SUPERGEN Wind

Wind Energy Technology

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

Prof Simon Watson

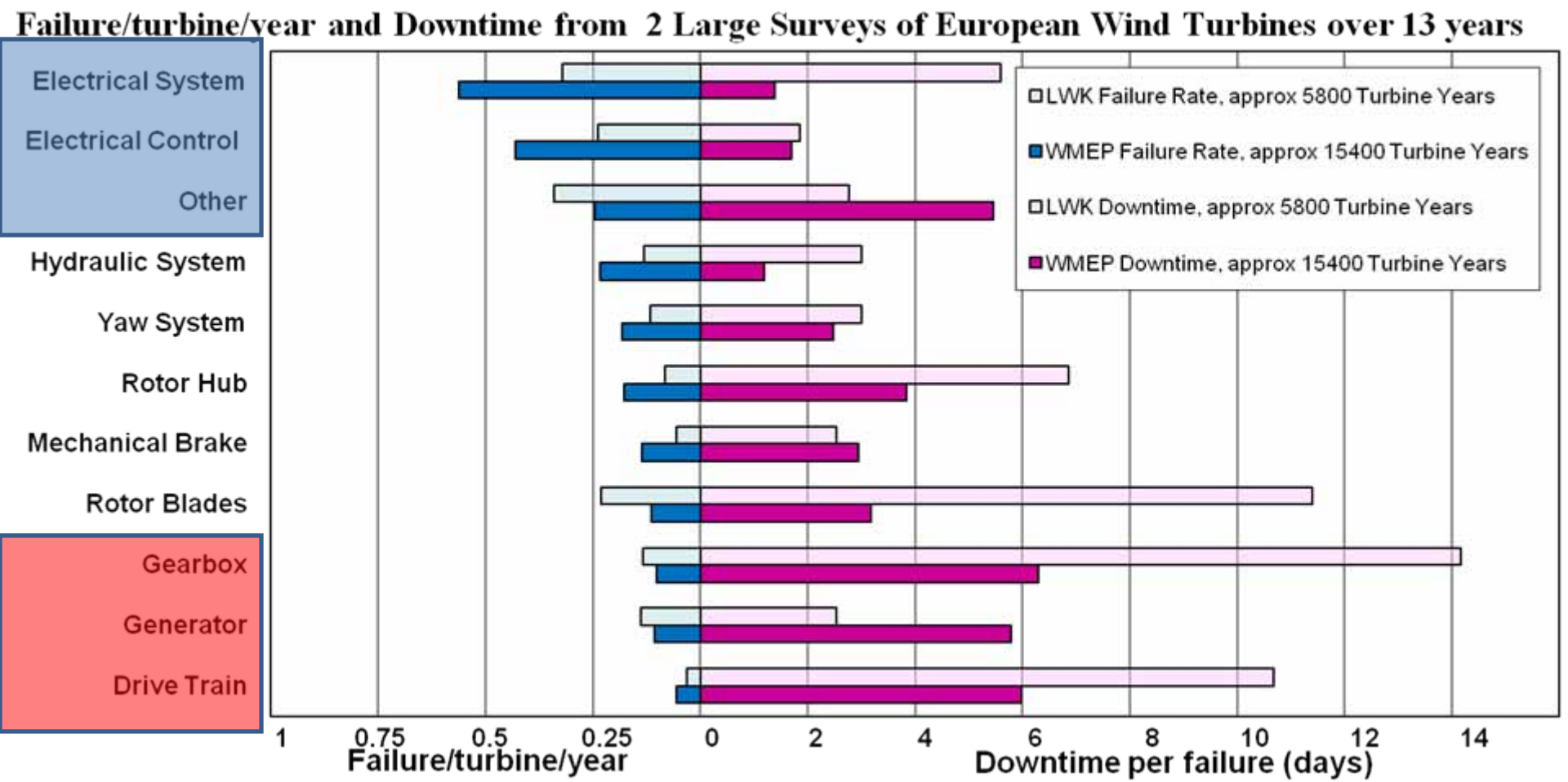
CREST, Loughborough University

Workshop on Offshore Condition Monitoring
renewableUK Offshore 2010
30th June 2010

Introduction

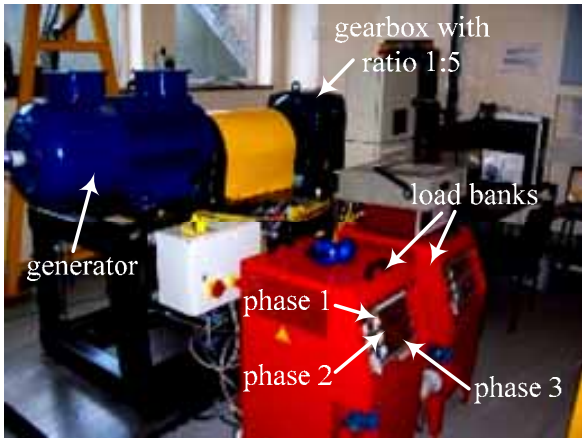
- Analysis of wind turbine failures
- Drive train monitoring
- Analysis of electrical signals
- Process modelling
- Physics of failure analysis
- Summary and recommendations

Reliability & Downtime & Subassemblies, EU

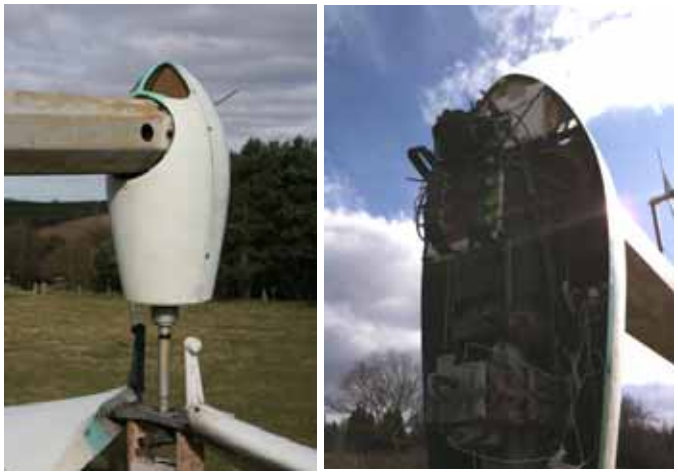


Drive Train Test Data

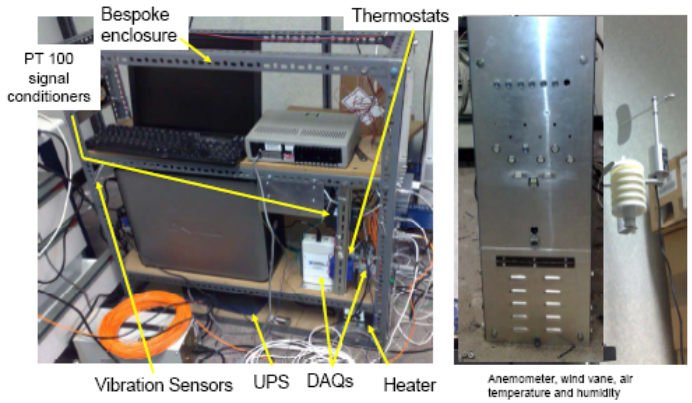
Electrical Generator Test Rig



Generator Gearbox Test Rig



Small Wind Turbine CMS



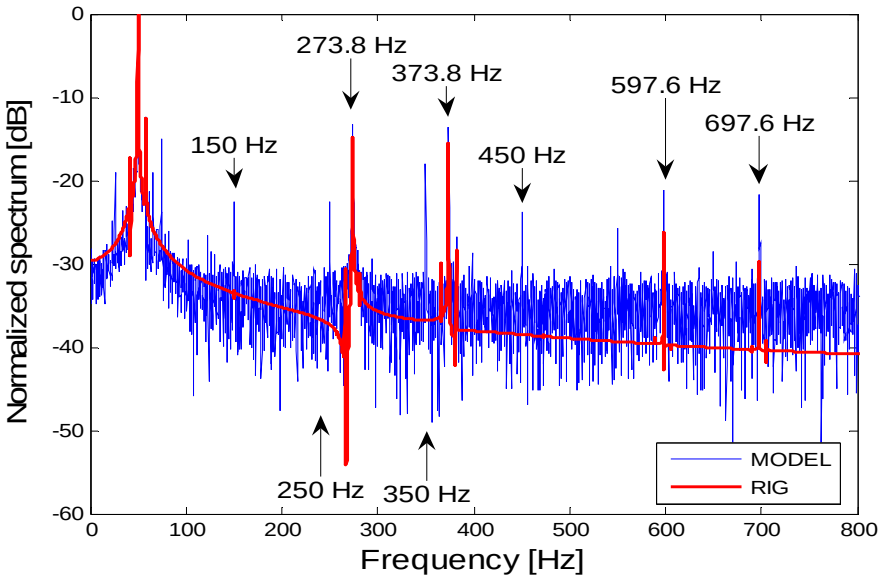
Large Wind Turbine CMS

Loughborough University

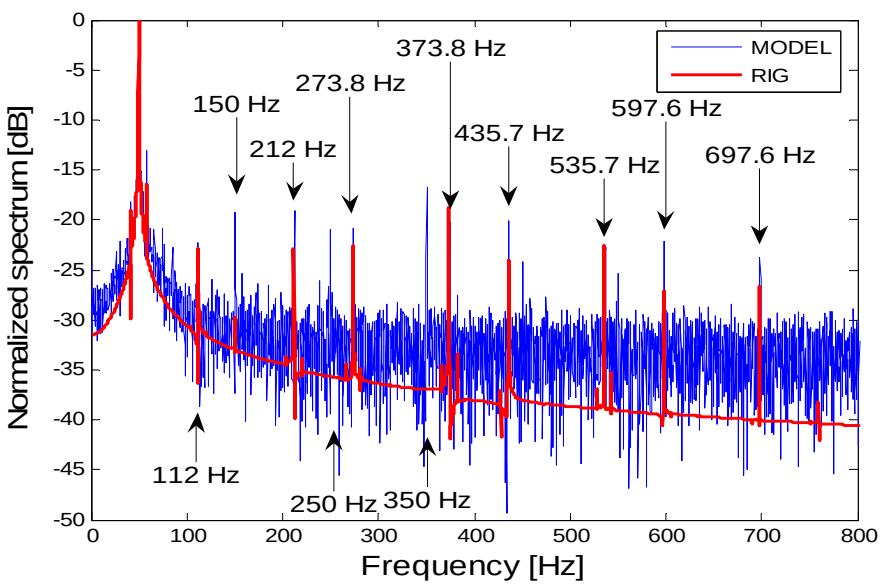
Monitoring Generators

- 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

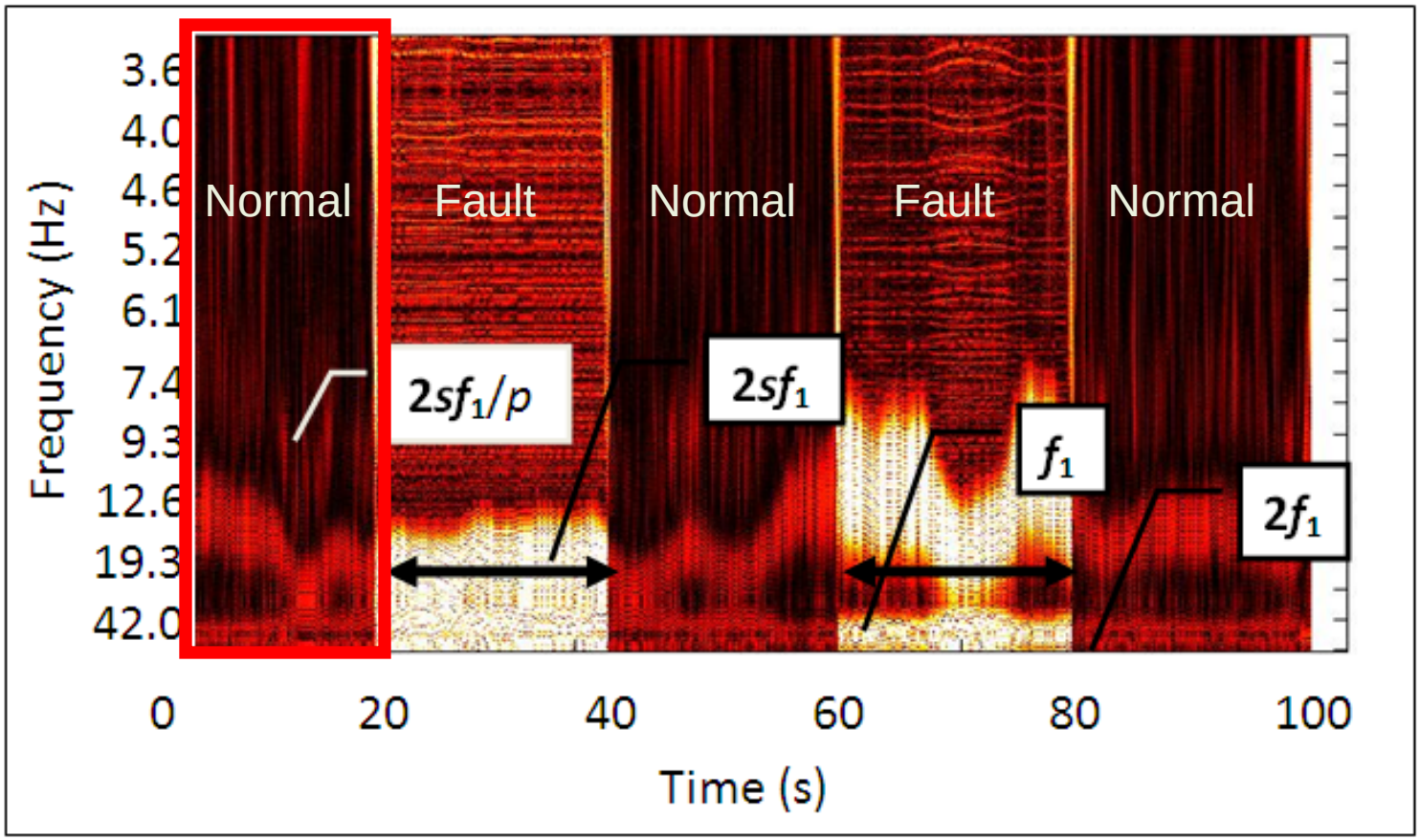


b) Stator winding open circuit fault

Wavelet Analysis

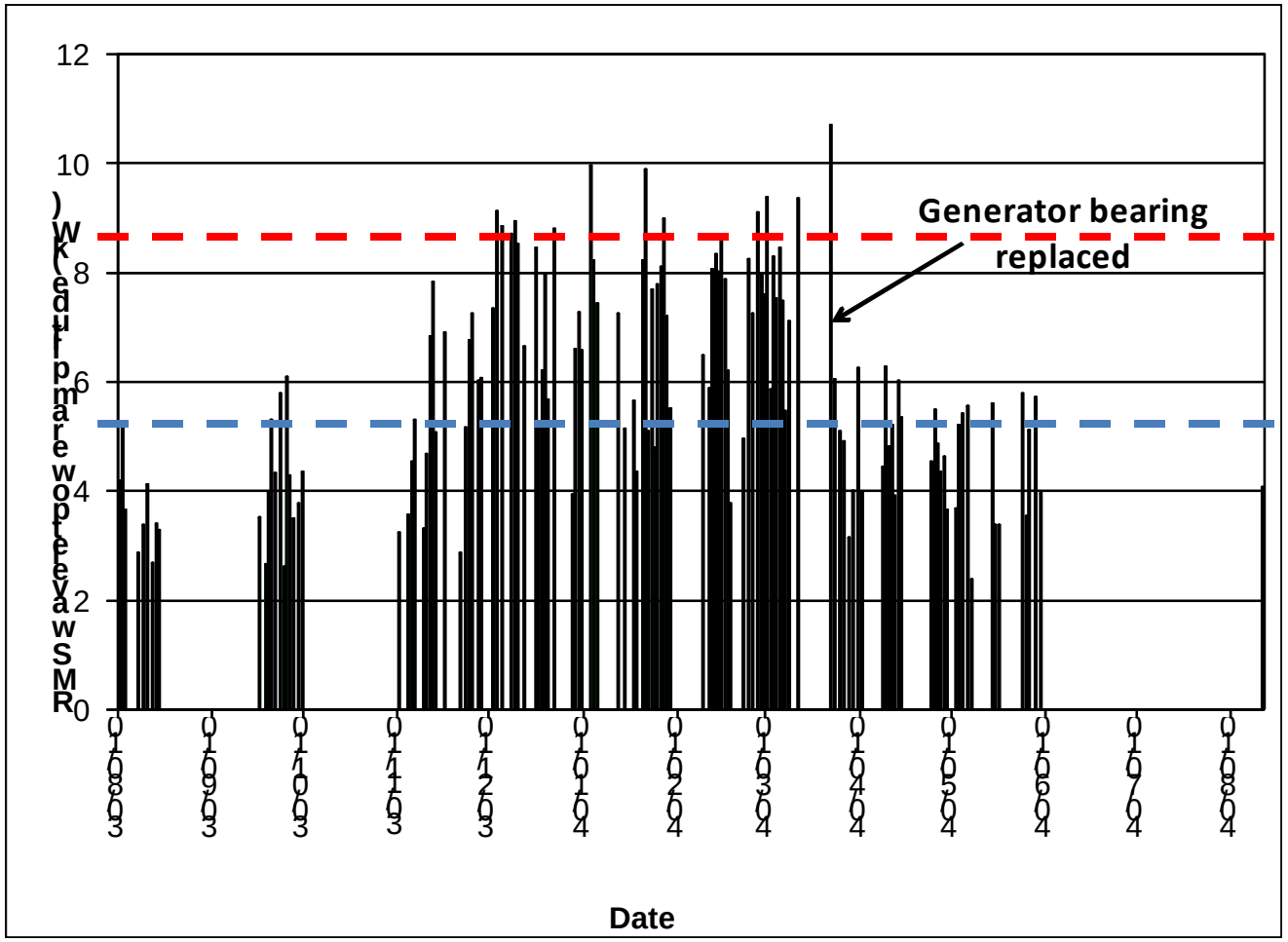
- Extract particular component of electrical power signal using a wavelet
- Analyse magnitude of particular frequencies (which may vary in time) indicative of faults
- High magnitude indicates fault
- Generator misalignment leading to possible bearing failure

Analysis of Test Rig Faults



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

Analysis of Real Turbine CMS Data Generator Bearing Fault



Faulty generator bearing

Normal generator bearing

Analysis of Real Turbine CMS Data Gearbox Bearing Failure

Brass bearing cage on intermediate stage collapsed

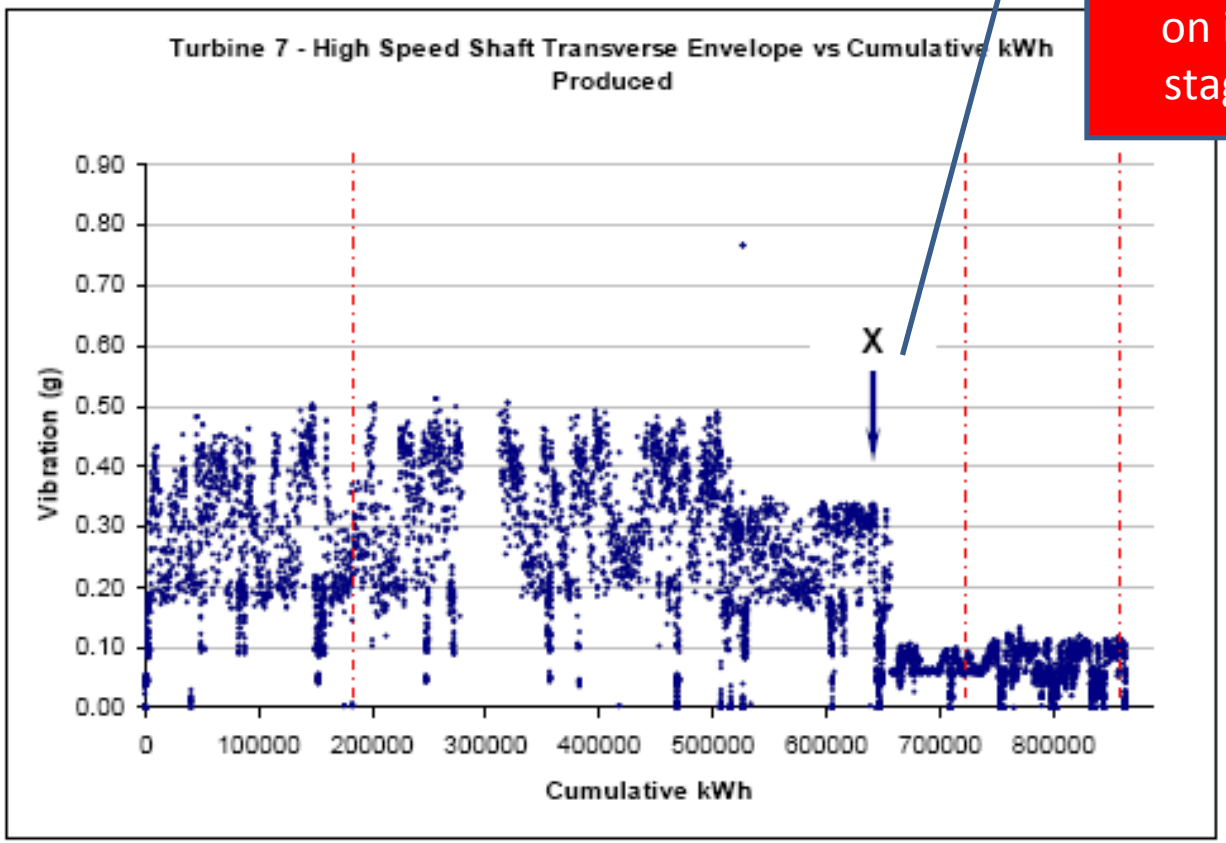
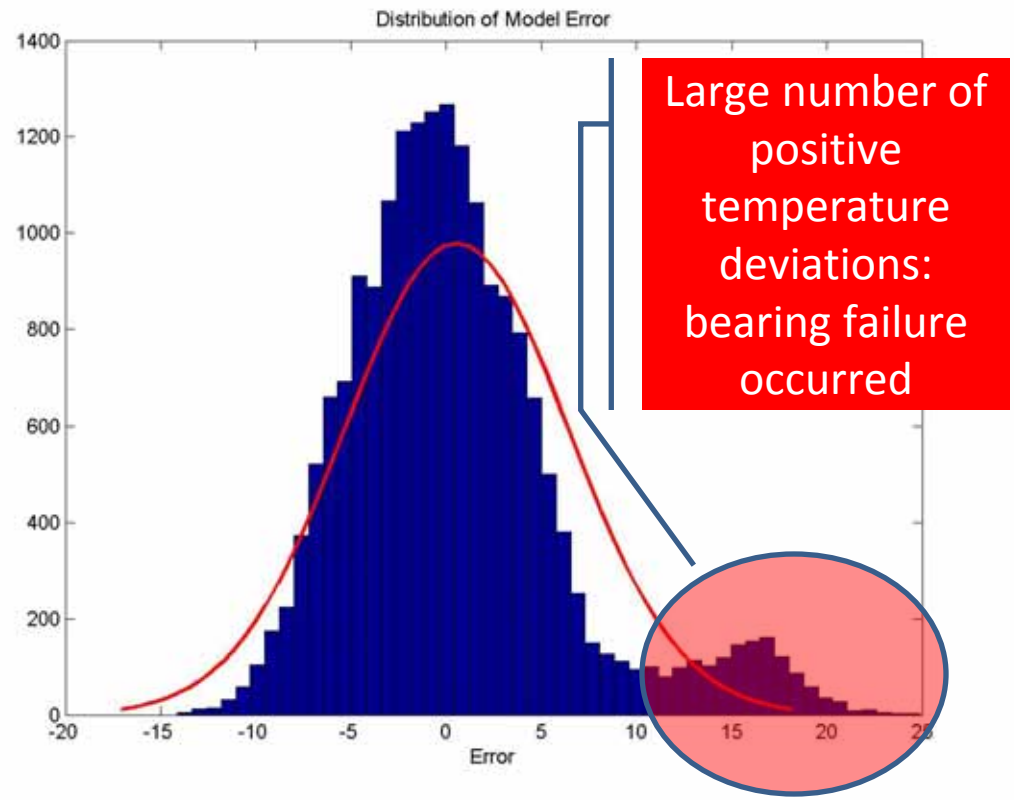


Figure 4 - Gearbox High Speed Shaft Transverse Vibration Envelope against cumulative energy produced

Process Modelling Using SCADA Data

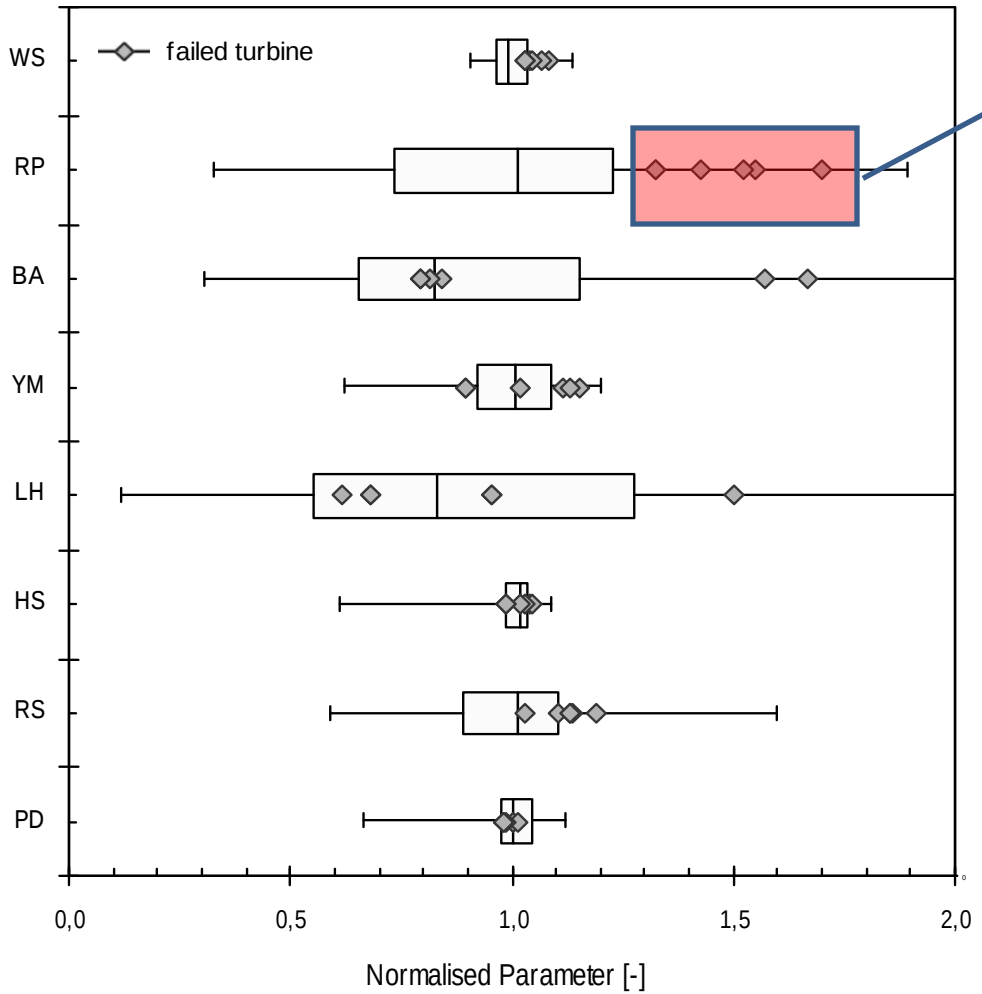


- Time series process model of generator bearing temperature
- Compare actual with prediction
- Discrepancy possible indicator of fault

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

Gearbox Failure Using SCADA Data



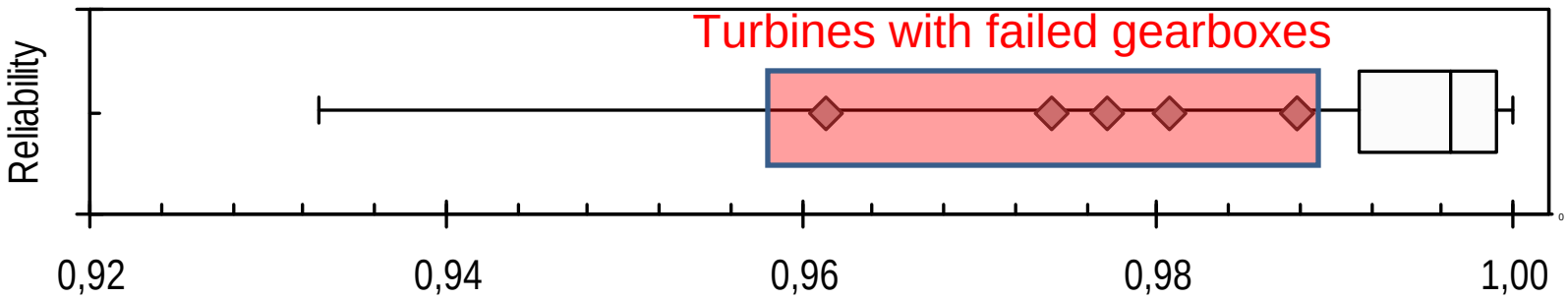
Turbines with failed gearboxes in top 25th percentile in terms of hours at rated power

WS- Wind Speed
RP - Hours at Rated Power
BA - Brake Applications
YM - Yaw Movement
LH - Hours at Low Speed High Power
HS - Hours at Rated Speed
RS - Rotor Starts
PD - Absolute Power Differential

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 a specific failure mode

Summary and Recommendations

- Drive train key focus for condition monitoring
- Electrical power (high, medium, low frequency – give different information), temperature 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