

TKI W_oZ D4REL

Monitoring and Control Review

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Overview

- **Aim of WP4:** reduce material costs and unplanned maintenance by **intelligent control** that adapts itself to the environmental and operational conditions
- Introduction to how intelligent control can reduce OM costs
- Failures in WTs
 - Components leading to downtime
 - Monitoring methods and challenges
- Modelling study using ECN O&M Tool
 - Quantify maximum benefit of modified O&M strategy utilising intelligent monitoring and control
- Next steps in intelligent control

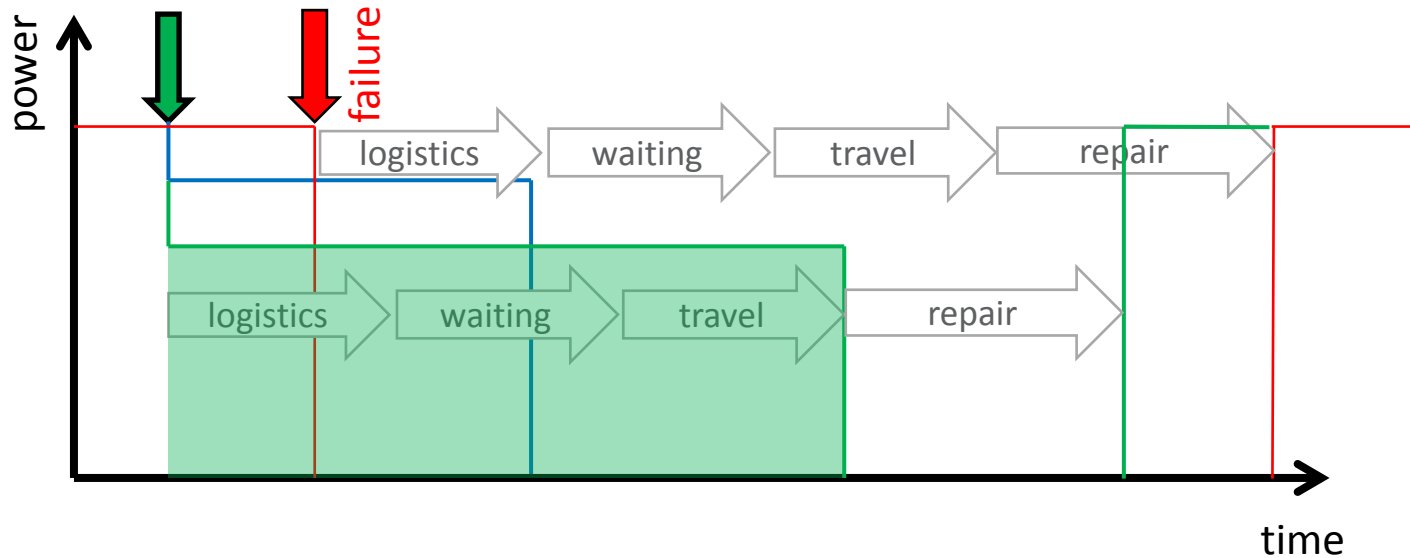
Offshore WT Maintenance

- Downtime and stoppages in wind farms and turbines attributed to:
 - Faults
 - Poor conditions
 - Preventative maintenance
 - Corrective maintenance
- Lower availability in offshore wind farms compared to the onshore case due to:
 - Longer logistic times
 - Waiting periods (weather windows)
 - Large distance to shore (travel times)
 - Accessibility to turbine
- Availability of an offshore wind farm can be increased through:
 - Condition monitoring measurement system
 - Analysis of signals for detection of faults prior to failure
 - Modified OM strategy taking into account failure prediction

Operation and Maintenance Strategy

Component degradation => Failure => shutdown => repair

Result: stand still => missed production

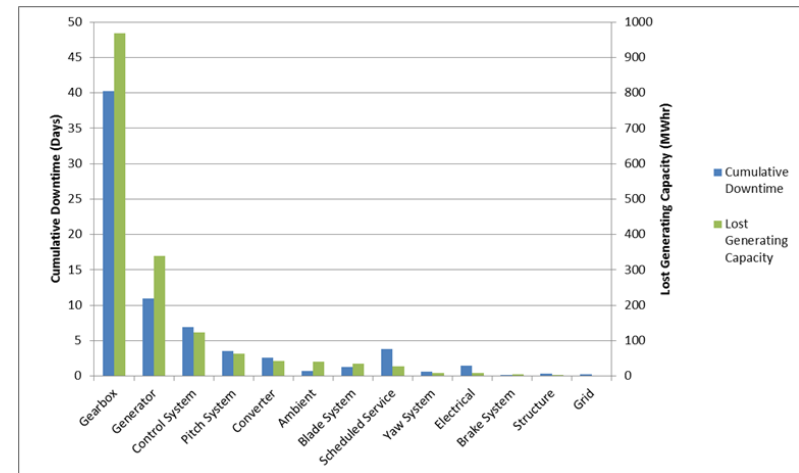


Literature Review

Subsystem Failures

- Target systems which contribute most to high downtime of wind turbines
 - Minimize payback period of CM system
 - High failure frequency
 - High downtime per failure
- Identifying systems not straightforward
 - Minimal data for reliability of offshore turbines available
 - Failure frequencies and downtimes vary between studies
 - Manufacturers/time period/turbine size
- Components identified for measurement/monitoring:
 - Generator
 - Gearbox
 - Main shaft/bearing
 - Pitch and Yaw Systems
 - Blades and Hub
 - Structure/Tower

Average yearly downtime and lost generating capacity Egmond aan Zee 2007-2009^{[1][2][3]}



[1] Nordsee Wind CV. (2008, October) Operations Report 2007. Document Number: OWEZ_R_000_20081023. [Online]. http://www.noordseewind.nl/wp-content/uploads/2012/02/OWEZ_R_000_20081023-Operations-2007.pdf
 [2] NoordzeeWind CV. (2009, August) Operations Report 2008. Report Number: OWEZ_R_000_20090807. [Online]. http://www.noordseewind.nl/wp-content/uploads/2012/02/OWEZ_R_000_20090807-Operations-2008.pdf
 [3] NoordzeeWind CV. (2010, November) Operations Report 2009. Document Number: OWEZ_R_000_20101112. [Online]. http://www.noordseewind.nl/wp-content/uploads/2012/02/OWEZ_R_000_20101112-Operations-2009.pdf

Wind Turbine Monitoring

- Criterion for fault detection:
 - Reliable detection ability
 - Early detection possibility
 - Potential reduction in maintenance costs (economic feasibility)
- Monitoring broken down into four categories
 1. SCADA (<0.002 Hz, continuous)
 2. Structural health monitoring (<5 Hz, on demand)
 3. Condition monitoring (<50 Hz, continuous)
 4. Diagnosis (>10 kHz, on demand)
- Different components require different monitoring and analysis systems
 - Temperature sensors, accelerometers, speed sensors, stress wave sensors, piezoelectric transducers, acoustic emission sensors, ultrasonic emission sensors, strain gauges
- Limiting the expense of the monitoring system is key

Modelling Study

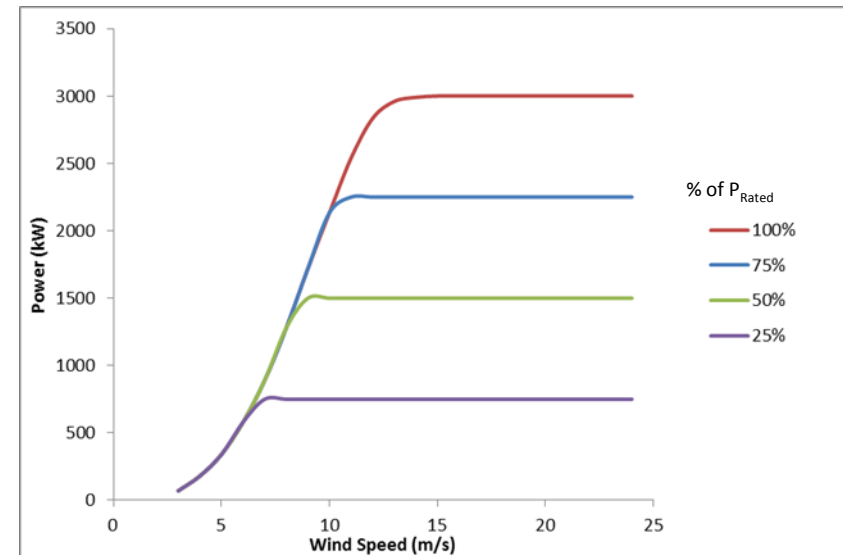
O&M Modelling Study

- ECN O&M modelling tool to determine energy saving potential
 - State of the art tool for predicting ideal OM strategies for offshore wind farms
 - Stochastic determination of power loss due to OM corrective maintenance events
- Reference wind farm:
 - 130 turbines – Vestas V90-3 MW machines
 - Strategy using mother vessel stationed close to wind farm
 - Failure rates indicative of likely WF values
- Revised strategies for 8 components:

– Rotor System – Blades	– Yaw Gearbox
– Rotor System – Hub	– Generator
– Blade Adjustment	– Gearbox
– Main Shaft/Bearing	– Turbine Tower/Structure
- Assumption that monitoring can predict failure for 50%/100% all occurrences

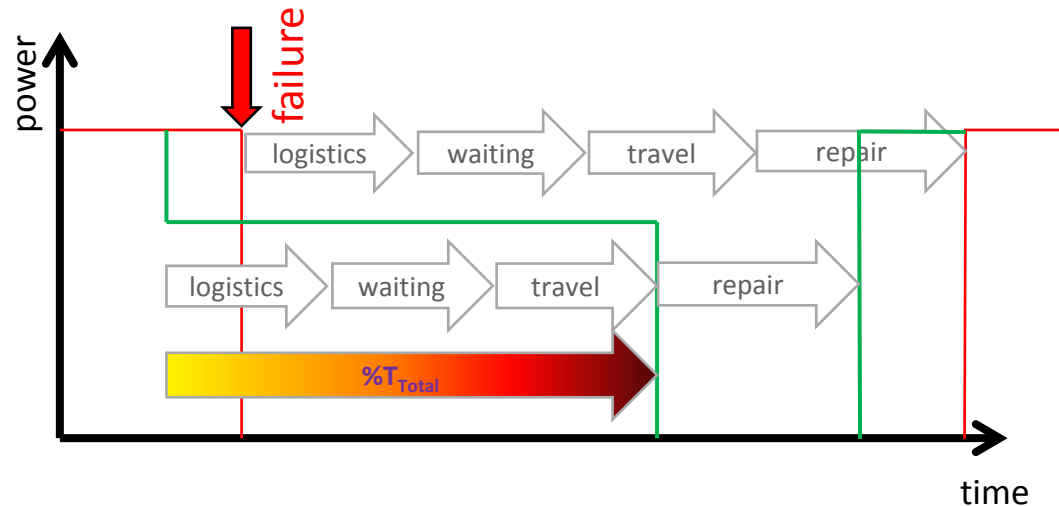
O&M Modelling Study

- Energy saving potential function of:
 - Rated power
 - Time of operation before failure
 - Sensitivity analysis modifying these variables
- Load reductions achieved through
 - Variations of rated power
 - No quantification of the increased component lifetime when derating



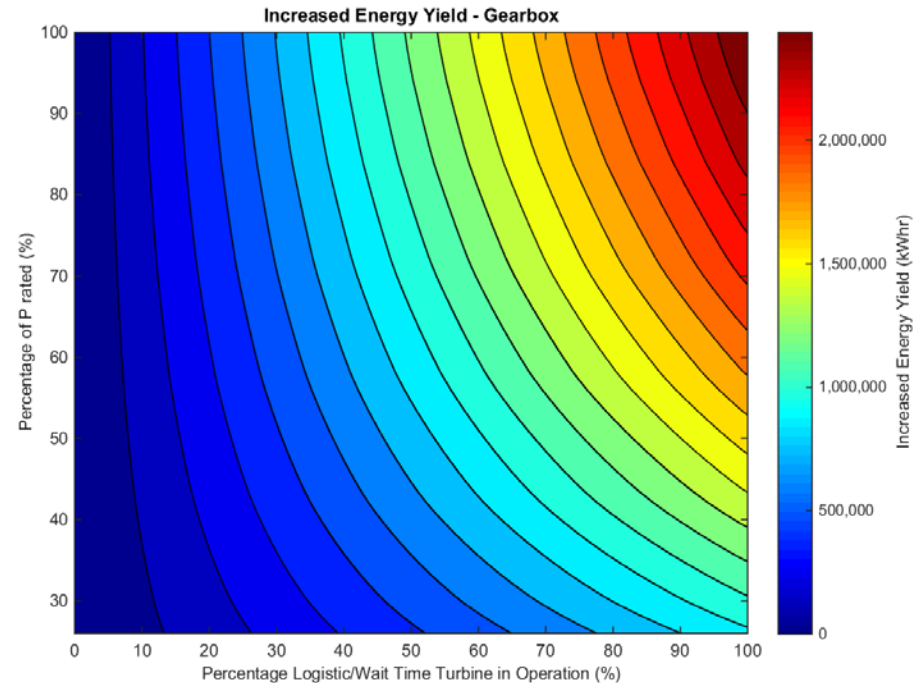
O&M Modelling Study

- Energy saving potential function of:
 - Rated power
 - Time of operation before failure
 - Sensitivity analysis modifying these variables
- Operation time before failure expressed as a percentage of:
 - Logistic time
 - Waiting time
 - Travel time
- Damaged component fixed as quickly as possible



Preliminary Results

- Increased energy yield can be mapped for each component:
 - Almost linear dependence on %logistic time
 - Limiting gains as P_{Rated} increases
- Results are highly dependent on assumptions and inputs
- Maximum benefit of 27,900 MWhr/yr
 - Assuming all faults can be detected for selected components and no derating occurs
 - 3.6 M€/year
 - 27 k€/turbine/year
 - Increase in energy yield of 1.07%
 - Reduction in LCOE of 40c/MWhr



Future Steps

- **Aim:** To translate load reductions to lifetime extensions in specified components to fully quantify benefits:
- Correlation of power reduction to load reductions
 - Design equivalent loads
 - Extreme loads
- Use of Phatas (load calculation) integrated with Focus (WT design tool)
 - Modelling based study
- Various challenges to overcome – pitch system example
 - Reduction of the loads vs increasing in pitching
 - Optimal for lifetime extension?



Please address questions to
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Planning

- Time planning

	Year	2014				2015				2016				2017			
	Period	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
WP4.2 Self-adapting wind turbine control using identified models																	
Task 4.2.1 Controller re-optimization based on identified models																	
Task 4.2.1.1 Offline controller optimization based on identified models with reduced uncertainties																	
Task 4.2.1.2 Online adaptive control for changing turbine parameters																	
Task 4.2.2 Controller reconfiguration for degraded wind turbine components																	

- Deliverables and milestones

D4.2.1	Sep-17		D	Adaptation of controller parameters using identified models, report
M4.2.1.1	Sep-17			Algorithm for offline controller optimization from low-uncertainty identified models
M4.2.1.2	Sep-16			Algorithm for online controller adaptation
D4.2.2	Sep-17	expected Sep-16	D	Accommodation of degraded wind turbine components by controller reconfiguration, report
D4.3	Sep-17		D	Integral impact of the results from WP1, WP2, WP3, and WP4 on the cost of energy at system level