Load based testing of wind turbine control systems using Hardware-in-the-Loop

03. November 2016

more wind
engineering solutions

morewind

- morewind was founded in 2013
- Team of engineers with more than 10 years of experience in the wind energy sector

Service Portfolio

R & D – Load Analysis

- Control Development
- Load Simulation
- Prototype Testing

Performance Optimisation

- SCADA Analytics
- Lifetime Extension

Consulting

- General Consulting
- Training
- RCA

Products

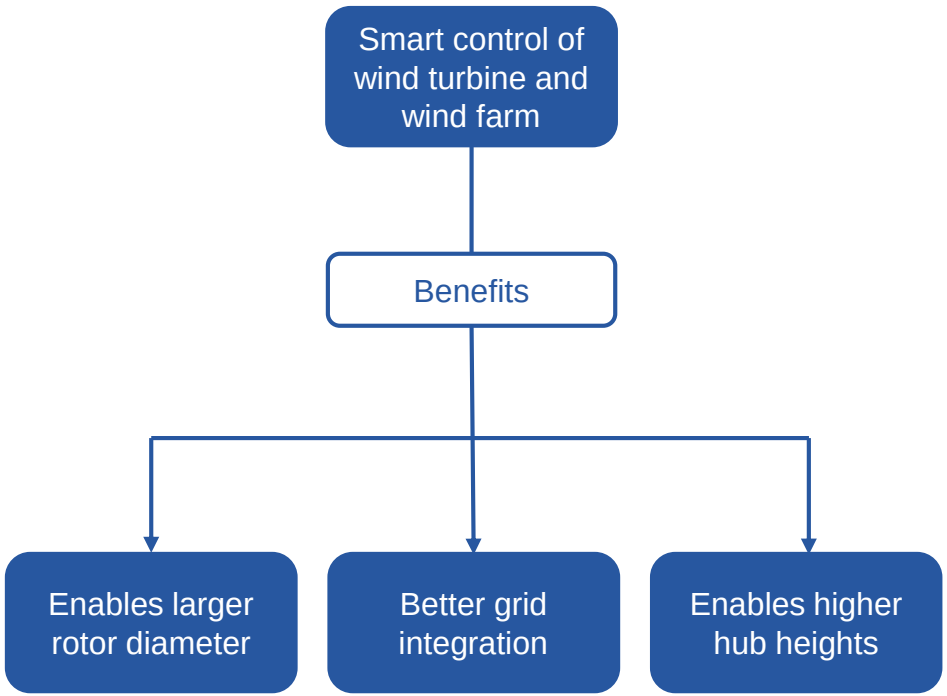
mwLoADS

Load Analysis and Distributed Simulation Toolbox

ABO WIND · DEKRA Alles im grünen Bereich. · NORDEX · Ocean Breeze Energy · SUZLON POWERING A GREENER TOMORROW

Motivation

Control technology is a major enabler for further CoE reduction in wind energy



Cost and Production benefits to be gained using advanced controls:

Without accounting for larger rotor

Increased Production

- Power Curve (AEP), 2-3% annual production increase

Cost Savings

- Rotor, 5-15 % cost savings
- Tower & Foundation, 10-20 % cost savings
- Drivetrain, 10-20 % cost savings

Source: MITA Teknik

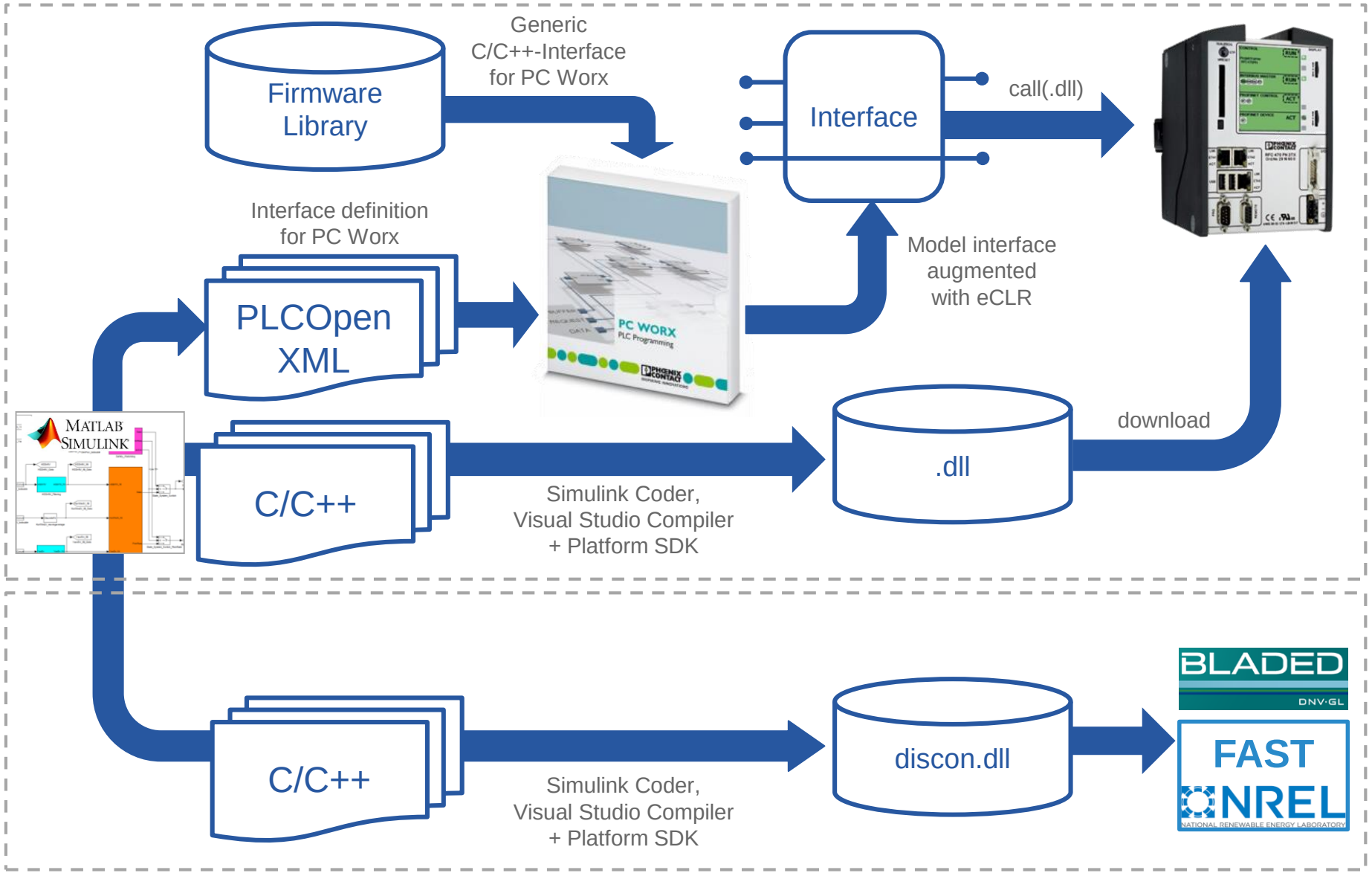
Control development workflow

New technology	Turbine concept	Turbine final design	Validation & Verification

• Development of new control and safety features with the target to reduce loads and increase AEP
• Development of new secondary functions concepts for better grid integration
	• Main Control system design (pitch, torque contrlol, safety Sys)
	• Load Simulation with compiled control system
	• Requirements for secondary control functions
		• Final load simulation and control parameter freeze
		• Implementation of main control scheme on PLC
		• Implementation of secondary control functions on PLC
			• Subsystem testing
			  • Functional control test
			  • Hardware testbench like pitchdrives, gearbox…
			• Prototype testing
			  • Load, Power Performance and Power Quality Testing

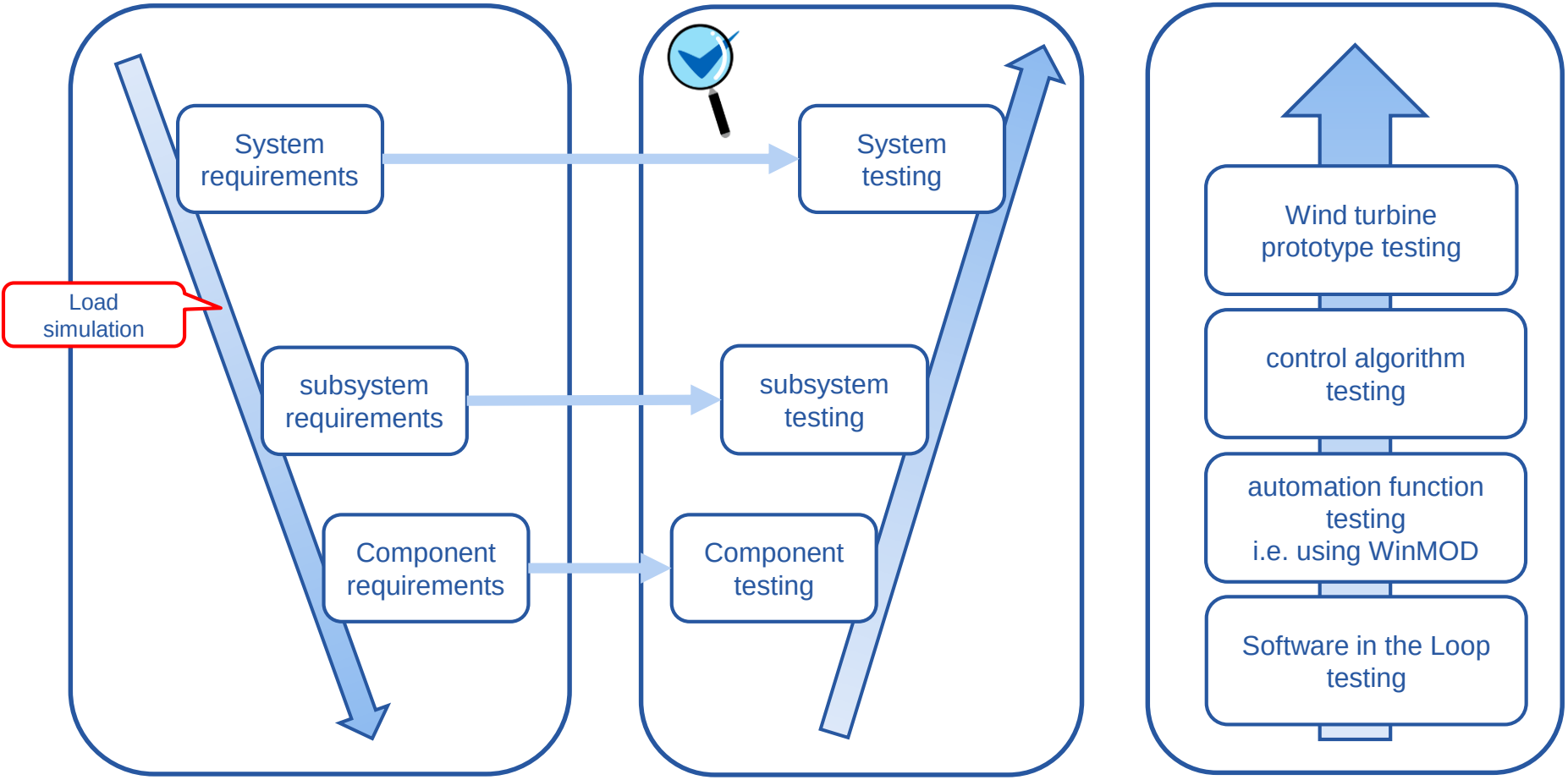
	Use of Matlab/Simulink combined with load simulation software	Use of code generation from Matlab/Simulink to PLC	**Requirement for Hardware-in-the-loop testing**

Code generation process



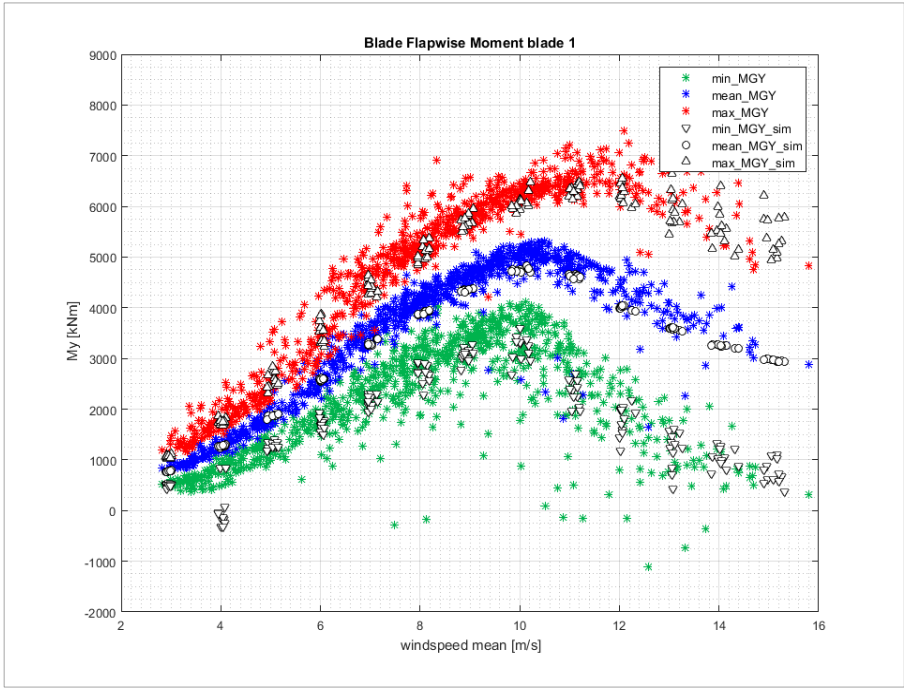
PLC Software Testing

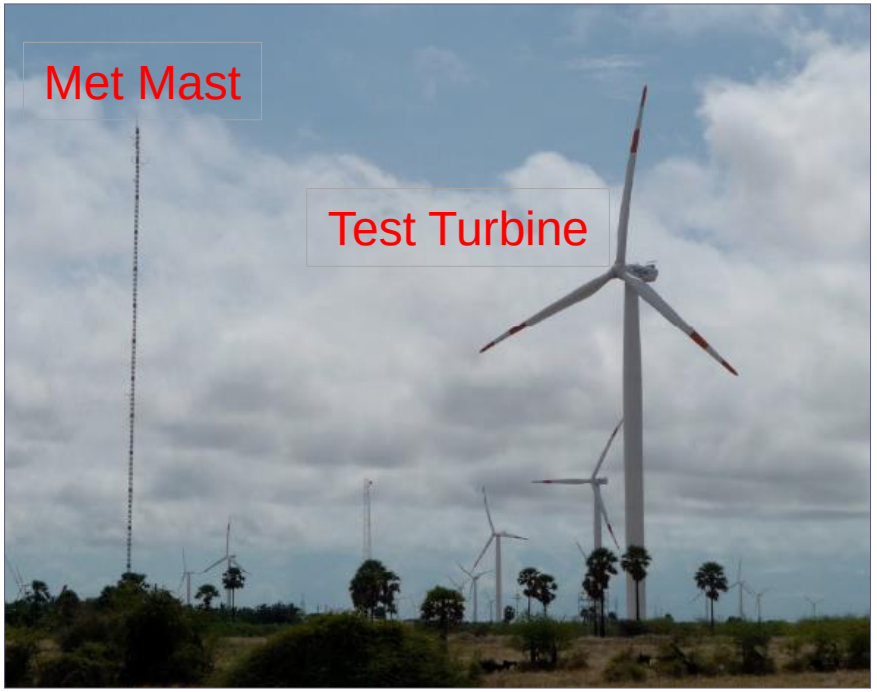
Software Testing



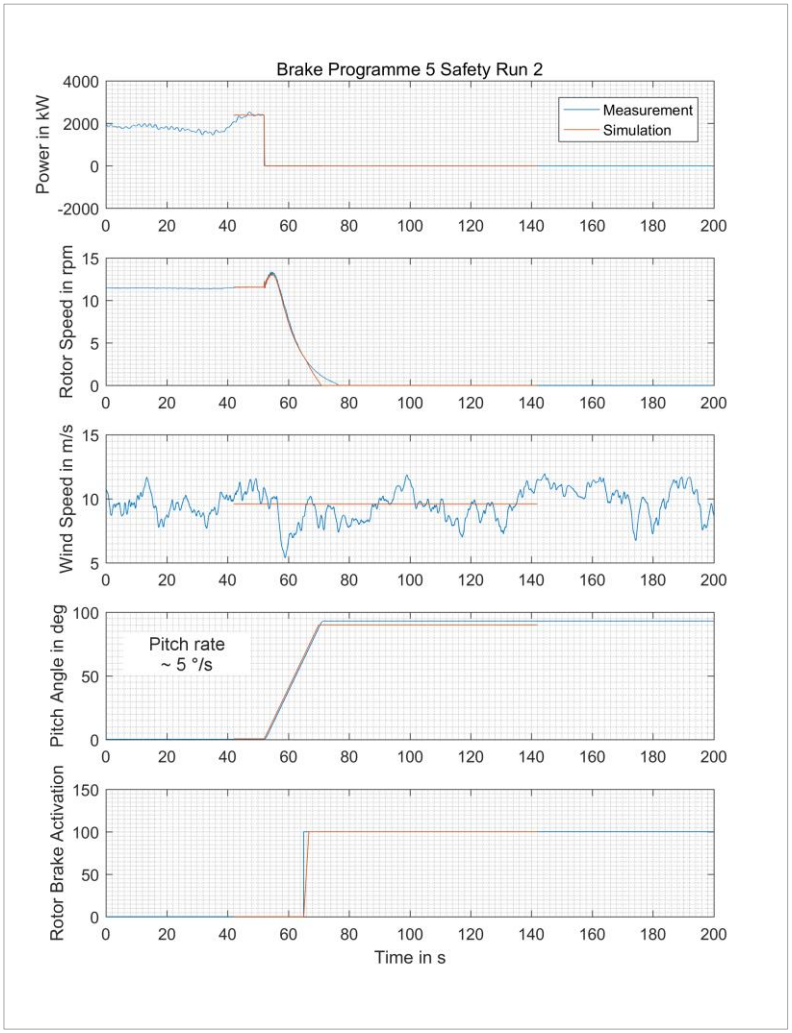
Prototype Testing

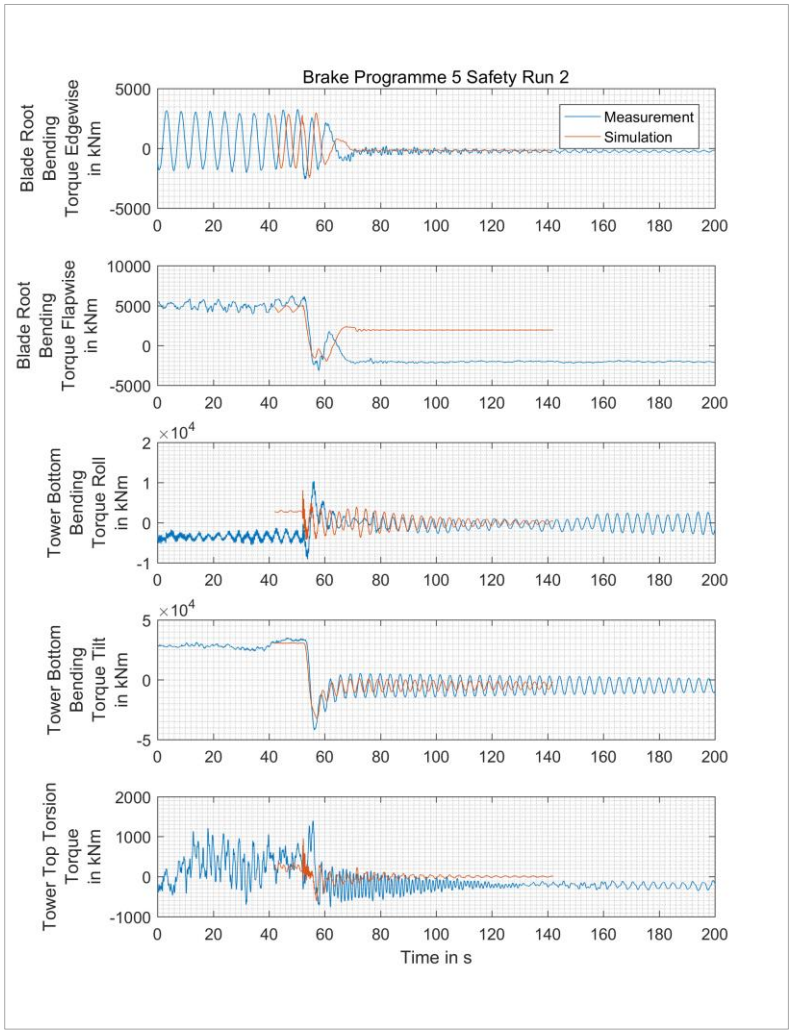
- Wind speed is measured at one point upwind
- Problems are found when it´s too late
- Risks in case of instability





Prototype Testing: transient event





Status quo

- Component level testing is done with rudimentary turbine models
- Prototype testing is costly, difficult and under time pressure

➡ GAP

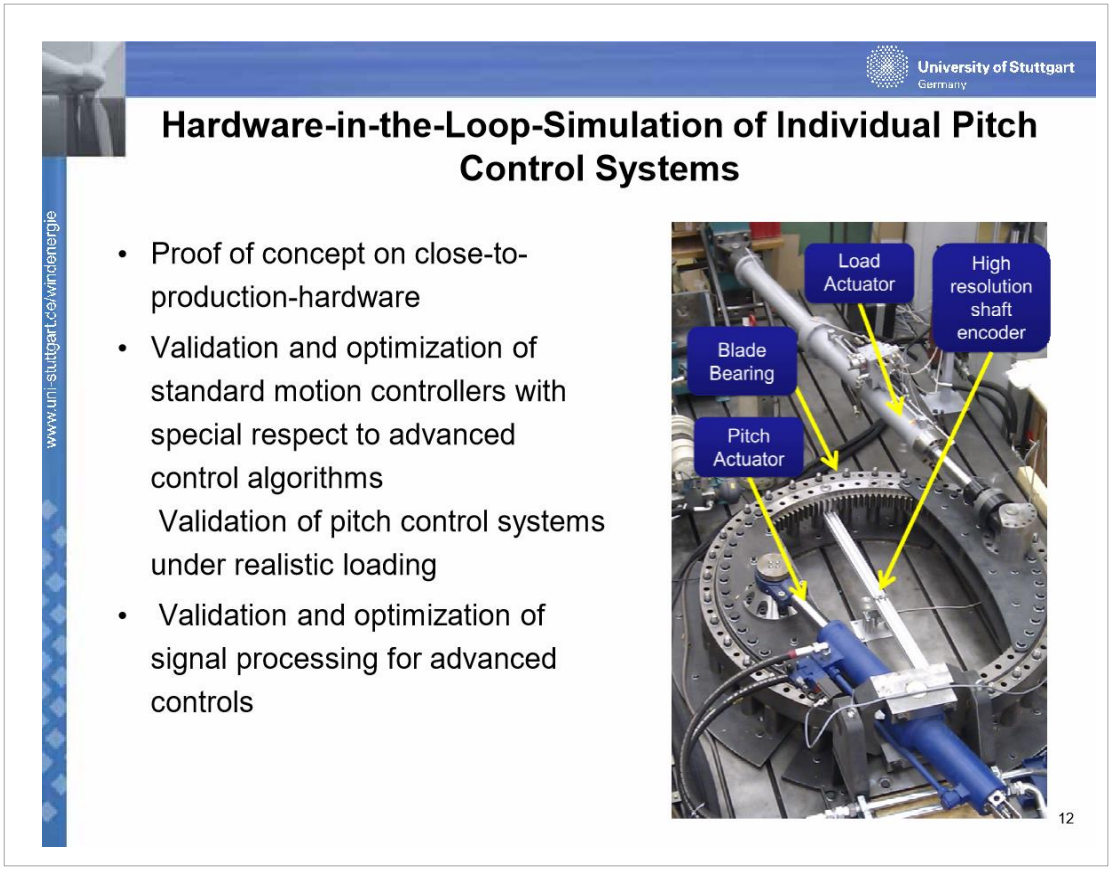
- Need for more consistent component and subsystem level testing

This approach supports the requirements for the LRF verification by functional testing according to GL2010 guideline

HIL Testing for Pitch Systems

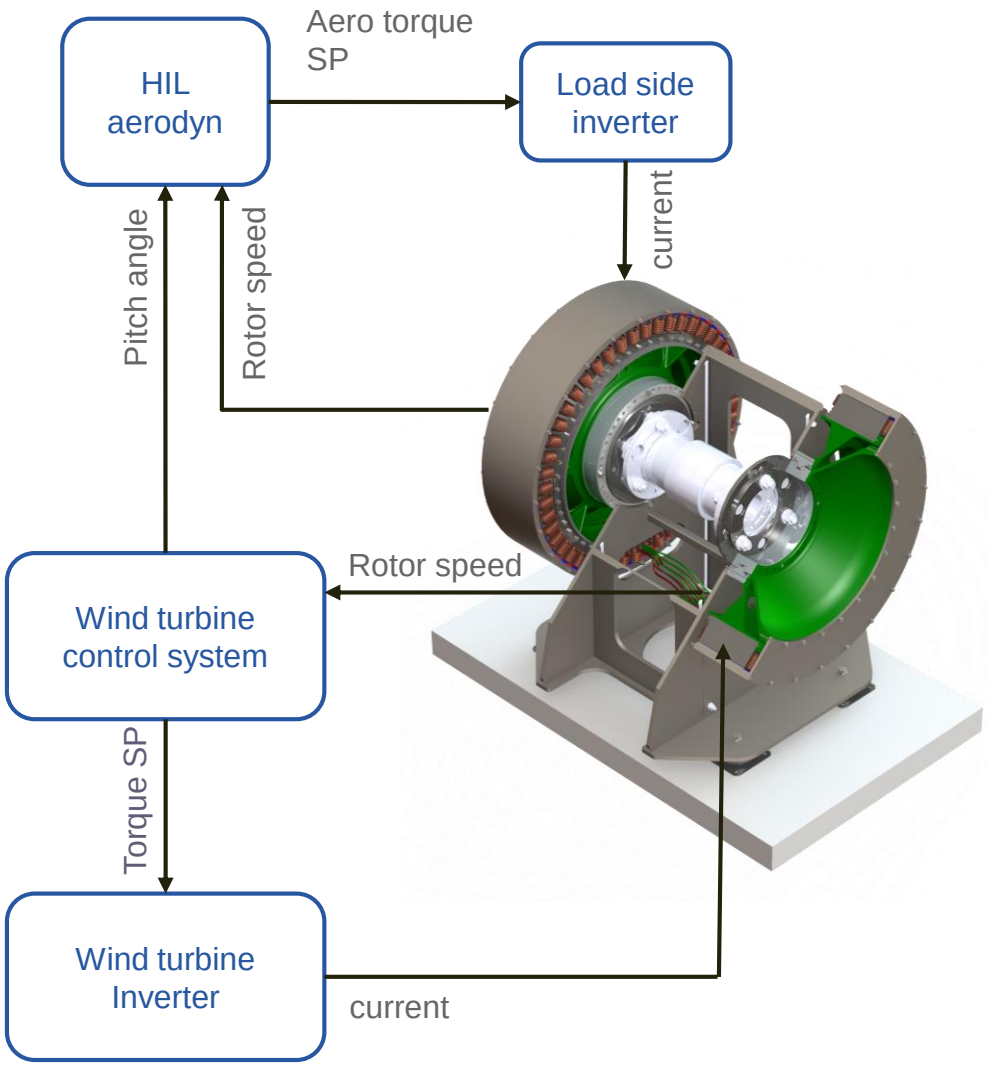
- Possibility to test underlying control loops in pitch inverters

- Testing of pitch system components under „real“ loading conditions



Source: University of Stuttgart

Generator HIL-Testbench



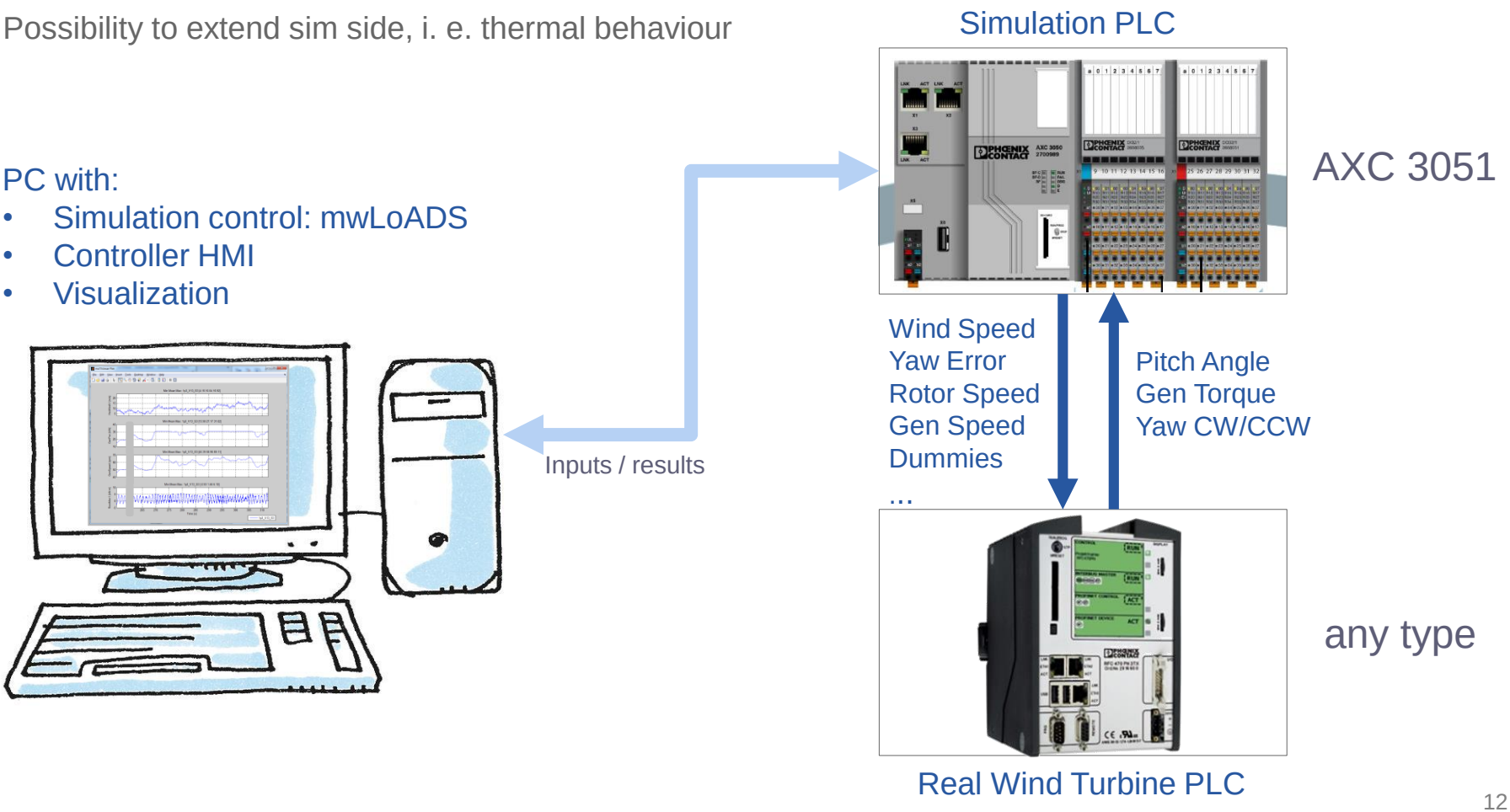
Goal:

- Generator testing
- Inverter testing
- Control system testing

Under construction

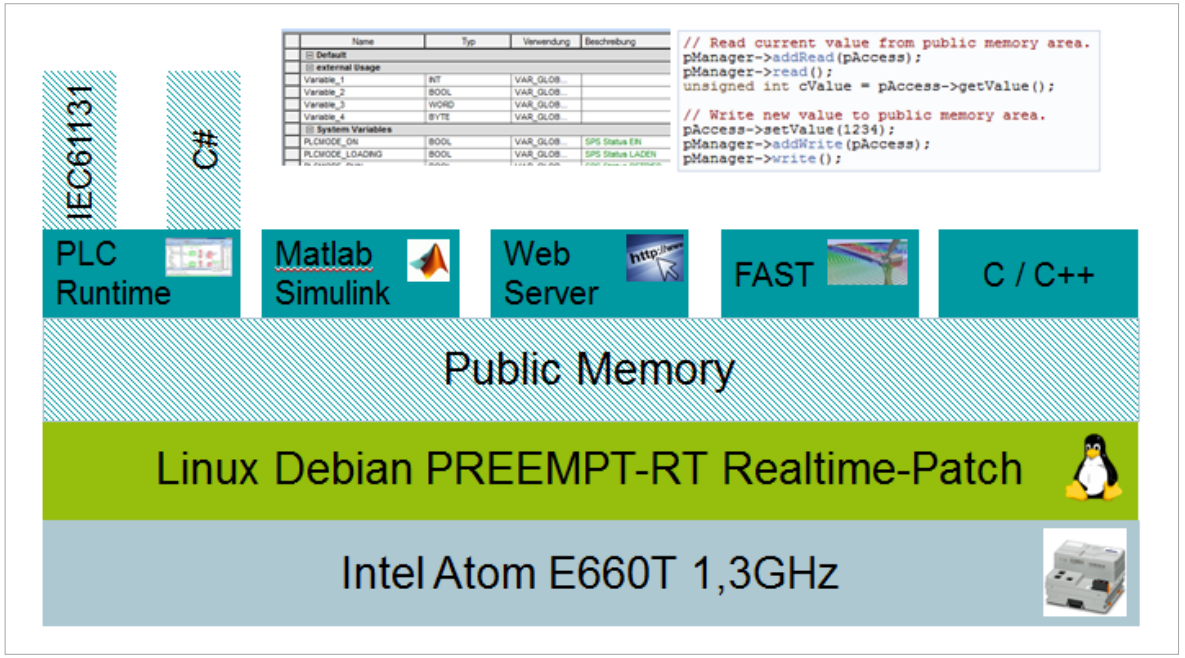
HIL Setup

- Simulation based on load simulation software FAST/AD from NREL
- Load based validation approach
- Possibility to extend hardware side, i. e. pitch drives
- Possibility to extend sim side, i. e. thermal behaviour



Simulation on Axiocontrol – AXC 3051

open PLC architecture

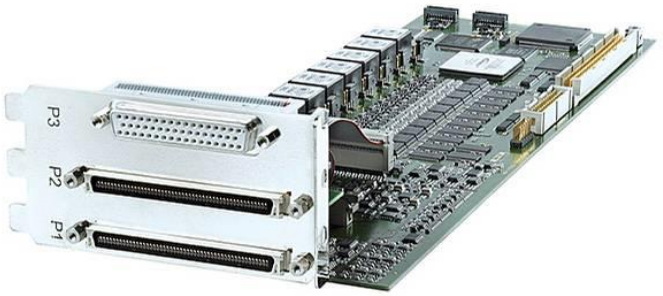


OSADL debian

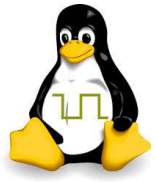
Enables data exchange between real time simulation running under Linux environment and PLC task

Other Solution for higher performance

- PC with high performance CPU
- Dedicated I/O Card



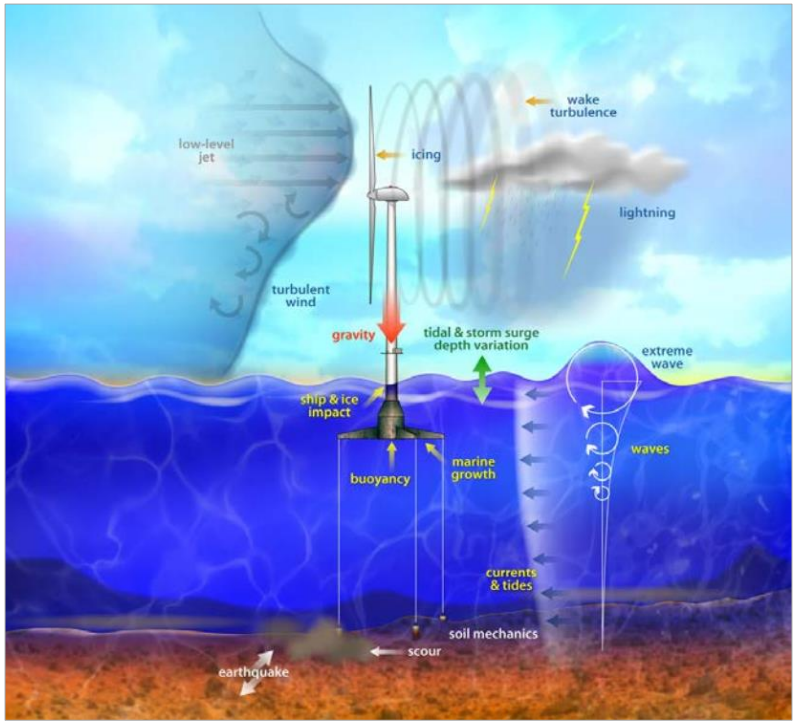
- LINUX PREEMPT-RT



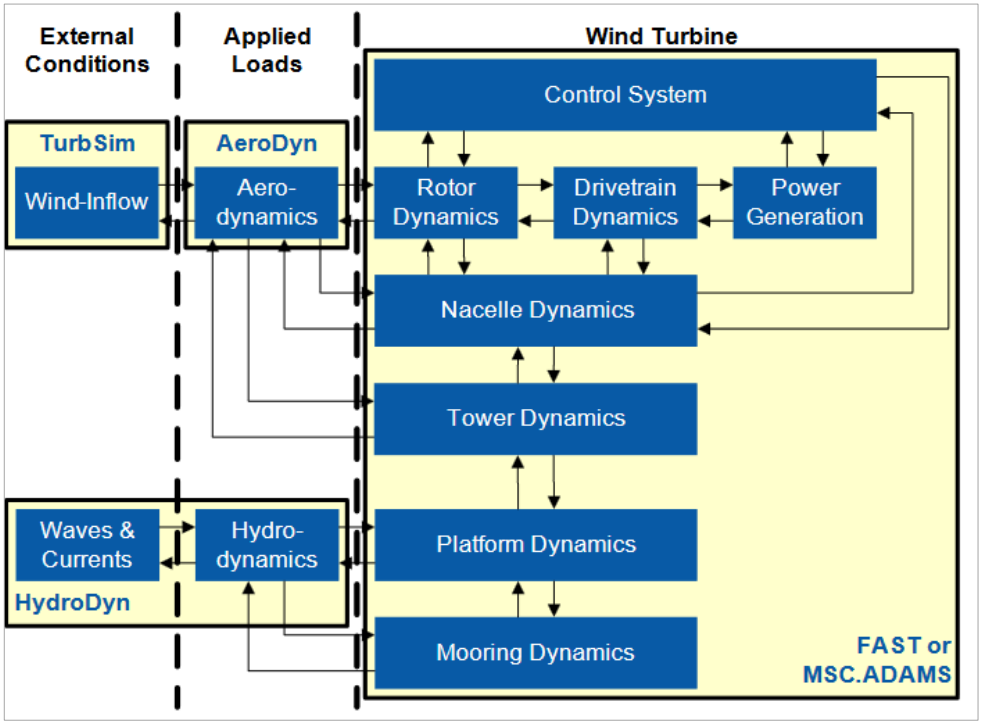
→ Expensive I/O card

→ dedicated API needs to be developed

Aero-elastic simulation model

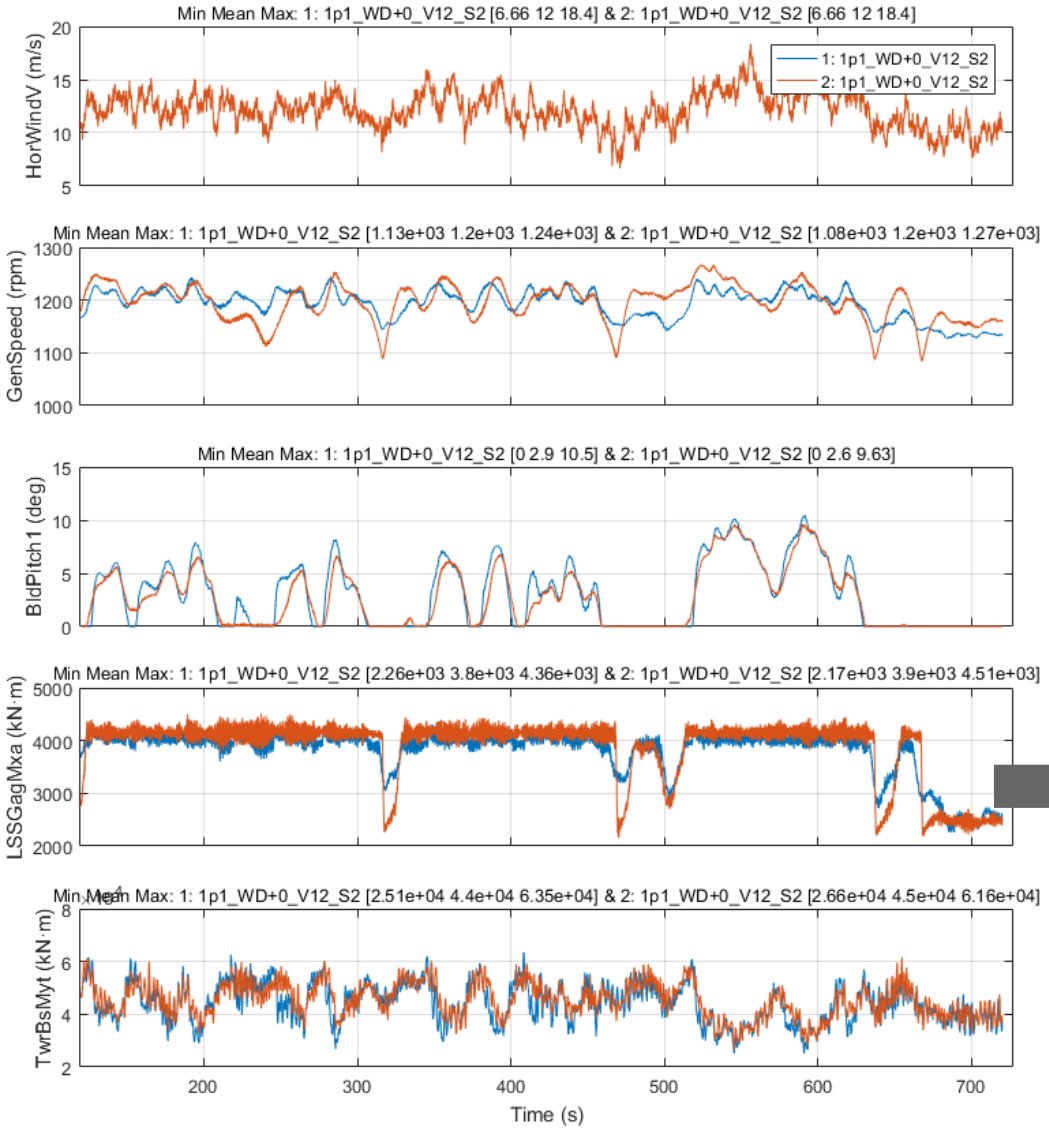


Source: NREL



A dedicated API with real time application was developed by morewind to exchange values between FAST and PLC

Load Comparison as Test Criteria



Test criteria:

- statistical quantities
- Damage equivalent loads
- Differences in Behavior like stops

	LSSGagMxa (kN·m)		
m	101	501	Difference
3.00	575.82	651.09	13.07%
4.00	677.80	771.70	13.85%
5.00	820.83	931.44	13.48%
6.00	957.26	1077.59	12.57%
7.00	1077.56	1202.69	11.61%
8.00	1182.49	1309.43	10.73%
9.00	1274.38	1401.44	9.97%
10.00	1355.38	1481.73	9.32%
11.00	1427.30	1552.62	8.78%
12.00	1491.57	1615.88	8.33%
mean	2508.48	2537.11	1.14%

Outlook

- From demonstrator to full scale test rig

- Use of HIL-setup to support wind farm operators in:
  - Retrofit solutions
  - Load related root cause analysis
  - Lifetime extension

Contact

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