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

03. November 2016
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
Motivation

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

Cost and Production benefits to be gained using advanced controls:

**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
- 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

Turbine concept
- Main Control system design (pitch, torque control, safety Sys)
  - Load Simulation with compiled control system
  - Requirements for secondary control functions

Turbine final design
- Final load simulation and control parameter freeze
  - Implementation of main control scheme on PLC
  - Implementation of secondary control functions on PLC

Validation & Verification
- 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

- Firmware Library
- Interface definition for PC Worx
- PLCOOpen XML
- C/C++
- Simulink Coder, Visual Studio Compiler + Platform SDK
- .dll
- discon.dll
- Simulink Coder, Visual Studio Compiler + Platform SDK
- Model interface augmented with eCLR
- Interface
- call(.dll)
- download
PLC Software Testing

- System requirements
- subsystem requirements
- Component requirements

Load simulation

Software Testing

- System testing
- subsystem testing
- Component testing

Wind turbine prototype testing
- control algorithm testing
- automation function testing i.e. using WinMOD
- Software in the Loop testing

Load simulation
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

Hardware-in-the-Loop-Simulation of Individual Pitch Control Systems

- Proof of concept on close-to-production-hardware
- Validation and optimization of standard motion controllers with special respect to advanced control algorithms
  Validation of pitch control systems under realistic loading
- Validation and optimization of signal processing for advanced controls

Source: University of Stuttgart
Generator HIL-Testbench

HIL aerodyn → Aero torque SP → Load side inverter

Pitch angle → Rotor speed

Wind turbine control system

Torque SP

Wind turbine Inverter

Rotor speed

current

current

Goal:
- Generator testing
- Inverter testing
- Control system testing
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

PC with:
- Simulation control: mwLoADS
- Controller HMI
- Visualization

Simulation PLC

AXC 3051

Wind Speed
Yaw Error
Rotor Speed
Gen Speed
Dummies

... Pitch Angle
Gen Torque
Yaw CW/CCW

Real Wind Turbine PLC

any type
Simulation on Axiocontrol – AXC 3051

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
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

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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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