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SUPERGEN Wind

Wind Energy Technology

Fault Analysis and Condition Monitoring for Wind Turbines: Practical Techniques for Wind farms

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(on behalf of Loughborough, Durham, Strathclyde and Manchester)

Research towards a Highly Reliable Offshore Wind Power Station

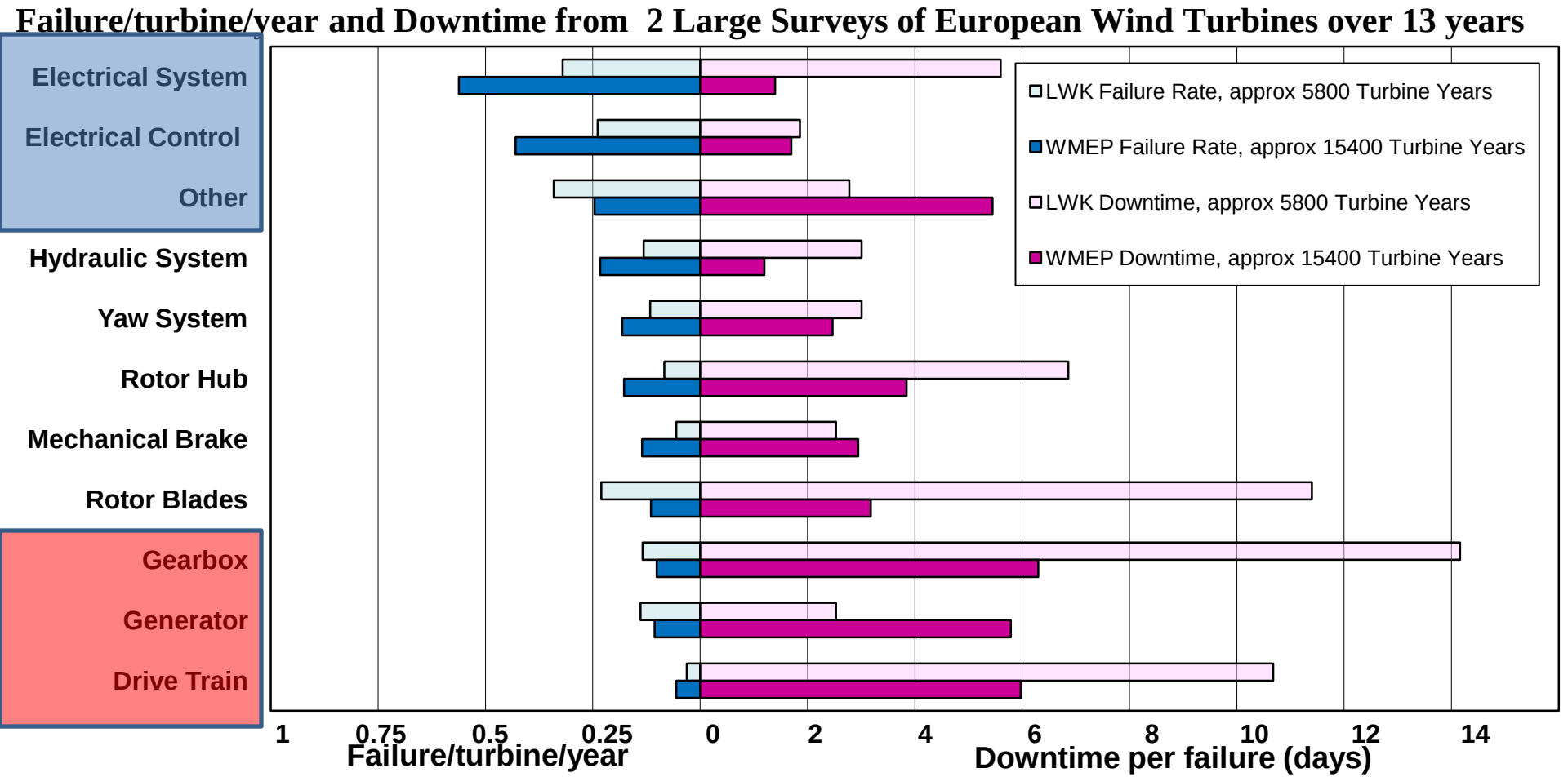
EWEC 2010, Warsaw

20th April 2010

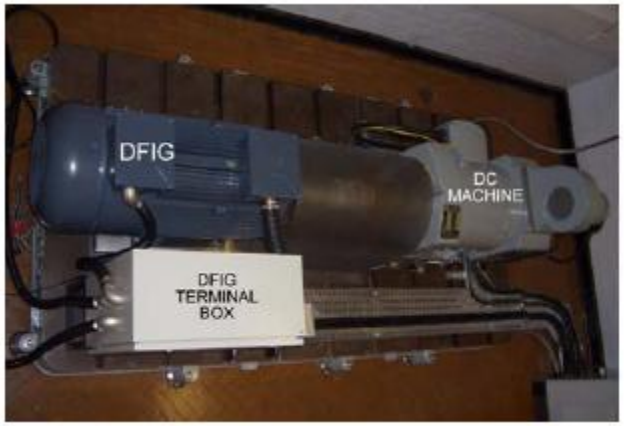
Introduction

- Analysis of wind turbine failures
- Drive train monitoring
- Analysis of electrical signals
- Process modelling
- Physics of failure analysis
- Industry impact
- Summary and recommendations

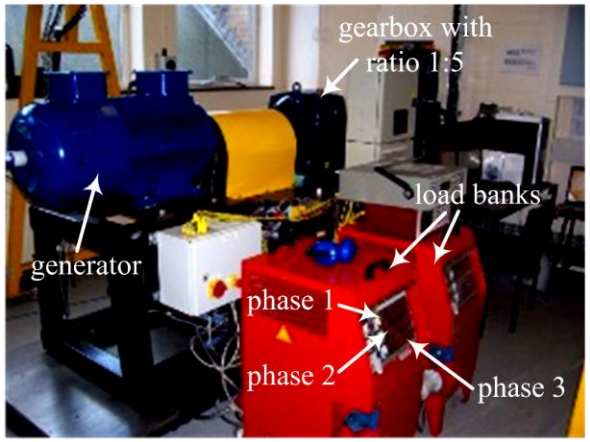
Reliability & Downtime & Subassemblies, EU



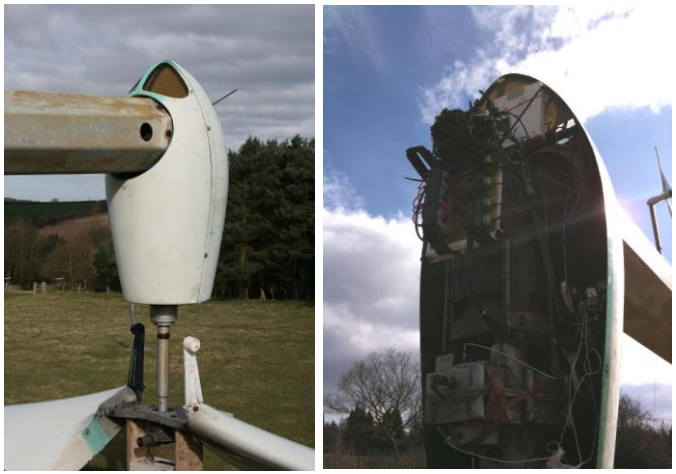
Drive Train Test Data



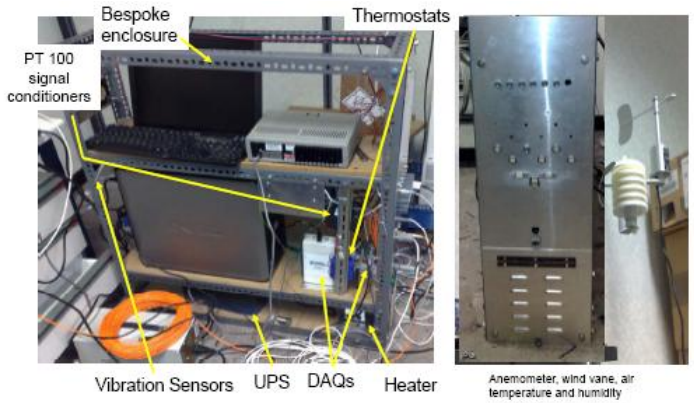
Electrical Generator Test Rig



Gearbox/Generator Test Rig



Small wind turbine CMS



Large wind turbine CMS

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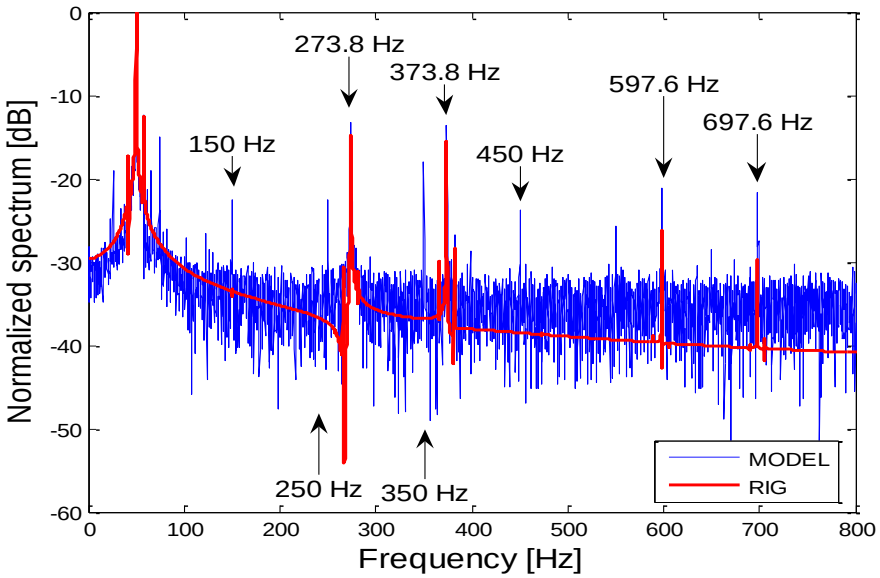
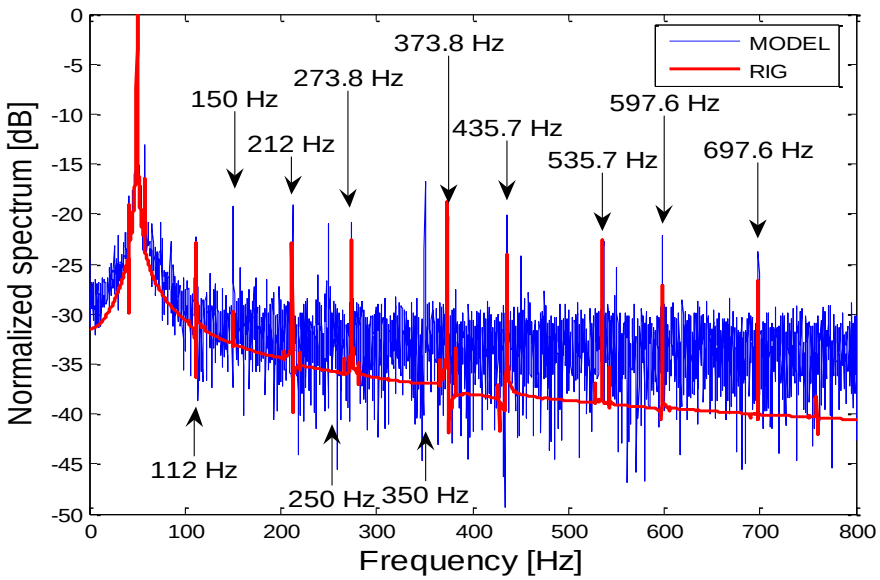
Monitoring Generators

- Mathematical modelling
- Test rig simulations of faults
- Numerical analysis of test rig and real turbine data
- Validation against actual faults

Frequency Analysis of Healthy and Faulty DFIG



a) Healthy DFIG



b) Stator winding open circuit fault

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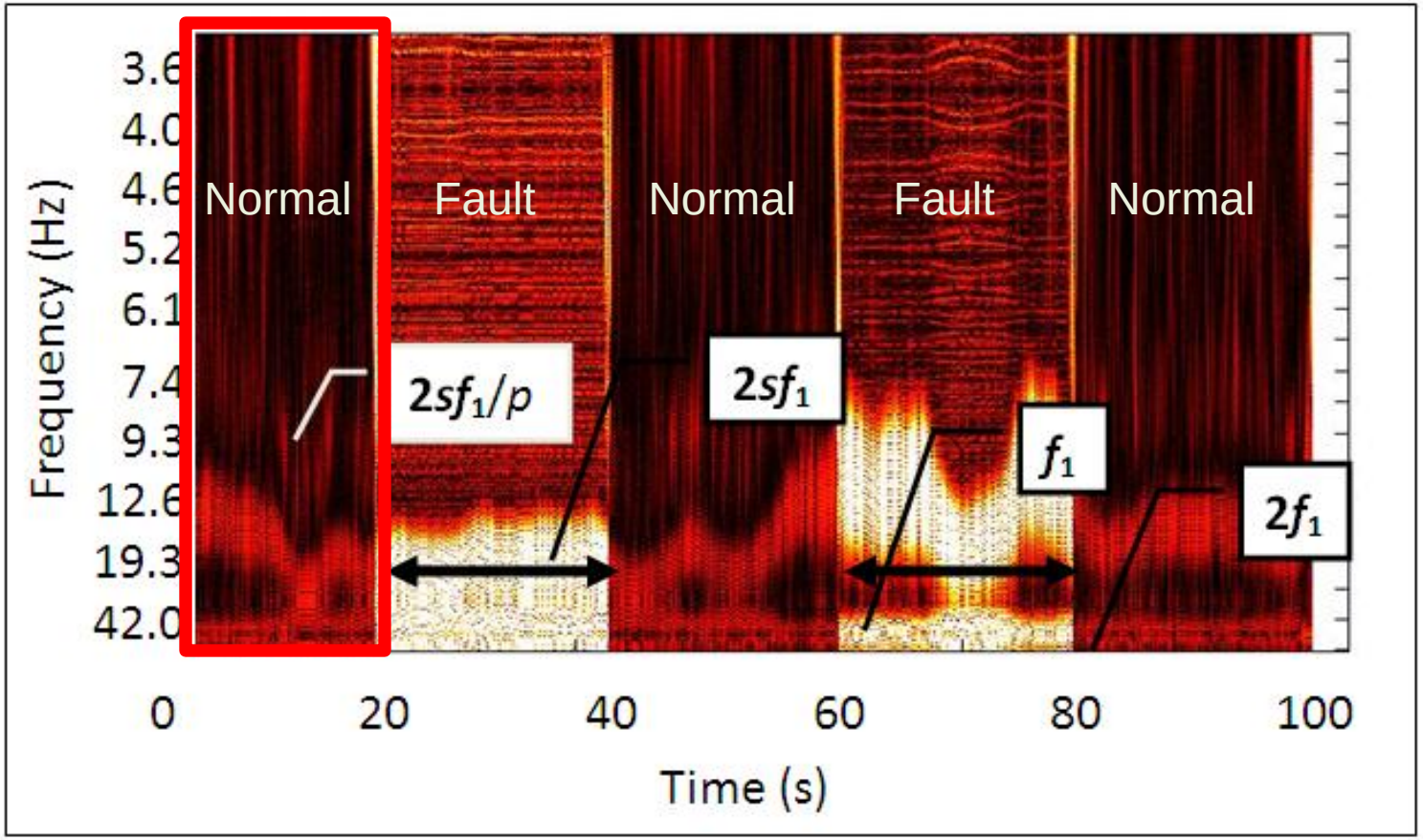
Wavelet Analysis

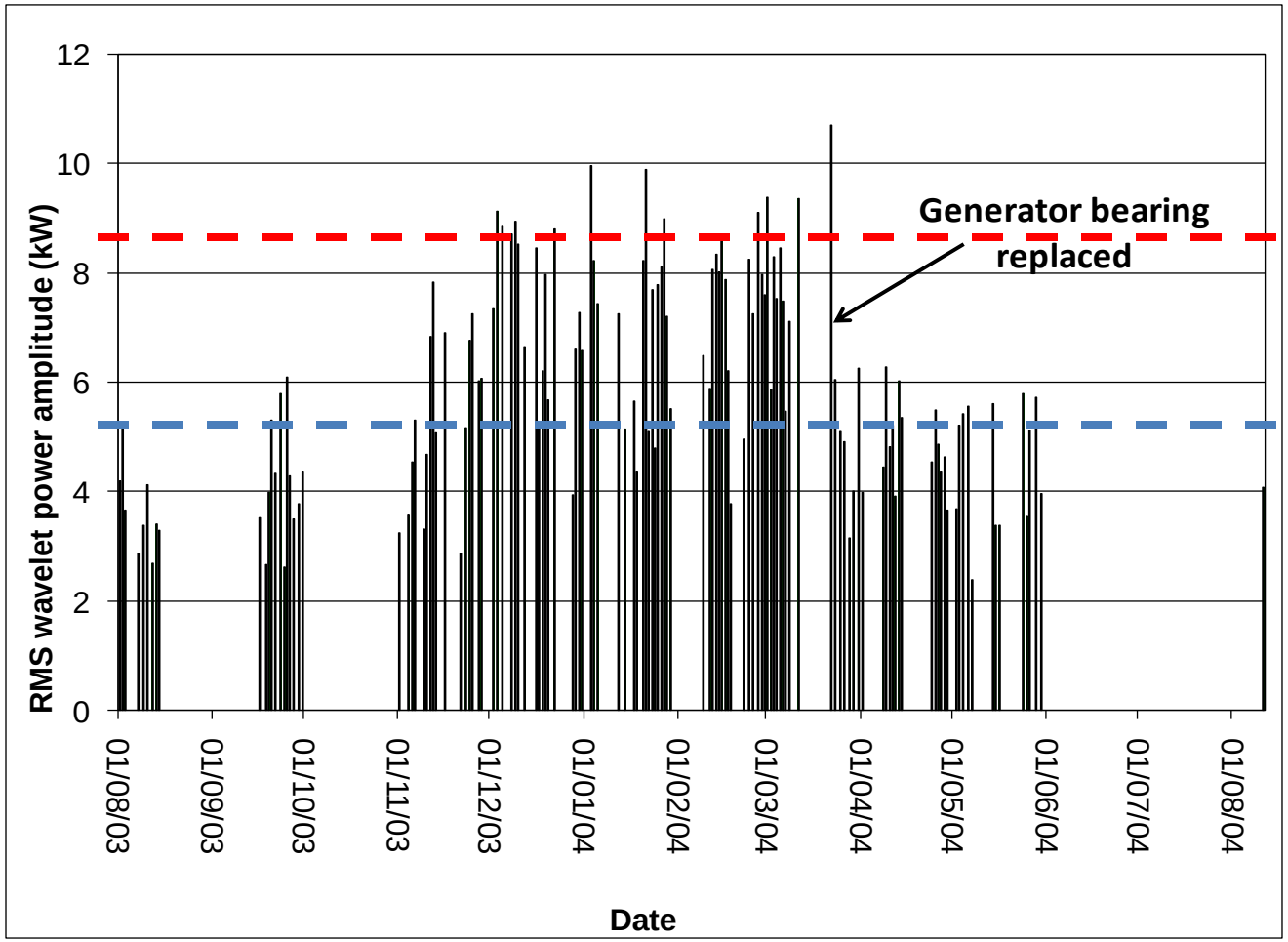
- Extract particular component of electrical power signal using a wavelet
- Analyse magnitude of particular frequencies (which may vary in time) indicative of faults
- High magnitude indicates fault
- Generator misalignment leading to possible bearing failure

Analysis of Test Rig Faults



$2sf_1$ - Relatively low frequency signal which can be monitored

Analysis of Real Turbine Data



Faulty generator bearing

Normal generator bearing

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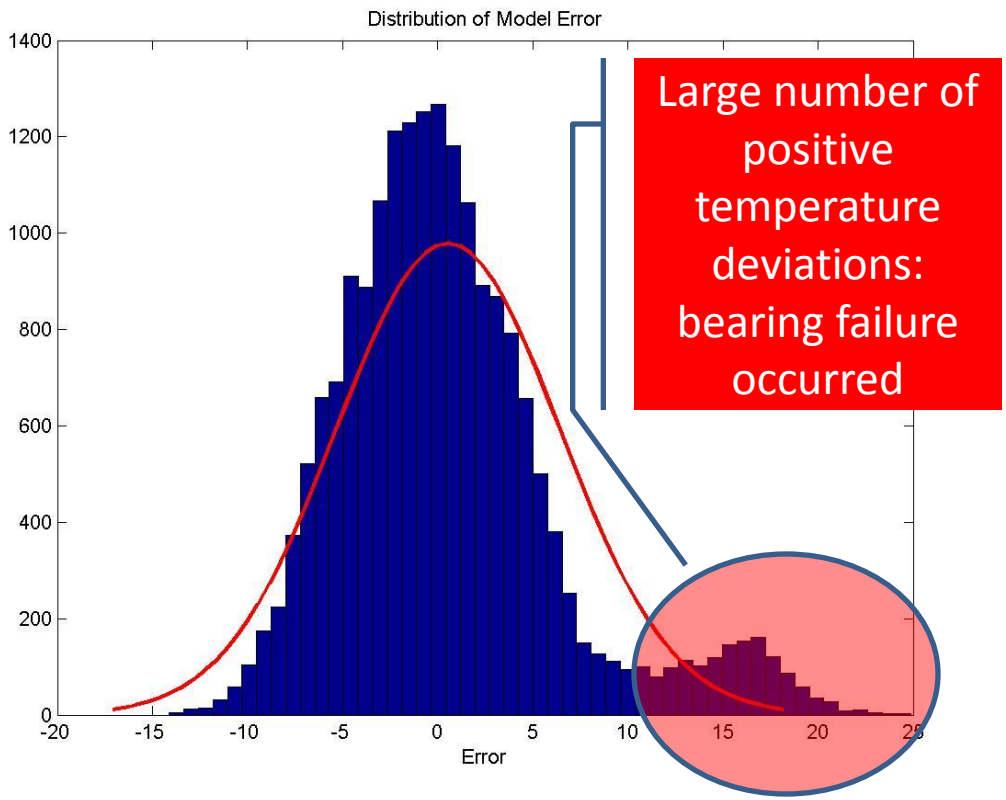
Physics of Failure Using (SCADA Data)

- FMEA analysis to determine failures, causes and indicators
- Identify key failure indicators from data
- Develop theoretical damage model
- Monitor damage accumulation
- Determine probability of failure

Process Modelling Using (SCADA Data)



- Time series process model of generator bearing temperature
- Compare actual with prediction
- Discrepancy possible indicator of fault

Analysis of Real Turbine CMS Data Gearbox Bearing Failure

Brass bearing cage on intermediate stage collapsed

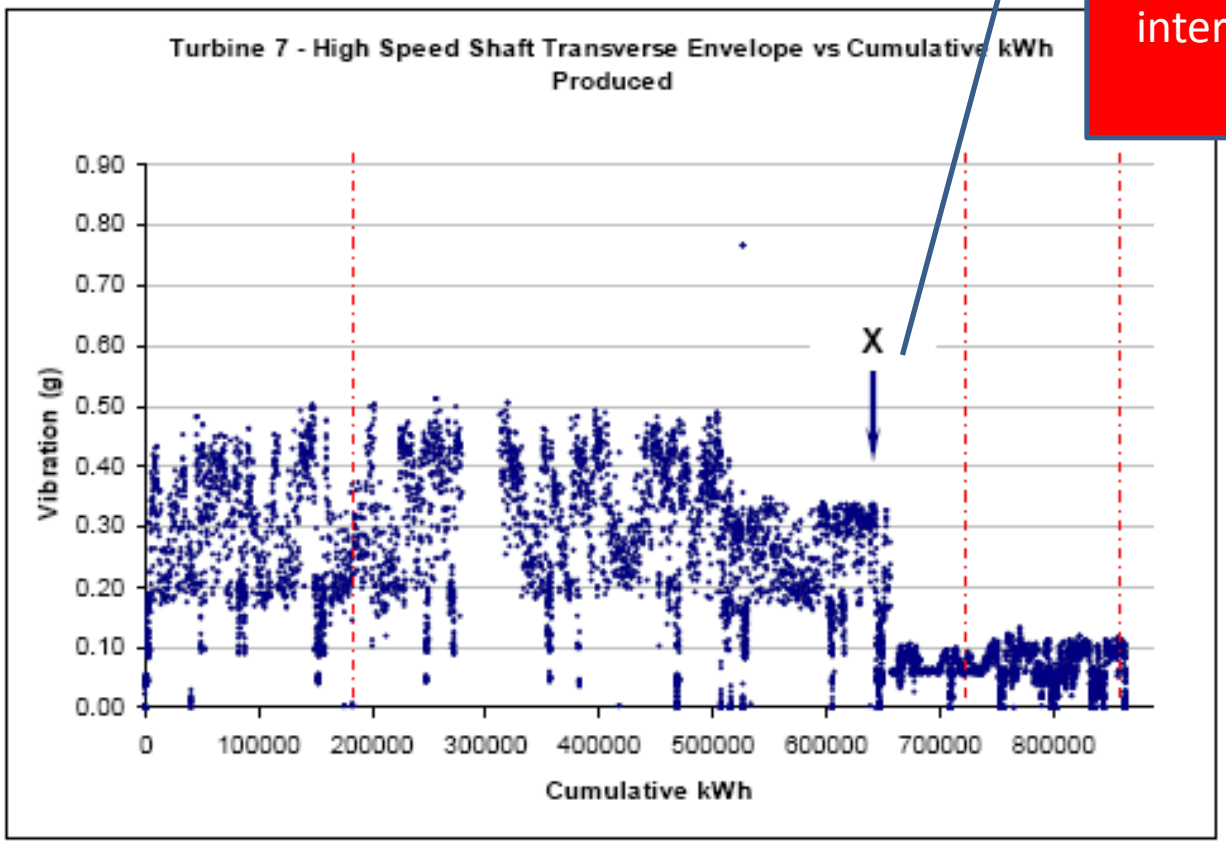
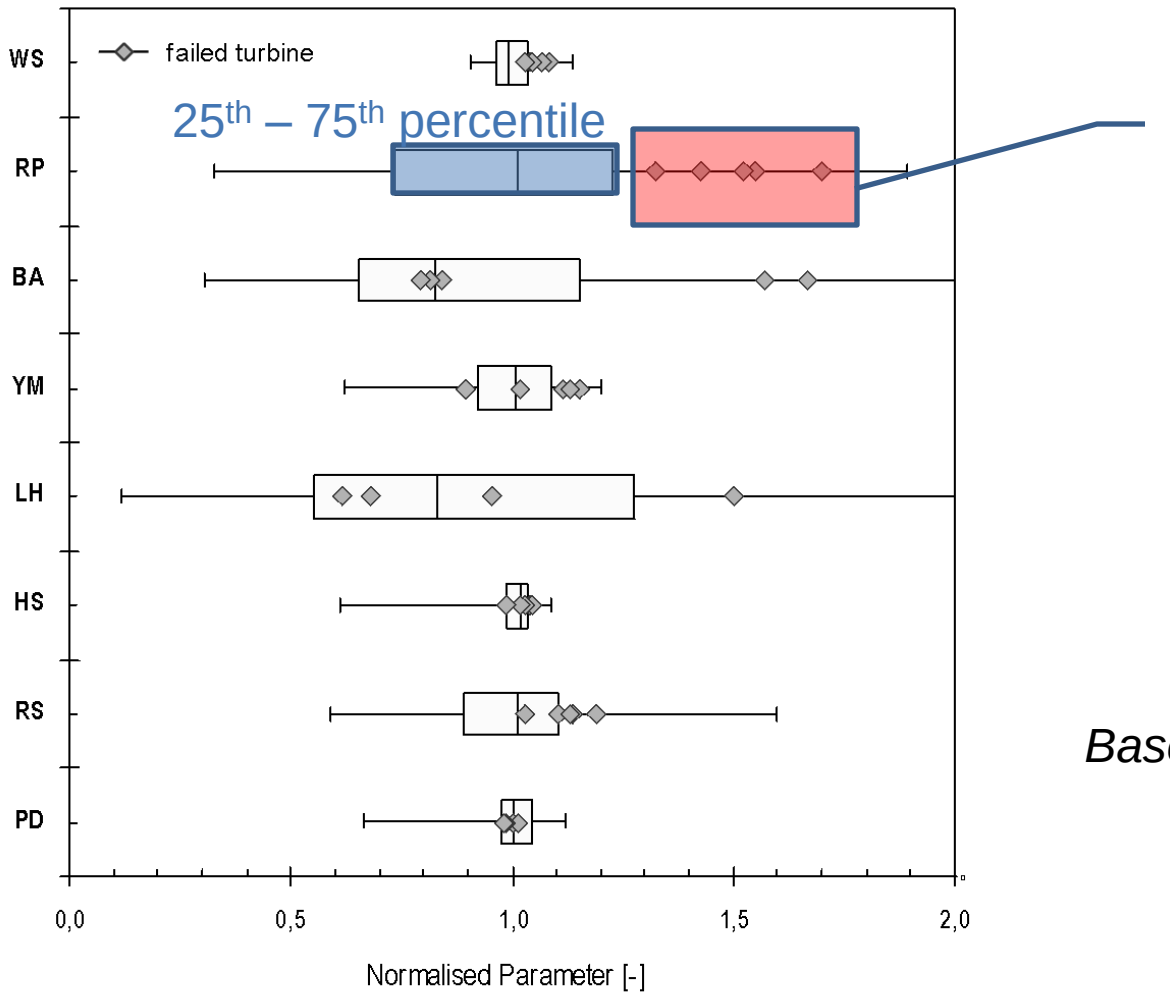


Figure 4 - Gearbox High Speed Shaft Transverse Vibration Envelope against cumulative energy produced

Gearbox Failure



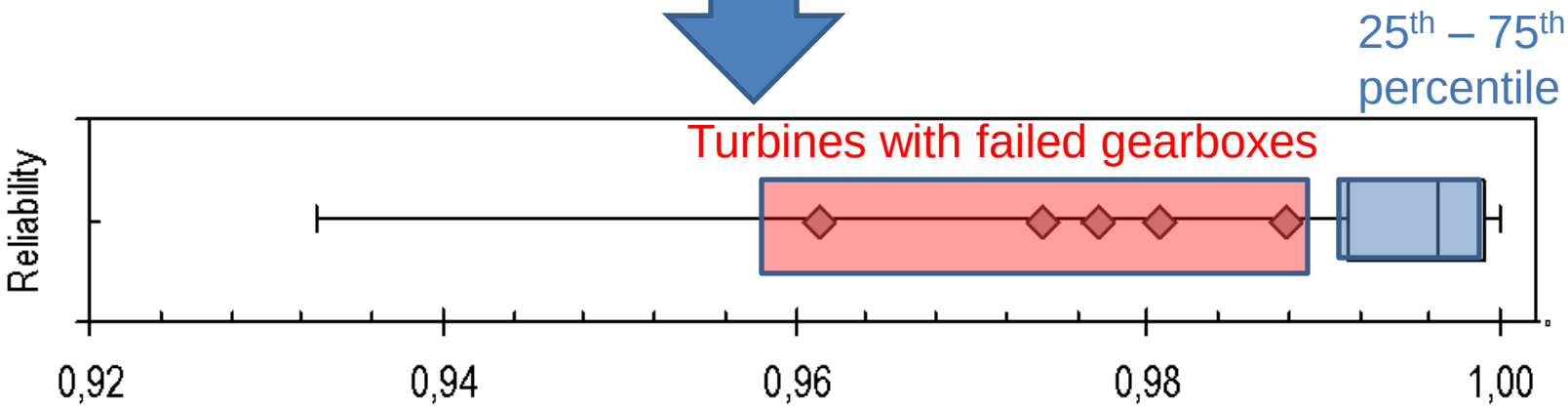
Turbines with failed gearboxes in top 25th percentile in terms of hours at rated power:

High cycle fatigue due to poor contact conditions between roller and raceway and occurring at conditions of high stationary power

Based on a large US wind farm

Damage Model - Reliability

Damage Accumulation Model Based on Electrical Power and Rotor Speed



Distribution of calculated reliability based on damage calculation for specific failure mode "bearing High Cycle Fatigue due to edge loading"

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Industry Impact

- Fault prediction capability
- Proactive maintenance – early intervention
- Target turbines where faults most likely to occur
- Optimise O&M scheduling
- Reduce O&M costs
- Increase wind farm availability

Summary and Recommendations

- Drive train key focus for condition monitoring
- Electrical power (high, medium, low frequency – give different information), temperature, oil and vibration monitoring
- SCADA data valuable for process and damage modelling
- Combined approach – use several indicators to give confidence in prediction of the probability of failure of subassemblies