

Wind Turbine Condition Monitoring at Durham

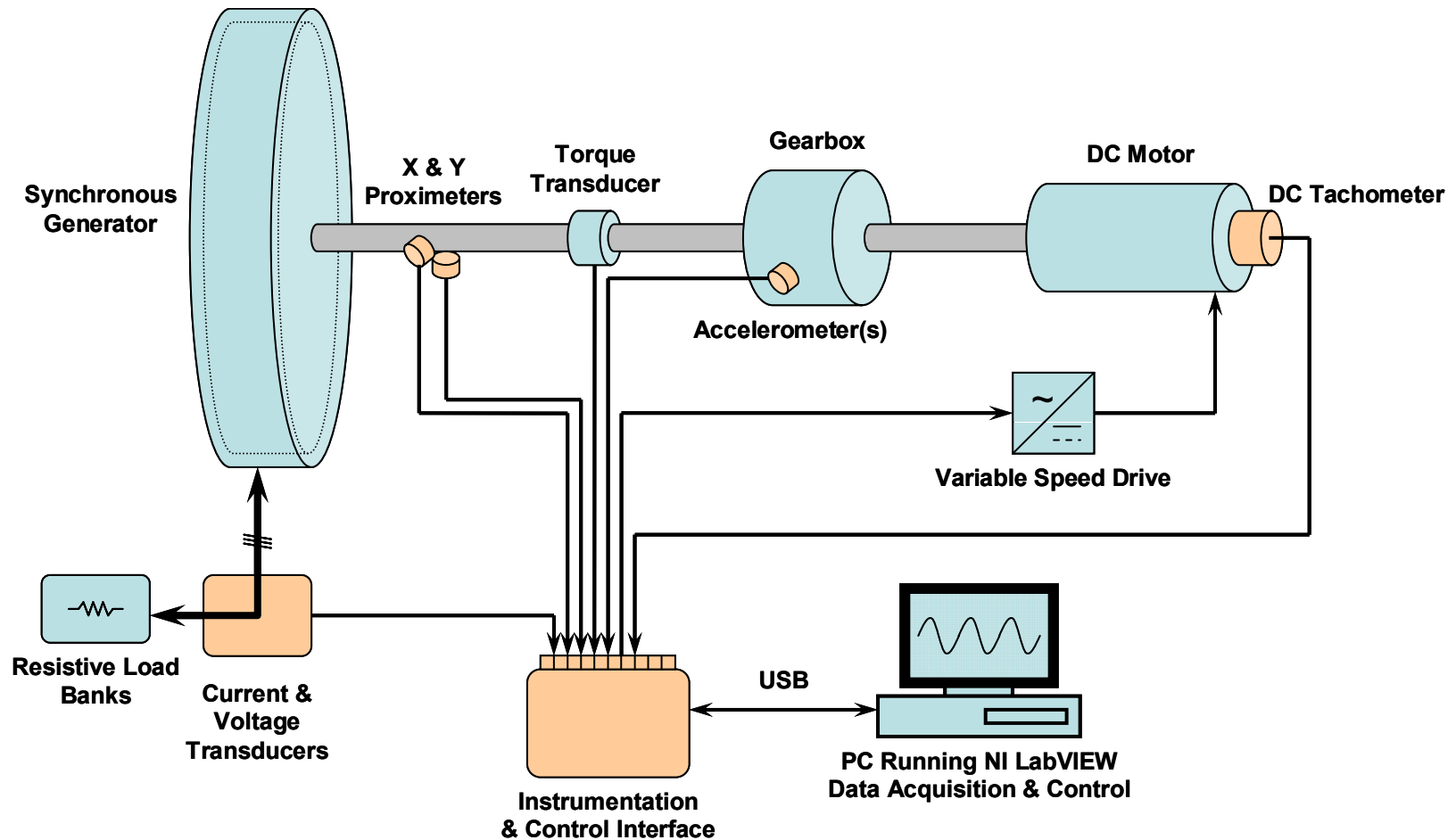
Summary of Durham Research to Date and into the Future

Presented by CJ Crabtree, Dr. W Yang, Prof. PJ Tavner

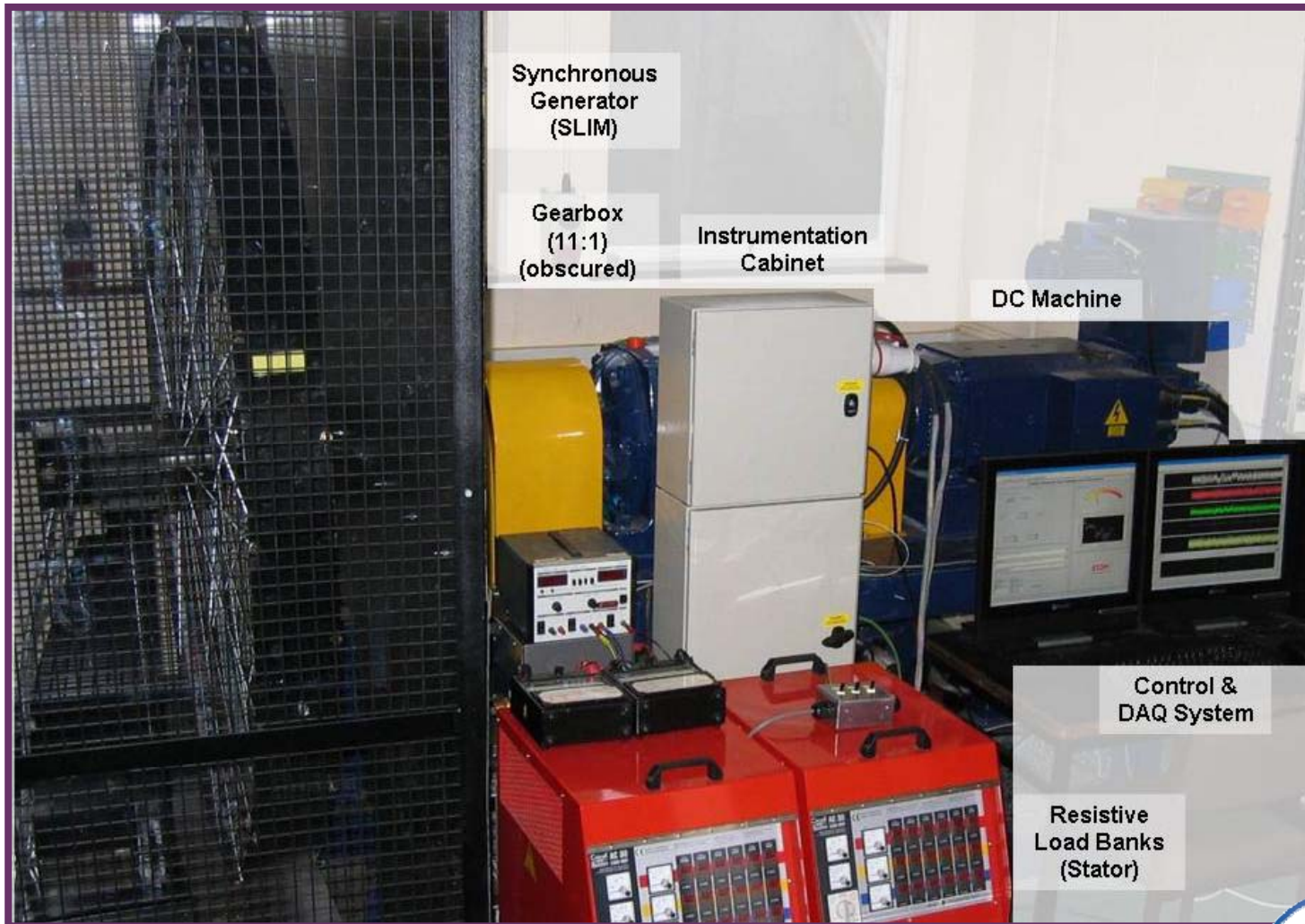
22nd January 2009



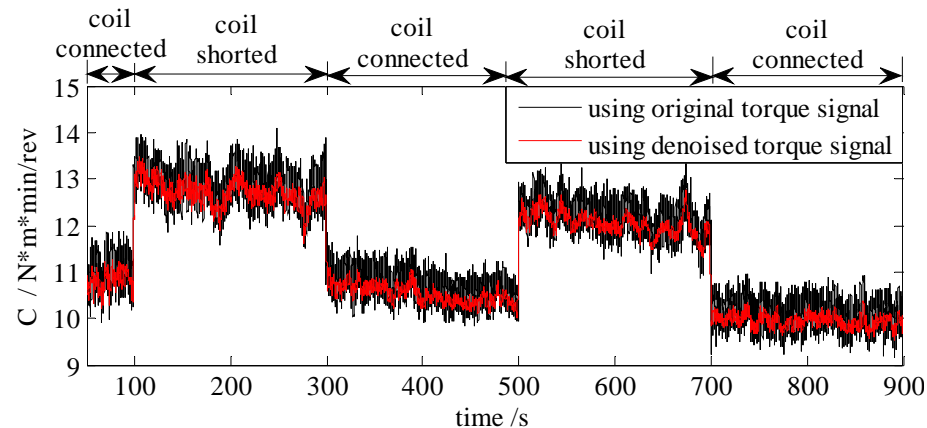
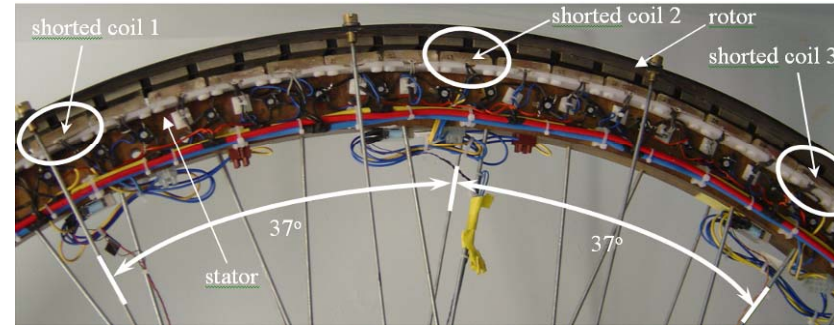
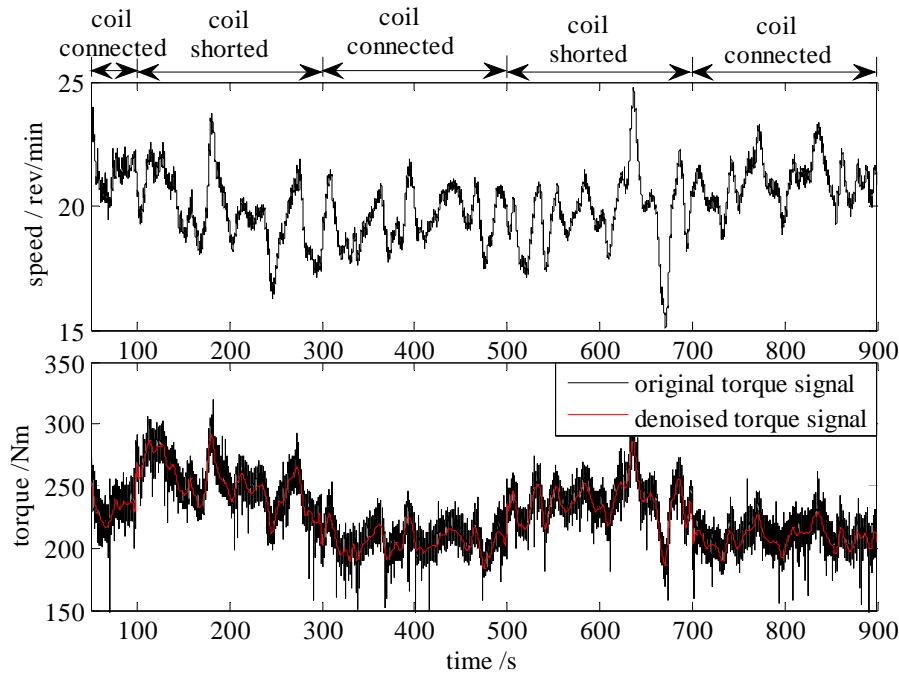
Test Rig - Synchronous Generator



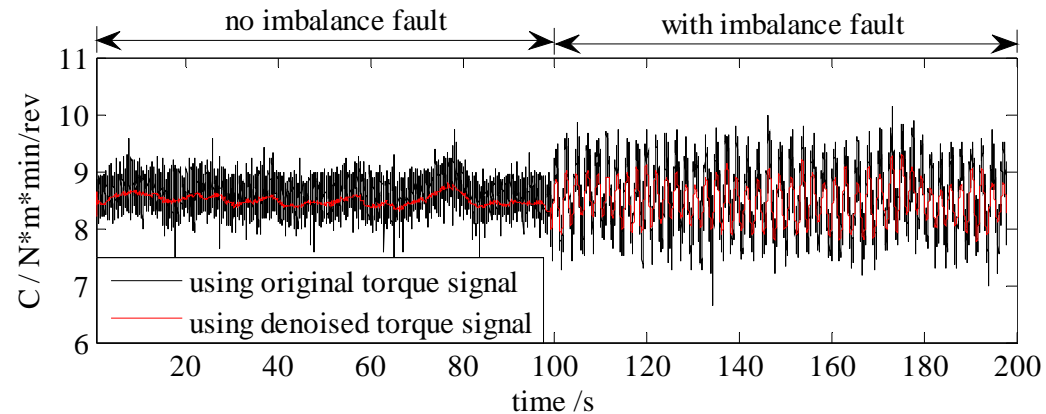
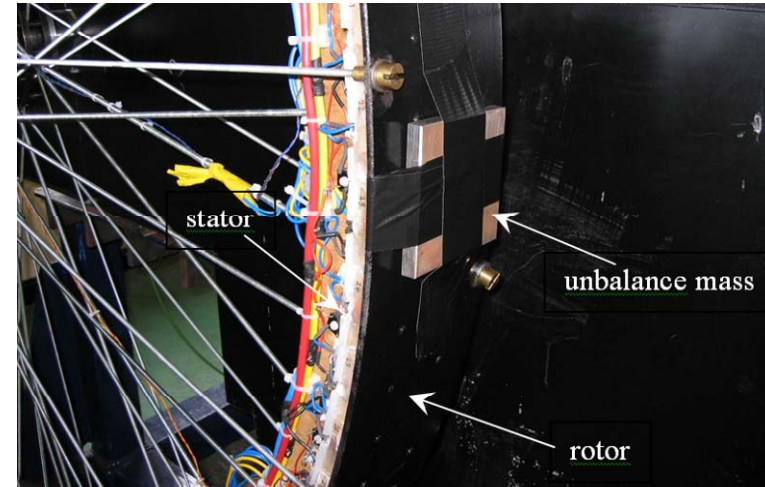
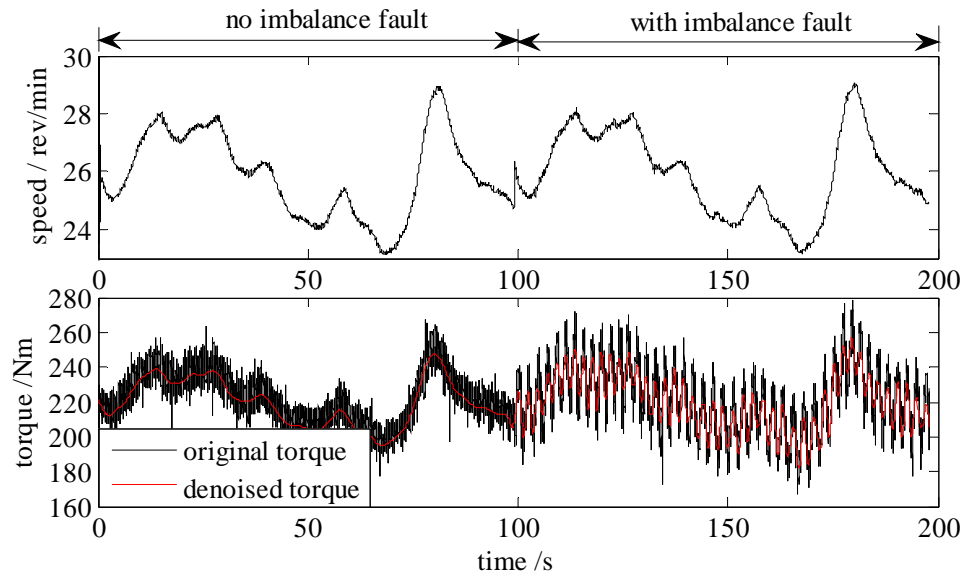
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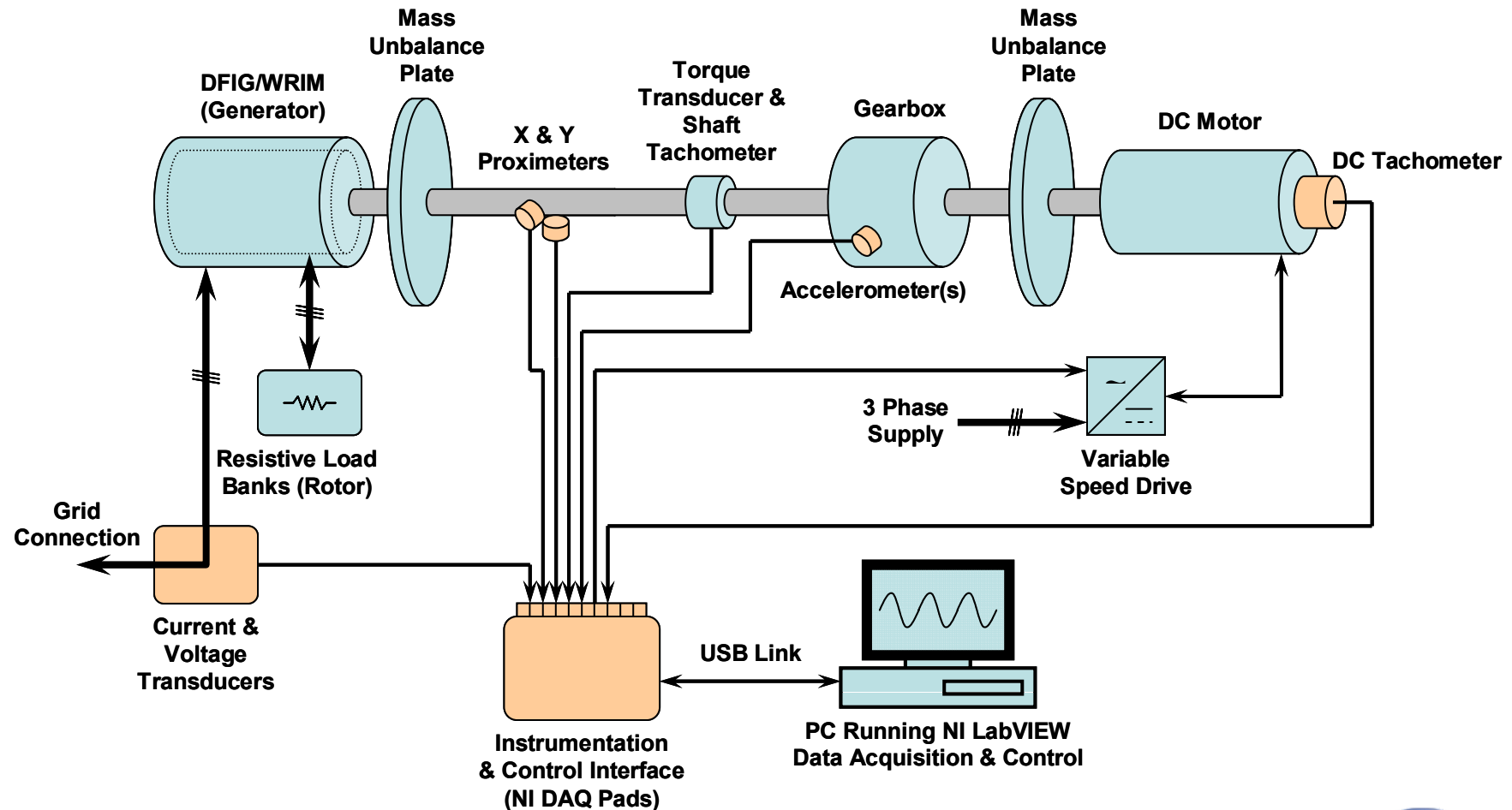
Results - Synchronous Generator



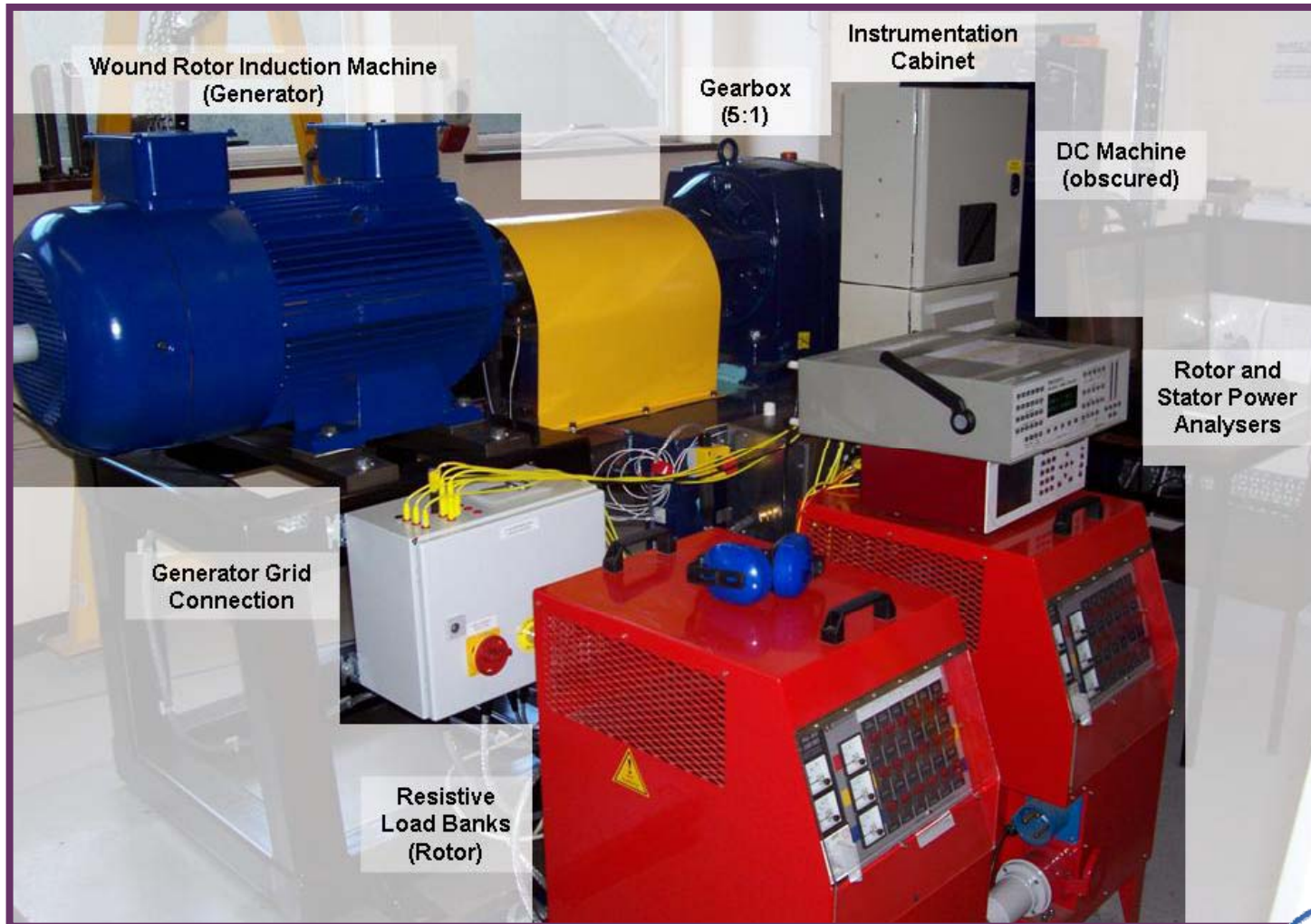
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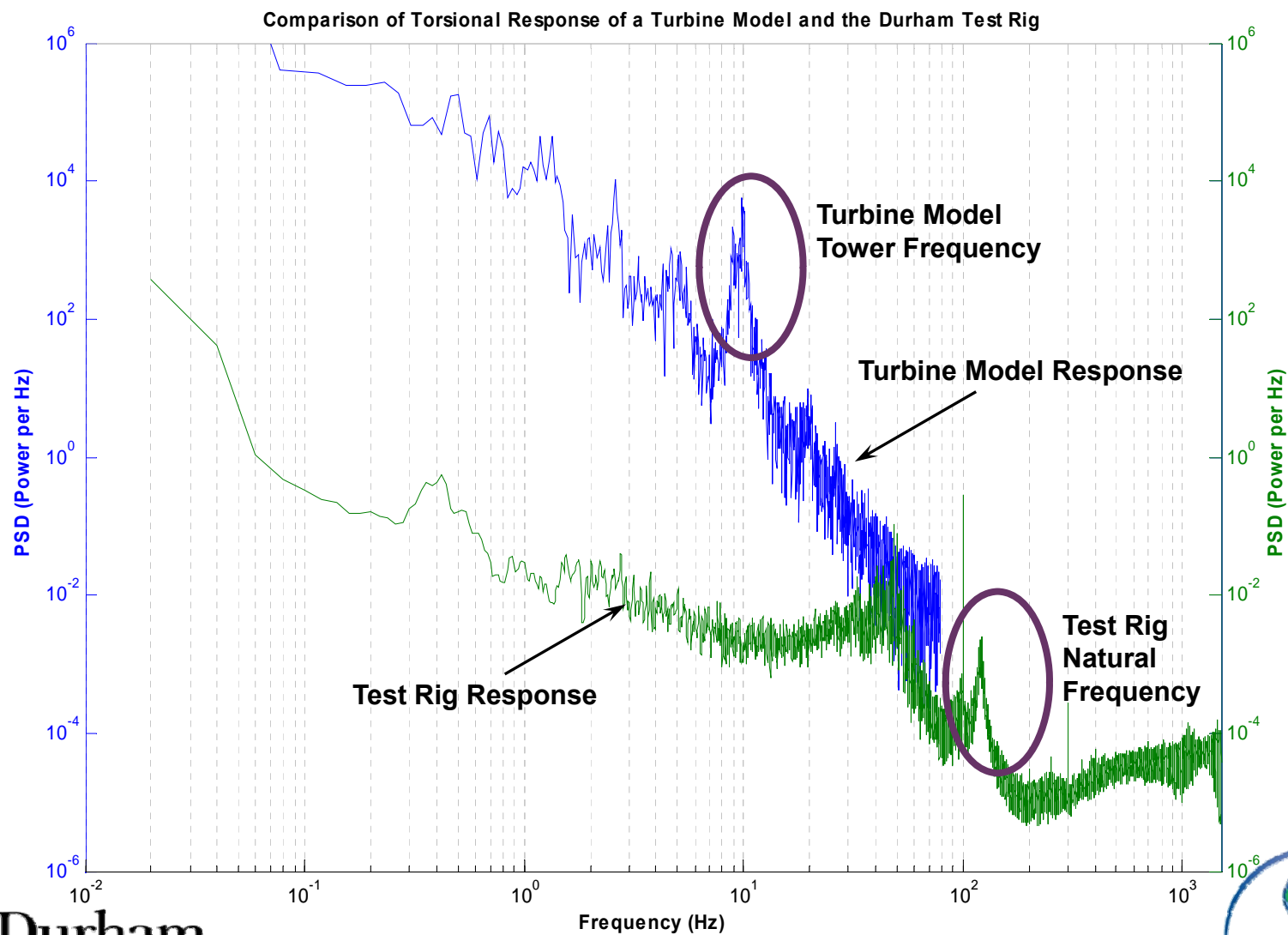
Test Rig - Induction Generator



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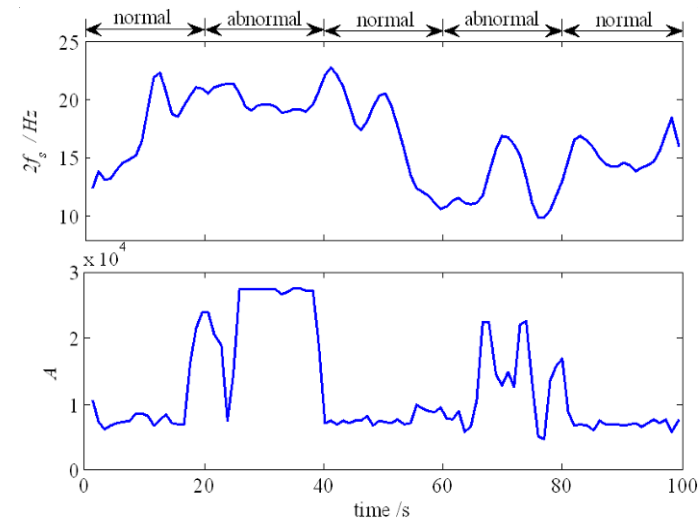
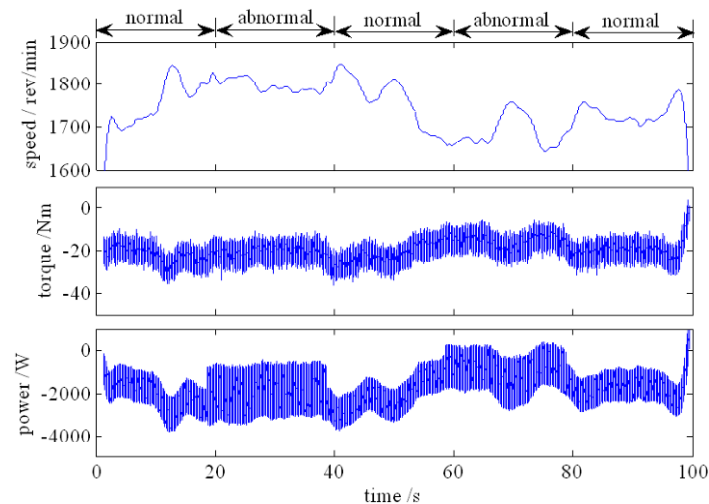


Characterisation - Real vs. Test Rig



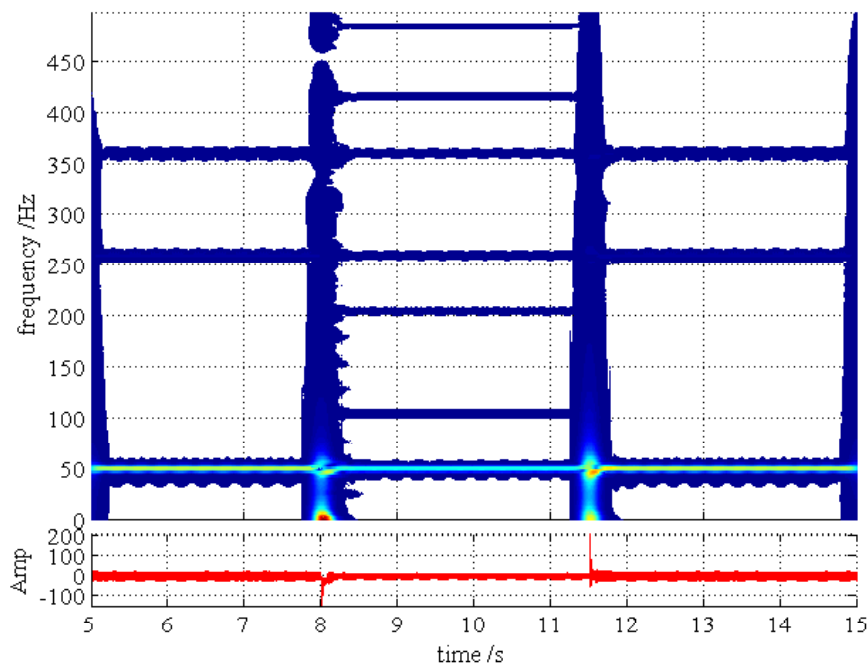
Results - Induction Generator

- One phase to phase rotor coil resistance is changed – marked ‘abnormal’

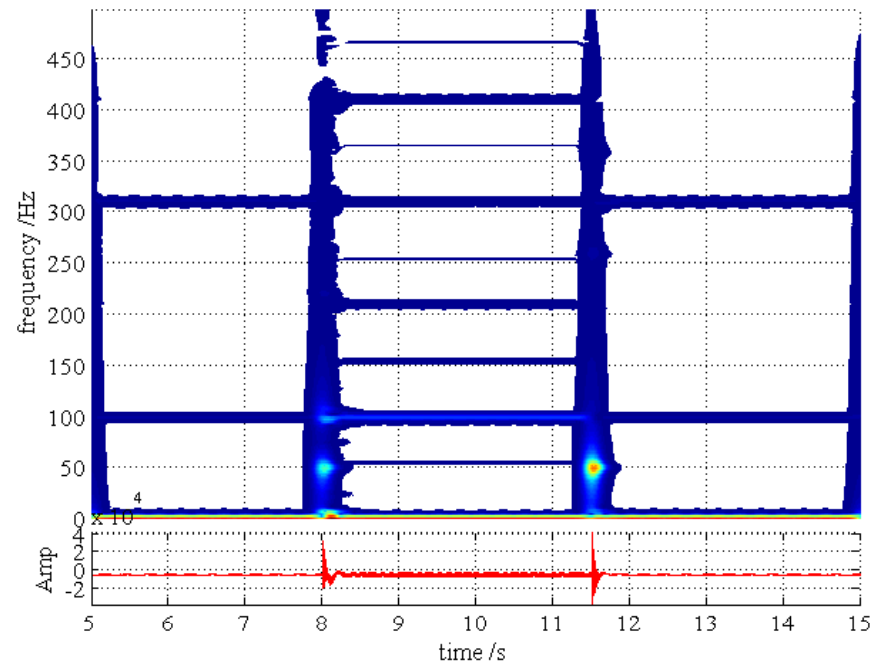


- Rotor and shaft mass imbalance results will follow over coming weeks

Interaction - Manchester University



STFT Analysis of Stator Current Signal Obtained when an Open-Circuit Fault Occurs in the Stator.



STFT Analysis of Generator Total Power Signal Obtained when an Open-Circuit Fault Occurs in the Stator.

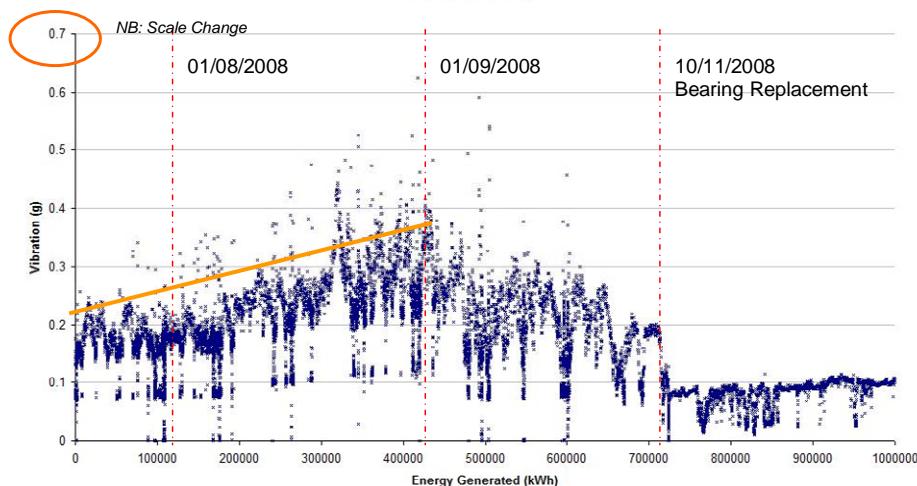
Interaction - Industrial Partner (I)

- **Data collected from an SKF condition monitoring system**
 - Known faults investigated
- **Analysis of data from initial visit shows successful fault detection based on trend data**
 - Oil debris counts
 - Gearbox vibration
- **Additional data has recently been collected for analysis**
 - How do vibration and debris levels compare before and after maintenance?
 - Is there consistency between turbines?
- **The same SKF condition monitoring system is to be installed on the Durham Test Rig**

Interaction - Industrial Partner (II)

- Gearbox intermediate shaft bearing fault
 - Inspection confirms damage and bearing has been replaced

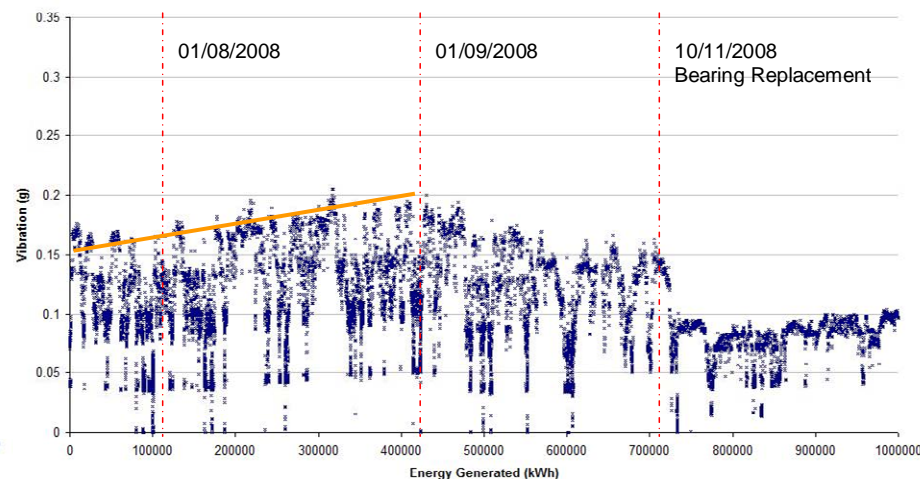
Gearbox High Speed Shaft Axial Vibration Envelope (g) against Cumulative Energy Generated (kWh)



Initial damage causing increased vibration

Severe bearing deterioration possibly causing reduction in vibration transmission path

Gearbox High Speed Shaft Transverse Vibration Envelope (g) against Cumulative Energy Generated (kWh)



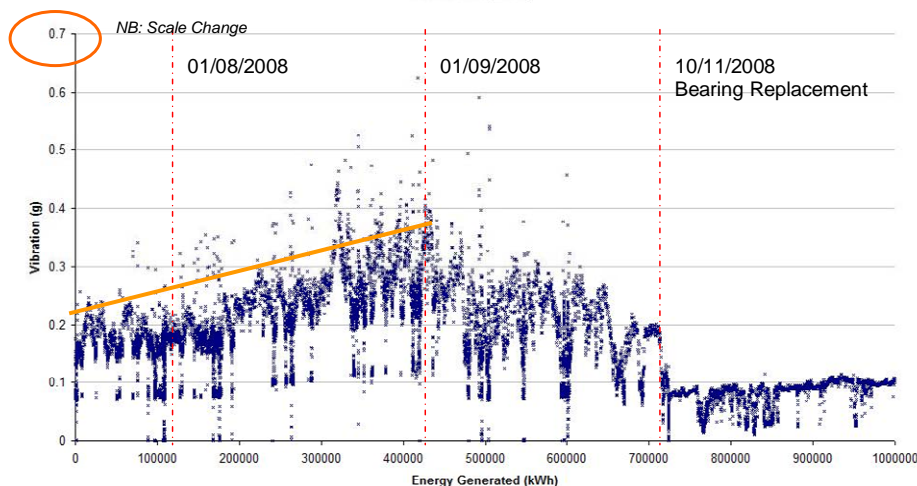
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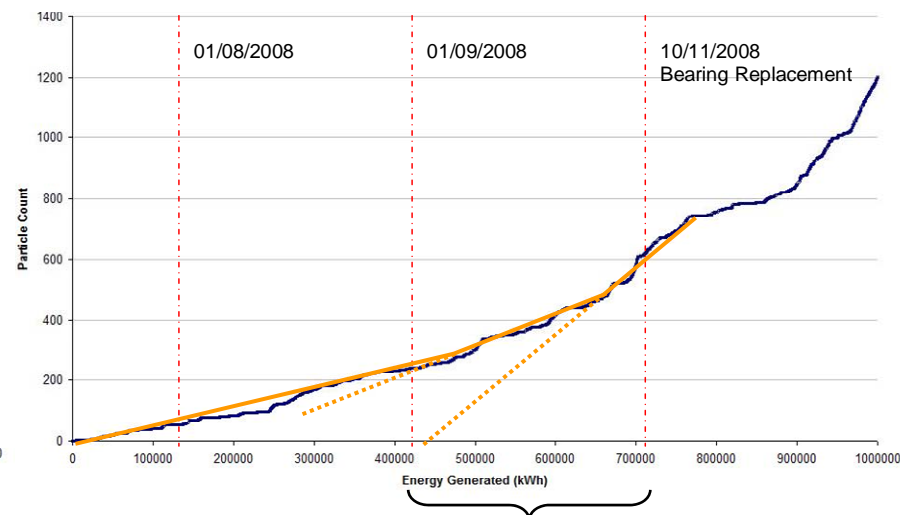
Gearbox High Speed Shaft Axial Vibration Envelope (g) against Cumulative Energy Generated (kWh)



Initial damage causing increased vibration

Severe bearing deterioration possibly causing reduction in vibration transmission path

Cumulative Ferrous 50 µm Bin Count against Cumulative Energy Generated (kWh)



Increased particle count rate coinciding with change in vibration trend

Direction of Future Work

- **To continue working with our industrial partners**
 - Collection and analysis of turbine data from the field
 - Advance the test rig based on industrial information
- **To converge work between Durham and Manchester**
- **Further development of test rig ‘fault-like perturbations’**
 - Rotor mass imbalance – emulating blade faults
 - Emulate wind turbine gearbox damage
 - Emulate wind turbine bearing damage
 - Emulate generator mechanical faults
 - Grid faults including grid synchronisation problems
- **Instal SKF WindCon condition monitoring system on Test Rig**
 - Run SKF system in parallel with current DAQ system
 - Compare test rig results with real turbine data

Published Work to Date

- W. X. Yang, P. J. Tavner and M.R. Wilkinson, Condition Monitoring and Fault Diagnosis of a Wind Turbine Synchronous Generator Drive Train, IET Journal of Renewable Power Generation, 3(1), 2009, p1-11.
- W. X. Yang and P. J. Tavner, Empirical Mode Decomposition, an Adaptive Approach for Interpreting Shaft Vibratory Signals of Large Rotating Machinery, Journal of Sound and Vibration, In Press, 2009.
- Wenxian Yang, P. J. Tavner and Michael Wilkinson, Condition Monitoring and Fault Diagnosis of a Wind Turbine with a Synchronous Generator using Wavelet Transforms, IET Power Electronics, Machines and Drives (PEMD2008), 2-4 April, York, UK, 2008.
- Wenxian Yang, P. J. Tavner and Michael Wilkinson, Wind Turbine Condition Monitoring and Fault Diagnosis Using both Mechanical and Electrical Signatures, IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM2008), 2-5 July, Xi'an, China, 2008.
- Wenxian Yang, P. J. Tavner, C. J. Crabtree, Research on a Simple, Cheap but Globally Effective Condition Monitoring Technique for Wind Turbines, XVIII International Conference on Electrical Machines (ICEM'08), 6-9 Sept, Vilamoura, Portugal, 2008.
- Wenxian Yang, Jiasheng Jiang, P. J. Tavner, C. J. Crabtree, Monitoring Wind Turbine Condition by the Approach of Empirical Mode Decomposition, The 11th International Conference on Electrical machines and Systems (ICEMS 2008), 17-20 Oct, Wuhan, China, 2008.
- Wenxian Yang and P. J. Tavner, Wind Turbine Condition Monitoring and Fault Diagnosis using Wavelet Transforms, the 4th PhD Seminar on Wind Energy in Europe, 1-2 Oct, Magdeburg, Germany, 2008.
- C. Crabtree and P. J. Tavner, Development Of A Test Rig For Condition Monitoring Offshore Wind Turbines, the 4th PhD Seminar on Wind Energy in Europe, 1-2 Oct, Magdeburg, Germany, 2008.
- **Further journal and conference papers have been submitted for publication**

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Any Questions?