

Wind Turbines: An Engineering Reliability Perspective

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Overview

- European and UK research
- Wind turbine reliability
- Analysis of standard SCADA data (10 min)
- High frequency 'standard signal' analysis ($\sim 30\text{Hz}$)
- Blade monitoring
- Wakes
- Potential drive train CM system
- The role of control in wind turbine reliability
- Lessons learnt

Research in Europe

- CONMOW – developing condition monitoring techniques that could be used for offshore wind turbines
- RELIAWIND – understanding wind turbine reliability

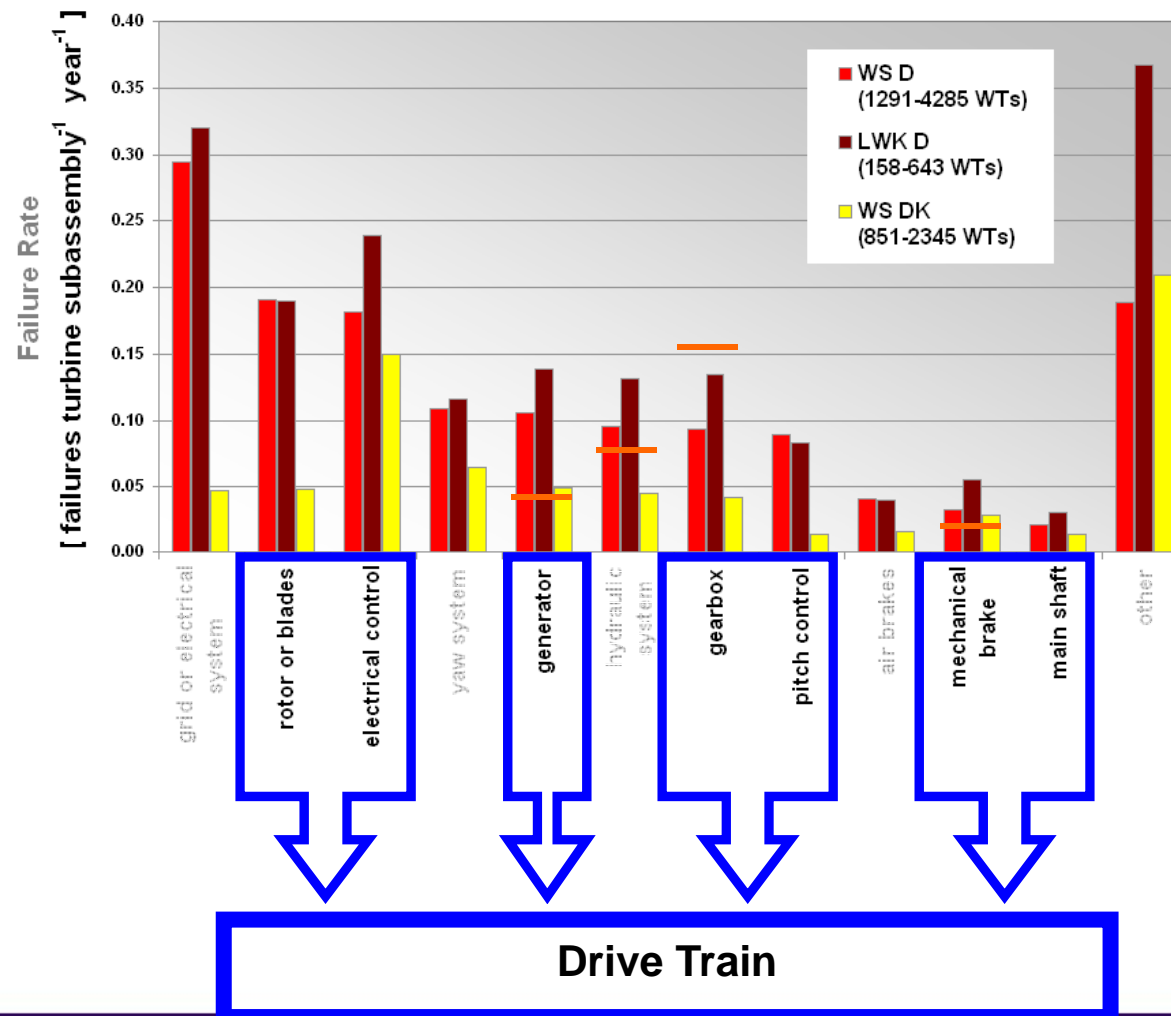
Research in the UK



- EPSRC Supergen V – Wind Energy
- Consortium of nine university groups and several industrial stakeholders
- Aim: to increase reliability and availability of wind turbines

Wind Turbine Reliability

Surveys failure rate comparison : period 1993-2004

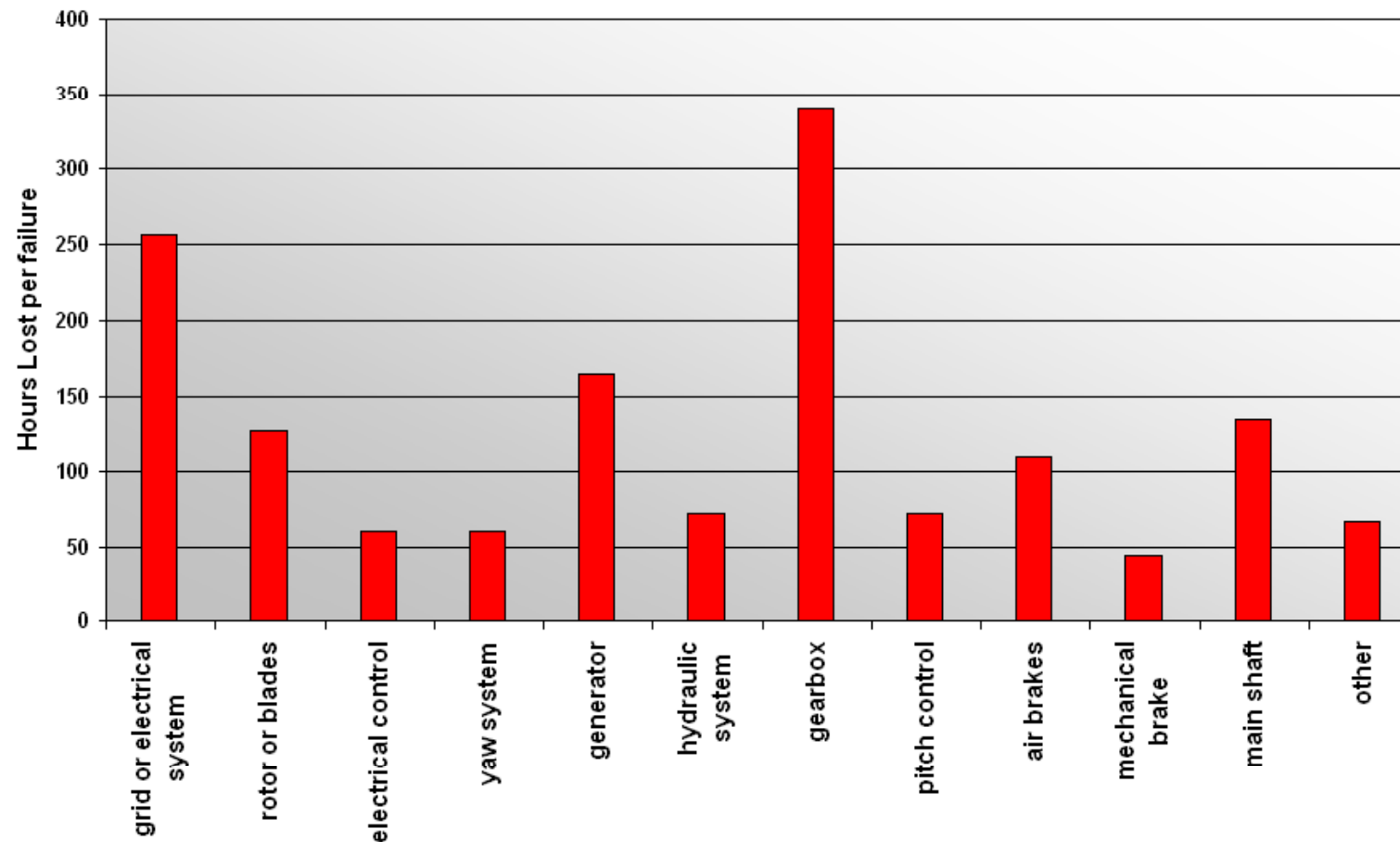


Industrial Reliability figures



Downtime

LWK Survey hours lost per failure comparison : period 1993-2004, 158-643 turbines



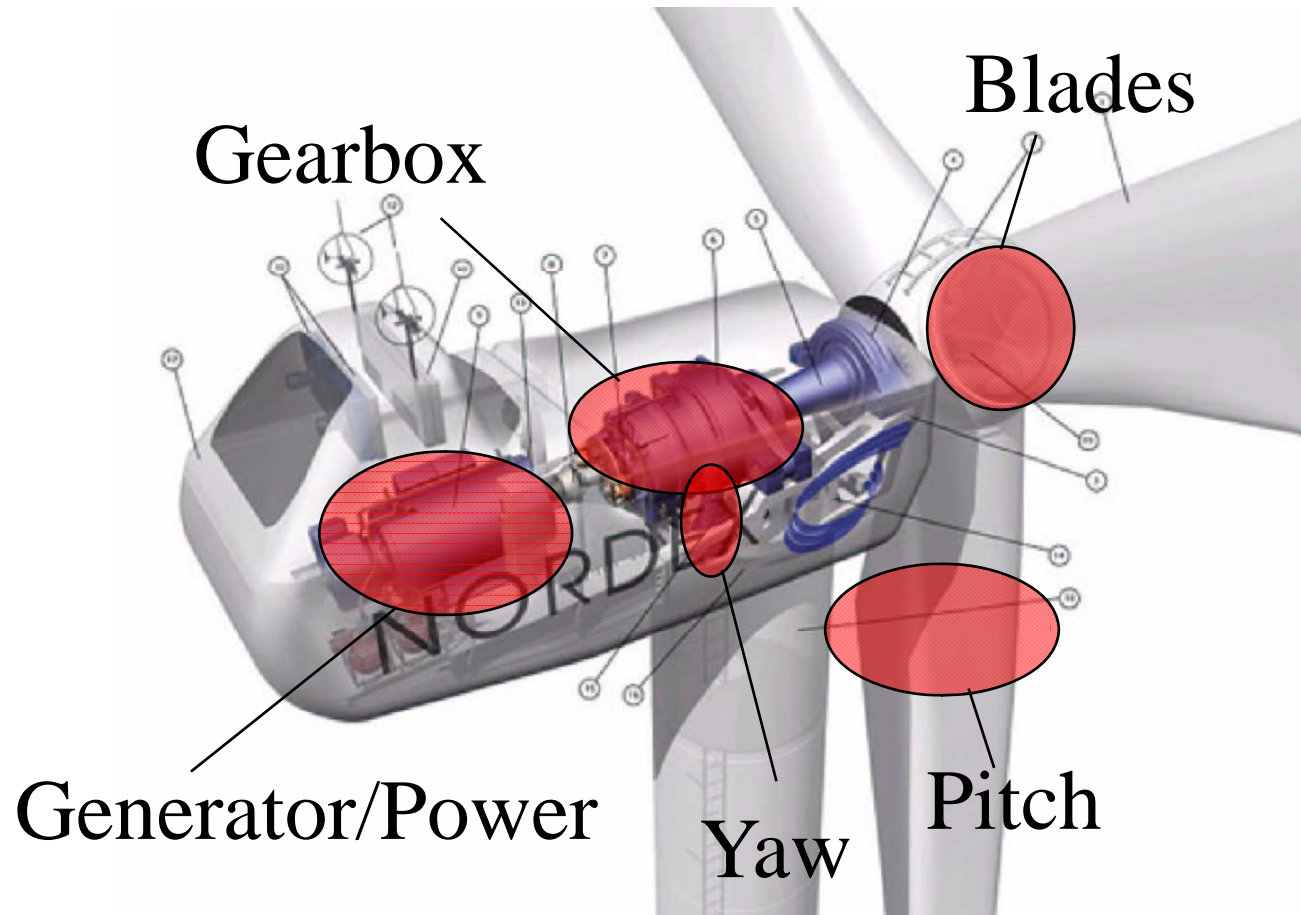
The role of condition monitoring

- Access to turbines particularly moving offshore limited
- Need to predict possible failure well ahead of time to schedule maintenance
- Possible change turbine control strategy to 'back off' load to prolong lifetime until repair can be effected

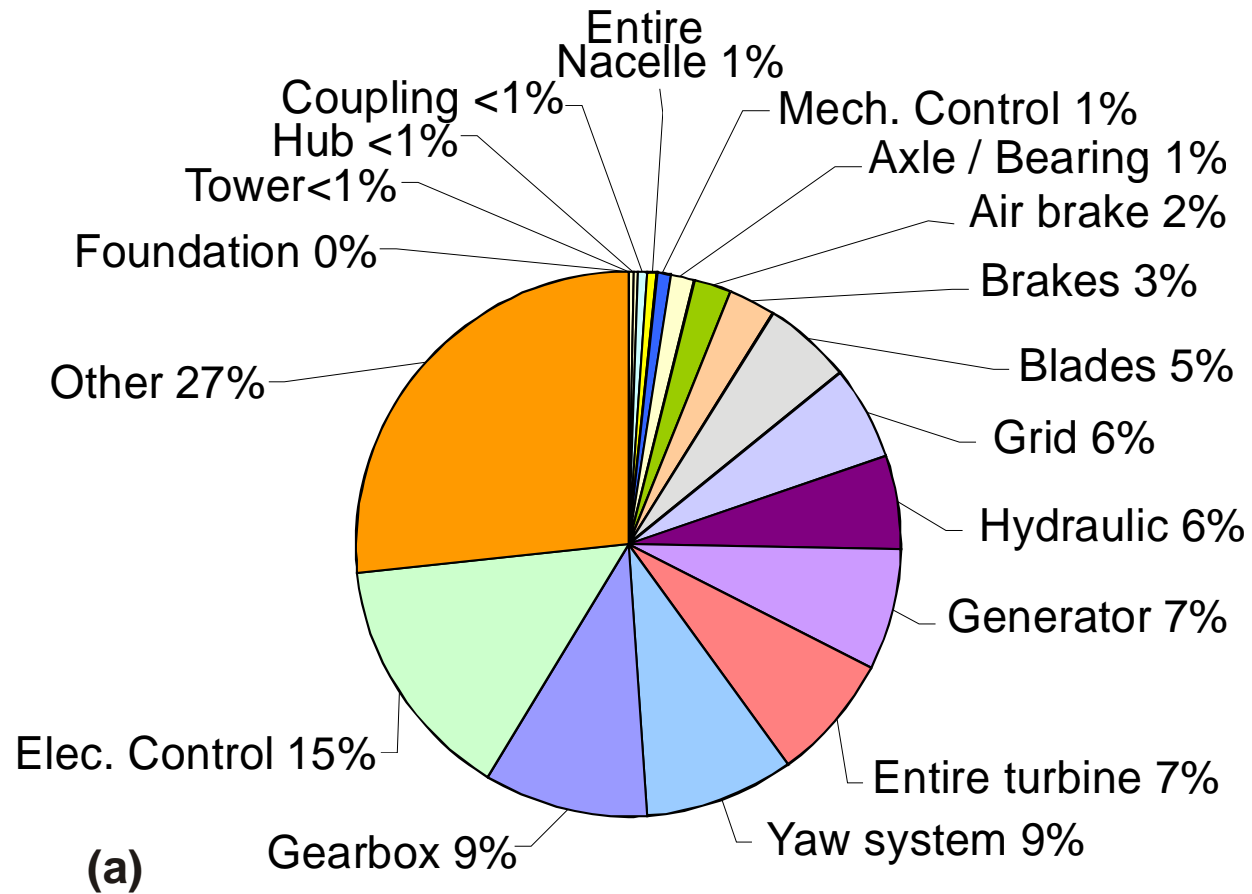
Techniques

- Trending
- Time/frequency domain analysis
- Mathematical/theoretical mechanical/electrical modelling and comparison to measurements

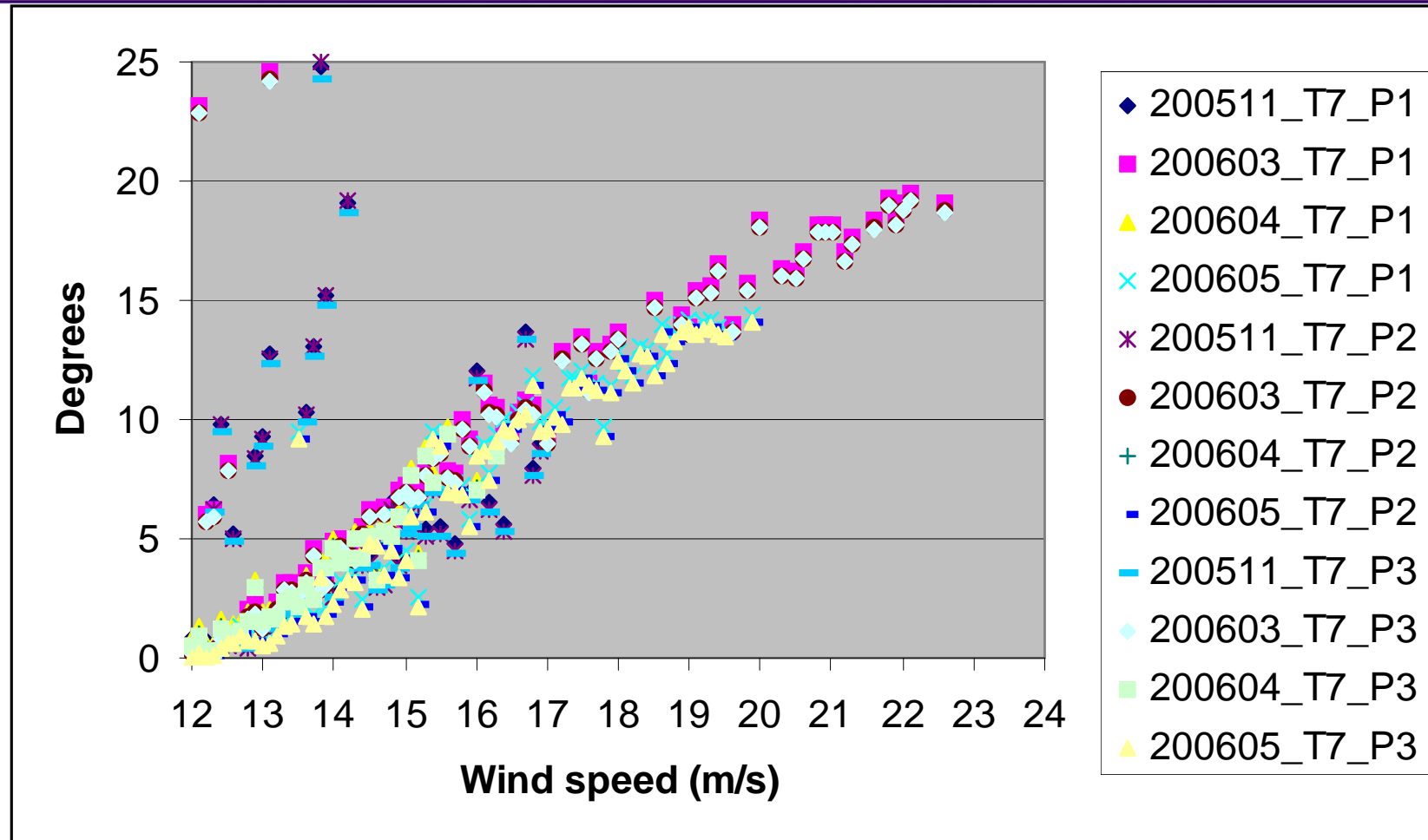
Focus of Analysis (CONMOW)



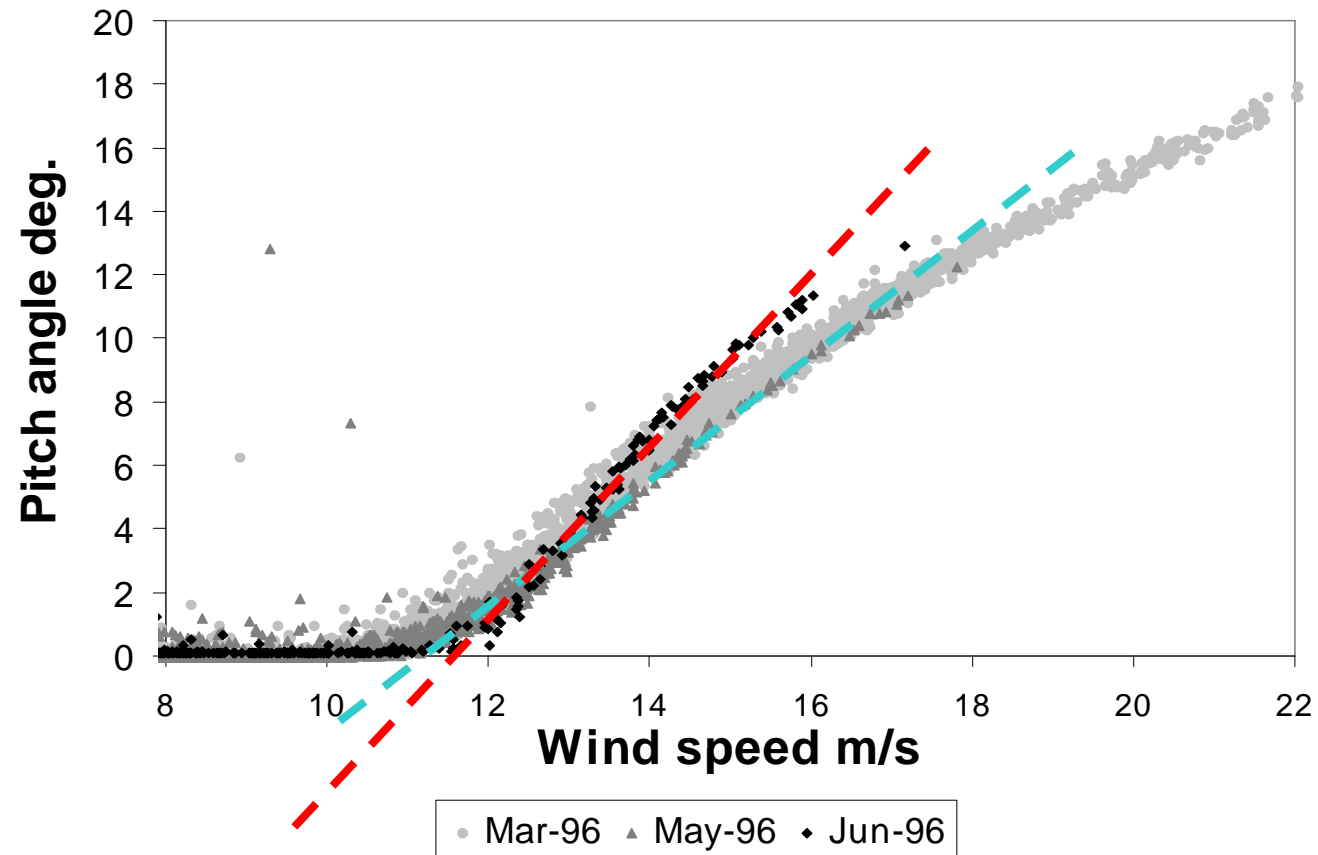
Component Failures DK -2002



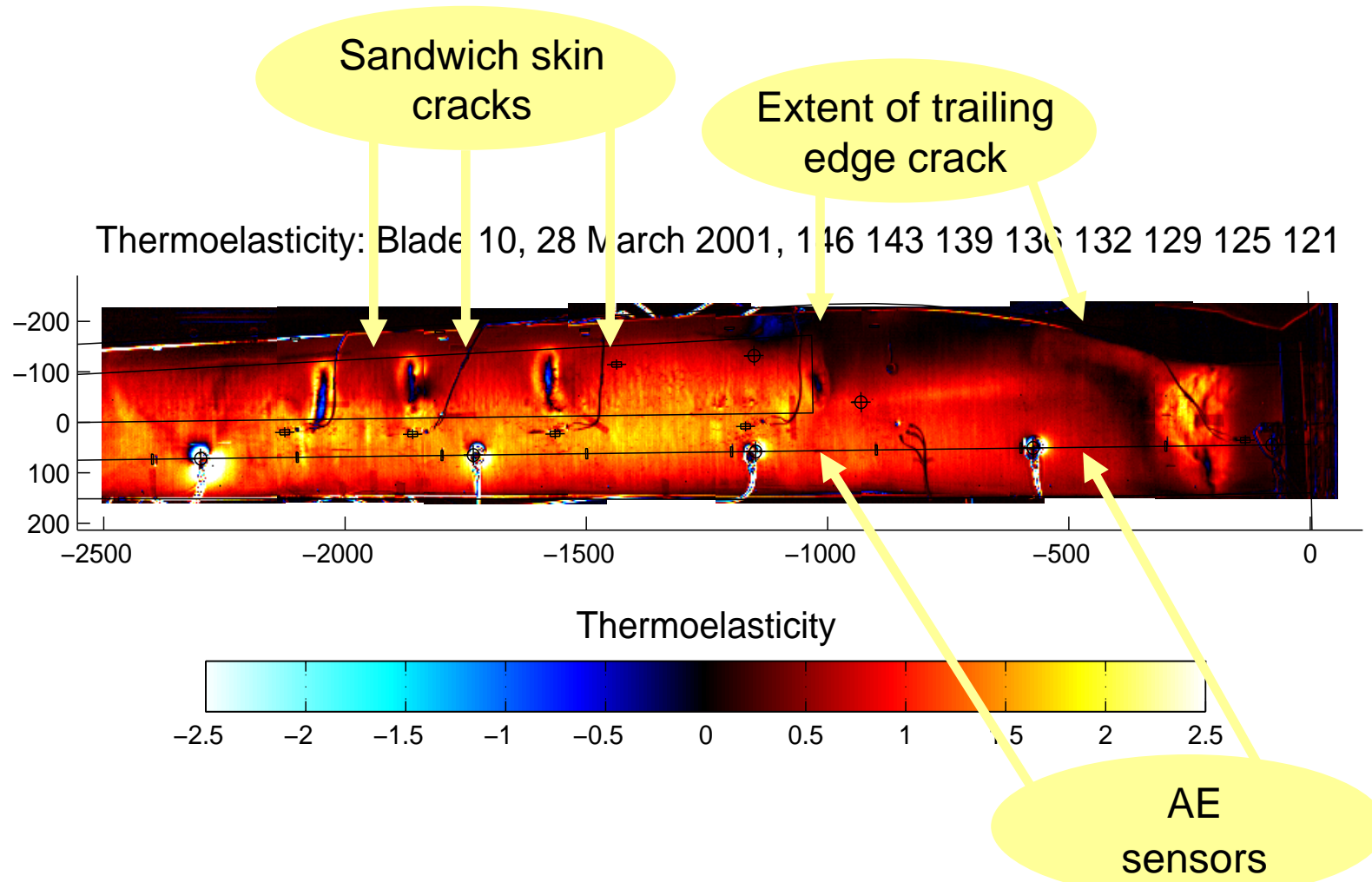
Pitch Trends in Time



Detect Pitching Problem



Non-Destructive Testing of Blades



Wind Tunnel Simulation of Wakes



Set-up in A-tunnel

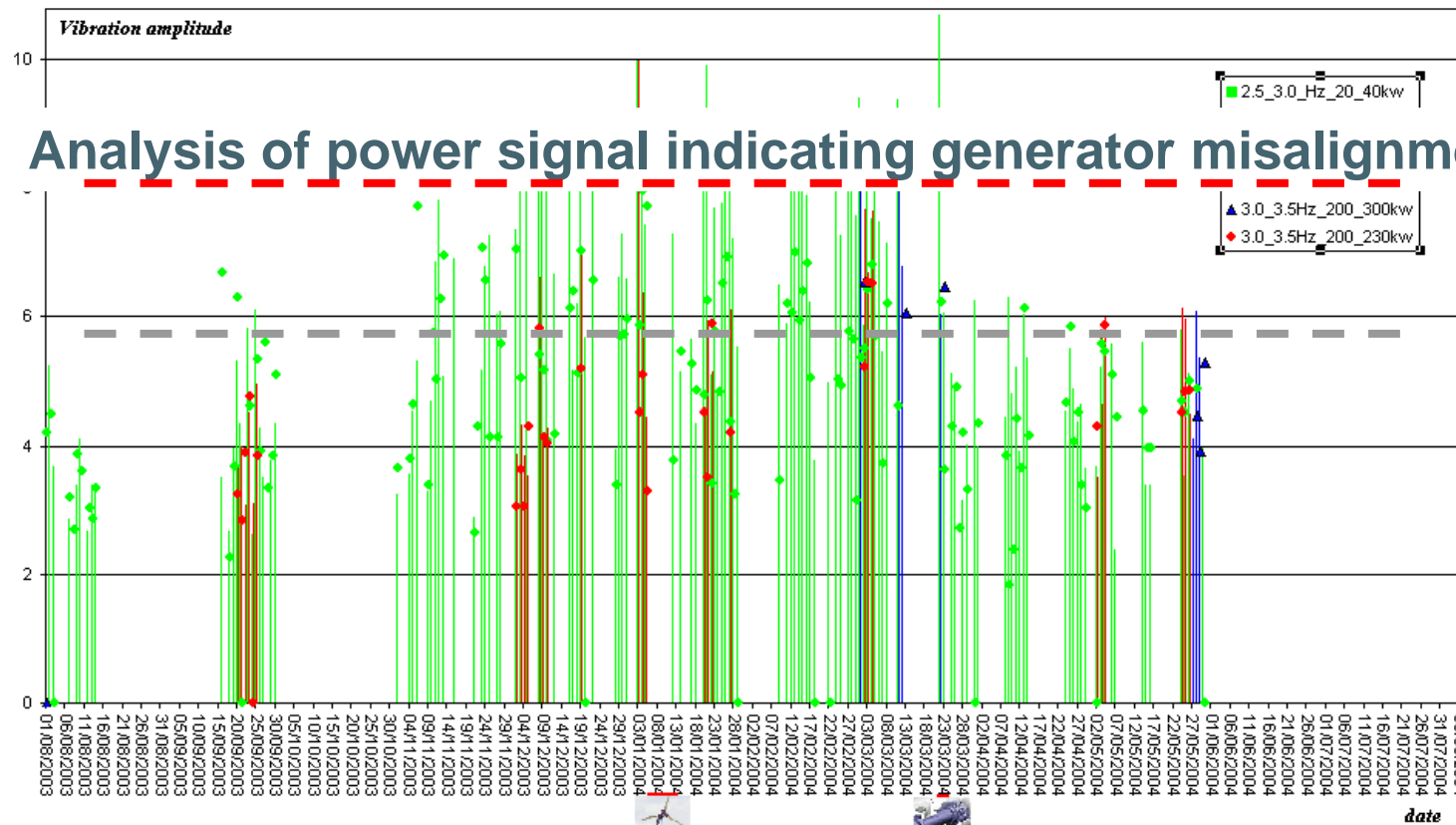
Uniform flow conditions (low turbulence)



Power Signal Analysis

- Wavelet/fourier transform analysis
- Trend appropriate frequency component magnitude
- In CONMOW project have twice detected generator misalignment (first resulted in bearing failure)
- Second occasion confirmed by vibration analysis

Power Signal Analysis

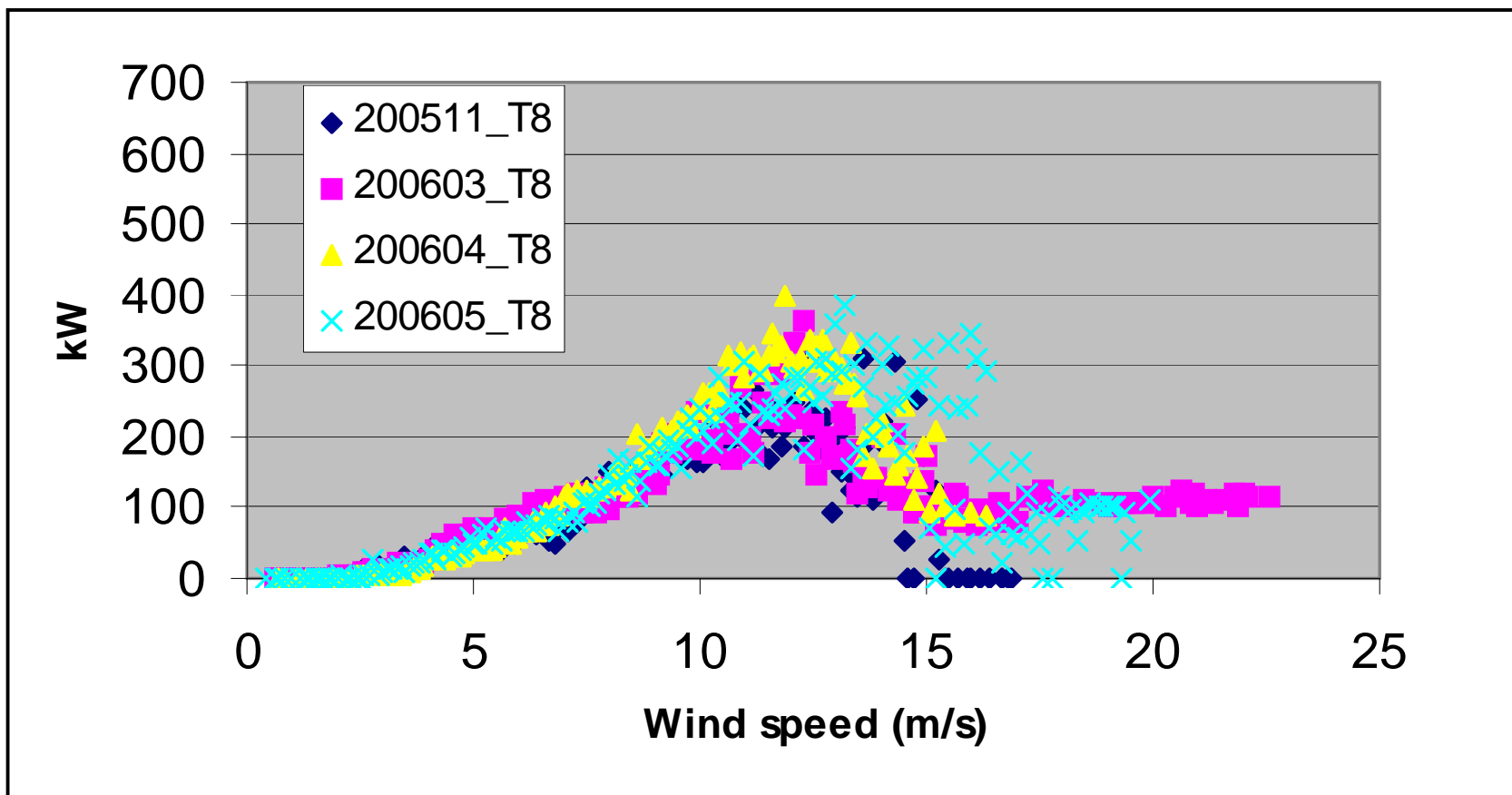


Analysis of power signal indicating generator misalignment

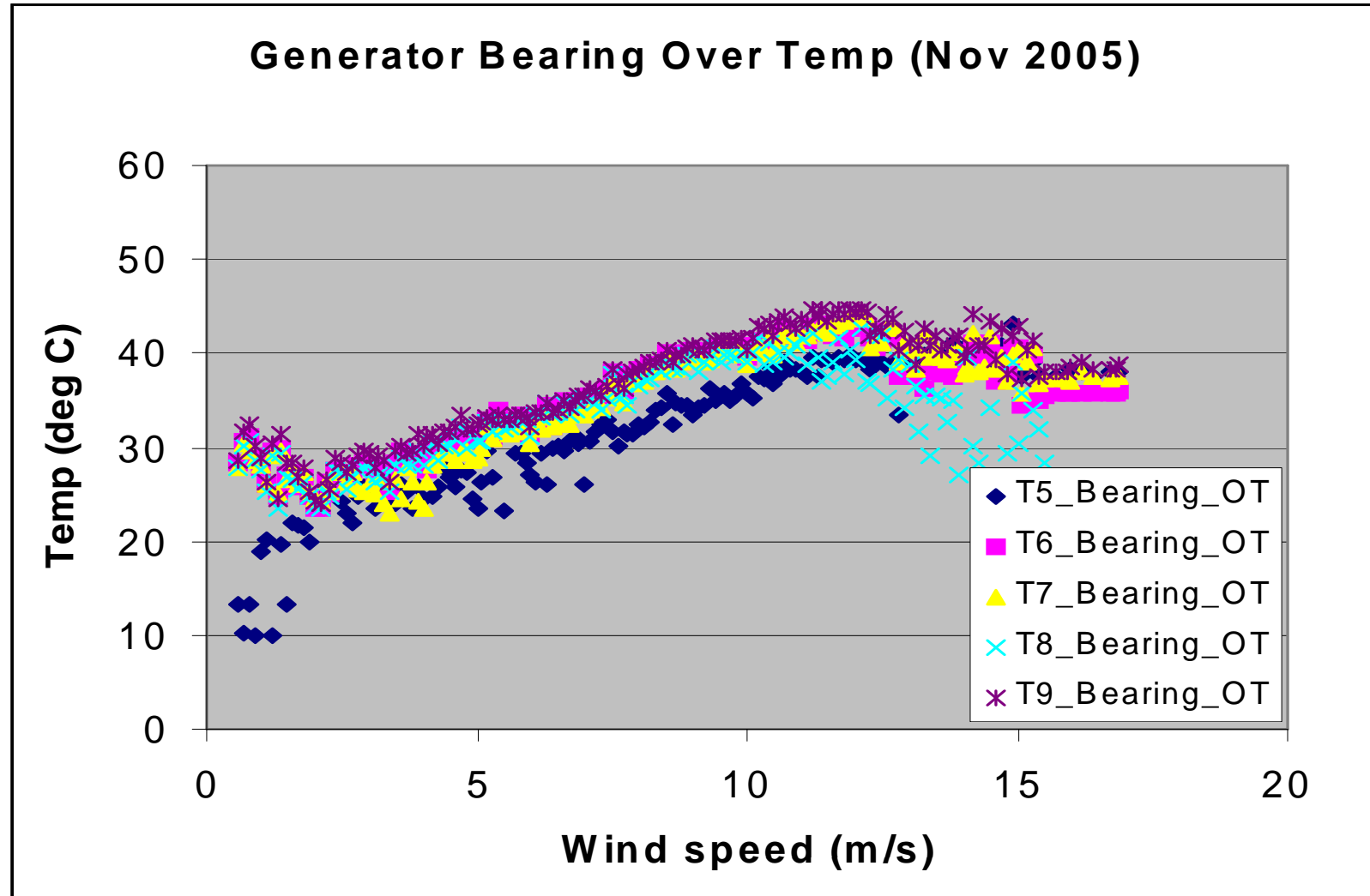
06/01/2004-13/01/2004
misalignment of the generator

22/03/2004-23/03/2004
bearing failure

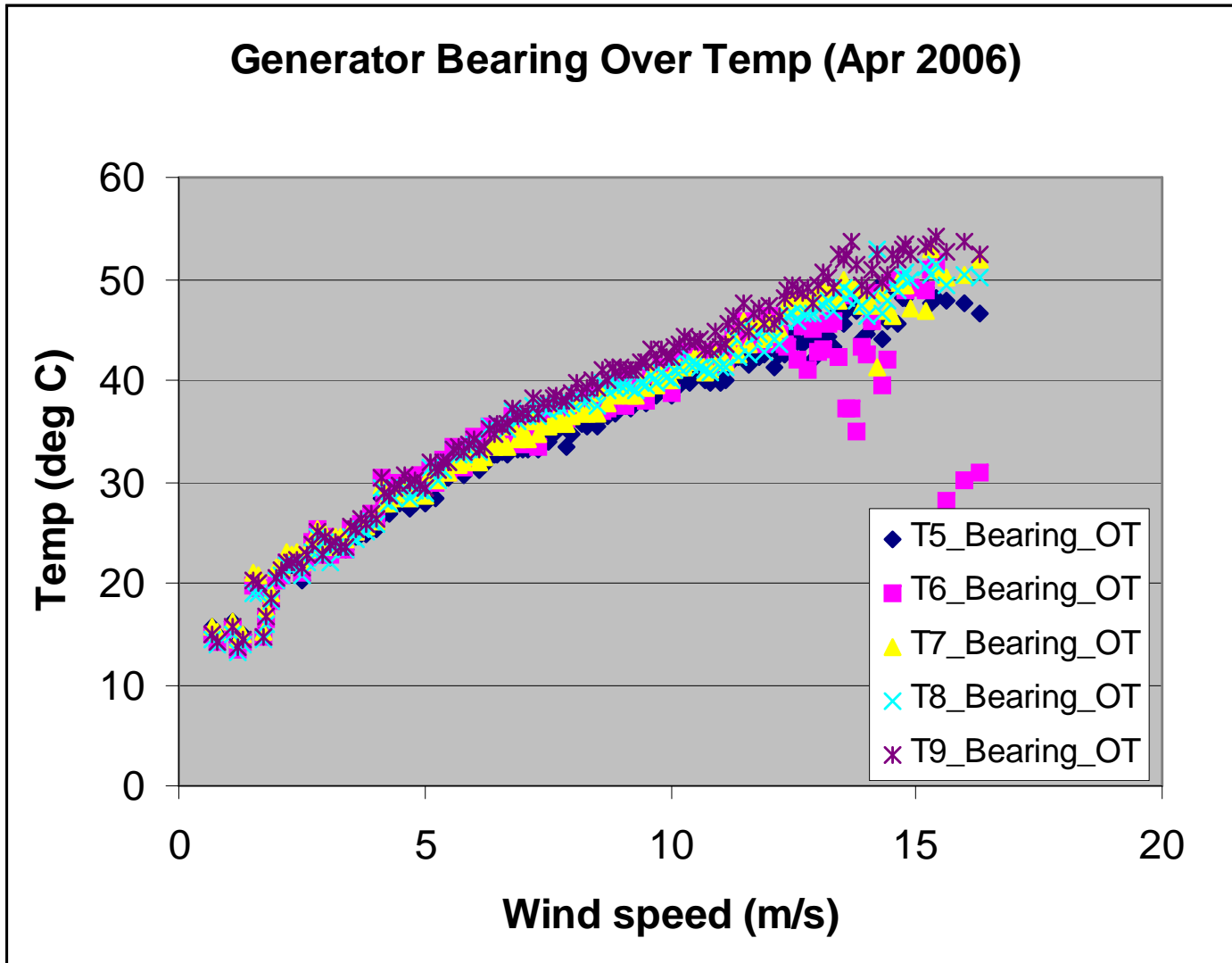
Power Standard Deviation



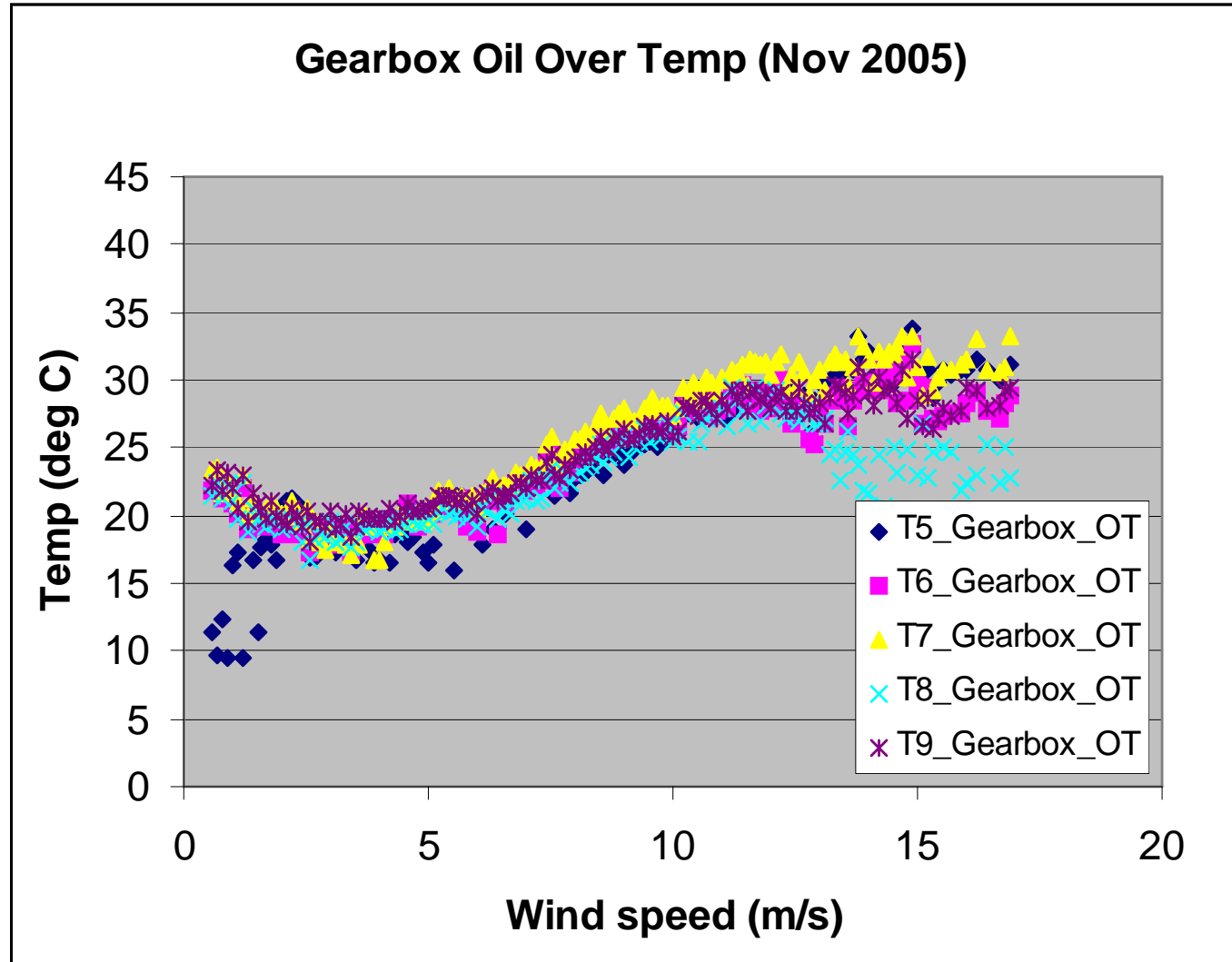
Generator Bearing Over Temp (Nov 2005)



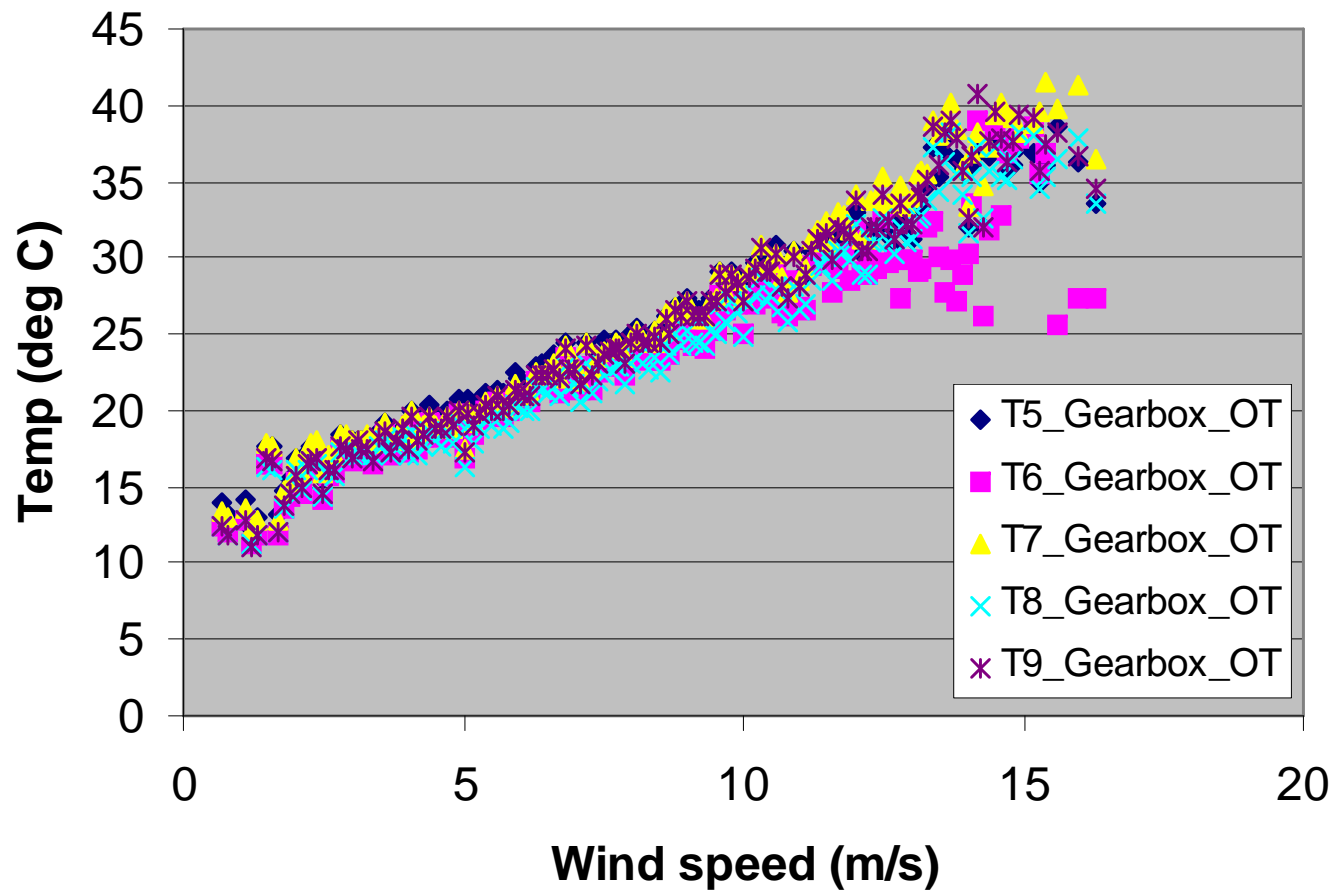
Generator Bearing Over Temp (Apr 2006)



Gearbox Oil Over Temp (Nov 2005)

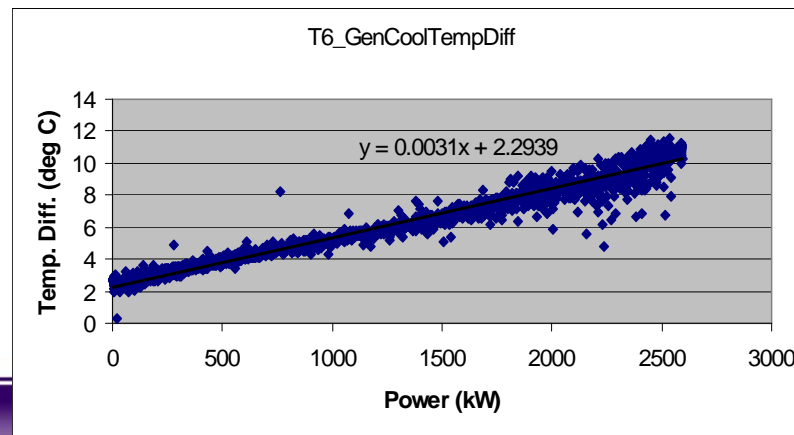
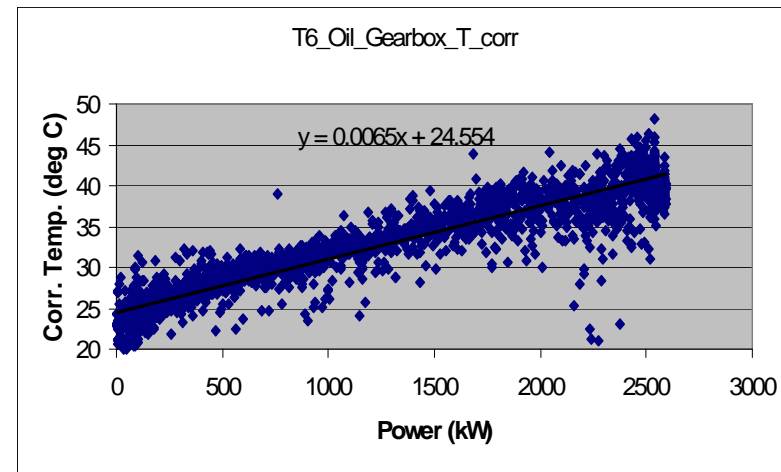
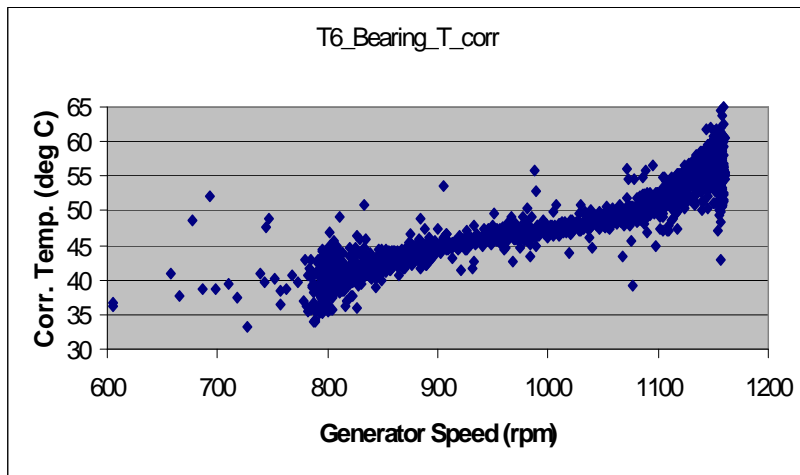
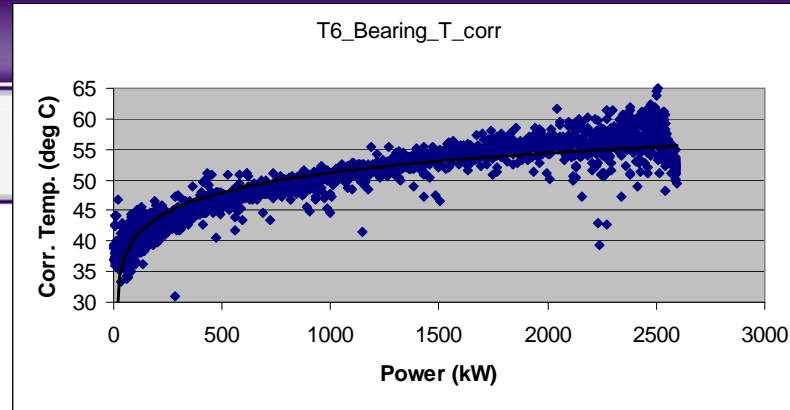


Gearbox Oil Over Temp (Apr 2006)



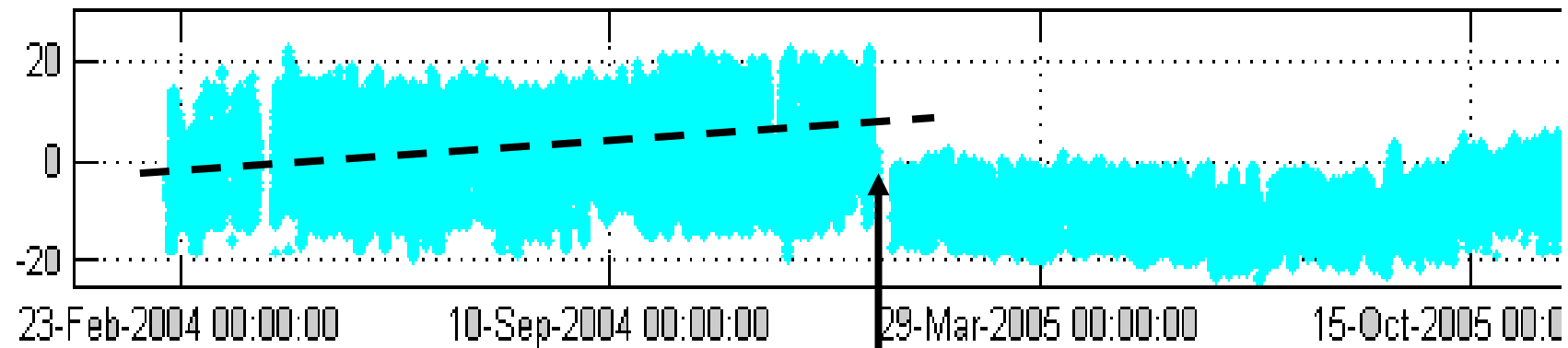
Temperature Trends

- Correct SCADA temp. measurements for ambient (not necessarily 1 deg rise for 1 deg in ambient)
- Clear trends as function of power/rotor speed
- Use to establish 'normal bounds' and monitor potential failure



Analyse de-trended residuals in time

Generator bearing temperature



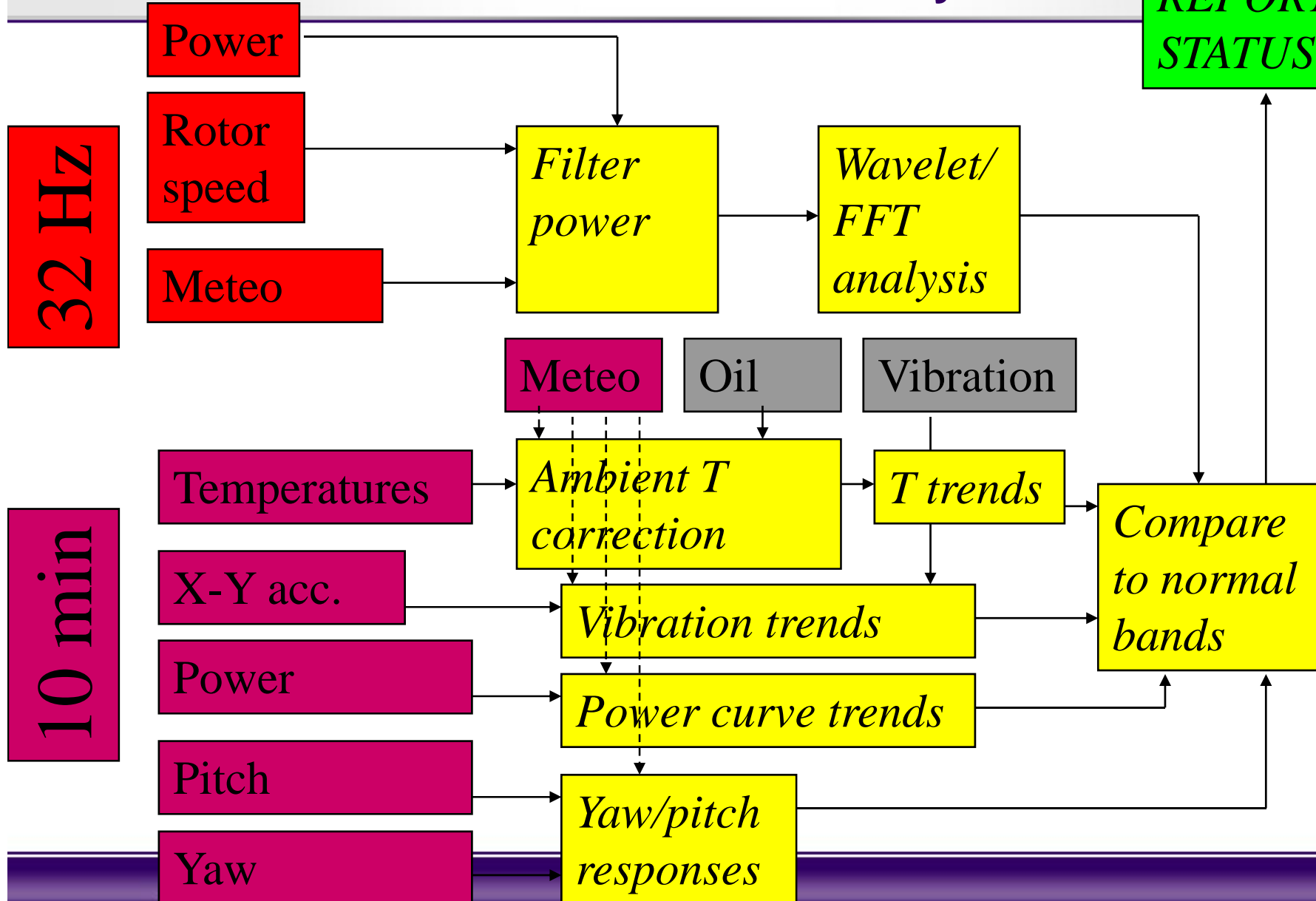
Bearing failure and replacement

The role of control in wind turbine reliability

- Dynamically controlled actuators to alleviate forces on blades and towers
- Individual pitching of blades during tower passing
- Control of torque on drive train
- Response to potential failure – back off load on wind turbine until repair possible

Potential drive train CM system

REPORT STATUS



Lessons Learnt from Work on Condition Monitoring

- Do not expect much information from manufacturers
- Installation of additional measurement equipment problematic due to liabilities
- Trending/time domain/frequency domain analysis fruitful in detecting misalignment bearing problems (look at power and vibration)
- Trending useful in general but theoretical modelling needed for proper insight