CertBench

On the Impact of Mechanical-HiL on Electrical Properties of Wind Turbines

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Supported by:

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Center for Wind Power Drives

Overview

I^3-Institute: **Integrated Interdisciplinary Institute:**
aerodynamics, control technology, electrical and mechanical engineering under one umbrella

CWD Center for Wind Power Drives | RWTH AACHEN UNIVERSITY

Directorate: Prof. Abel, Prof. Brecher, Prof. De Doncker, Prof. Hameyer, Prof. Monti, Prof. Jacobs, Prof. Schröder

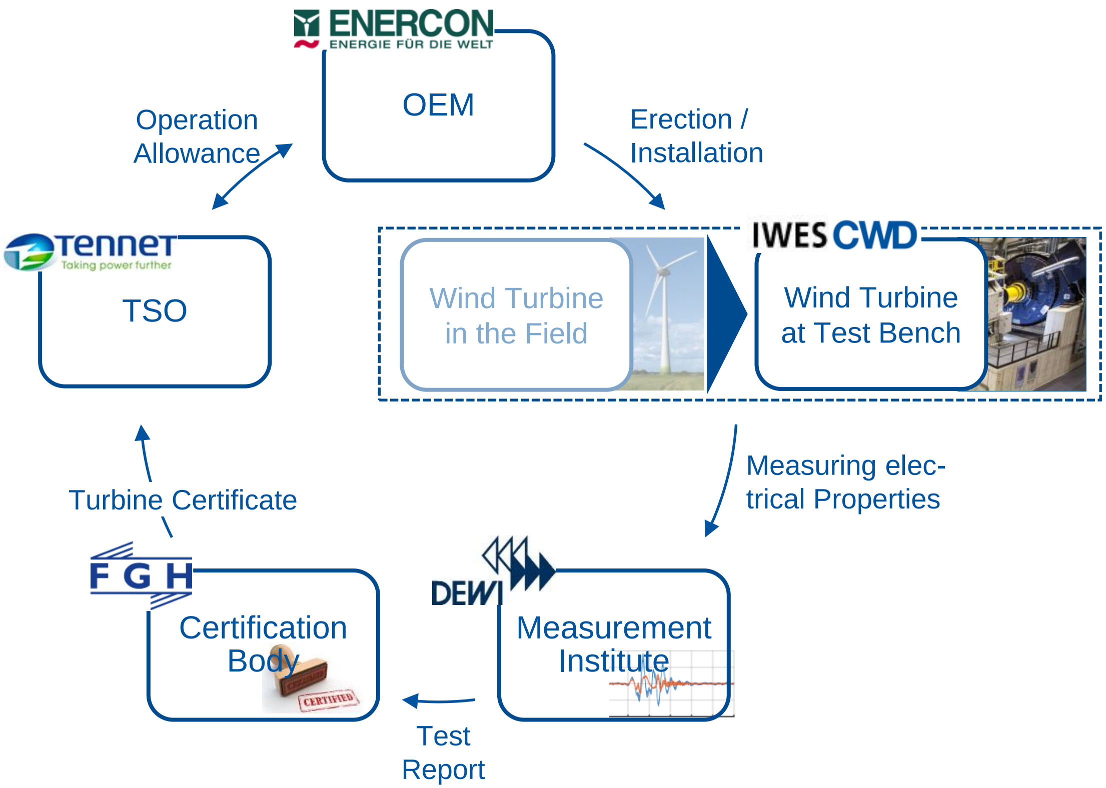
CTO: Prof. Schelenz

Prof. Abel	irt Institute of Automatic Control	Controls
Prof. Brecher	WZL	Gears
Prof. De Doncker	E.ON Energy Research Center	Power Electronics
Prof. Hameyer	IEM Institut für Elektrische Maschinen	Generators
Prof. Monti	E.ON Energy Research Center	Grids
Prof. Schröder	AIA Aerodynamisches Institut Aachen RWTH AACHEN	Aerodynamics
Prof. Stich	fir RWTH AACHEN	Logistics

Prof. Jacobs — Chair for Wind Power Drives — CWD Chair for Wind Power Drives — Systemdesign & Test

Industrial Partnerships: OEM & Suppliers

Joint Research Project: CertBench
Certification Process Germany



Goals

- Definition of required modelling detail (rotor)
- Design of mechanical-level HiL-Systems and Control
- Assessment of the grid emulator's influence
- Validation of results with the help of commercial ENERCON Turbine and field tests

Required Rotor Modelling Detail

- Aerodynamic modelling details
  - BEM-based aeroelastic Code
  - Static Cp-grid
  - Tower shadow
- Structural properties
  - Inertia & Eigenfrequency
- ➢ Relevant impact on electrical power only noticeable up to 10Hz (and realistic to apply)

Agreed Requirement

		0Hz	2Hz	10Hz	20Hz
No.	**Description of mode**	**MT1**	**MT2**	**MT3**	**MT4**
1	1^{st} tower fore-aft swing	0.63	0.61	0.61	0.61
2	1^{st} tower lateral swing	0.63	0.63	0.63	0.63
3	1^{st} asym. blade flap bending axis	-	0.98	0.98	0.98
4	1^{st} asym. blade flap yaw axis	-	0.98	0.98	0.98
5	1^{st} collective blade flap	-	1.04	1.03	1.03
6	1^{st} sym.blade edgewise mode	-	1.76	1.76	1.76
7	1^{st} asym. blade edgewise mode	-	1.80	1.80	1.80
8	1^{st} rotor edgewise-drive train mode	2.91	2.46	2.45	2.45
9	2^{nd} asym. blade flap bending axis	-	-	2.80	2.80
10	2^{nd} asym. blade flap yaw axis	-	-	2.84	2.84
11	2^{nd} collective blade flap	-	-	2.90	2.90
12	2^{nd} rotor edgewise-drive train mode	-	5.87	4.51	4.50

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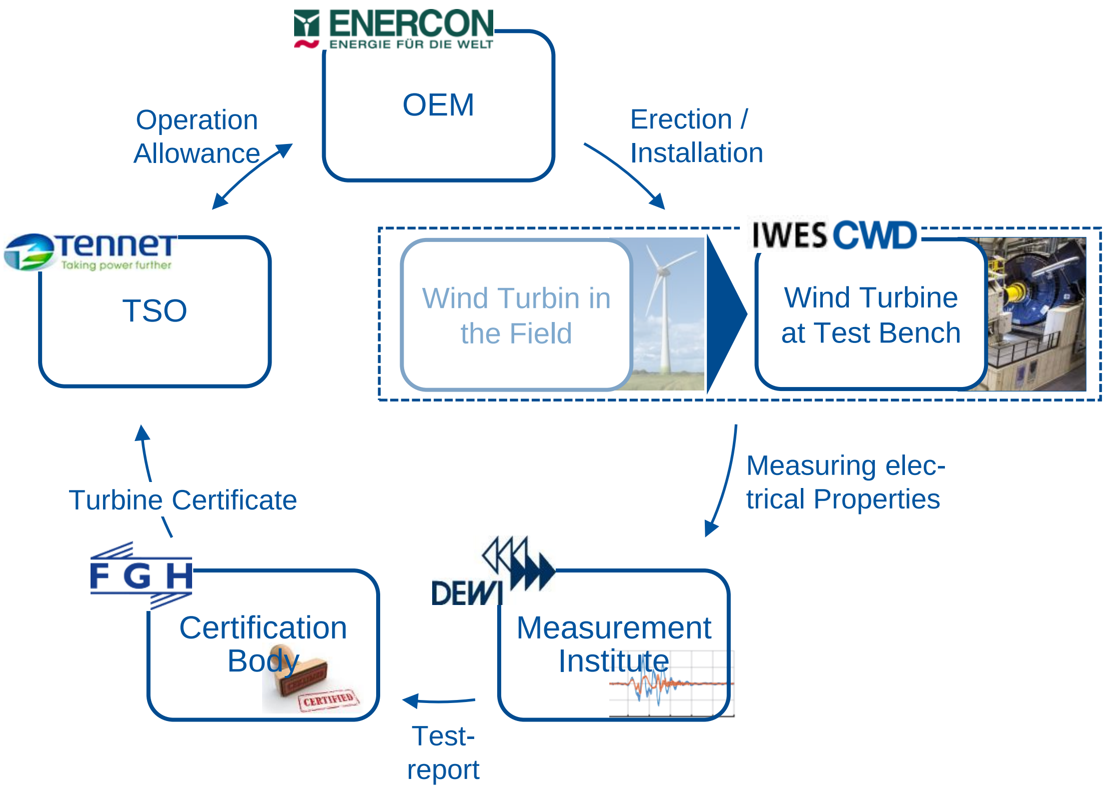

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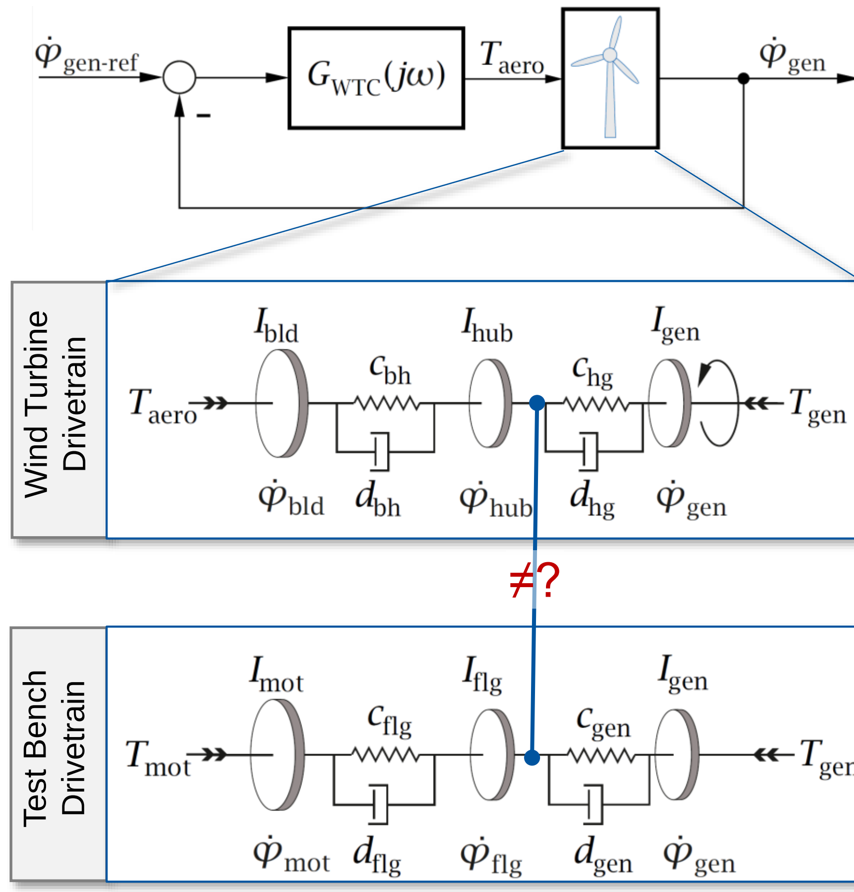
Mechanical-Level HiL System
Problem Description

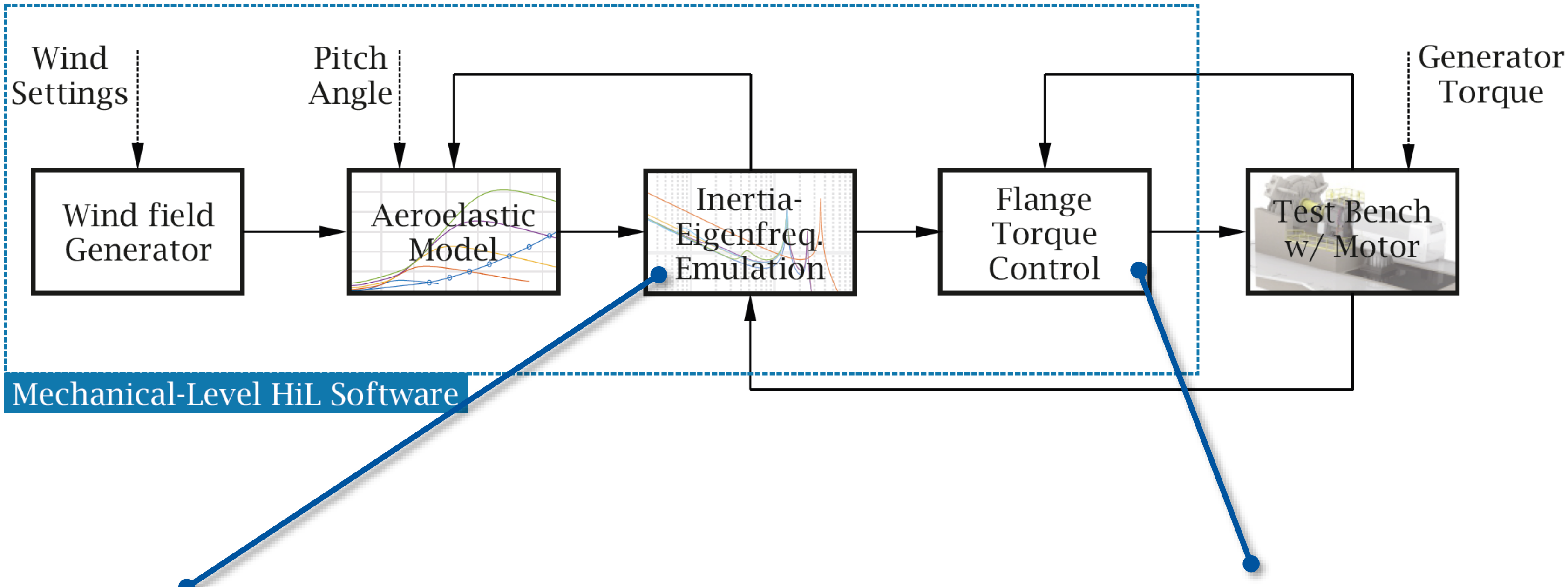
Requirements for MHiL

- Allow the operation of the wind turbine with activated WTC controller
- Reproduce rotor-drive train dynamics
- Apply “correct” rotor torque at flange



Mechanical-Level HiL System

Concept and Methods



Emulation Methods

- Baseline Inertia Emulation
- Extended Inertia Eigenfreq. Emulation
- Model-based Inertia Eigenfreq. Emulation
- IMC-based Inertia Eigenfreq. Emulation

Flange Control

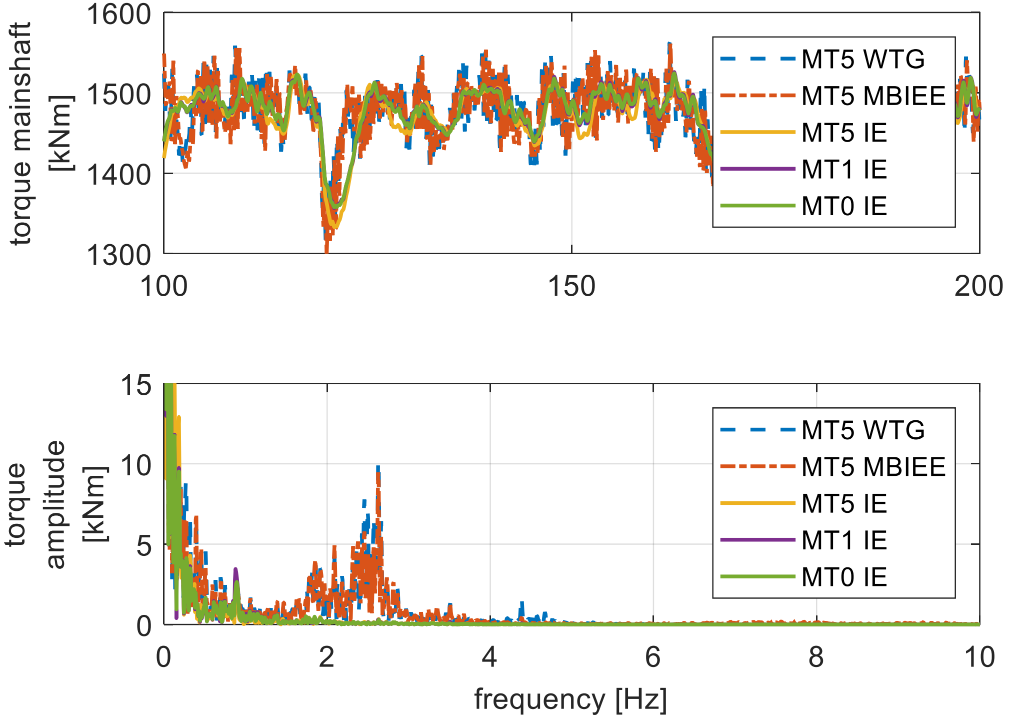
- Damping test bench related dynamics

Mechanical-Level HiL System

Modelling depth and HiL-Methods

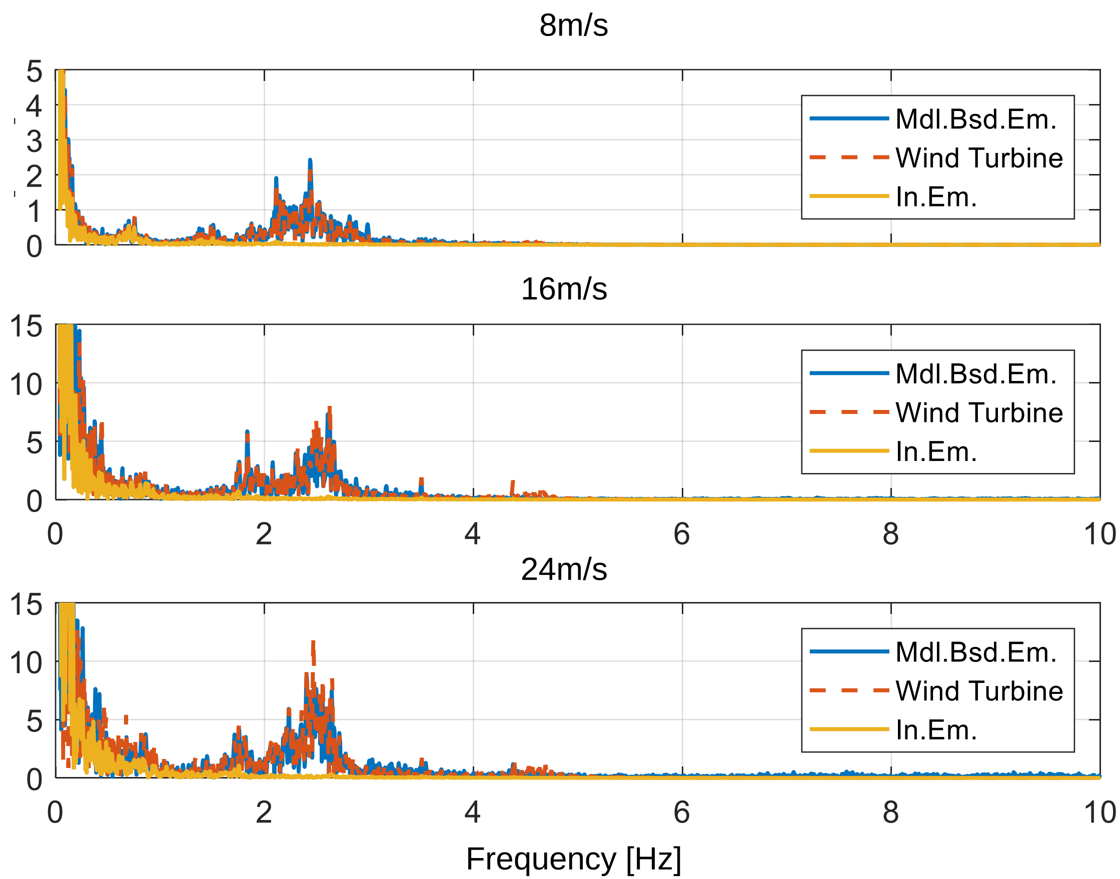
Comparison of Modelling Depth at 16m/s

- Baseline Inertia Emulation (IE)
  - Covers tower shadow only
  - Does not emulate 6P excitement when combined with MT5
- Model-Based Inertia Eigen-frequency Emulation (MBIEE)
  - Emulates WTG dynamics almost precisely
  - Over estimates damping of 2nd rotor drive train Eigenfreq. 4.5Hz



Performance Comparison at different wind speeds

- Power density spectrum of flange torque
- Characteristic is emulated also at high wind speeds
- Over estimation of damping remains at all wind speed level



Summary and Conclusion

Summary of preliminary results

- Rotor modelling up to 10-20 Hz agreed to be sufficient
- Robust and precise HiL-Methods are available, which
  - allow closed loop wind turbine operation
  - allow drive train dynamic emulation up to the 2nd rotor-drive train eigenfrequency
- Limiting factor seem to be the motor torque change rates

Future Work

- Experimental validation of the methods and modelling depths
- Expanding the simulation and assessment of all certification test cases
- Validation of HiL with commercial wind turbine and compare to field data

- Summarize requirements on system test bench hard- and software
- Transferring results to certification documents FGW TR3 and IEC61400-21

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Thank you for your attention

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