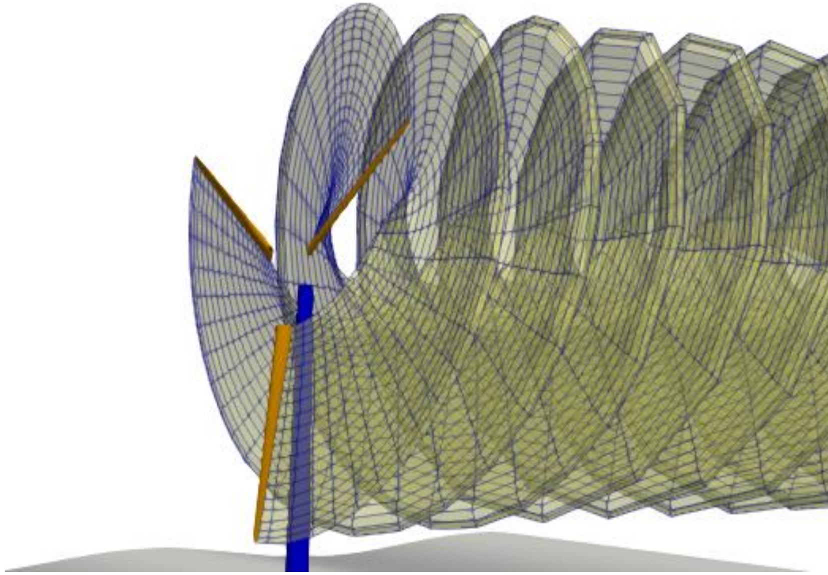
Comparison of modelling approaches for the Floatgen wind turbine in surge motion

1 Simulation models
- Blade Element Momentum Theory (BEMT) method
- BEMT with unsteady corrections
- Panel method

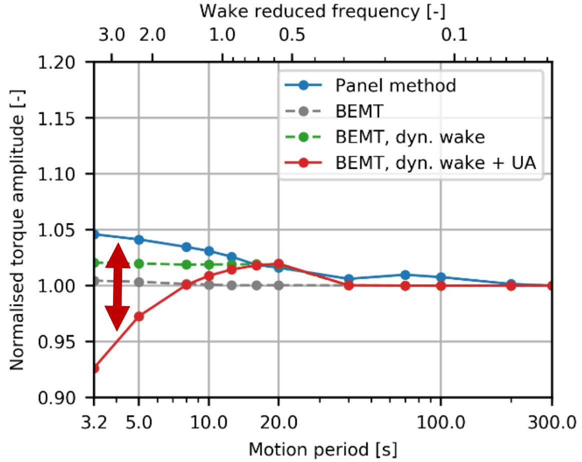
2 Simulation setups

3 Results: Transient load response to
- variation of rotational speed
- surge motion

4 Conclusion and outlook



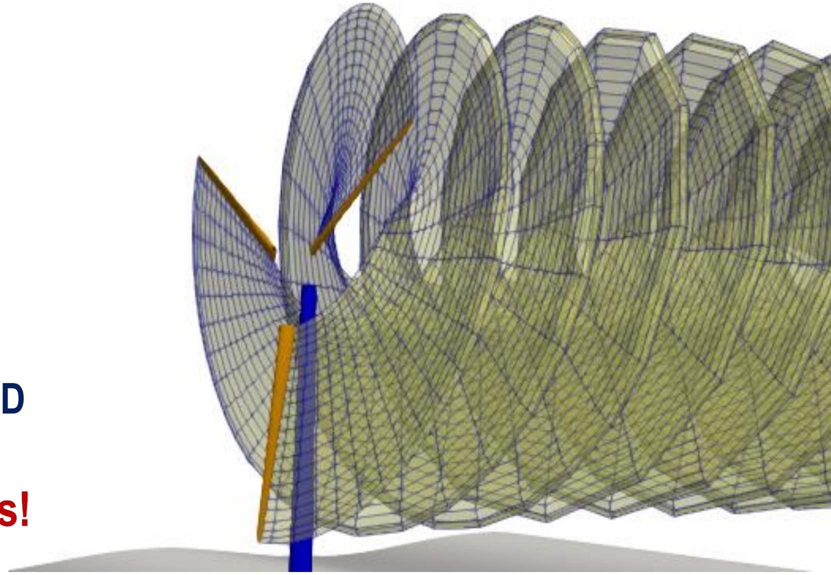
Comparison of modelling approaches for the Floatgen wind turbine in surge motion



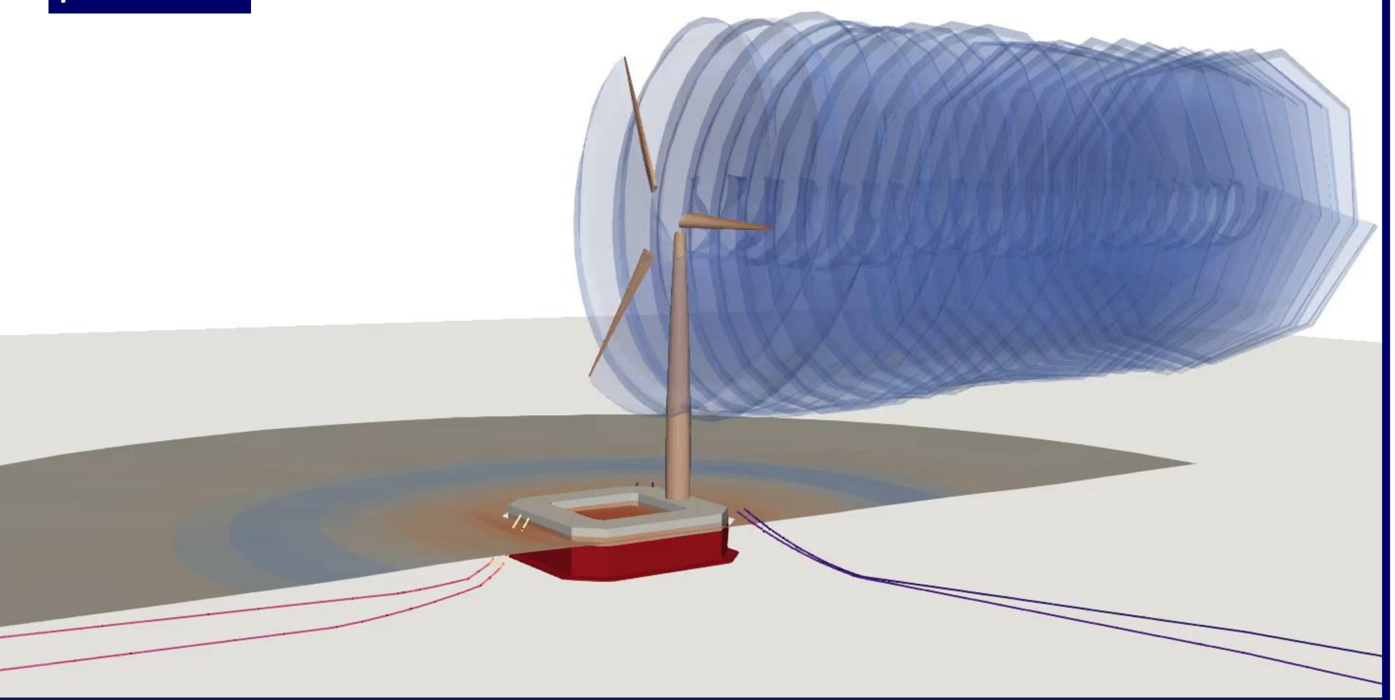
- **Significant influence** of **transient phenomena**
  - Rotor speed variation
  - Surge motion

  → Investigate influence under realistic operation conditions
- BEMT with **unsteady corrections**
  - **General trend** for moderate frequencies **matched**
  - **Deviations in absolute numbers**
- **Contradiction** between **panel method** and **unsteady airfoil** correction
  - Most probable reason: **Further aerodynamic phenomenon**
  - Phenomenon cannot be captured by BEMT corrections because of its **3D nature**

To be evaluated with other numerical methods and experiments!



Acknowledgements



Universität Stuttgart
SWE Stuttgarter Lehrstuhl für Windenergie @ Institut für Flugzeugbau
sowento
BW ideol
LHEEA CENTRALE NANTES
cnrs
UL
DNV·GL
Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

C. W. Schulz, U. Özinan, S. Netzband,
P.W. Cheng, M. Abdel-Maksoud