ENGL

Innovation through integration: "Joined up" approaches to wind energy R&D

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My history in Renewables ....

- Graduated in engineering in 1980
- Worked for BAe Dynamics in Bristol designing spacecraft control systems
- Joined Wind Energy Group in 1982
  - involved in design and testing of LS1 wind turbine on Orkney
- Joined Garrad Hassan & Partners in 1988
  - became responsible for turbine engineering consultancy, software and R&D
- Head of Turbine Engineering Competence Centre for GL Garrad Hassan from 2009
- Now “Senior Technical Advisor” for DNV GL with focus on Renewables technology, R&D and strategy
Clearing up the confusion…….

What has happened to Garrad Hassan?

We became GL Garrad Hassan in 2009

We are now DNV GL
Two complementary players joining forces

- Global companies with strong heritage as ship and offshore classification societies
- Complementary market segments in maritime, oil and gas and energy markets
- Shared ambition for quality and innovation
- Common values
- Complementary skills
Combined strength to support Energy customers

3000 energy experts help customers throughout the electrical power industry realise efficient, reliable and clean energy for today and the future

*Renewables Certification services are offered separate from remaining services to ensure impartiality and to fulfill accreditation requirements of DIN EN ISO IEC 17065:2013
A global service portfolio

- Power testing, inspections and certification
- Renewables certification
- Renewables advisory
- Energy advisory
- Sustainable energy use
Assisting companies in solving the energy trilemma

Affordability

Reliability  Sustainability
DNV GL: Experts in renewable energy

Key Services

- Project Development
- Project Engineering
- Asset and Operation Management
- Measurements
- Turbine Engineering
- Offshore
- Solar
- Wave and Tidal
Geographical reach in renewables

More than 1000 renewables staff, in 50 locations, across 27 countries
What we do in Turbine Engineering

- Design and analysis
  - Loads
  - Control
  - Mechanical engineering
  - Electrical engineering

- Software: Bladed, TidalBladed and WaveDyn
- Technology evaluation
- Research and innovation
Our involvement with SUPERGEN Wind

- Longstanding cooperation with Strathclyde University back to early 1990’s
- Joint research activities with other SUPERGEN Wind Universities
- 10 research licences for Bladed, 4 dedicated to SUPERGEN Wind
- Industrial Partner in SUPERGEN Wind Phase 1 and 2
- Member of Project Management Board
- Involvement will continue into SUPERGEN Wind Hub
  - Industrial Partner
  - Member of Executive Board
  - Advice and feedback on research activities and Grand Challenges
  - Assist with engagement of industry
- SUPERGEN Wind has put UK academic research “back on the map”
SUPERGEN Research Programme

- Mission statement
  - “To undertake research to achieve an integrated, cost-effective, reliable & available Offshore Wind Power Station.”
- Context: Large scale development of offshore wind farms.

UK government efforts very much concentrated on offshore
Wind capacity installed and future projection

Global installed capacity of 290 GW including 7 GW offshore

- China
- USA
- Germany
- Spain
- India
- France
- Italy
- UK
- Canada
- Portugal
- RoW

Forecast of 1,000 GW global installed capacity by 2020

Source: Citi Research
Cost of offshore wind - historical CapEx trend

All wind farms >50MW

FUTURE COST TRENDS?
Cost reduction potential for offshore wind

Target of 100 £/MWh by 2020 – UK DECC and Crown Estate

DONG predicts that a cost of €100/MWh is within reach for 2020 projects
Scope for cost reduction in almost every aspect of the process

- Design and analysis
- Testing and confidence
- Standardisation
- Manufacture
- Installation
- Operation
- Financing – understanding risk and confidence
- Alliencing
- Contracting and risk distribution

Effective solutions will be found through “joined up” approaches to innovation to tackle “joined up” challenges
An example of a “joined up” innovation project: FORCE (FOr Reduction of Cost of Energy)

FORCE

- Aims to reduce LCoE by using an integrated approach to offshore wind turbine and support structure design
- Incorporates advanced control strategies and rotor design to reduce loading and hence CAPEX of turbine and support structure
- Major DNV GL project involving team of 25 engineers
- Very promising results!
Approach taken in FORCE to reduce LCoE

- Baseline: 7MW, 160m rotor diameter, IEC 1A, 1P IPC pitch control, 40m water depth using directional wave data of Dogger Bank, UK North Sea

Tools used to reduce LCoE

- 1P and 2P individual pitch control – to reduce fatigue torsional loading on jacket
- Nacelle LiDAR assisted control to reduce fatigue thrust loads
- Higher tip speed ratio (10) and max tip speed (100m/s), lower solidity more flexible blades to reduce fatigue thrust, torsional loads and drive train rated torque
- Removal of jacket design frequency constraint and load mitigation with advanced control (funded by Technology Strategy Board)
- Use of cost modeling to influence controller optimisation
- Fully integrated loads calculations including wind and wave loading with turbine and jacket support structure defined

All technology is ‘near term’
Baseline cost breakdown

Turbine and support structure CAPEX

LCoE
Support structure design processes

- Offshore wind support structures ~ 50% of CAPEX costs (18% LCoE)
  - significant savings possible if design is optimised

- Current design process:
  - Iterative approach between manufacturer and foundation designer
  - Computationally onerous, not always robust
  - Depending on level of coupling, may miss important effects

- Integrated design process:
  - GH design tool ‘Bladed’ offers integrated analysis
  - Fully coupled structural dynamics and wind/wave loading
  - Computationally efficient

- Advanced control methods can further optimise design
  - Individual pitch control, advanced tower feedback control
  - Direct quantification of frequency constraint relaxation
  - Reduced fatigue loading = fabrication cost savings
Current commercial situation

- Established process:
  - Aero-elastic design tool: turbine manufacturer
  - Offshore structural design tool: foundation designer
  - IP barrier leads to un-optimised design

- Contractual issues:
  - Turbine manufacturer Intellectual Property (IP)
  - Contractual status quo
  - Timing of contract awards differ

- Solutions:
  - New turbine manufacturer entrants willing to collaborate?
  - Turnkey solutions: manufacturer-designer-fabricator consortia?

➢ The R&D in FORCE aims to strengthen the case for change
Relaxation of support structure frequency constraints

- The turbine designer typically establishes the optimum stiffness for the combined foundation, support structure and tower to give the lowest fatigue loading for the turbine. This frequency tends to force a very unoptimised jacket design, BUT the support structure is 23% of farm CAPEX at this scale excluding installation (18% LCoE).

- Four jackets & towers considered: 0.271Hz, 0.286Hz, 0.312Hz and 0.333Hz.

- Loads calculated for all four.

- LCoE comparison for all four, two selected for full optimisation (that work is in progress, Feb 2014).

- Jacket #4 (far right) is 25% lower cost than jacket #1.

- This aspect equated to 5% LCoE reduction (having accounted for <0.2% energy penalty for jacket #4).
Benefits of relaxation of frequency constraint

CAPEX reduction

Weight reduction
Higher speed, more slender, more flexible blades

- Objectives:
  - Reduction of thrust fatigue loads. As the blade speed is increased, the effect of variations in wind speed becomes relatively less significant to the blade and fatigue thrust loads are reduced.
  - Reduction in drive train rated torque. For constant rated power, an increase in rotational speed results in a corresponding reduction in torque and hence mass of the major drive train items such as the gearbox.
  - Although blade leading edge erosion remains a challenge, these results motivate further development in the area of blade leading edge protection

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>New Blade</th>
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<tbody>
<tr>
<td>Tip Speed Ratio</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Max tip speed</td>
<td>90 m/s</td>
<td>100 m/s</td>
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Key fatigue load reductions

- Damage equivalent loads were used as input to the cost of energy model.
- Relative changes to the **baseline load level** are summarised below:
Conclusion: 10 – 15% LCoE reduction is possible:
Points to note from FORCE

- Results to date are encouraging but more can be achieved! DNV GL is currently outlining future directions for FORCE.
- Monopiles not yet considered but are likely to be particularly sensitive to the design approaches and control strategies investigated – substantial cost reduction may be possible through reduction of design dominating fatigue loads.
- Potential to make significant improvements in the contribution of LiDAR to LCOE reduction through further R&D.
- The results underline the importance of an integrated approach to the design of offshore turbines and support structures.
- The existing contracting structure for offshore wind needs to change to facilitate the fully integrated design approach; separate procurement of turbines and support structures does not lend itself to integrated design.
SPARTA

System Performance, Availability, Reliability
Trend Analysis
The need to capture energy at a cost per kWh which is competitive with other sources of energy is vital if the offshore industry is to enjoy a secure, long term future.

Industry focus to date has been on reducing capital cost

O&M is c.1/3 of project lifetime cost

SPARTA will enable informed decisions relating to:
- Availability of turbines
- Reliability of equipment
- Optimum performance of plant and wind farms
Equipment failures – cost to the industry

- The total lost revenue due to equipment failures to the UK offshore wind industry in 2012 is estimated to be around £150 million*
- If the UK meets the 2020 target of 18GW installed capacity without reducing these, it could cost the industry £860 million per year in 2020

* Based on mean failure data (Source: WEP) with assumed 95% availability from experience
**Value proposition**

**SPARTA – The performance data exchange platform for offshore wind**

- **System Performance, Availability and Reliability Trend Analysis** will enhance the reliability and safety performance of the offshore wind industry, and drive down lifetime costs.

- The Crown Estate, in collaboration with DNV GL, has initiated this joint industry project inspired by the offshore oil industry’s **Offshore Reliability Datatbase, OREDA**.

- The project is sponsored by The Crown Estate and the ORE Catapult.
OREDA success factors

- OREDA is a highly recognised and well established database
- SPARTA is keen to emulate this success, particularly:

  **Stakeholder engagement**
  - OREDA is actively supported by the industry, with 10 members, some of the largest oil and gas companies in the world.

  **Data management**
  - OREDA provides a comprehensive databank with quality data collected from worldwide offshore installations.

  **Independence**
  - OREDA is managed by an independent organisation, ensuring anonymity and protecting commercial interests.

  **Knowledge exchange**
  - OREDA provides a forum for sharing of experience within the oil and gas industry and beyond.
Project objectives

- **Improve safety**
  - by reducing major component failures and the frequency of offshore interventions
  - by providing verified data for risk analysis

- **Improve performance**
  - by using failure data to benchmark performance and drive reliability improvements

- **Joint industry commitment to continuous improvement**
  - by enhancing OEM and supply chain engagement

- **Improve maintenance effectiveness**
  - by using field data to optimise maintenance strategies and drive operational cost reduction

- **Enhance industry knowledge**
  - by providing visibility of aggregated availability, reliability and performance data
**Deliverables**

- A means of measuring and benchmarking performance and reliability of offshore wind farms including turbines and complete balance of plant (to offshore substation)
- Data confidentiality and security
- Reporting structure informed by EU Reliawind project
- Indicative reporting metrics (TBA)
  - Availability (annual, mean)
  - Production (annual - inc average per turbine)
  - Performance (design/actual)
  - Capacity factor
  - No of failures by type
  - No of serial/type/generic defects
  - Mean time between interventions
  - Ratio of planned/unplanned maintenance
  - Average transit time
  - No of crew transfers
And finally, the Wind Power Station Simulator: Strategic innovation for a “next generation” design tool

- **Background**
  - In 1984 GH developed “Blades”, a computer program to calculate the steady state power curve of a wind turbine
  - Over three decades this has been transformed into “Bladed v4.4”, the world’s most sophisticated simulation software for predicting the performance, dynamic behaviour and loading of onshore and offshore wind turbines
  - This has been possible because of investment in innovation, ingenuity of engineering staff, and an enormous increase in computer processing power!

- **Time for the next “game changing” development**
  - A “next generation” tool which provides comprehensive time domain simulation of a wind farm as a power station rather than collections of individual, autonomous machines
  - To include representation of all external conditions, flow within the array, loading of each individual turbine and support structure, control of the power station as a whole, and electrical interaction with the grid
  - Within 5 – 10 years, simulation of wind power stations will be routine!
Wind Power Station Simulator

- Scope and outcome of project
  - Development and validation of engineering models and software package for comprehensive simulation of an offshore wind power station
  - CFD treatment of wind flow within the wind farm representing wake flow, turbulence etc.
  - Integration of CFD wind flow model with Bladed turbine simulations enabling time domain calculation of energy yield, loading, fatigue damage etc across the power station
  - Coupling with electrical network model enabling simulation of power station interaction with grid
  - Representation of power station control strategies to optimise overall energy yield, fatigue loading, grid interaction etc
  - Potential coupling with SESAM for enhanced modelling of offshore support structures, floating systems etc
  - Software architecture and implementation – use of HPC technology most appropriate for the hugely intensive computation involved
  - Validation and testing
CFD coupled with turbine simulations - example from University of Auckland
And finally, to inspire us....... 

“The UK has many strengths in research and development; we have world-class universities and a track record of innovative companies. We need to nurture and build on those strengths. We must forge partnerships between industry, government and the most innovative minds in business and academia to identify, develop and deploy technologies that will transform the ways in which we generate and use energy.”

Rt Hon David Willetts MP, Minister of State for Universities and Science 
“Coordinating Low Carbon Technology Innovation Support; The LCICG’s Strategic Framework”, February 2014

“We must find our Brunels, our Edisons and the Stephensons of our low carbon time. Innovators that can literally change the world. We need a new urgency around innovation. We must build a new consensus forged around the belief that we can deliver technological solutions to climate change and these solutions will deliver economic prosperity in the long-term.”

Tom Delay, CEO of The Carbon Trust 
“The Low Carbon Manhattan Project”, March 2014

Roll on SUPERGEN Wind Hub!
Sneek peak of our 2050 vision – coming in 2014!

2014 – «Year One and 150 Years!»