 Durham University School of Engineering and Computing Sciences	<b>FINAL REPORT ON RCUK SUPPORT FOR  2<sup>ND</sup> FRENS FLAGSHIP SEMINAR  ZHEJIANG UNIVERSITY  HANGZHOU, 20<sup>TH</sup>-22<sup>ND</sup> SEPT 2010</b>	Doc No	TR 0031
		Date	Dec 2010
		Rev	A
Technical Report			

<b>PROJECT/DEVEL No:</b>	RW10-07	<b>WORK ORDER No:</b>	RF080126
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<b>MACHINE No:</b>	-	<b>MACHINE TYPE:</b>	-
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<b>CUSTOMER:</b>	Research Councils UK	<b>SITES:</b>	Zhejiang University, Hangzhou, China
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<b>COUNTRY:</b>	China	<b>SITE DATE:</b>	20 <sup>th</sup> -22 <sup>nd</sup> Sept 2010
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<b>AUTHORS:</b>	P J Tavner, L Ran
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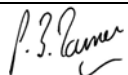

<b>SUMMARY:</b>	Summary of 2 <sup>ND</sup> FRENS Flagship Seminar
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<b>TOPIC KEYWORDS:</b>	Understanding Ageing Mechanisms and Improving Reliability in Renewable Energy Systems
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<b>ASSOCIATED REPORTS:</b>	
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<b>CIRCULATION:</b>	RCUK, Zhejiang, Durham, Warwick, Newcastle & Nottingham Universities
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Approved by:		Authorised by:	
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 <p>Durham University School of Engineering and Computing Sciences</p>	<b>FINAL REPORT ON RCUK SUPPORT FOR 2<sup>ND</sup> FRENS FLAGSHIP SEMINAR ZHEJIANG UNIVERSITY HANGZHOU, 20<sup>TH</sup>-22<sup>ND</sup> SEPT 2010</b>	Doc No	TR 0031
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## 1. INTRODUCTION TO FRENS

Future Reliable Renewable Energy Conversion Systems & Networks (FRENS) is a research project in UK funded by the Engineering and Physical Sciences Research Council (EPSRC), under their Energy China Call.

The research is aimed at increasing the reliability of renewable energy sources and includes mechanical and electrical engineering.

The project consists of a Consortium of five UK Universities:

- Durham University, Consortium Chair, Professor Peter Tavner, EP/F061811/1.
- Newcastle University, Professor GY Tian, EP/F06151X/1.
- Edinburgh University, Dr M Mueller, EP/F06182X/1.
- Warwick University, Professor P Mawby, EP/F061463/1
- Nottingham University, Professor Mark Johnson, EP/F063350/1.

Each University is funded from EPSRC and has a Principal Investigator and the Consortium has links to the following UK industrial enterprises:

- New & Renewable Energy Centre Ltd
- Control Techniques Drives Ltd
- Mott Macdonald U K Ltd
- Convertteam Ltd

The Consortium also has links with the following Universities in China and industrial enterprises:

- Chongqing University, 周洛维/Professor Luowei Zhou
- Tsinghua University, 李永东/Professor Yongdong Li
- Sichuan University, 尹国富/Professor Guofu Yin
- Zhejiang University, 何湘宁/Professor Xiangnin He
- Chinese Academy of Sciences, Professor Liye Xiao
- Nanjing Aeronautical University, Professor Wang
- GE Global Research
- Xinjiang Goldwind Science & Technology

The UK and China Universities are supervising a number of PhD students who are working on research related to the Consortium and are all listed on the Consortium's website:


<http://www.reliable-renewables.com/>

The Consortium organises a Flagship Seminar each year alternately in UK and China. The 1<sup>st</sup> Flagship Seminar was held in Warwick in 2009 and the 2<sup>nd</sup> Flagship Seminar was held in Zhejiang University, Hangzhou, China in 2010.

This Report concerns this latter Seminar entitled:

- Understanding Ageing Mechanisms and Improving Reliability in Renewable Energy Systems.

Funded by Research Councils UK (RCUK) through the Medical Research Council (MRC) under project RW10-07.

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## 2. FRENS 2<sup>ND</sup> FLAGSHIP SEMINAR IN ZHEJIANG UNIVERSITY, HANGZHOU, CHINA, 2010

The seminar was organised by Professor Xiangnin He and the administrative staff at Zhejiang University to whom the author of this Report is grateful for their thorough organisation and efficient management of this exciting event. Photographs of the Seminar are shown in Appendix 1 of this Report.

The Seminar hosted 77 delegates including 35 PhD Chinese, UK and other nationality students and 12 delegates from industrial organisations in China and overseas. The delegate list is included Appendix 2 of this Report.

There were 19 presentations the majority of which were made by PhD students but some keynote presentations were presented by our industrial partners. The Agenda and Abstracts for the Seminar are in Appendix 2 of this Report.

These presentations were excellent and well received by the participants.

The Seminar included an excellent cultural event at the West Lake, a visit to the Department of Electrical & Electronic Engineering at Zhejiang University and a Seminar dinner.

Following the Seminar visitors from UK took the opportunity to visit the Universities of their Chinese partners to strengthen research links.


## 3. FEEDBACK FROM SEMINAR

Feedback from those who attended the seminar – students, supervisors and FRENS Consortium members- was uniformly positive, both as regards the academic sessions, and as regards the domestic arrangements for the seminar.

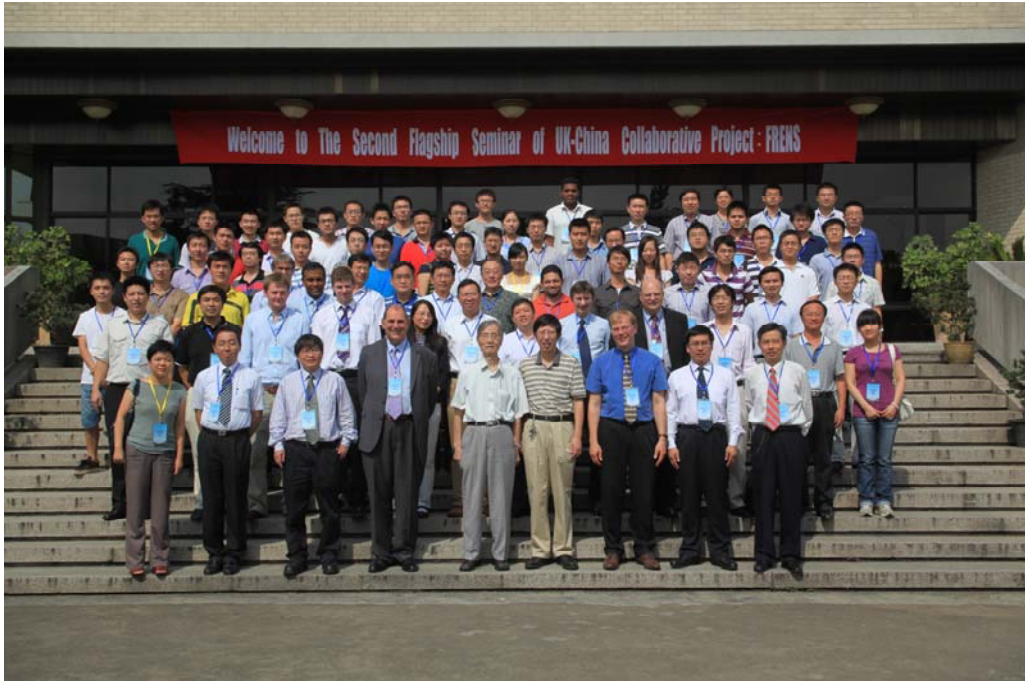
## 4. CONCLUSIONS

The Seminar was judged a huge success by the participants and the Zhejiang University organisers who believe that this has established this research in the minds of China and UK researchers. There was strong interaction between UK and China researchers with the promise of further collaboration in the future.

Prepared by Peter Tavner and Li Ran  
21<sup>st</sup> December 2010

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5. APPENDIX 1, PHOTOS



**Assembled delegates outside Zhejiang University Conference Centre**



**Professor Gui Tian, Newcastle University addressing Delegates on NDE**


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**Professors Xiangning He, Gui Tian and Peter Tavner discussing Seminar progress**



**Professors Gui Tian, Peter Tavner & Li Ran leading Seminar discussions**

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**Dr Tusitha Abeseyakara, visitor from Vestas Wind Power, addressing the Seminar**



**Peter Wyllie, PhD Student Durham University, addressing the Seminar**

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6. APPENDIX 2, DIGEST INCLUDING DELGATE LIST

**Second FRENS Flagship Seminar**

**Understanding Ageing Mechanisms  
and Improving Reliability  
in Renewable Energy Systems**

**Zhejiang University**

Hangzhou, Sept.20-22, 2010

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## Seminar Information and Services

### Organizing Committee:

**Chairman:** Prof. Yousheng Wang (Member of Chinese Academy of Engineering, China)

**Co-Chair:** Prof. Xiangning He (Fellow IEEE, Fellow IET)

### Secretariat:

Prof.. Li Ran

E-mail: li.ran@durham.ac.uk

Tel: +44-191-3342431

Address: Electrical Power and Control, School of  
Engineering and Computing Sciences,  
Durham University, UK

Ms. Xia Zhou

E-mail: lianazhou@zju.edu.cn

Tel: +86-571-87952706

Address: College of Electrical Engineering,  
Yuquan Campus, Zhejiang University  
38# Zheda Road, Hangzhou, 310027, China

### Participants & Supporting Universities (Members of the Consortium):

**China Side:** Zhejiang University, Tsinghua University, Sichuan University, Chongqing University, Nanjing University of Aeronautics and Astronautics, and Institute of Electrical Engineering (CAS)

**UK Side:** Durham University, Edinburgh University, Newcastle University, Nottingham University and Warwick University

### Sponsors:

RCUK China Office;

National Natural Science Foundation of China (NSFC)

### Industrial Supporters:

GE Global Research & Development Center (Shanghai) Co., LTD;

Emerson Network Power Co., LTD;

Zhejiang University – Fuji Innovation Center

### About FRENS:

Sponsored by Engineering and Physical Sciences Research Council (EPSRC) of UK, the second FRENS flagship seminar will be held in Hangzhou, China on September 20-22, 2010. It will

include some regular sessions on the major aspects of circuit theory, simulation analysis, system considerations and applications on the reliability and networks for future renewable energy conversion. It provides an opportunity for UK and Chinese PhD students to exchange their experience and ideas in their related research projects, in addition to speeches by leading industrialists and academics on the forefront of reliability research and applications.

### **About Hangzhou:**

Hangzhou is one of China's most important tourist venues with its famous natural beauty and cultural heritages. The West Lake is undoubtedly the most renowned feature of Hangzhou, of which the "Ten West Lake Prospects" have been specially selected to give visitors outstanding views of the lake, mountains and monuments.

### **About Zhejiang University:**

Founded early in 1897, Zhejiang University is a key comprehensive university in China. Along with its priority to education and research, it seeks to offer service to the nation's economic development, and to make every effort to build itself into an institution on a par with the first-class university in the world. Endowed with a pleasant climate, picturesque surroundings and a favourable academic atmosphere, Zhejiang University is an ideal place for teaching, research, and learning.

*Please refer to details of the seminar below for further information.*

### **Seminar Venue**

#### **ShaoYiFu Science Building**

Address: Yuquan Campus, Zhejiang University, Hangzhou

Tel: +86-571-87951547

### **Accommodation Venue**

#### **Lily Hotel**

Address: 156 Shuguang Road, Hangzhou

(about 10 minutes walking distance from Yuquan Campus of ZJU)

Tel: +86-571-87991188

Fax: +86-571-87991166

[www.lilyhotel.com](http://www.lilyhotel.com)

### Name Tags

Delegates are reminded to wear their name tags throughout the Seminar period.

### Bus Service

Seminar bus is arranged to enable delegates an easy travel between Lily Hotel, ShaoYiFu Science Building and other venues. Details are as follows:

#### Sept. 20 (Monday)

Departure Time	From	To
8:15	Lily Hotel	ShaoYiFu Science Building
17:15	ShaoYiFu Science Building	Lily Hotel
19:25	Lily Hotel	the Performance venue ( <i>Impression West Lake</i> )
21:05	the Performance venue ( <i>Impression West Lake</i> )	Lily Hotel

#### Sept. 21 (Tuesday)

Departure Time	From	To
8:15	Lily Hotel	ShaoYiFu Science Building
13:40	ShaoYiFu Science Building	Lily Hotel
14:30	Lily Hotel	Labs of College of Electrical Engineering, ZJU
18:00	Lily Hotel	Shanwaishan Restaurant

### Tour to City and West Lake Area

It is an optional service. Delegates who showed interest in the tour please ask for detailed information on registering.

### FRENS Contacts

Prof Xiangning He: 13758128616 (M)

Prof Li Ran: 07596720923 (M-UK); 18980781765 (M-China)

Ms Xia Zhou: 13655718000(M)

Dr Mingyao Ma: 13957120412 (M)

## Delegate list

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NSFC	Prof. Lijian Ding	<a href="mailto:dinglj@nsfc.gov.cn">dinglj@nsfc.gov.cn</a>
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Vestas Wind Systems A/S	Dr. Tusitha Abeyasekera	<a href="mailto:tusab@vestas.com">tusab@vestas.com</a>
Zhejiang University	Prof. Yousheng Wang Prof. Zhaoming Qian Prof. Dehong Xu Prof. Xiangning He Prof. Guozhu Chen Prof. Kuang Sheng Prof. Zaiping Pan Dr. Hao Ma Dr. Heng Nian Dr. Min Chen Dr. Wei Zhang Dr. Yan Deng Dr. Lijun Hang Dr. Xinke Wu Mr. Yi Zhao & about 15 graduate students	<a href="mailto:ewangys@zju.edu.cn">ewangys@zju.edu.cn</a> <a href="mailto:qian@zju.edu.cn">qian@zju.edu.cn</a> <a href="mailto:xdh@zju.edu.cn">xdh@zju.edu.cn</a> <a href="mailto:hxn@zju.edu.cn">hxn@zju.edu.cn</a> <a href="mailto:gzchen@zju.edu.cn">gzchen@zju.edu.cn</a> <a href="mailto:shengk@gmail.com">shengk@gmail.com</a> <a href="mailto:panzaiping@zju.edu.cn">panzaiping@zju.edu.cn</a> <a href="mailto:mahao@zju.edu.cn">mahao@zju.edu.cn</a> <a href="mailto:nianheng@zju.edu.cn">nianheng@zju.edu.cn</a> <a href="mailto:heaven@zju.edu.cn">heaven@zju.edu.cn</a> <a href="mailto:weizhang@zju.edu.cn">weizhang@zju.edu.cn</a> <a href="mailto:dengyan@zju.edu.cn">dengyan@zju.edu.cn</a> <a href="mailto:leejean_hang@yahoo.com.cn">leejean_hang@yahoo.com.cn</a> <a href="mailto:wuxinke@zju.edu.cn">wuxinke@zju.edu.cn</a> <a href="mailto:zhao.yi@foxmail.com">zhao.yi@foxmail.com</a>

# Agenda

*19th September, 2010 (Sunday)*

<b>12:00 – 24:00</b>	<b>Check in &amp; Registration</b> ( <i>Lobby of Lily Hotel</i> )
<b>18:30 –</b>	<b>Welcome Reception</b> ( <i>Lily Hotel</i> )

*20th September, 2010 (Monday)*

**Session Chair: Prof Xiangning He**

<b>8:30 – 8:35</b>	<b>Welcome Message from College of Electrical Engineering, Zhejiang University</b>
<b>8:35 – 8:40</b>	<b>Message from the NSFC</b>
<b>8:40 – 9:00</b>	<b>The Current Reliability of Wind Turbines</b> Prof. Peter John Tavner (Durham University)
<b>9:00 – 9:20</b>	<b>Title to be announced</b> Prof. Guiyuan Tian (Newcastle University)
<b>9:20 – 9:50</b>	<b><i>Group Photo &amp; Coffee Break</i></b>
<b>9:50– 10:15</b>	<b>The Progress of Superconducting Power Technology in China</b> Prof. Liye Xiao (Institute of Electrical Engineering (CAS))
<b>10:15 – 10:40</b>	<b>Electrothermal Modelling for Converter Reliability</b> Mr. Peter Wyllie (Durham University)
<b>10:40 – 11:05</b>	<b>A Study of Optimization Algorithm and Design Theory for Large-size Wind Turbine Blades</b> Mr. Long Wang (Nanjing University of Aeronautics and Astronautics)
<b>11:05 – 11:30</b>	<b>Comparison of Equalisation Schemes for Improving Supercapacitor's Reliability</b> Mr. Simon Lambert (Newcastle University)
<b>11:30 – 11:55</b>	<b>Grid Friendly Power Conversion for Reliable Renewable Energy</b> Dr. Yunfeng Liu (GE Co.)
<b>11:55 – 13:30</b>	<b>Lunch ( <i>ShaoYiFu Science Building</i> )</b>

**Session Chair: Prof Li Ran**

<b>13:40 – 14:05</b>	<b>Power Electronic Conversion and Control for PEM Fuel Cell Power System</b> Prof. Dehong Xu (Zhejiang University)
<b>14:05 – 14:30</b>	<b>Reliability of Power Electronic Systems in Wind Turbines</b> Dr. Tusitha Abeyasekera (Vestas Co.)
<b>14:30 – 14:55</b>	<b>Research Progresses on Reliability in Renewable Energy Systems of CQU</b> Dr. Xiong Du (Chongqing University)
<b>14:55 – 15:25</b>	<b>Coffee Break</b>
<b>15:25 – 15:50</b>	<b>Physics-of-failure Based Lifetime Prediction Models for Power Modules</b> Ms. Li Yang (Nottingham University)
<b>15:50 – 16:15</b>	<b>CFD-RANS Analysis of Wind Turbines with a Parameter-calibrated Turbulence Model</b> Mr. Wei Zhong (Nanjing University of Aeronautics and Astronautics)
<b>16:15 – 16:40</b>	<b>Lifetime Prediction for Power Converters</b> Mr. Hui Huang (Warwick University)
<b>16:40 – 17:05</b>	<b>The Introduction of the Action for the Renewable Energy Projects of Fuji Electric</b> Dr. Takehiko Kojima (Fuji Co.)
<b>18:00 – 19:30</b>	<i>Dinner (Lily Hotel)</i>
<b>19:45 – 20:55</b>	<i>Performance - “Impression West Lake”</i> <i>(Address: 29 Yang Gong Causeway ,West Lake area, Hangzhou)</i>

*21st September, 2010 (Tuesday)*

**Session Chair: Prof Peter John Tavner**

<b>8:30 – 8:55</b>	<b>DC-link Voltage Ripple Reduction for a Transformerless Modular Wind Generator System</b> Prof. Yongdong Li (Tsinghua University)
<b>8:55 – 9:20</b>	<b>Multi-stress Ageing Modelling of Electric Insulation Systems, and Its Impact upon the Reliability of Electric Machines</b> Mr. Isaac Portugal (Edinburgh University)
<b>9:20 – 9:45</b>	<b>Research on Single-phase Transformerless Photovoltaic Inverter Connected to Grid</b> Mr. Yi Zhao (Zhejiang University)

9:45 – 10:15	<i>Coffee Break</i>
10:15 – 10:40	<b>Dynamic Behavior of Doubly Fed Induction Generator Based Wind Turbines under Three-phase Voltage Dips</b> Dr. Lie Xu (Tsinghua University)
10:40 – 11:05	<b>A Parametric Investigation of the Effect of Generator Misalignment upon Bearing Fatigue Life in Wind Turbines</b> Mr. Matthew Whittle (Durham University)
11:05 – 11:30	<b>Grid Integration Technology for Renewable Energy</b> Dr. Xiaoming Guo (GE Co.)
11:30 – 11:55	<b>Microwave Induced Heating for Defect Detection in Wind Turbine Blades</b> Mr. Liang Cheng (Newcastle University)
11:55 – 13:30	<i>Lunch ( ShaoYiFu Science Building)</i>
14:30 – 17:00	<b>Tour to labs of College of Electrical Engineering, ZJU</b>
18:00 – 20:00	<i>Banquet (Shanwaishan Restaurant)</i> <i>Address: No.8 Yuquan Road, West Lake area ( located inside Hangzhou Botanic Garden)</i> <i>Tel: +86-571-87986621</i>
20:30 – 21:30	<b>Consortium Members Meeting (Lily Hotel)</b>

22nd September, 2010 (Wednesday)

	<b>Tour to City and West Lake Area (option)</b> <i>(The travel fees are at your own expense)</i>
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**FRENS**

**Second Flagship Seminar**

**Hangzhou, SEPT. 20-22, 2010**

**ABSTRACTS**

# The Progress of Superconducting Power Technology in China

Prof. Liye Xiao, Institute of Electrical Engineering (CAS)

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This presentation will review the recent progress of power application of superconductor in China. In last 5 years, the fault current limiter, HTS cable, HTS power transformer have been developed and demonstrated in live distribution grid. Since 2008, 35kV/2kA fault current limiter and 100kW motor have been developed, and a DC power cable with 380 meter in length and 10kA in capacity, a FCL with voltage up to 220kV and a superconducting substation are being developed. Besides, a 500kJ/150kVA SMES unit was developed and tested, and 1.0 MJ/0.5MW SMES will be demonstrated in a substation soon. Besides, a new kind equipment of fault-current-limiting SMES is being developed and a 100kJ/25 kW prototype has been made and tested. And a 10.5kV superconducting substation which includes HTS cable, transformer, FCL and SMES are being built.

# Electrothermal Modelling for Converter Reliability

Peter Wyllie, Durham University

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Fluctuating power in a wind turbine (WT) results in cyclic thermal loading on the generator and converter. The semiconductor components (diodes and IGBTs) used in the back-to-back converter will suffer accelerated aging effects. These effects will have consequences for both reliability and lifetime of the converter. An accurate thermal model is required in order to improve reliability prediction and allow insight into likely failure modes.

Conventional steam turbogenerator units can outlast WTs by as much as 20 years: given the considerable research effort in the area of wind generation over the past 20 year this is a significant concern. A key distinguishing feature between the two operating environments is the fluctuating load developed by the stochastic nature of the wind. An understanding of the reliability implications of this stochastic mode of operation is crucial to allowing accurate prediction of turbine availability and lifetime energy yield.

An electrothermal model of a large wind turbine is needed to allow us to understand the effect the varying wind has on the key electrical systems in the turbine. Reliability of converter and generator will, in part, be determined by the cycling of heat that arises due to varying electrical losses. In the case of a DFIG machine the magnitude of this thermal cycling has been shown to be greater in the IGBTs that comprise the machine side converter than in those within the grid side converter. This problem may be used as a vessel to carry out research and to develop knowledge that may be applied to other topologies.

An electrothermal model of a 2.3 MW DFIG turbine has been developed using Matlab-Simulink to model the control of the WT and PLECS to model the electrical system. Representative parameters for IGBT and diode loss characteristics are taken from power module datasheets. Various load profiles are applied and loss data is extracted with a view to understanding the effects of thermal cycling on semiconductor aging in the converter.

# **A Study of Optimization Algorithm and Design Theory for Large-size Wind Turbine Blades**

Long Wang, Nanjing University of Aeronautics and Astronautics

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A novel genetic algorithm coupled with an adaptive, sharing and niche technology is developed for the optimization design of wind turbine blades to avoid the only local convergence and “evolutionary stagnation” which occur usually in simple genetic algorithm. This approach is then applied to design a series of 1.5MW variable speed pitch regulated wind turbine blades. The effects of various smoothing procedures, various design targets and tip speed ratios are investigated. To model the tip loss effect usually included in the blade element/momentum method, a combination of CFD computational results with the experimental data of NREL Phase VI rotors has been studied, and consequently, a new thrust coefficient correction formula and tip loss correction formula is obtained. These formulas can successfully be used in the wind turbine aerodynamic performance prediction, showing good convergence when a relaxation factor is included in the new algorithm.

# Comparison of Equalisation Schemes for Improving Supercapacitor's Reliability

Simon Lambert, Newcastle University

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Many applications in electric vehicles, traction, distribution and generation make use of the high power density of supercapacitors. Using a supercapacitor energy storage system either as part of a hybrid or on its own is a common method to deal with transient energy flow.

Many renewable generation systems suffer wear – either electrically or mechanically – due to transients in energy flow; shaft torque variations in wind generation for example. In some applications it is possible to insert a supercapacitor energy storage system as an electrical flywheel to help smooth transient energy flow and reduce wear on the system increasing reliability.

Individual supercapacitor cells have manufacturing tolerances which mean that when connected in series – to attain a system level voltage – the cells in the stack will have varied voltage. Exceeding the cells voltage limit can result in device failure or explosion. It is therefore necessary to employ a system which regulates the cell voltages across the stack increasing the reliability of the energy storage system. Utilising the entire energy storage capacity of the energy storage system through an equalisation system also increases the storage efficiency of an energy storage system. A number of supercapacitor equalisation schemes have been presented in literature. Presented is a critical analysis and simulation of these existing schemes leading to conclusions and recommendations for systems which employ very high capacitance devices.

# Grid Friendly Power Conversion for Reliable Renewable Energy

Dr. Yunfeng Liu

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Requirement for energy is keeping to increase in last 10s years and will ask for more in the future. For example, global electricity demand will double in next 20 years. On the other hand, with the price increase of traditional fossil energy such as oil and coal, people have to look at diversified energy resources especially clear energy resource such as wind/solar to decrease the cost for carbon emission. However, recent booming wind and solar power leads to new challenges upon traditional power system for its uncertain productivity and lack of grid support capability based on previous power conversion technology.

In this presentation, we will introduce the grid integration challenge for renewable power and how GE tried to provide solution with advanced grid friendly power conversion technology.

# **Power Electronic Conversion and Control for PEM Fuel Cell Power System**

Prof. Dehong Xu, Zhejiang University

[xdh@zju.edu.cn](mailto:xdh@zju.edu.cn)

# Reliability of Power Electronic Systems in Wind Turbines

Dr. Tusitha Abeyasekera, Vestas Wind Systems A/S

[tusab@vestas.com](mailto:tusab@vestas.com)

The talk focuses on reliability impact of power electronic converter systems in the wind industry. A background into achieving reliability through design, verification and accelerated life testing techniques will be presented with practical case studies.

# Research Progresses on Reliability in Renewable Energy Systems of CQU

Dr. Xiong Du, Chongqing University

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In order to evaluate the reliability issues in renewable energy systems, the failure mechanism of IGBT modules and schemes to realize reliable operation of wind turbine employing storage elements are studied. Focus on multi-chip IGBT modules, wire-bond lift-off effect is investigated. The electrical behavior of multi-chip IGBT gate driver is affected by electromagnetic coupling through the layout of IGBT. A simple practical method for IGBT prognostics using the electrical behavior of multi-chip IGBT gate driver will be presented. An equivalent model of gate driver considering stray parameters inside IGBT is built up, and then the electrical interaction between gate driver and the power stage is analyzed, finally the dynamic change of gate voltage is used as precursor parameter to evaluate the health state of IGBT. Fault ride-through capability improvement of direct-drive wind generator employing super-capacitor will also be presented.

# Physics-of-failure Based Lifetime Prediction Models for Power Modules

Li Yang, Nottingham University

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Inclusion of power electronic converters in large turbines is one of the primary causes of poor reliability in wind generation systems. Power converters are made up of power electronic modules. The performance of these modules is greatly limited by stress-induced failures in the packaging materials, brought about by harsh environments and operation conditions.

Physics-of-failure methodology is widely used to make reliability assessment for power electronic modules. The PoF approach aims to identify the root-cause of the potential failures. It allows the reliability to be incorporated into the design process and provides a scientific basis for evaluating new materials and electronics techniques.

The development of physics-of-failure lifetime prediction models is one of the crucial steps in the assessment procedure. Several typical lifetime prediction models are introduced in this presentation and some limitations are discussed. A modification solution is described to include the thermally activated processes. In addition, a concept of time domain modelling approach is proposed to effectively account for the time-dependent processes under extensive thermal loadings.

# CFD-RANS Analysis of Wind Turbines with a Parameter-calibrated Turbulence Model

Wei Zhong, Nanjing University of Aeronautics and Astronautics

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Computational aerodynamic analysis of wind turbine airfoils and rotor blades are performed using a RANS CFD approach. Primary simulations highlight a close correlation of inaccuracy between 2D airfoil simulations and 3D rotating blade simulations, suggesting that the 3D blade simulations may be improved by calibrating the computation method especially with the turbulence modeling by means of 2D airfoil simulations. To validate this idea, one key empirical parameter in  $k-\omega$  SST turbulence model was firstly calibrated in S809 airfoil simulations and then used to simulations of the NREL Phase VI blade. The results give a much better prediction of aerodynamic performance of the blade install conditions, compared to simulations with default turbulence model parameters.

# Lifetime Prediction for Power Converters

Hui Huang, Warwick University

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# **The Introduction of the Action for the Renewable Energy Projects of Fuji Electric**

Dr. Takehiko Kojima, Fuji Electric Systems Co., LTD

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In order to start smart grid business in China, the smart grid laboratory has been located in Zhejiang University - Fuji Electric Innovation Center, where has been contracted. We introduce not only the business of our company but also outline of our laboratory.

# DC-link Voltage Ripple Reduction for a Transformerless Modular Wind Generator System

Prof. Yongdong Li, Tsinghua University

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An important issue in the single phase converter system is to deal with the pulsating power which is the twice of the fundamental frequency. The pulsating power may shorten the lifetime of the dc-link capacitor and affect the system control performance. This paper has presented some methods to reduce the dc-link voltage ripple caused by the pulsating power in a modular converter for a multi-coil direct-drive permanent magnet wind generator system. At the generator side, the generator coils with 90 degree phase shift are rectified through power factor correction (PFC) circuit and connected in parallel to counteract the pulsating power to achieve the stable dc-link power. At the grid side, the pulsating power frequency (100Hz or 120Hz) will be twice of the grid frequency, which can be compensated by adjusting the wind generator output power, thus reducing the required dc-link capacitor value. A proportional-integral-resonant (PIR) controller is introduced in the dc-link voltage control loop and generator coil current control loop to generate the required pulsating power to compensate the grid-side pulsating power. The corresponding impact of the current harmonics to the generator torque is analyzed in the paper. Meanwhile, the required dc-link capacitor value is also given in the paper. The simulation results validate the proposed control scheme.

# **Multi-stress Ageing Modelling of Electric Insulation Systems, and Its Impact upon the Reliability of Electric Machines**

Isaac Portugal, Edinburgh University

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Reliability studies in electric machines can be divided in three different subgroups, the structure, the bearings and the insulation systems. All of them are indispensable for the proper functioning of a machine. This research project aims to investigate the electric insulation systems and their effects in terms of reliability.

Ageing models of electric insulation systems were first formally introduced during the 40's, when a very well established equation for the rate of chemical reactions was used to determine the life of an insulation system subjected to thermal stresses. Then, along the past century, this theory was modified to account for electric stresses. However, due to the complexity and lack of understanding of the involved phenomena, all the up-to-date developed models are from a phenomenological nature (based on empirical observations rather than only scientific principles). The project investigates the validity of a recent and sound insulation deterioration model, and utilises it to predict machine problems before they occur.

# Research on Single-phase Transformerless Photovoltaic Inverter Connected to Grid

Yi Zhao, Zhejiang University

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A novel inverter topology for transformerless PV systems is proposed to meet the requirements of high efficiency, small size, light weight and low cost. The proposed inverter can guarantee not to generate the variable common-mode voltage, and the common-mode leakage current is nearly eliminated. Meanwhile, the three-level output voltage is achieved and only the same low input voltage is required as the conventional full-bridge inverter. Furthermore, not only the unipolar SPWM but also the double frequency SPWM can be both applied in the proposed inverter, and a lower ripple and a higher frequency of the filter inductor current can be achieved. Therefore, a smaller filter inductor can be employed and the copper losses and core losses are reduced greatly, or the higher quality and lower THD of the grid-connected current are achieved. At last, a 1kW prototype has been built and tested to verify the theoretical analysis.

# **Dynamic Behavior of Doubly Fed Induction Generator Based Wind Turbines under Three-phase Voltage Dips**

Dr. Lie Xu, Tsinghua University

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Due to the relative small rating of the power converters, wind turbines based on the doubly fed induction generators (DFIG) are sensitive with grid disturbances, especially when voltage dips during grid faults. In this paper, the EMR (Energetic Macroscopic Representation) is adopted in DFIG system modeling and two control strategies of the stator flux, which includes synchronous approach with an open-loop flux control and asynchronous approach with a closed-loop flux control, are proposed. Furthermore, a comparison of the two methods is also discussed with relative simulation results to validate the discussion about their influence on dynamic behavior of the wind turbine system against voltage dips.

# **A Parametric Investigation of the Effect of Generator Misalignment upon Bearing Fatigue Life in Wind Turbines**

Matthew Whittle, Durham University

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Numerous studies have shown that wind turbine (WT) generator failure rates compare unfavourably to electrical machine failure rates in other industries. Furthermore, because a crane is required to change out a generator the downtime per generator failure is high. There is therefore a significant economic motivation for research into the failure modes of wind turbine generators.

The main differences which characterise the operation of generators in WTs compared to other industries are: the fluctuating nature of operation; exposure to extreme ambient conditions; and novel system integration.

This study has attempted to further the understanding of the effects of system integration upon the fatigue life of the bearings of the generator. Generator misalignment has been investigated using RomaxWIND drivetrain modelling software to undertake a parametric study to quantify the impact of generator misalignment and coupling stiffness upon the generator bearing fatigue life. The findings indicate the value of considering system integration in wind turbine design.

# Grid Integration Technology for Renewable Energy

Dr. Xiaoming Guo

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Lack of grid support capability based on previous power conversion technology is a key challenge for future renewable power application. In a few cases, from the system stability point of view, the grid operators have to limit the total injection of renewable energy to power system. However, since most of the renewable energy sources are powered by power electronic device, they are naturally controllable, which guarantee their compatibility with traditional power system. Besides, due to the fast response timing of power electronic devices, they can even provide grid stability supporting from transient to steady state.

In this presentation, we will talk about the grid requirements and grid integration challenge in current power system; then the demonstration of our research work in grid integration; finally, the trend and the possible future in grid integration technology for renewable energy.

# Microwave Induced Heating for Defect Detection in Wind Turbine Blades

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Recent developments in defect detection in wind turbine blades have concentrated in two directions: 1) sensors and arrays for local defect detection at both macro- and/or micro-levels; 2) large-scale component imaging and monitoring such as thermography. In this presentation, microwave induced heating thermography are proposed as potential technique for evaluating wind turbine blades. To project microwave for heating generation in blades, two different set-ups using horn and rectangle waveguide are conducted and compared via both numerical simulation and experiment. To undertake the feasibility study, a hybrid simulation method has been applied, according to the strengths and weaknesses of finite integration technology (FIT) and finite element method (FEM) in terms of computation time and accuracy. For experimental studies, 9 mm diameter holes in a blade to simulate surface defects are evaluated. Through comparison studies, rectangle waveguide is more efficient on heating blades in terms of temperature rise within safe power level on a local area. As a trade-off, the sensing area using rectangle waveguide is smaller than that utilising horn, which requires scanning scheme for whole blade inspection. In the feasibility studies, the edge of holes achieves larger temperature rise than surrounding area, which enables to detect hole-shape defect. Moreover, the limitations and problems are also discussed in the presentation.

