



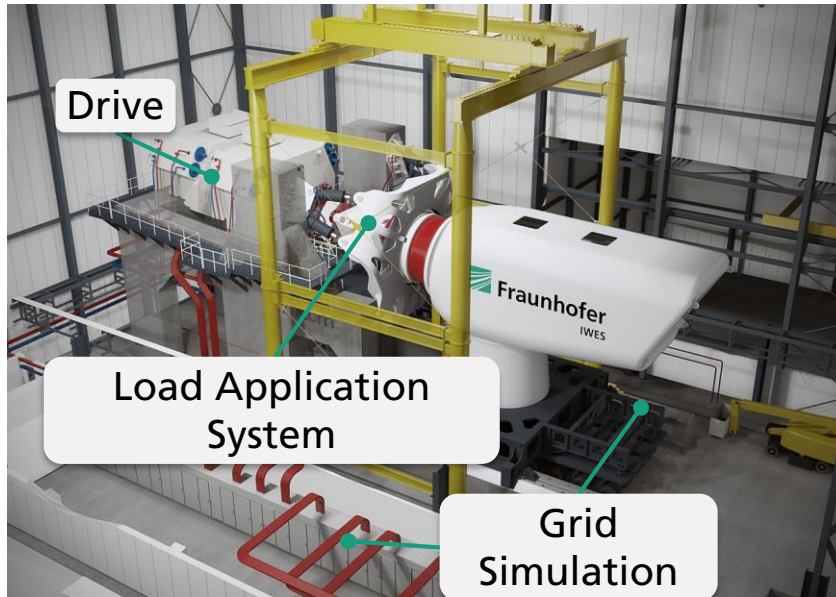
Real Time Simulation of Wind Turbines for HiL-Testing with MoWiT

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19.06.2019

Introduction

The DyNaLab – Dynamic Nacelle Testing Laboratory



Drive

- ↪ 10/15 MW Power
- ↪ 8.6/13 MNm (nominal/peak)
- ↪ 5° inclined Drivetrain



Hydraulic load application system

- ↪ Simulation of wind loads
- ↪ Thrust: ± 1900 kN
- ↪ Radial forces: ± 2000 kN
- ↪ Bending: ± 20000 kNm



Grid simulation

- ↪ 10/20/36 kV nominal voltage level
- ↪ 44 MVA installed converter power
- ↪ < 2% Total Harmonic Distortion (THD) @ 50 Hz 45...65 Hz



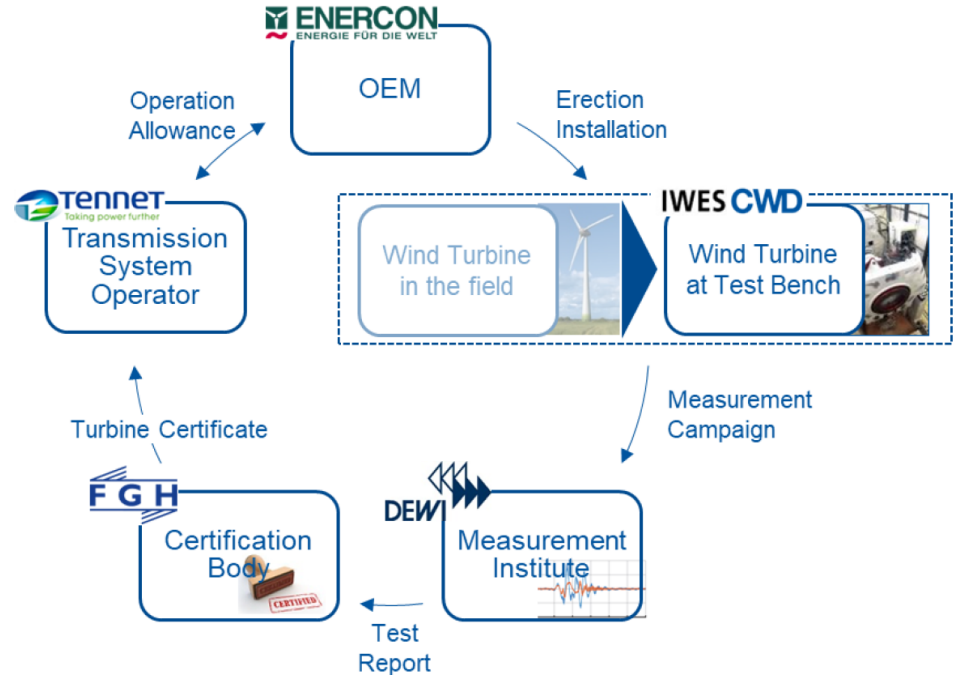
Commissioned 2015 → 6 specimen tested

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Introduction

CertBench – Systematic Validation of System Test Benches Based on the Type Testing of Wind Turbines

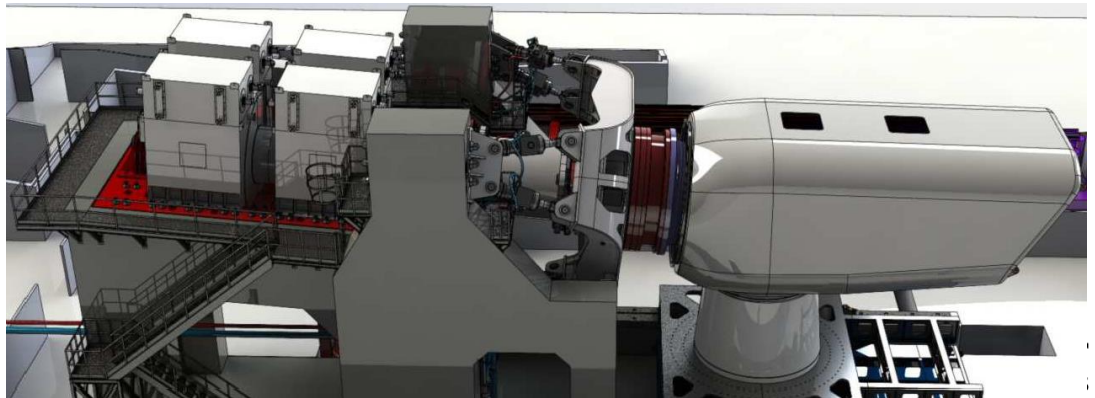
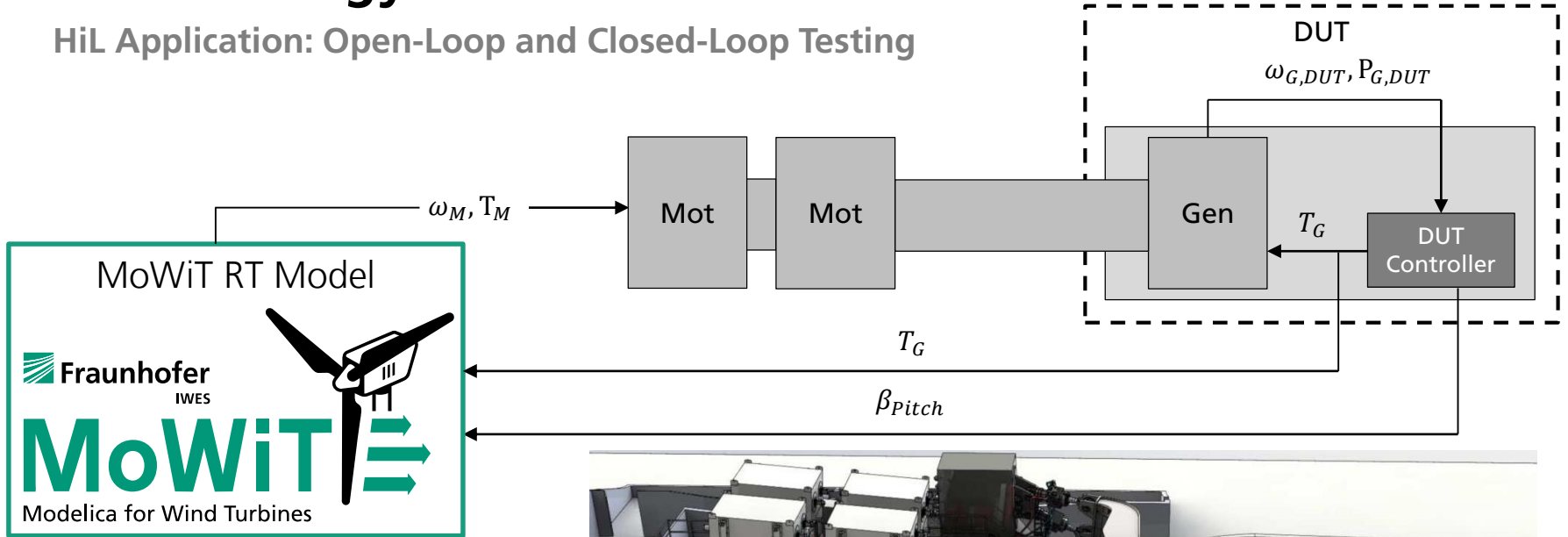
- > Certification of electrical properties on system test benches
- > Realistic rotor/nacelle load interaction via real-time models for HiL application
- > Demonstration of grid-side loads with the virtual grid



Jassmann et al.: CertBench: On the Status of Certifying Electrical Properties of Wind Turbines on Hardware-in-the-Loop System Test Benches

Methodology

HiL Application: Open-Loop and Closed-Loop Testing



← What to simulate in the model?

Methodology

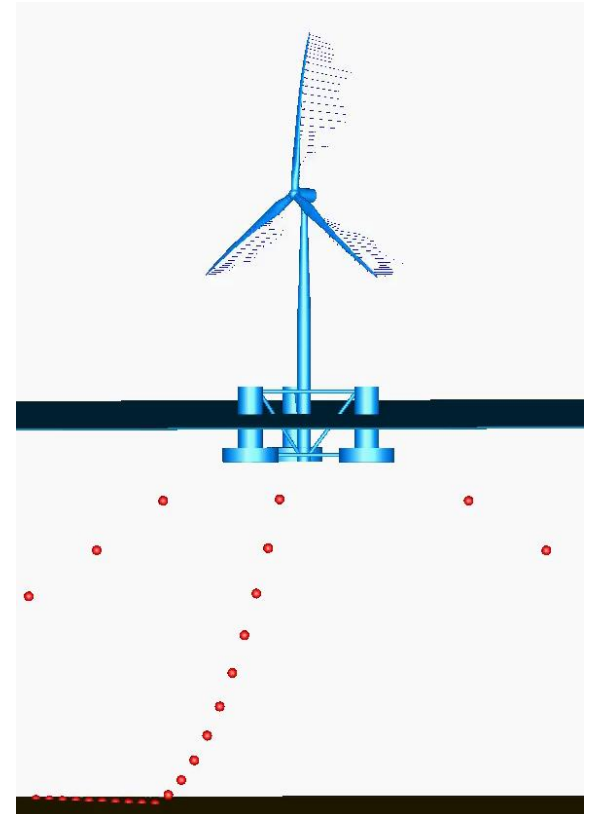
What is MoWiT?



- ↪ MoWiT = **M**odelica for **W**ind **T**urbines
- ↪ Computational model for wind turbine load calculations

Features of MoWiT

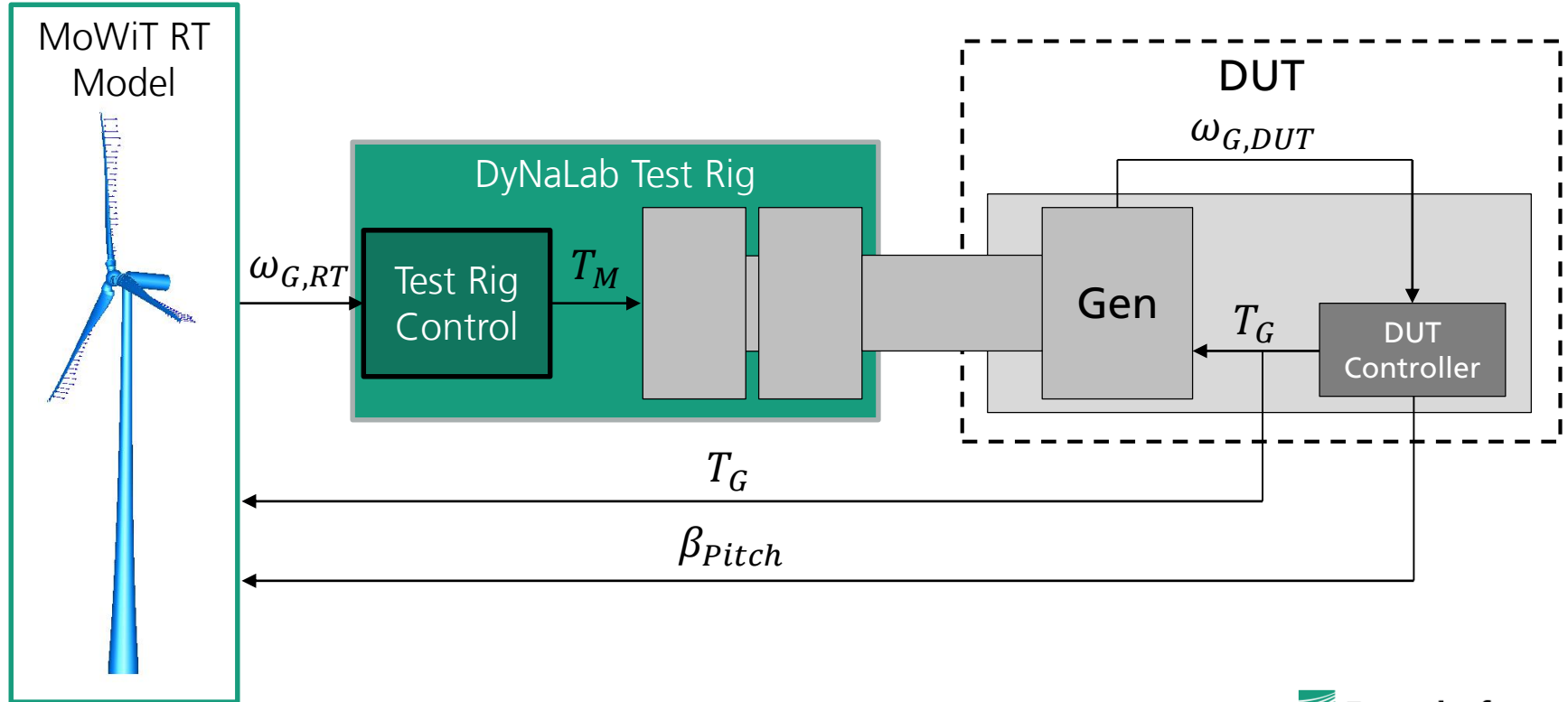
- ↪ Fully coupled aero-hydro-servo-elastic simulation
- ↪ Load assessment in time domain
- ↪ Component-based modeling
- ↪ Flexibility of model adaption and high extensibility
- ↪ Real-time capable
- ↪ Free of charge for academic use



IEA Task 30 OC4 Phase II semi-sub floating offshore wind turbine.

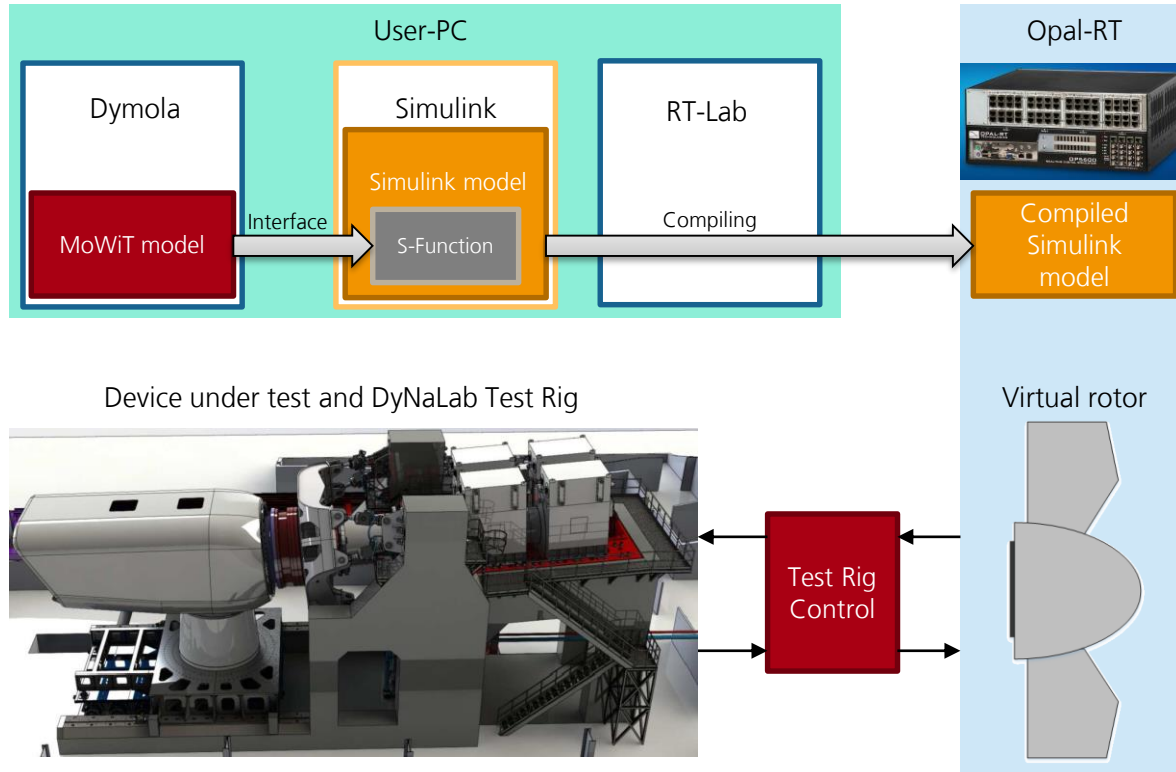
Methodology

HiL Application: Closed-Loop Testing Schematic



Methodology

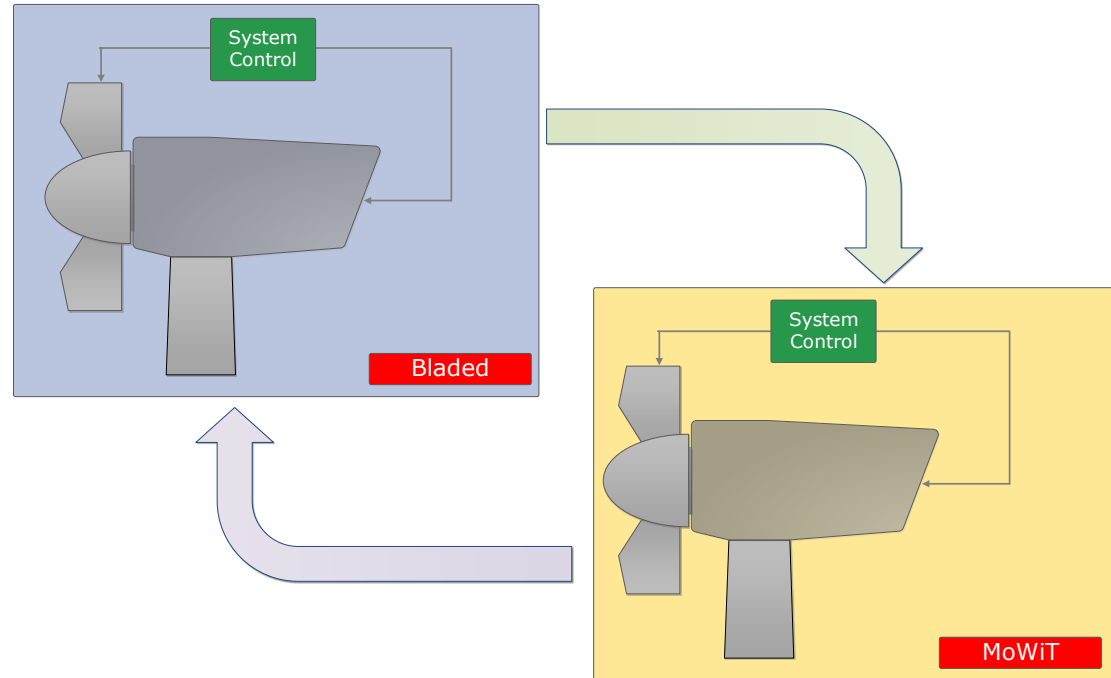
HiL Application: Software and Hardware Coupling



Methodology

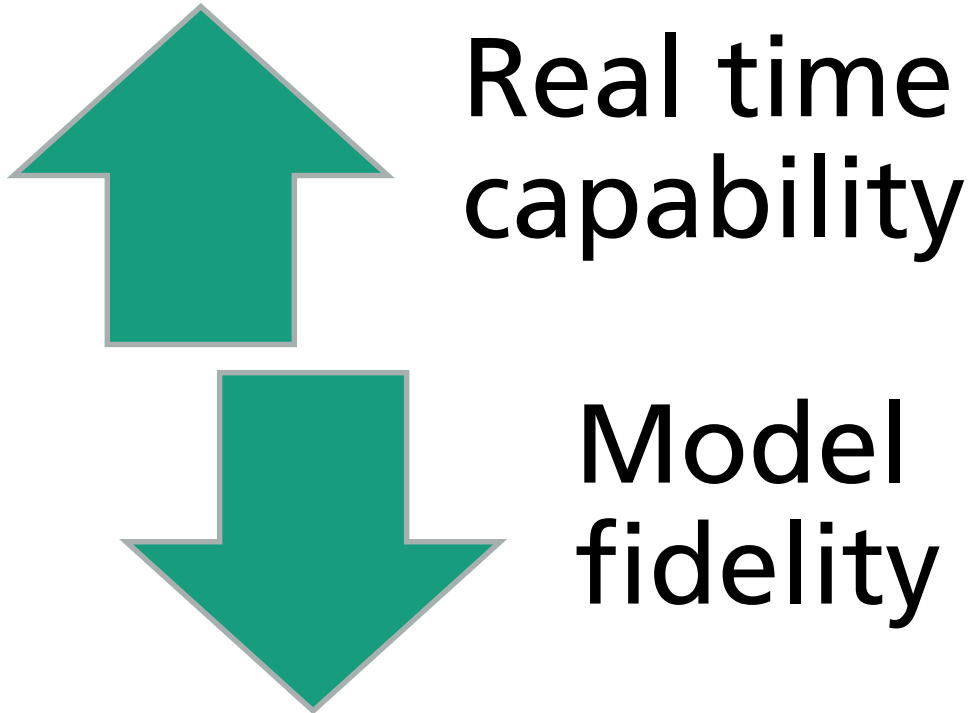
MoWiT Reference Model Implementation

- > 1) Bladed model
- > 2) Conversion to MoWiT model
 - > Static load cases
 - > Constant wind speed
 - > Turbulent wind speed
- > 3) Verification and model tuning



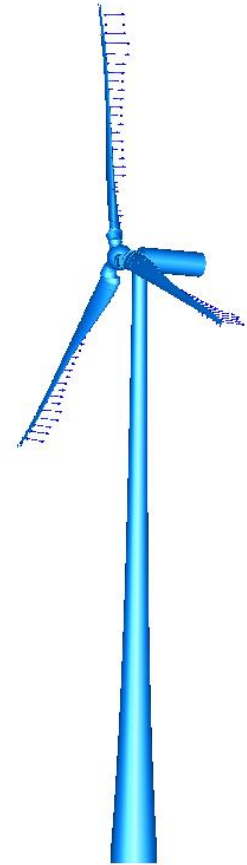
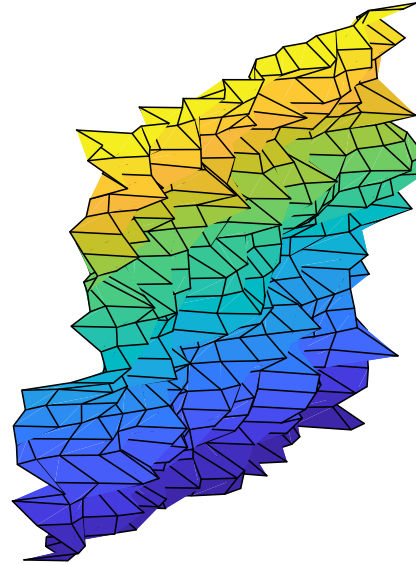
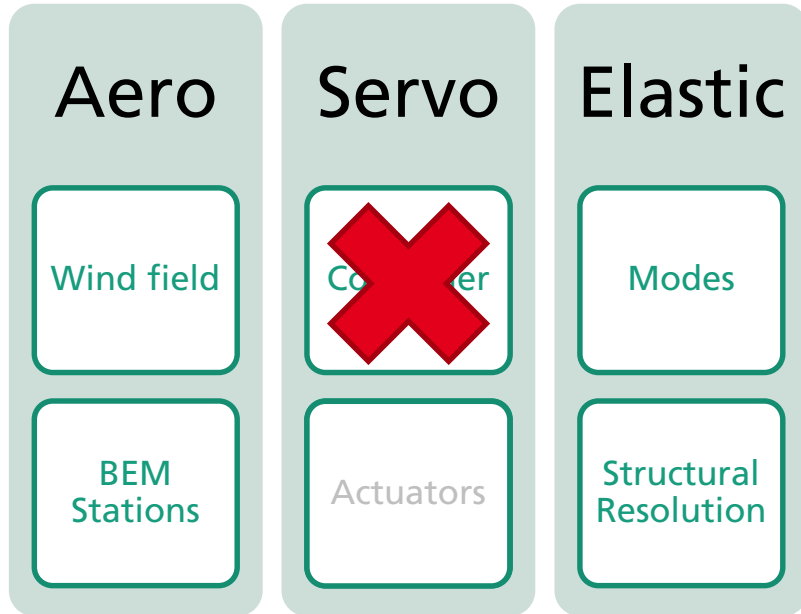
Methodology

Model Reduction for Real Time Simulation



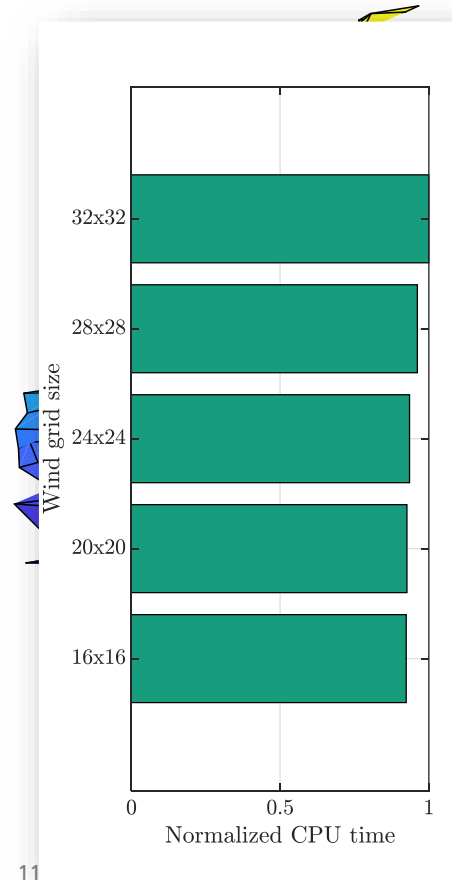
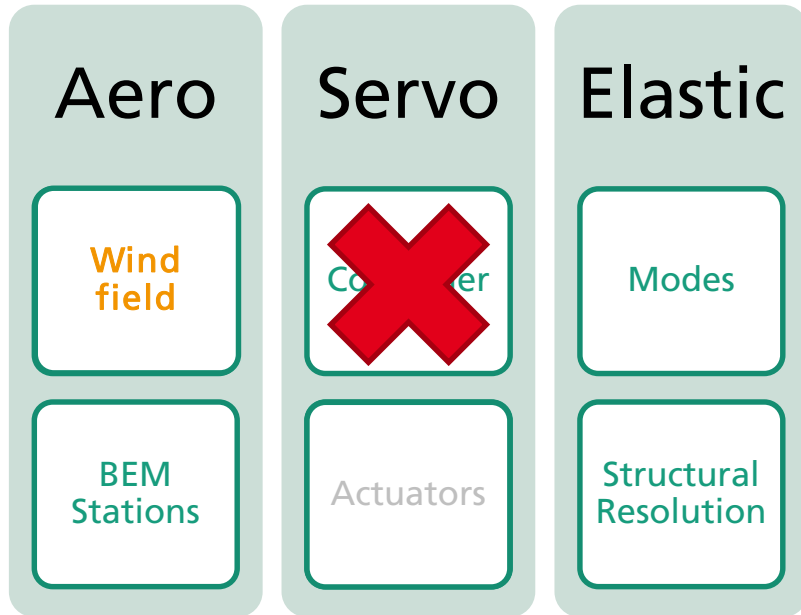
Methodology

Model Reduction for Real Time Simulation



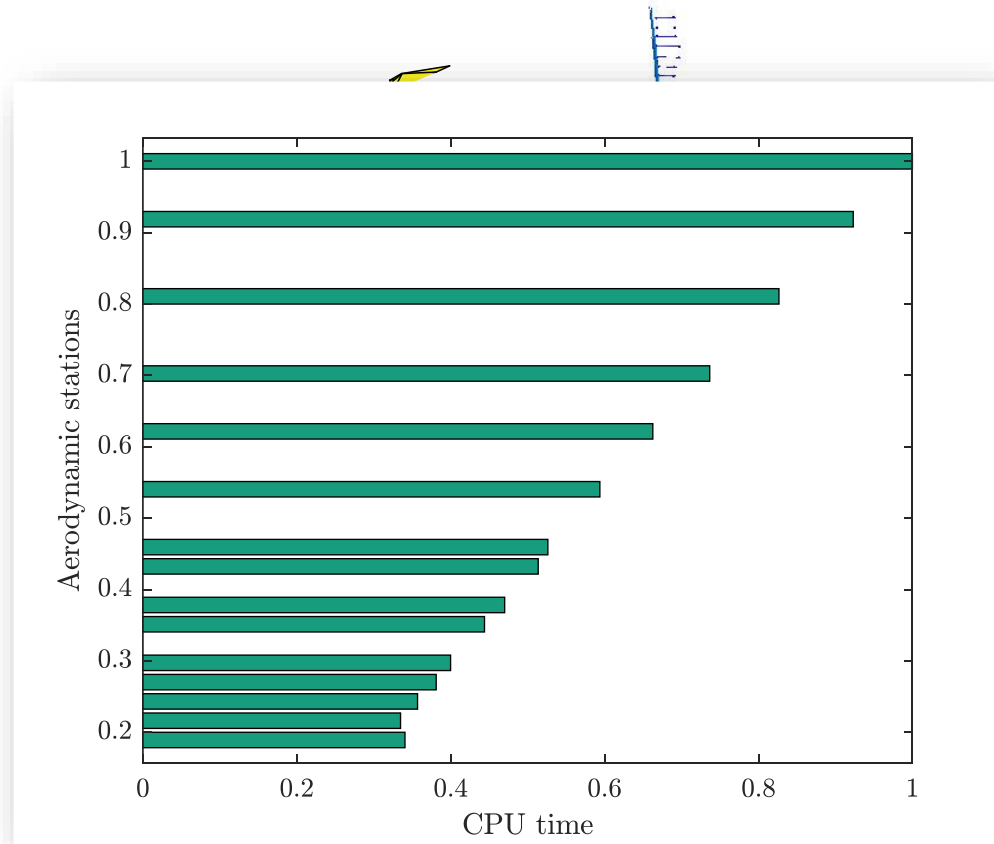
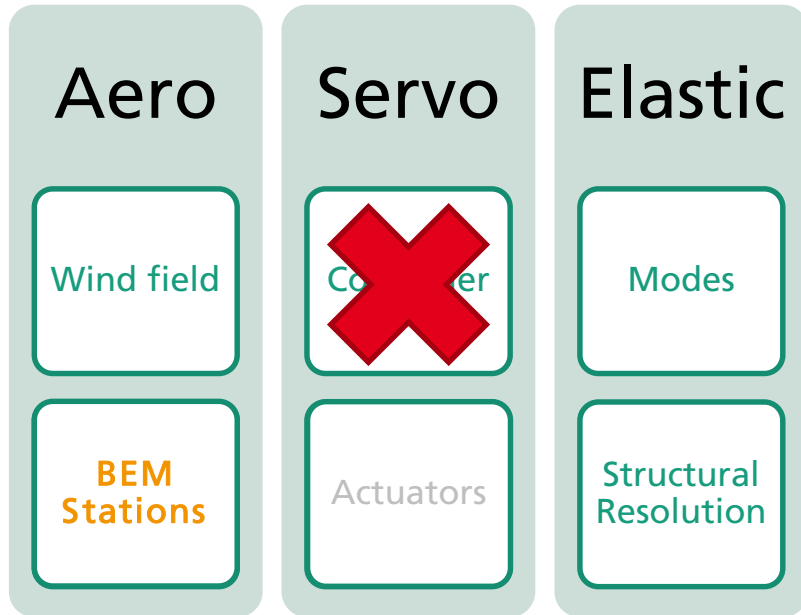
Methodology

Model Reduction for Real Time Simulation



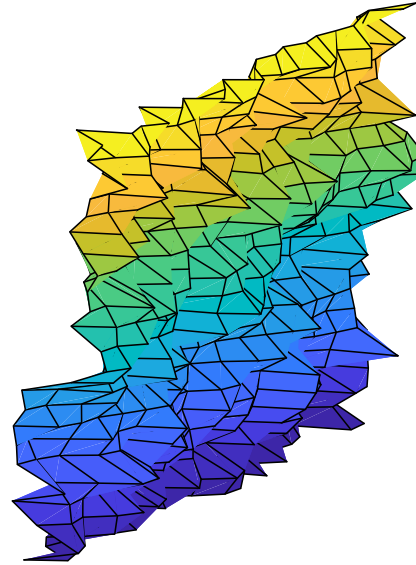
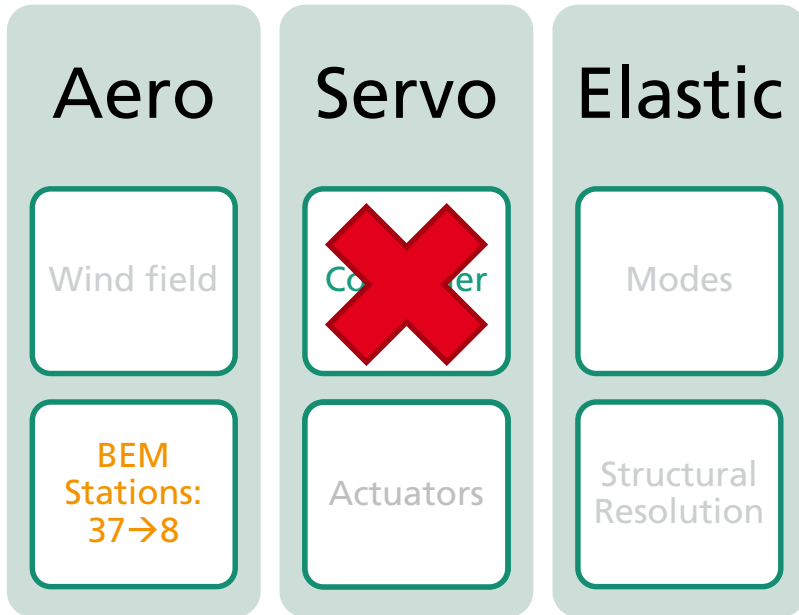
Methodology

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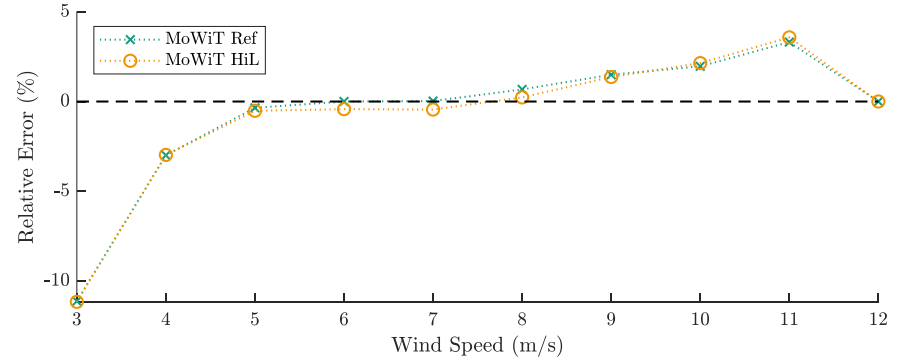
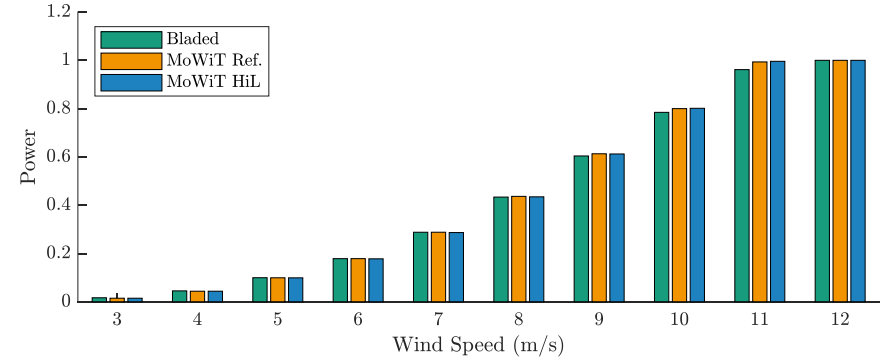
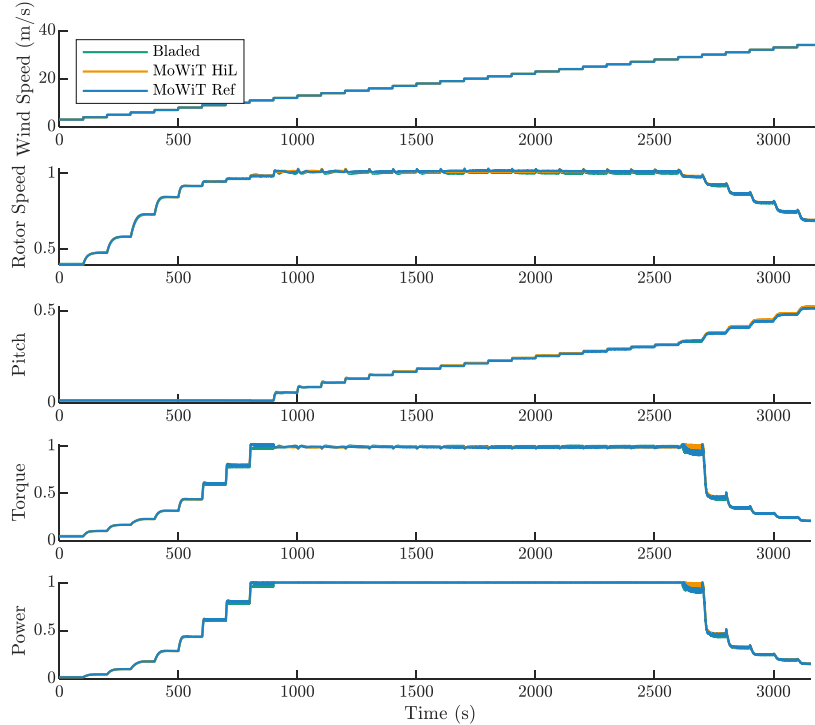
Results

Model Reduction for Real Time Simulation



Results

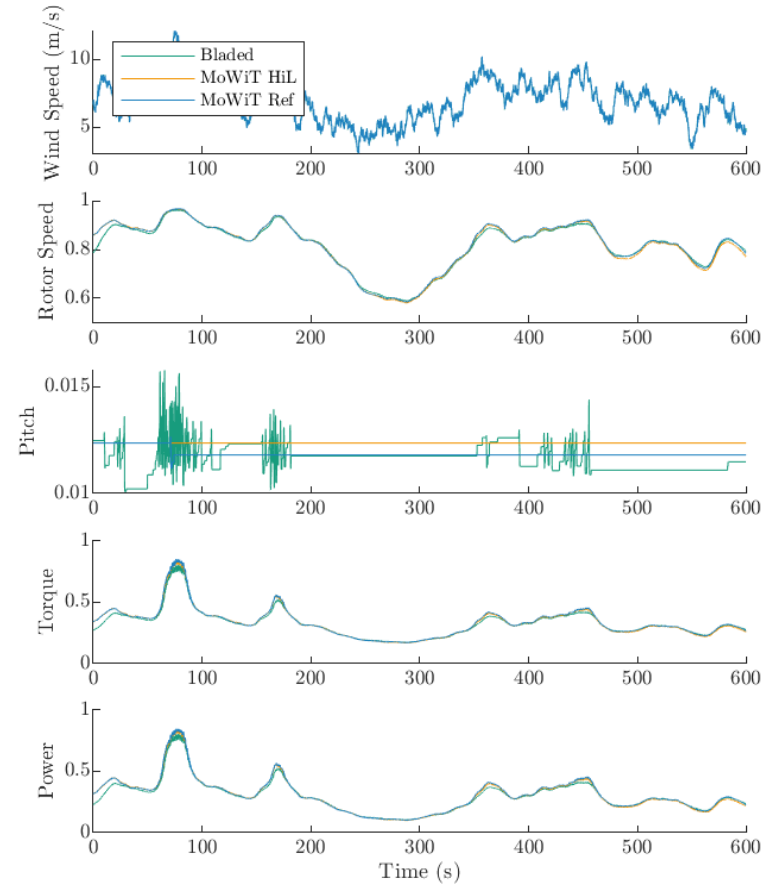
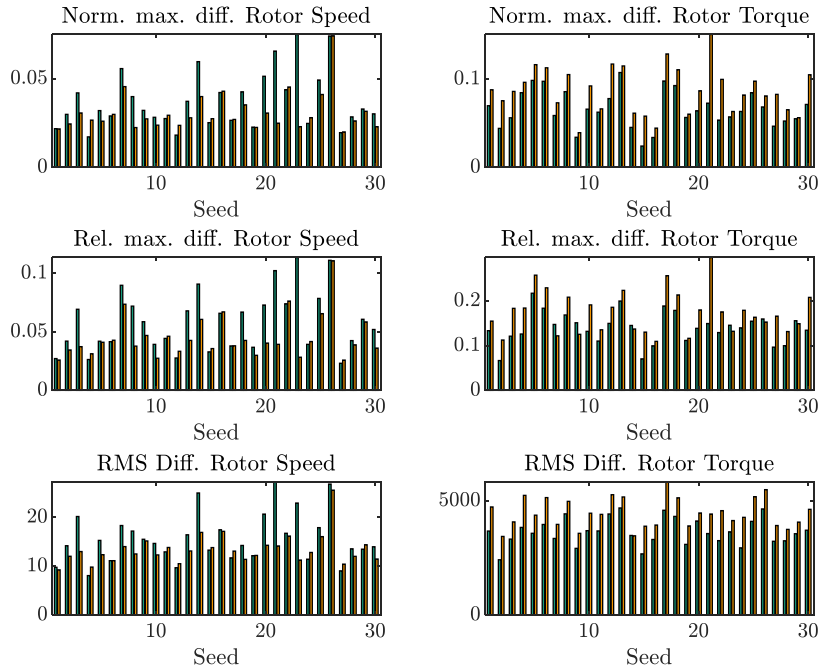
Verification of the RT model: Power curve comparison



Results

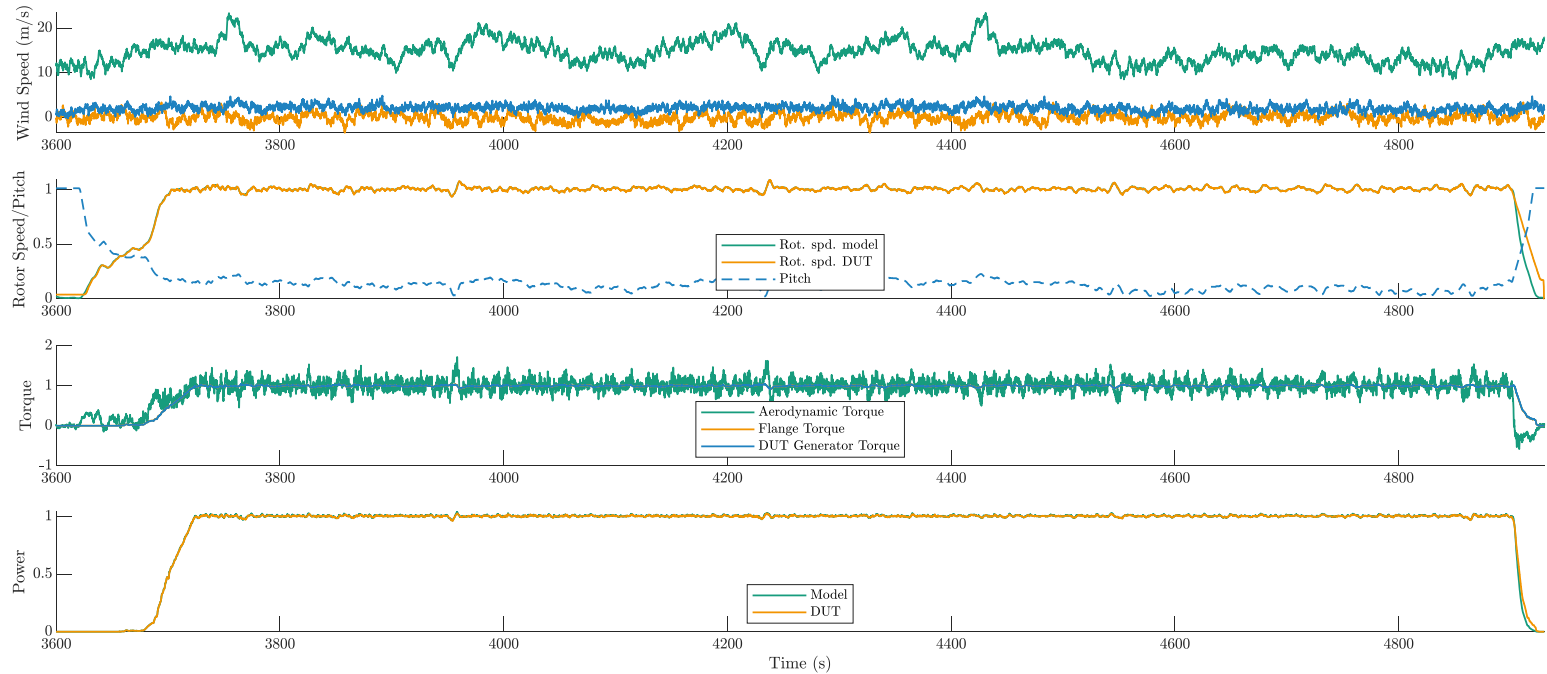
Verification of the RT model: Turbulent wind

← Example: 7m/s wind speed, 30 seeds



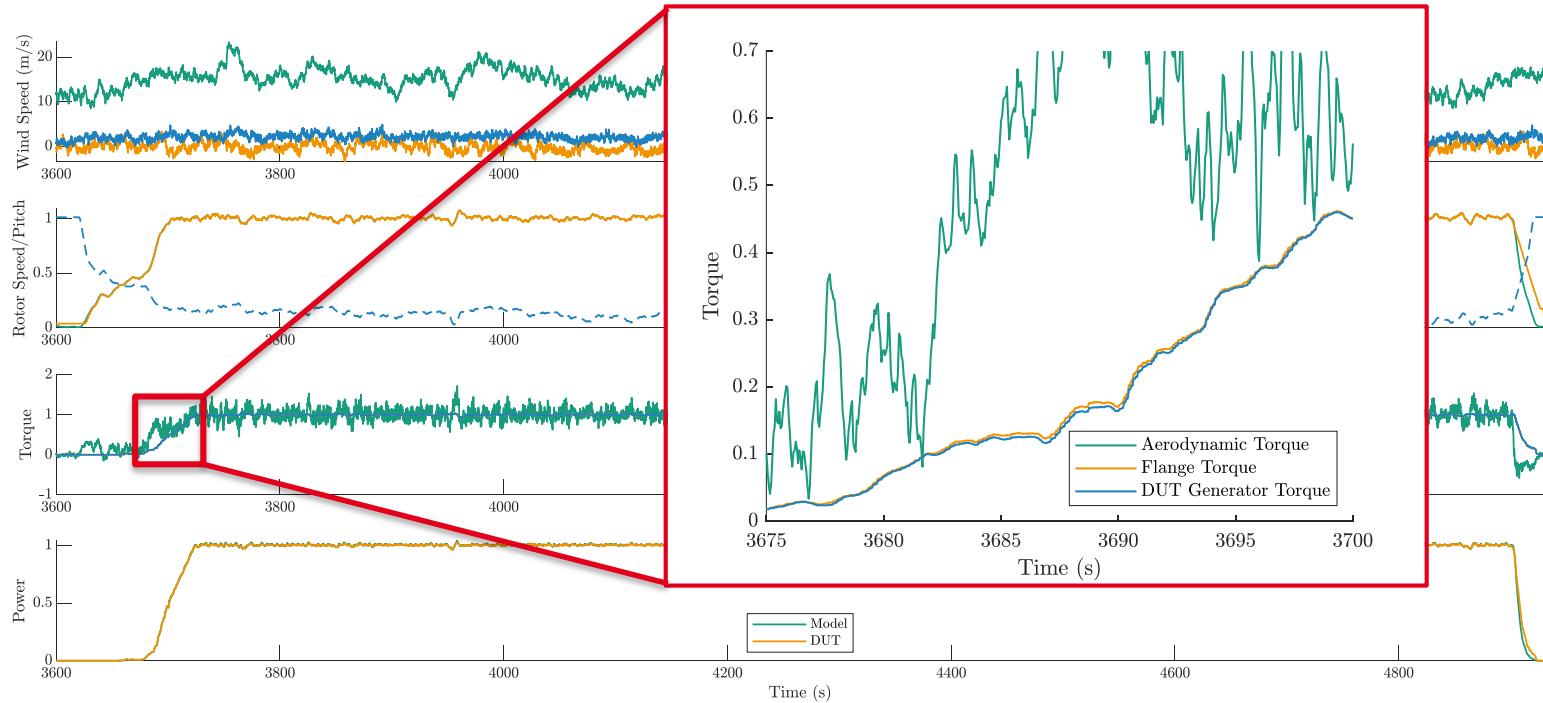
Results

HiL Testing Campaign



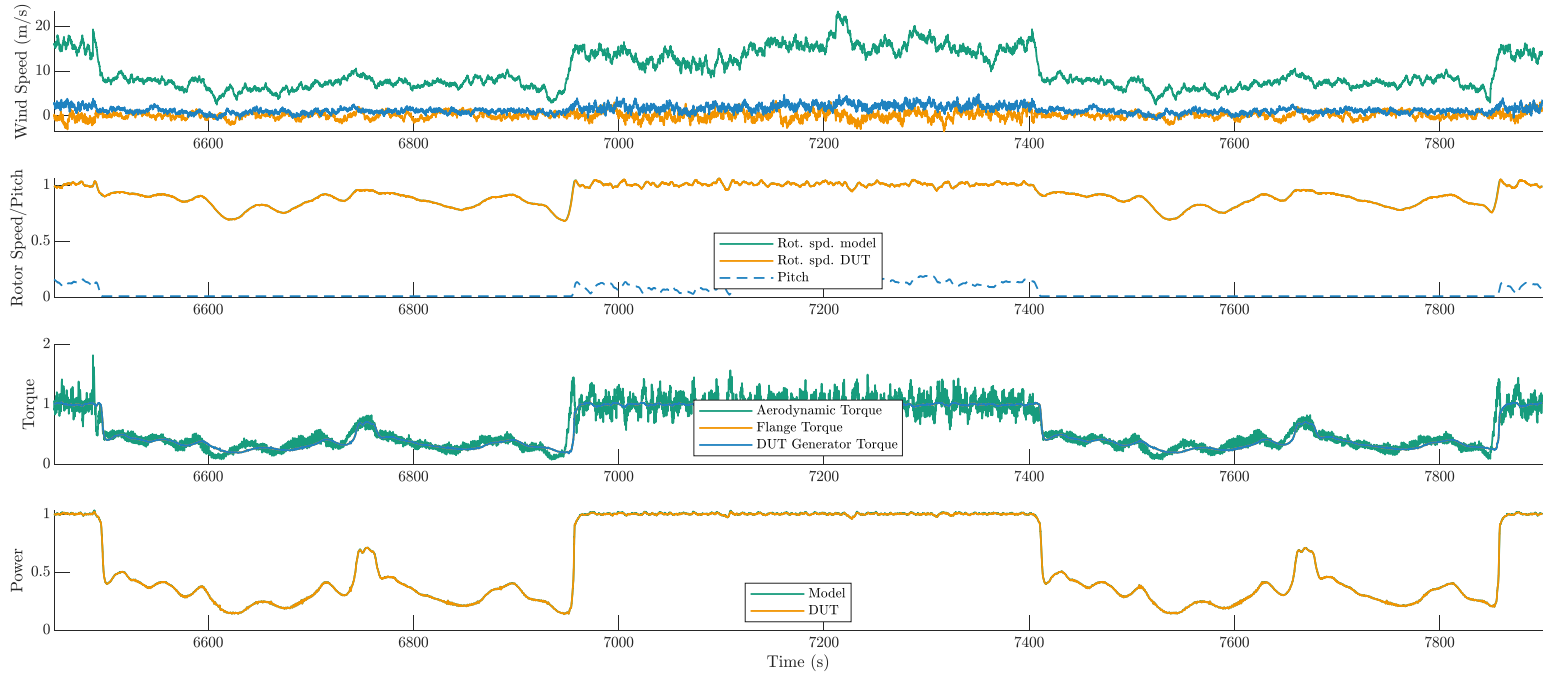
Results

HiL Testing Campaign

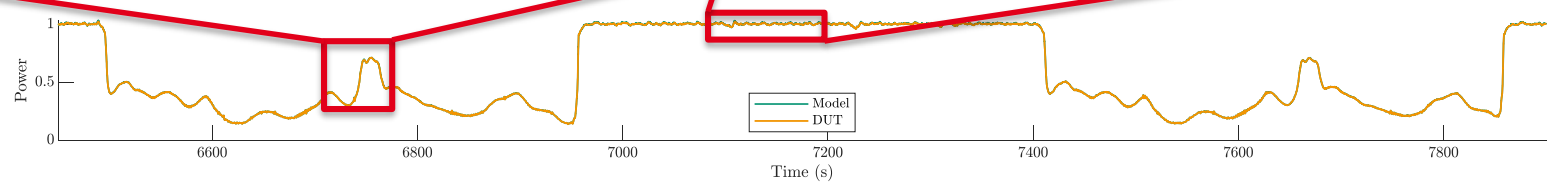
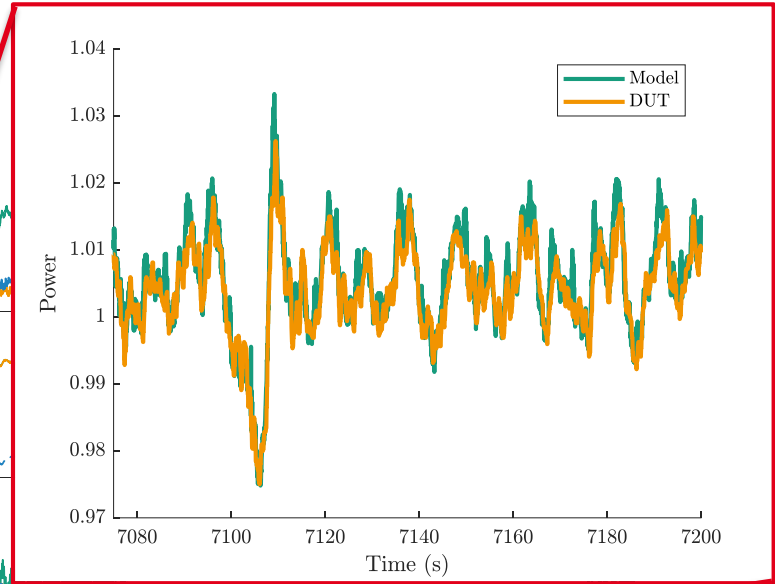
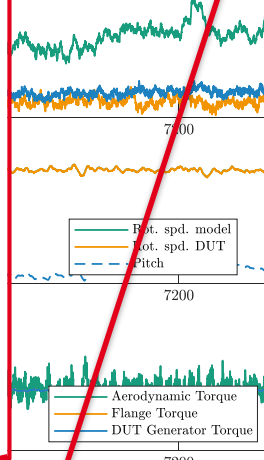
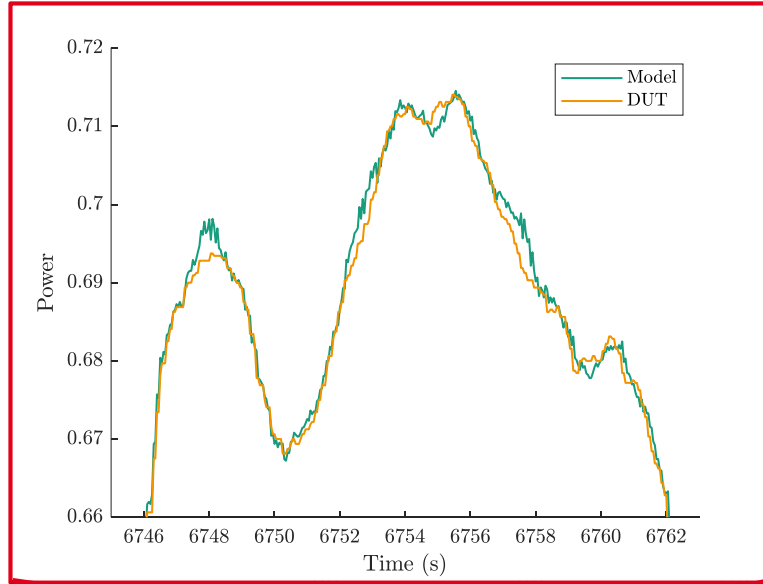


Discussion

HiL Testing Campaign: Results

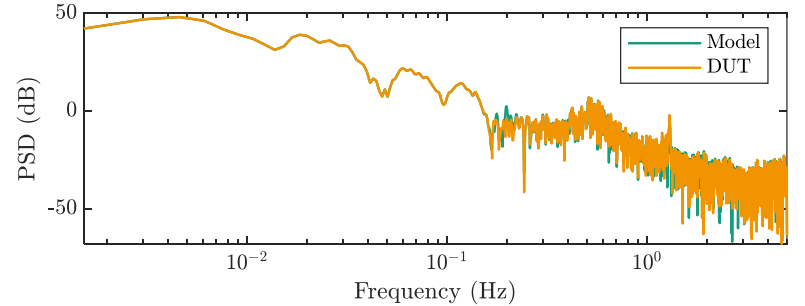
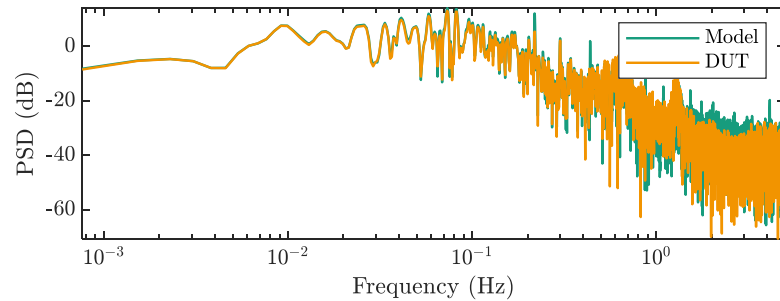
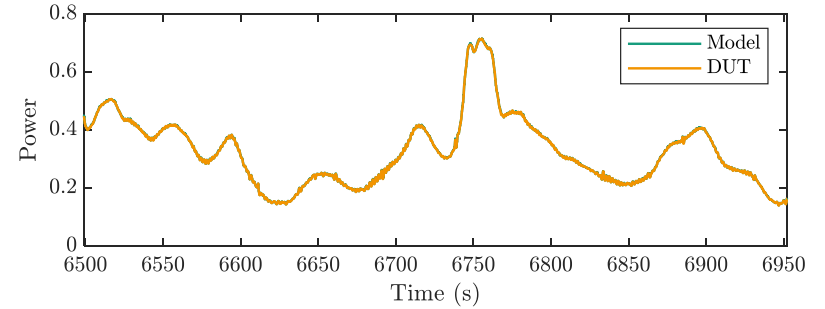
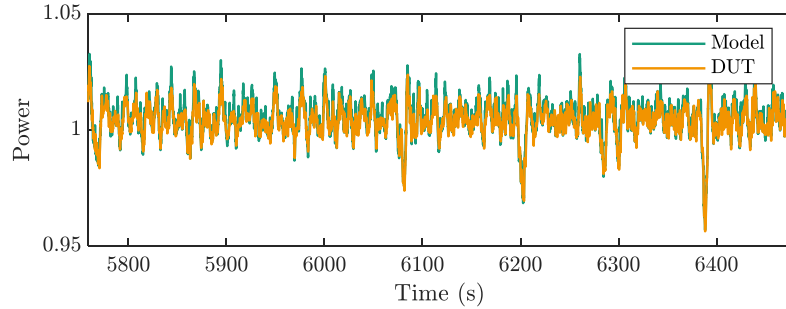


Discussion



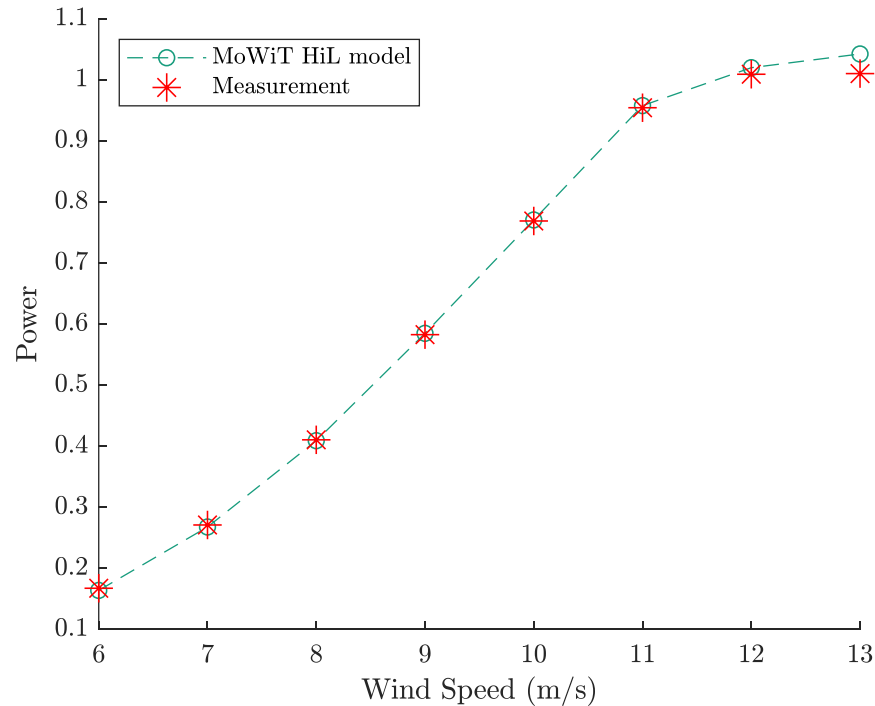
Discussion

HiL Testing Campaign: Results



Discussion

HiL Testing Campaign: Results



Conclusions

What did we learn?

- > Closed-loop HiL testing for electrical certification successful
- > Improve simulation speed via aerodynamics
- > Drastic reduction with good results
- > Generator torque setpoint unknown

Outlook

What are we planning to do next?

- < Improve simulation speed
 - < Parallelization of calculations
 - < Implementation of new models?
- < Transfer to other real-time hardware platforms
- < Improve model interfaces for torque control
- < Include parasitic rotor loads in HiL control

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Free and Hanseatic City of Hamburg



Niedersachsen





Thanks a lot for your attention!

Any questions?

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