ISSUE 02 • 201

GL Garrad Hassan GL

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energize renewables

energy. efficiency. engineering.

Winning Perspectives

north america Winds of Change

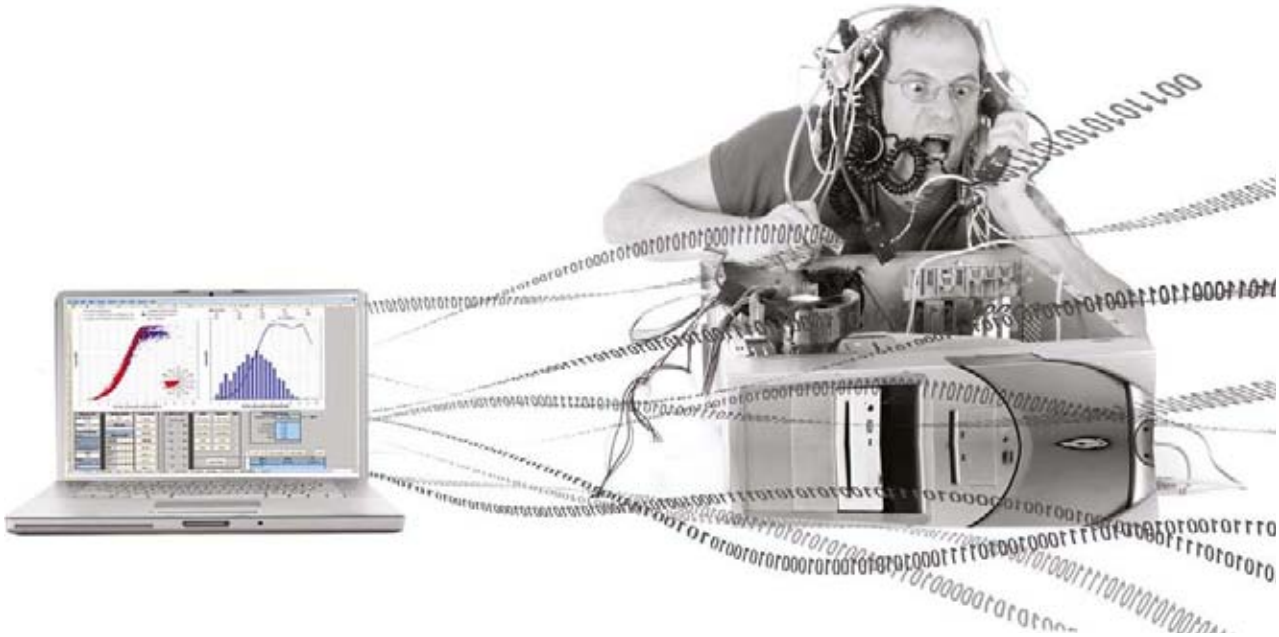
offshore Pinpointing Operation Costs

certification Balancing the Grid

Renewable energy consultants

GL Garrad Hassan

GET IT OUT OF YOUR SYSTEM



WindHelm

Portfolio Manager

Good data management and analysis reap financial rewards yet disparate systems often make the process challenging. WindHelm provides a single platform for the monitoring, optimisation and control of any combination of operational turbines, farms and portfolios. Its reporting functionality is based on GL Garrad Hassan's years of experience providing asset management and optimisation services to the wind industry.

windhelm@gl-garradhassan.com

To Our Readers

Andrew Garrad

Our aim is to harness the power of the wind. The question for us is: When you have harnessed that power what do you do with it? Bringing that power to where you can make best use of it is at the heart of many of the topics in this edition of *energize renewables*.

As wind power has matured and the volume of projects connected to the grid has risen, there is an increasing number of geographical areas where projects experience curtailment issues, especially in North America. Due to the rapid expansion of wind energy unsupported by grid reinforcement, networks are put under severe strain. Therefore, it is of utmost importance that wind turbines become increasingly "grid-friendly". GL Renewables Certification show how they are supporting the industry by offering an updated version of their grid code guideline (page 30).

Benjamin Bell, President and Chief Executive of GL Garrad Hassan North America, explains that green energy can hope for a powerful future in North America but must tackle many challenges before being fully integrated into the region's energy mix (page 8).

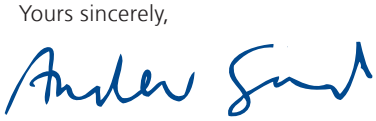
Governmental regulation and environmental sensitivity are key factors in the design, installation and operation of any renewable project. Large-scale development and increased investment in renewables create opportunities, but operating within the complex regulatory regimes requires special expertise (page 18).

Offshore wind energy projects are different; more dangerous, more complex and more costly. Handling the challenging conditions of the maritime environment competently requires special expertise. GL Garrad Hassan experts provide seminars to engineers, helping to prepare them for these particular challenges (page 24). Owners and operators are under increasing pressure to reduce operational costs while improving the efficiency of their wind farm portfolios. Read more about how GL Garrad Hassan's newly developed software tool "WindHelm" helps to achieve this end on page 14.

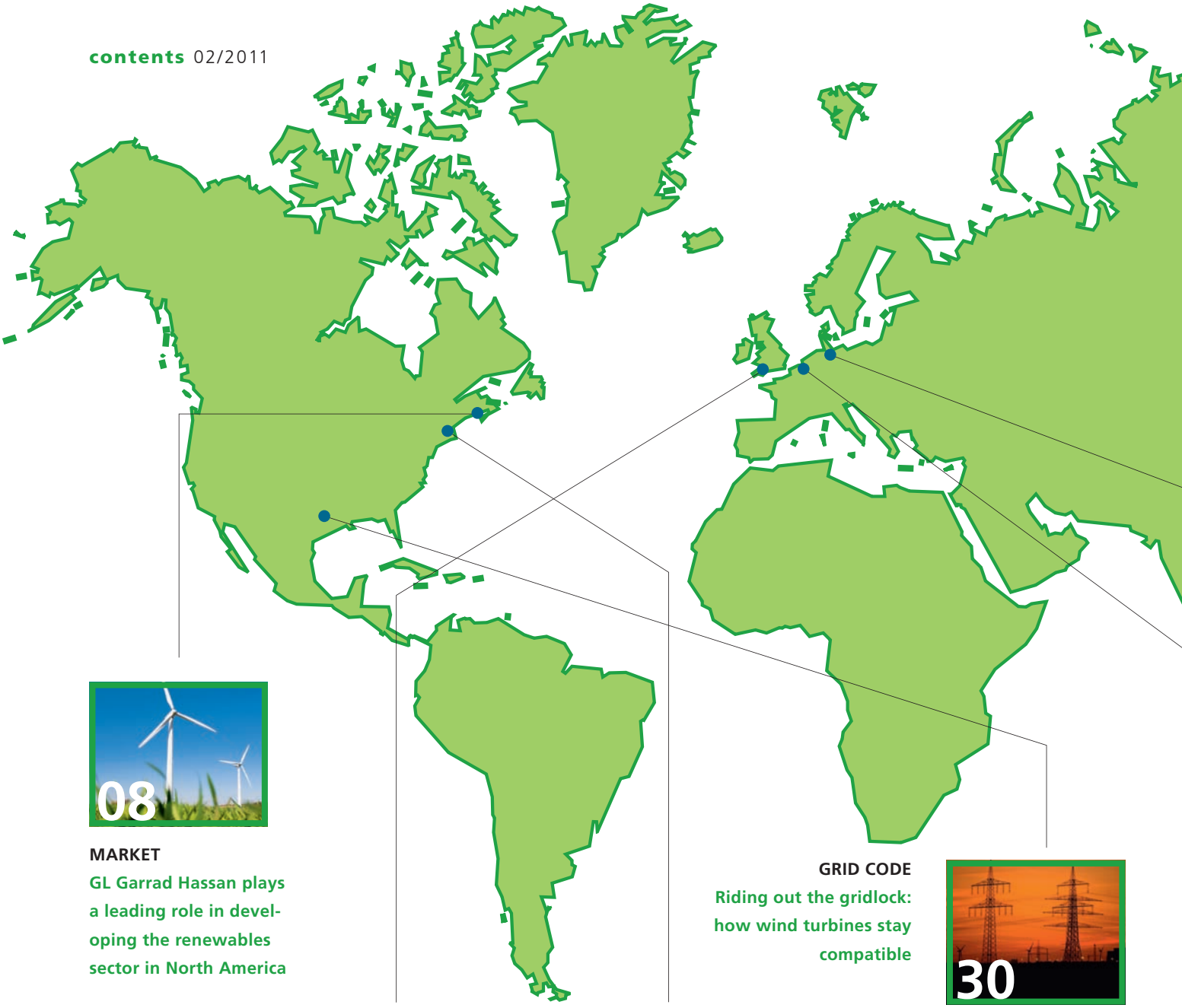
A wind turbine is made up of many different components, and only the certified quality of all parts safeguards the profitability of the whole installation. GL Renewables Certification highlights their role in ensuring that developers can be confident that their installations meet all the necessary standards and requirements (page 34).

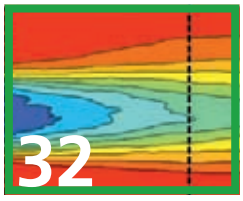
I hope you enjoy this issue of *energize renewables*.

Yours sincerely,



Andrew Garrad
President of GL Garrad Hassan





TOPFARM
Turbine wakes and their interaction affect wind farm performance

COMPONENTS
Certification reduces the losses resulting from outage

In Brief:
GL's Renewables Business Segment

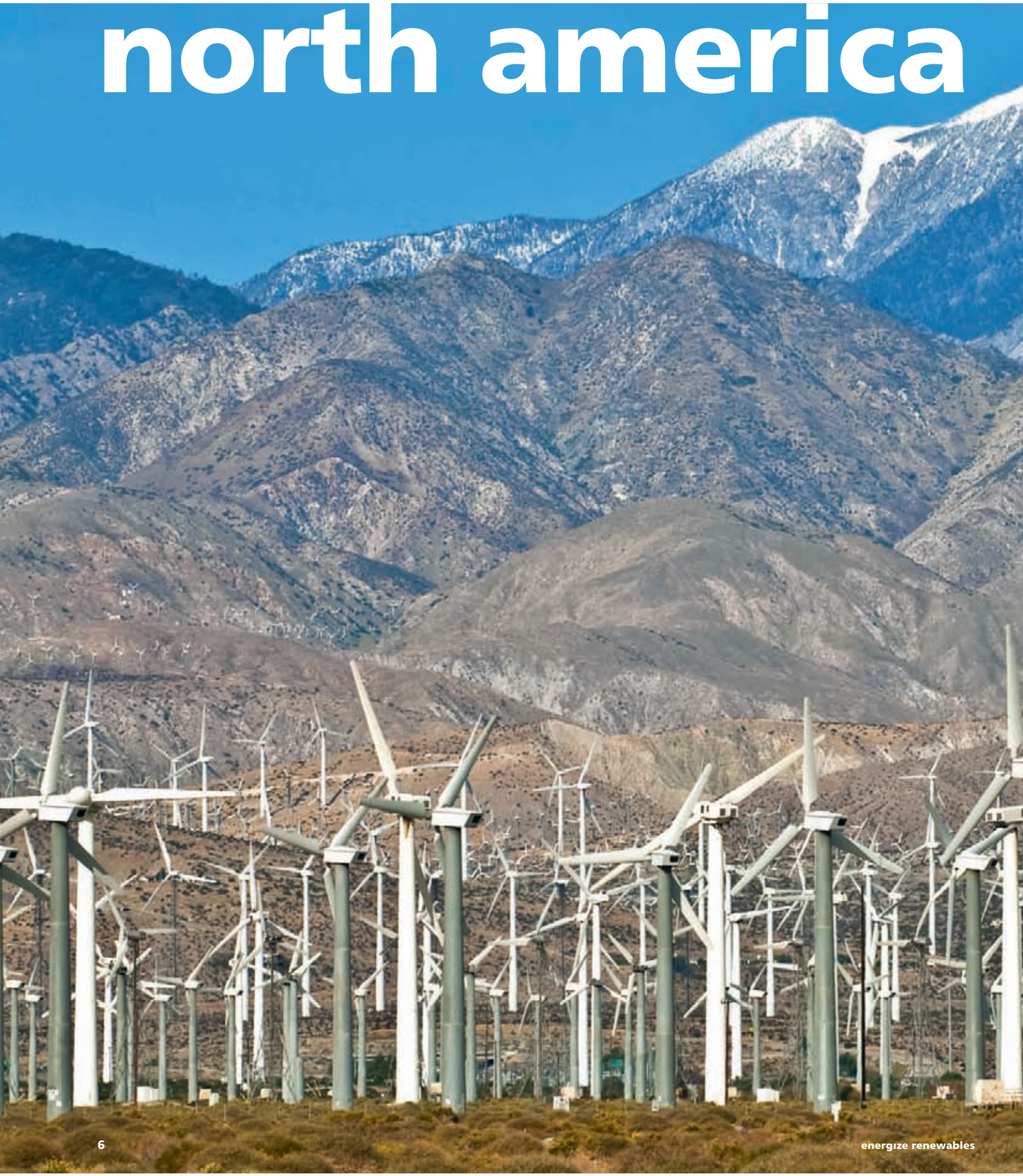
- **GL GARRAD HASSAN** is one of the world's largest renewable energy consultancies. It offers a unique level of service expertise and global presence across the whole project lifecycle with 750 members of staff in 42 locations, across 23 countries. Its technical scope covers all relevant aspects of onshore wind, offshore wind, marine renewables, and solar energy. It addresses the requirements of manufacturers, operators, investors, project developers, authorities, and the supply industry with regard to all technical aspects of renewable energy applications. Given the current focus on wind energy, GL Garrad Hassan is able to provide a comprehensive set of services including the optimal design of wind parks, improvement in the performance of existing wind farms, measurement projects (wind resource, wind turbine performance and structural behaviour), inspection services, a large array of software products and turbine design services. In addition, GL Garrad Hassan has gained substantial experience in tidal and wave power generation and is involved in various solar projects.

- **GL RENEWABLES CERTIFICATION** is a leading certification body primarily focused on the certification of wind farms, wind turbines and their components as well as marine renewable energy. At the forefront of know-how in renewables technology, it is abreast of all the necessary standards and requirements and takes a harmonised approach in ensuring that these are met. Manufacturers, banks and insurers around the world rely on the state-of-the-art service provided by GL Renewables Certification.

  Together, **GL GARRAD HASSAN AND GL RENEWABLES CERTIFICATION** form the Renewables business segment of the GL Group.

- **GL GROUP** is a technical assurance and consulting company for the energy industries and also a leading classification society. GL employs almost 6,900 engineers, surveyors, experts and administrative staff. Its global network consists of more than 200 stations in 80 countries.

north america



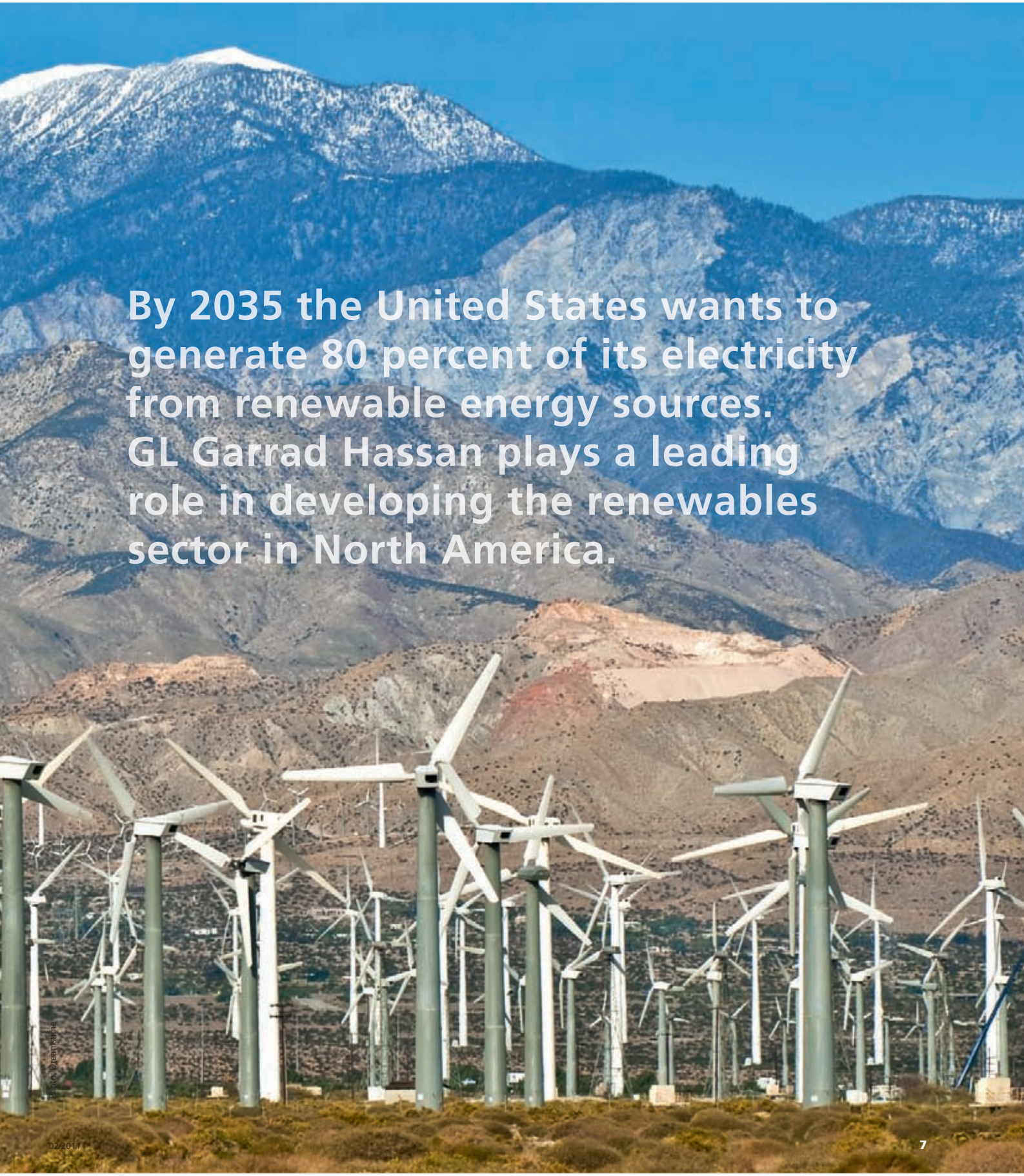


Photo: Dreamstime

Think Tank for Evolving Power Technologies

Green energy can hope for a powerful future in North America but must tackle many challenges before being fully integrated into the region's energy mix

After a period of organic growth, mergers and acquisitions, GL Garrad Hassan is now one of the world's largest renewable energy consultancies with an expanding market share of North America's potentially vast renewables market. Today, two years after international consultancy Garrad Hassan joined GL's Renewables group, the company is an internationally key supplier of independent technical and engineering services, products, and training courses to the onshore and offshore wind, wave, tidal and solar sectors.

As President and Chief Executive of GL Garrad Hassan North America, Benjamin Bell is based in the regional Head Office in Peterborough, New Hampshire and is responsible for a 150-strong team of technical and commercial experts. He is well-placed to plot GL Garrad Hassan's role in developing the renewables sector, being familiar with the challenges overcome by the vanguard of a new industry; onshore wind in the 1980s.

Providing know-how to project developers, financing institutions and insurers of renewable energy has placed GL Garrad Hassan at the heart of the

ABSTRACT

- GL Garrad Hassan plays a leading role in developing the renewables sector in the U.S.
- The U.S. market requires creative thinking and state-of-the-art technology

Photo: iStockphoto.com

Empty Land. **Setting up onshore windfarms in North America is relatively inexpensive.**

sector's growth. The company offers consulting on all phases of wind farm developments from initial siting studies to project decommissioning. In America, "our largest market is onshore wind, where we offer the renewables industry technical and commercial expertise to help get projects developed, financed, and operating efficiently," says Mr Bell. "We are able to support the industry with a wide range of renewable energy services including grid measurements and short-term forecasting services for wind plant operators and energy traders".

Critical Factor

The group is also currently working on solar and marine energy measurement campaigns, energy assessments, and is providing technical due diligence for lenders and investors. "Whether our client is seeking input into device ▷

Profile: Benjamin Bell

Mr Bell has over 30 years' experience in the engineering, manufacturing, operations, and commercial development of wind energy technology. He joined Garrad Hassan America, Inc. as CEO and President in January 2007. Prior to that Mr Bell spent nine years at GE Wind Energy. During his tenure there he served as Director of Research & Development, VP of Manufacturing Engineering, and VP of Wind Facilities Operations. At GE, he led GE Wind Energy's commercial and development activities regarding offshore wind energy in the Americas. In 1999, Mr Bell received the Technical Excellence Award from the American Wind Energy Association.

U.S. Wind Market 2010

Top 5

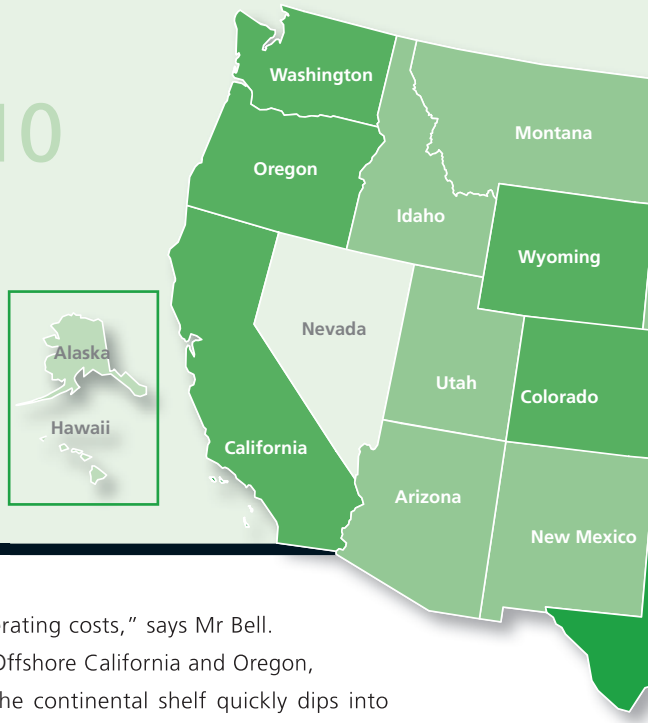
BY TOTAL WIND CAPACITY

Texas:	10,085 MW
Iowa:	3,675 MW
California:	3,177 MW
Minnesota:	2,192 MW
Washington:	2,105 MW

Top 5

BY NEW WIND CAPACITY IN 2010

Texas:	680 MW
Illinois:	498 MW
California:	455 MW
South Dakota:	396 MW
Minnesota:	396 MW



▷ design, site assessment or due diligence services, we are able to call upon GL Garrad Hassan specialists," says Mr Bell. As the wind energy sector matures and the number of projects connecting to the grid increases, GL Garrad Hassan's Power Market Analysis service for North America offers wind farm developers key data about how to predict and account for risk related to curtailment and corresponding loss of revenue. This is a critical factor in determining the value of a site proposed for project development and is an important element in its technical due diligence.

Attractive Onshore Wind Farms

GL Garrad Hassan is providing independent engineering services for the largest wind farm development in the U.S., the 845-megawatt Shepherds Flat Wind Farm in the northwest Pacific state of Oregon. The work scope includes an on-site assessment of the energy production, a technical assessment of the site suitability, the plant, the equipment and the material procurement, construction and operation contracts. In addition, GL Garrad Hassan experts analysed the project costs and carried out a full financial model review, ahead of the wind farm's expected 2012 start.

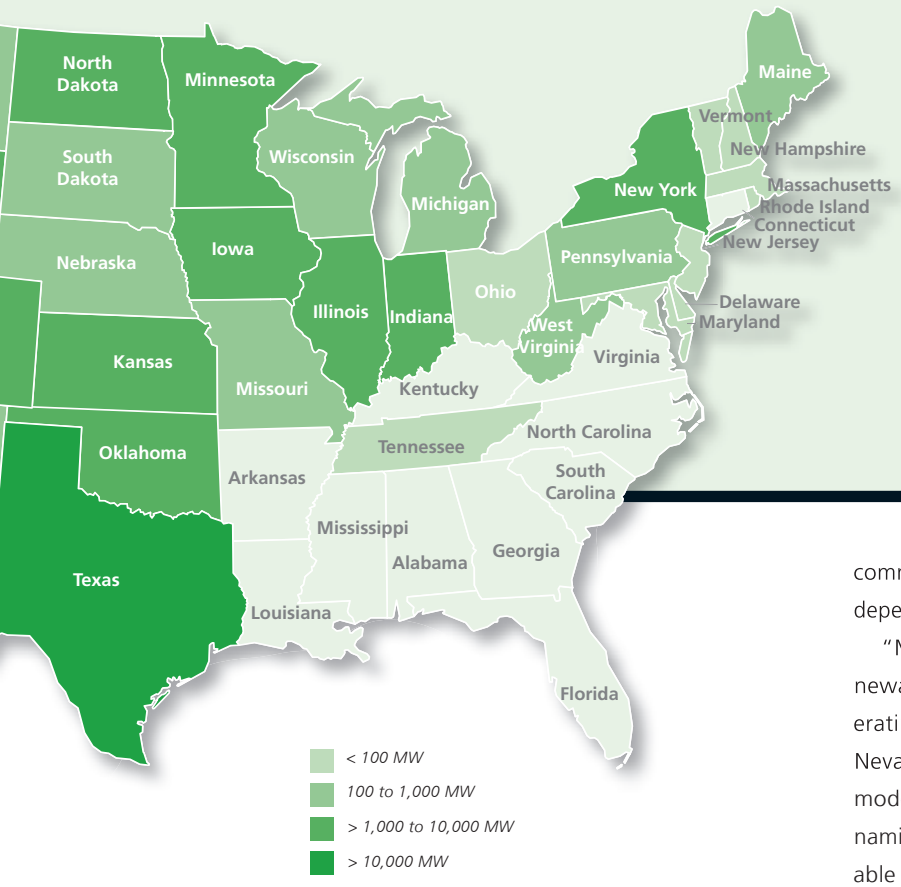
"Offshore wind is getting closer to being a reality in North America, but generally has more permitting hurdles than onshore wind. Offshore wind projects are also more expensive than onshore projects due to increased foundation, electrical infrastructure, installation and operating costs," says Mr Bell. Offshore California and Oregon, the continental shelf quickly dips into very deep water ruling out large-scale, near-shore offshore wind farms. Interest in offshore wind power is therefore focused on the north-eastern U.S. seaboard.

CFD. Computational fluid dynamics technique is used to produce simulations of the atmospheric boundary layer (ABL) for wind power applications.

However, produce too much wind energy and the distribution and grid capacity will soon be exceeded. Some wind power projects in western Texas saw significant curtailment due to a lack of capacity in the power grid. "This is a situation," says Mr Bell, "where our Power Market Analysis services can be used to predict demand for power and assess curtailment risk before the project is built. It is important for developers and lenders to better understand congestion and curtailment risks and determine the most favourable interconnection option to maximise economic return."

Forecasting wind and sunny days requires creative thinking and state-of-the-art technology. Thus, GL Garrad Hassan is developing forecasting and computational fluid dynamics (CFD) analyses for wind energy performance assessments while its WindHelm Portfolio Manager provides a single platform to monitor, optimise and control an individual or group of turbines.

"WindHelm gives owners and operators access to key data and operational parameters. This facilitates intelligent operational decisions, therefore maximising availability, efficiency, production and financial return," says Mr Bell. However, he says the industry must invest in more research and



Top 5

BY WIND PER CENT OF STATE GENERATION

Iowa:	15%
North Dakota:	12%
Minnesota:	10%
South Dakota:	8%
Kansas:	7%

Source: AWEA

innovation, particularly wind turbine performance and siting methods, in order to increase effectiveness.

Elsewhere, marine energy is not yet generating the much hoped-for green energy with tidal and wave power plants struggling to move on from the development stage. "Commercial arrays have yet to be commissioned, as developers are focused on ensuring that the arrays can survive environmentally hostile seawaters and do not suffer reliability problems," says Mr Bell.

Requirements for Providers

Financial, legislative and environmental constraints add to the complex mix of planning, constructing and operating renewable energy power stations. In the U.S. and Canada, investment in renewable energy is heavily influenced by government subsidies and financial support. The U.S. has huge reserves of onshore natural and shale gas, relatively cheap to produce and burn to generate power. However, while wind, solar and marine technologies have little in common, they are driven forward by the desire to reduce dependence on hydrocarbon and nuclear energy.

"Many U.S. states have embraced the potential of renewables," says Mr Bell. The top three solar power generating states in the U.S. are California, New Jersey and Nevada. He points to New Jersey, which lies on the only moderately sunny east coast of the U.S. as having a dynamic solar energy sector supported by the state's Renewable Portfolio Standard (RPS). An RPS is a state policy requiring electricity providers to obtain a minimum percentage of their power from renewable energy resources by a certain date.

So, while states like New Jersey may not have the best solar resources, the regulatory incentives including their RPS and strong local demand make solar work for New Jersey. In sunny but wind-poor states such as Florida, interest in solar power is growing. Florida's coasts are also being assessed as possible sites for wave and tidal arrays powered by the Gulf Stream.

The U.S. has a global lead on early-stage technology investment and GL Garrad Hassan is well-placed to develop future game-changing technologies that are needed to transform the renewables energy sector. ☐ **BM**

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One-Stop Shopping

GL Garrad Hassan's independent engineering services help to realise the largest U.S. wind farm development yet

The Shepherds Flat Wind Farm in Gilliam and Morrow Counties, Oregon, is one of the most ambitious inland wind farm project the world has seen to date. The 1.4-billion-dollar financing scheme arranged jointly by Citibank, N.A., The Bank of Tokyo-Mitsubishi UFJ Ltd., WestLB AG New York Branch, and RBS Securities Inc. required a full technical due diligence review which was provided by GL Garrad Hassan. In addition, the GL renewable energy consultancy has been put in charge of monitoring the ongoing construction work and providing technical support throughout the construction phase to underpin the anticipated term financing at commercial operation.

Full Financial Model Review

The independent technical due diligence review included an on-site assessment of the energy production, a technical assessment of the site suitability, the plant, the equipment and the material procurement, construction and operation contracts. In addition, its experts analysed the project costs and carried out a full financial model review. GL Garrad

Footing.
The construction of the Shepherds Flat Wind Farm in Oregon, USA, started in May 2010.

Schedule.
A total of 338 GE wind turbines with an installed capacity of 845 MW will supply electricity by 2012.

Hassan's final independent engineering and wind resource assessment reports served as a foundation for investment decisions made by over two dozen financial institutions involved in the project financing. Stuart Murray, a director in Citibank's Infrastructure and Energy Group said: "GL Garrad Hassan has worked diligently on this project, providing the project stakeholders with timely due diligence reviews and valuable technical support. Their continued involvement in the project will help to assure construction quality."

ABSTRACT

- Shepherds Flat Wind Farm is projected to be one of the largest land-based wind farms in the world
- GL Garrad Hassan has conducted a full technical due diligence review and is providing construction monitoring services

The 845-megawatt Shepherds Flat Wind Farm will consist of 338 GE 2.5-megawatt turbines, in the first large scale installation of this turbine type in North America. Construction commenced in May 2010, with commercial operation expected to begin in 2012. The credit facilities comprise 525 million US dollars in fixed-rate bonds with a tenor of construction plus 19.5 years, a 675-million-dollar floating-rate construction/term loan with a tenor of construction plus twelve years, and 226.2 million US dollars in letter of credit facilities with a tenor of construction plus five years. The senior funded debt and a portion of the letters of credit is 80 per cent guaranteed by the Department of Energy through the Financial Institutions Partnership Program.

Landmark Project

Phil Dutton, Senior Vice President of Independent Engineering at GL Garrad Hassan said: "The Shepherds Flat project represents a significant milestone in the history of wind power in North America, both in terms of its size – one of the largest wind power projects undertaken in the world – the technology – highly advanced GE turbines – and the creative financing structure with a DOE-backed loan guarantee. GL Garrad Hassan is pleased to support this landmark project." Its Operational Services group in North America will continue to support the project during operation, providing annual budget and summary performance reviews once the project has reached commercial operation. □ **BS**

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Information. Sophisticated software unlocks optimisation potential hidden in the operational data of wind turbines.

The 500-Million-Euro Job

Owners and operators are under increasing pressure to reduce operational costs while improving the efficiency of their wind farm portfolios. GL Garrad Hassan has developed a new software tool to help facilitate this

There are 200,000 megawatts of wind turbines currently operating globally and many of them do not meet their full production potential, because they are not operating at optimum production levels. While this is obviously an issue for both manufacturers and owners, it is also a significant problem for the wind industry as a whole: wind energy has arrived in the mainstream of electricity generation and therefore direct comparisons are made between it and other older sources of electricity.

For wind energy to consolidate and extend its position, and quash the detractors, it needs to perform at its full potential. What might the impact be? GL Garrad Hassan has used average figures to demonstrate what is at stake and provide food for thought for the industry as a whole.

ABSTRACT

- GL Garrad Hassan's WindHelm Portfolio Manager provides a single platform for data management and analysis
- Where performance is concerned, well-monitored sites can achieve 100 per cent power curve efficiency

Data is routinely recorded by many sensors on each individual turbine on a ten-minute basis and can be incredibly valuable in helping to monitor and optimise the performance of a turbine, a farm, or an entire portfolio. Realising the full value of this data, however, requires a significant understanding of real-world performance monitoring and some sophisticated data management as well as analytical tools. Original equipment manufacturers need data to facilitate their O&M and help them meet their availability and performance warranties. Owners also need data to enforce those warranties but, while they provide a good safety net in the early years of operation, they should not form the entire basis for any owner's asset management and optimisation decisions.

Value of the Approach

Even where there is some upside sharing, it is pretty clear that it is the owners who have the strongest motivation to maximise performance. In a multi-supplier or even multi-technology portfolio, they find themselves being the only party really able to squeeze maximum value from the whole

Photo: Dreamstime

Data. Realising the full value of operational data requires a significant understanding of real-world performance monitoring.

system – and there is a lot more value to be extracted from the data by taking that approach. Corrective action in the field costs owners money and requires comprehensive data management. The performance monitoring program will reduce those costs by allowing the related activity to be targeted in an accurate and timely manner.

Benefits of a Single Data Solution

GL Garrad Hassan's new WindHelm Portfolio Manager solution provides a single platform from which to access all data in a uniform way regardless of the turbine manufacturer. Imagine if all of the world's turbines were part of one giant portfolio and all the data were brought together in this way. The benefits to be extracted from being able to analyse the mountain of data which has been expensively collected, but does not currently get anywhere near the attention it deserves, are twofold:

- Efficiently crunching that data would facilitate smart and timely maintenance decisions.
- Maximum revenue would be earned.

Availability Still the Primary Focus

Although it is realistic to assume that a modern turbine can achieve an average availability of up to 98 per cent, this is not the average availability across the world's operating turbines. Published analyses by GL Garrad Hassan and others suggest that the European average is in the 97 to 98 per cent range, whereas the availability of the U.S. fleet is a couple of per cent lower. Offshore projects are a different story, with access problems multiplying up any downtime so that many projects are struggling to achieve over 90 per cent availability – a level which all but the most remote projects should be able to exceed comfortably. ▷

Photo: iStockphoto/volwag

So, there is still some scope to improve operational practice and, in the context of offshore projects, a pressing imperative to do so.

While availability has improved over the recent years, it remains the main focus of operators. GL Garrad Hassan's experience indicates that by also monitoring operational efficiency, to make sure that turbines perform at optimum levels during the time that they are available, the yield can improve by another one per cent. Common causes of degradation of performance such as de-rating, non-optimal controller settings, dirt, component misalignment and sensor error can all be rapidly identified and corrected with a comprehensive approach to collection and systematic scrutiny of data.

SCADA. Sophisticated Wind Farm Supervisory Control and Data Acquisition System.

Predictive Maintenance

GL Garrad Hassan is actively involved in the EC RELIAWIND R&D project – classifying every permutation of a physical part of a turbine, situation or failure mode. Structuring this methodology into an operational monitoring program allows data to be collected in relation to each classification, which, in turn, provides information on the seriousness and probability of each failure mode and operational deficiency. This approach enables predictive and targeted intervention – moving beyond capturing what has already gone wrong with a turbine. If short-term forecasting data is also at hand, then the timing of any required intervention can be set to minimise its impact on revenue, or for larger projects and portfolios, on the transmission system operation.

Achieving the above levels requires a joined-up approach with a single robust data management solution and the right analyses, whether these are performed by a person or by technology. This approach allows desk-based staff to provide those in the field with the guidance needed to make use of their resources with maximum benefit and minimum cost. Imagine if the global fleet of 200 gigawatts

WindHelm Portfolio Manager

Owners and operators are under increasing pressure to reduce operational costs while improving the efficiency of their wind farm portfolios. GL Garrad Hassan has developed a new software tool to help facilitate this. WindHelm provides a single platform for the monitoring, optimisation and control of any combination of operational turbines, farms and portfolios. It gives owners and operators uniform access to, and analysis of, their SCADA data. This facilitates intelligent operational decisions, thereby maximising availability, efficiency, production and financial return. WindHelm was developed out of GL Garrad Hassan's leading independent SCADA product.

With a rich reporting environment and an advanced analysis engine, WindHelm enables clients to get real val-

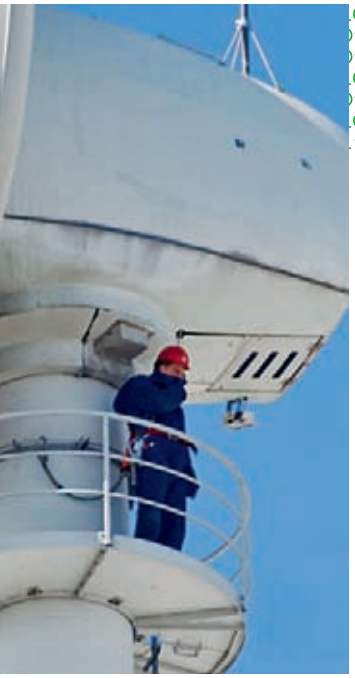

Photo: REpower Systems AG

Maintenance. Many of the wind turbines world-wide do not live up to their full production potential.

of operating wind turbines were managed that way. Taking into account the current levels of availability and operational efficiency, it is not outlandish to think that there could be scope for a global improvement of two per cent in output or 500 million euros more per annum – definitely worth the effort!

Operational Experience

With significant understanding of both the asset and the resource, GL Garrad Hassan has been bridging the gap for owners and operators for years, providing a range of services to help them get the most out of their portfolios and improve the bottom line. Its forecasting team provides short-term forecasting for over 33 gigawatts of wind projects and portfolios worldwide, from one hour to ten days in advance, and its asset management and optimisation team has analysed over 30 gigawatts of operational assets globally. GL Garrad Hassan's new WindHelm Portfolio Manager software complements the existing service range. It offers a core facility for owners and operators to access and exploit the data related to their turbines, regardless of manufacturer, in a uniform way across their portfolio. WindHelm combines the strength of GL Garrad Hassan's asset management and optimisation experience with the underlying technology from its independent SCADA system which is presently used to monitor over six gigawatts of operational wind farms around the world. It has a flexible analysis and reporting system for those that really want to drill into their data, a built-in Operational Analysis reporting pack, written by GL Garrad Hassan's asset management and optimisation experts, and facilitates the analysis and profiling of turbine and component reliability. □ **JH**

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ue out of their wind farm data. Experts from GL Garrad Hassan's SCADA and asset management as well as optimisation teams have worked together to offer a broad range of reports based on their significant experience in helping clients around the world to effectively manage and optimise their assets. WindHelm also offers the flexibility of user-defined reports for clients that would prefer to conduct their own advanced analyses.

Reporting. An advanced analysis engine enables clients to get real value out of their wind farm data.

Green Energy. Project developers have to carefully analyse and mitigate environmental and social impacts in order to receive necessary governmental approvals.

Building a Greener Future

GL Garrad Hassan offers an integrated approach for optimised project development. Dedicated experts successfully support the siting and permitting process of renewable energy projects

ABSTRACT

- GL Garrad Hassan offers E & P services to optimise renewable project designs
- A three-pronged approach clarifies the risks associated with prospective projects

Supporting the permitting process at the local State/province and federal level, GL Garrad Hassan has a dedicated team of environmental specialists that offer the complete range of environmental and permitting (E&P) services for renewable projects under development, under construction or in operation.

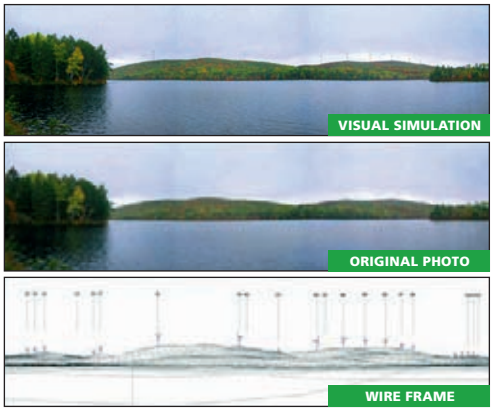
Its integrated approach to project development combines environmental and permitting, engineering and geographic information system (GIS) services, working together to ensure optimal project siting.

Experience in North America

GL Garrad Hassan is one of the world's largest renewable energy consultancies. Here is a selection of their recent siting and permitting work undertaken in North America:

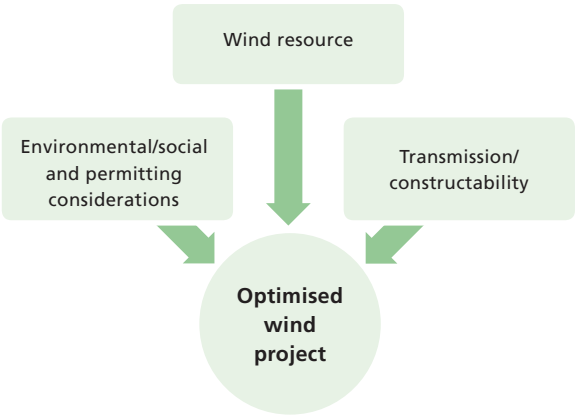
- More than 5,000 megawatts of environmental and technical studies such as noise monitoring/modelling, electromagnetic interference (EMI) studies, visual simulations, and shadow flicker for wind and solar projects
- More than 4,000 megawatts of federal, state, and local permits managed for wind and solar projects
- More than 7,000 megawatts of environmental due diligence for project financing and acquisitions
- More than 150 projects of critical issues analyses and fatal flaw studies
- Countless hours involving support to governmental agencies and industry associations in connection with policy developments, including onshore and offshore wind as well as solar issues.

Developers of a renewable energy project not only face engineering challenges. Permission for project development can only be granted once a number of environmental hurdles have been overcome. As a one-stop shop for ▷



Simulation. **GL Garrad Hassan provides a variety of essential technical studies.**

Photo: Dreamstime



Analysis. To achieve an optimised wind project, the environmental specialists of GL Garrad Hassan assess different potential impacts and propose site-specific mitigation measures to reduce environmental risk.

Photos: Dreamstime

Sources. Wind, wave, tidal and solar energy: Siting and permitting plays a key part in GL GH's integrated approach to project development.

▷ engineering and environmental services, GL Garrad Hassan offers an integrated approach to project development. The bottom line for the client is the harmonious integration of engineering and the environment to optimise project design.

Critical Issues Analysis

GL Garrad Hassan utilises a three-pronged approach, assessing potential environmental impacts, transmission and interconnection feasibility, and energy production. This provides clients with an approach to understanding the risks associated with prospective projects. The consultancy excels in assisting developers with decision-making based on project constraints.

Technical Studies

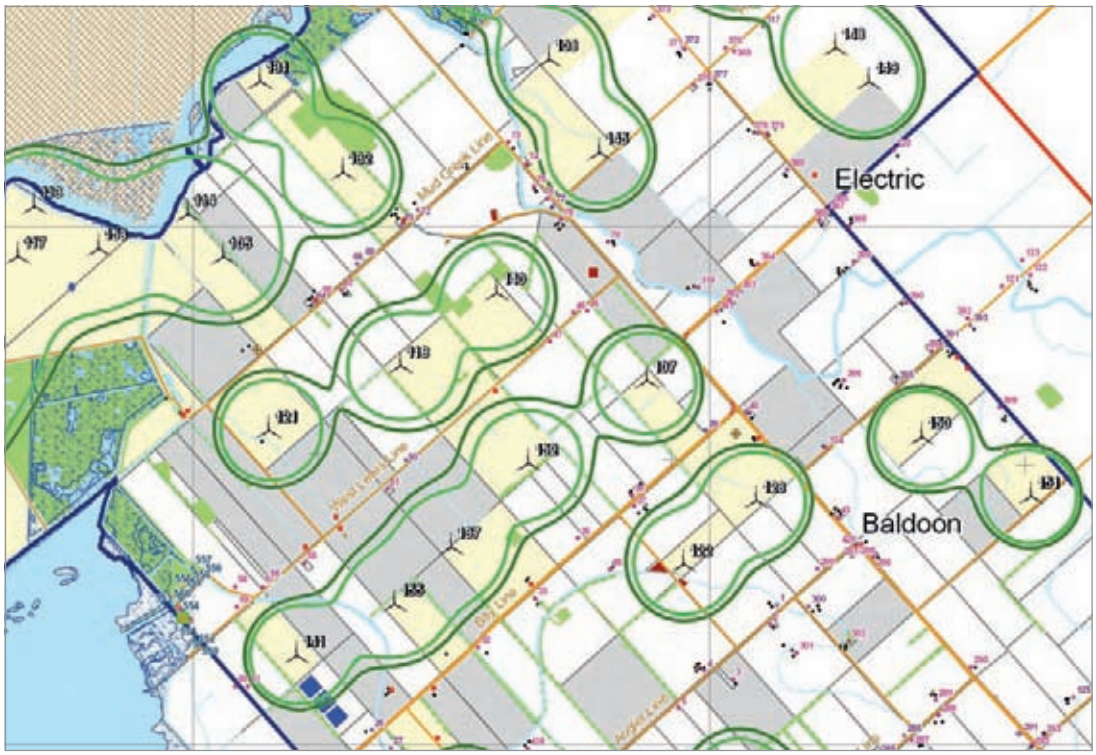
The engineers and land-use planners possess the in-house skills to provide a variety of essential technical studies for environmental agencies (EAs), environmental impact statements (EISs), and comprehensive state and local permits. These include the following:

- Visual simulations and visual impact assessments
- Shadow flicker analysis
- Noise modelling and on-site noise monitoring
- Radio-communication and radar interference studies.

Environmental Studies

An extended team of scientists and biologists conduct the required environmental studies for environmant agencies EAs and EISs, and comprehensive state and local permits. These include the following:

- Wetland and water surveys
- Wildlife surveys
- Rare-plant surveys



Permitting Process.
GL Garrad Hassan provides support to developers for public hearings.

- Cultural resource, geotechnical and palaeontological studies.

Comprehensive Permit Management

With over 4,000 megawatts of comprehensive permit management experience, GL Garrad Hassan is well-suited to handle permitting in all jurisdictions and is able to quickly adapt its approach to meet the requirements of local regulations and policies.

Agency and Stakeholder Involvement

Early and effective agency and stakeholder involvement promotes a timely permitting process. GL Garrad Hassan project managers draw from their experiences in working with lenders to tailor agency correspondence and documentation to mitigate future project risks. Whether working with USFWS on wildlife study methodology or the Federal Aviation Administration (FAA) on lighting plans, GL Garrad Hassan balances all aspects of developers' goals.

GL Garrad Hassan provides innovative services during stakeholder meetings, such as audio representation of turbine sounds, 3-D and animated simulations. The consultancy has also offered support to developers for public hearings as well as expert testimony on issues such as noise, aesthetics, electromagnetic interference and wildlife issues.

Construction and Operational Compliance

Once renewable facilities receive regulatory approvals and financing, construction and operations can present permitting and compliance challenges. GL Garrad Hassan provides the full range of construction oversight for NDPES compliance, biological and wetland monitoring, and other resource protection services. It has experience preparing management plans, such as project specific avian and bat protection plans (ABPPs); spill prevention, control, and countermeasure (SPCC) plans; as well as other general avoidance, minimisation and mitigation procedures. Developers have called upon the consultancy to manage post-construction wildlife and avian mortality monitoring and general use surveys. **PH**

USFWS.
The U.S. Fish & Wildlife Service aims to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people.

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offshore

As a technical authority on the offshore wind market and with its significant project management expertise, GL Garrad Hassan provides support across the complete project lifecycle.

Photo: iStockphoto

Offshore Uncertainties

Offshore wind energy projects are different. Handling the challenging conditions of the maritime environment competently requires special expertise. GL Garrad Hassan offers specialised seminars to engineers

ABSTRACT

- Designers of offshore wind turbines must consider a multitude of site conditions
- GL Garrad Hassan workshops help stakeholders understand the implications

Offshore installations must resist the onslaught of the elements for many years and run reliably without requiring costly maintenance and repair. Compared to onshore projects, offshore wind turbines face additional operational risks due to weather and access conditions, equipment exposure and subsea cabling. Nevertheless, reliable wind conditions at sea justify the effort.

GL Garrad Hassan offers seminars and workshops to help shipping companies, project managers, banks, developers and operators understand the complex natural, technical and risk-related factors involved in offshore power generation. Wind yield, wind climate and wave loading are of particular importance to design engineers, as are the technical details of turbines, support structures and electrical systems. GL Garrad Hassan renewables experts Peter Frohböse and Jérôme Jacquemin hold one-day workshops addressing all these issues.

Energy Yeld Uncertainties

Peter Frohböse explains how to predict the energy yield of an offshore wind turbine: First you determine the gross energy potential based on the turbine performance characteristics and the predicted wind regime on site. Then you subtract the losses: electrical system losses, availability and wake losses, as well as high wind hysteresis, ice build-up and blade degradation, substation maintenance and utility downtime.

The objective of wind and energy assessments throughout the development stage is therefore to reduce energy prediction uncertainty to an appropriate level, e.g. by improving instrument accuracy, the accuracy of wind flow modelling, wind data correlations and the consistency of reference sources. Wind mapping will also be beneficial to site selection and feasibility if performed at an early stage.

Seabed conditions and foundations

Wind turbine foundations can account for as much as 20 to 30 per cent of the project costs. Thorough seabed investigations are essential to minimise the risks associated with unexpected physical site conditions. "But in all this it is important to keep an eye on the cost factor," Peter Frohböse emphasises. "Start with less expensive desktop studies of all available data, such as water depth and ground strength, before considering more expensive preliminary geophysical surveys and then going on to full geotechnical investigations like boring holes for sample testing or on-site bathymetry."

The wind turbine foundation type is selected based on the results of the investigation. A gravity-base foundation can be a solution for deeper water, but careful planning with installation contractors and authorities is needed.

Key factors for the structural assessment of offshore wind turbines are the wind and wave loads. Integrated wind-and-wave calculations and the effects on fatigue behaviour are an essential part of the design process. The life of an offshore wind turbine is simulated by a set of design

Careful Design. Offshore wind turbines operate in a forbidding environment. Tower foundations must be matched to the seabed and wave conditions.

Photo: Siemens AG

Photo: REpower Systems AG

situations representing the most significant conditions the planned wind turbine will be exposed to. As for breaking wave and ice loads, designers have yet to develop a unified calculation method.

Electrical Systems

Another critical concern is subsea cabling. Burying the cables is the best but the most costly way of protecting them. A rocky seabed can cause the costs to skyrocket; in some cases, burying the cables may not be feasible at all.

Approximately 70 per cent of all cable failures are due to human activity, such as fishing or anchoring. In January 2005, the main export cable of the Arklow windfarm in Ireland was severed during a storm. The cause has not been confirmed but an anchor strike is suspected. It took two months to repair the damage. The loss in revenue was huge.

Wake Losses. In a wind farm, the quality of wind available affects the performance of the turbines located further back.

Project Management Skill Is Needed

Offshore projects differ from onshore projects in the proportion of non-turbine work required, which can account for up to 50 per cent of the project's capital costs, compared to 15 to 20 per cent for onshore projects. Well-timed and targeted engineering design and analysis are essential, and modelling is required to understand the risks and arrive at an optimal solution.

The success of any offshore project heavily depends on the availability of highly skilled personnel combining practical project management with high-end analytical engineering expertise. GL Garrad Hassan training courses can provide stakeholders with essential knowledge they need to make well-informed decisions. □ **NL**

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Platform.
A helicopter carries the service team to an offshore wind farm.

Service team Alfa is stationed on an island in the North Sea with a tidal harbour, involving a transit time of one hour to the offshore wind farm (OWF). Service team Bravo, on the other hand, is located in a tide-independent harbour on the North Sea coast of the Netherlands, with a transit time to the OWF of two hours. And then there is crew Charlie, also based in a tidal harbour but with a transit time of 1.5 hours.

Which of the three ports will prove to be the best choice for OWF maintenance? What at first glance appears to be a brain-teaser is really a top-priority challenge for an OWF operator. Selecting the right harbour as the base for a wind farm with a service lifetime of at least 20 years can have a decisive influence on its profitability. And it is only one of the many decisions that have to be made.

Long Computing Time

The German wind energy industry directed its attention to the oceans at an early stage. The fact that owners, developers and wind turbine manufacturers are only now processing the first offshore projects is due to several reasons. One of the major obstacles to an early start proved to be the problem of not being able to estimate to a sufficiently reliable degree the costs of operation and maintenance (O&M) of the OWFs

ABSTRACT

- The costs of operation and maintenance of offshore wind farms are hard to estimate
- GL Garrad Hassan's simulation tool "O2M Plus" is vital for performing a holistic analysis of the O&M strategy

Getting a Grip on Costs

The operating costs are a decisive factor for the profitability of an offshore wind park. A simulation tool can greatly facilitate the decision-making process

lying far off the coast. However, it is essential for the insurability and also for the project financing to get a grip on this cost accounting item.

GL Garrad Hassan, a wholly-owned subsidiary of Germanischer Lloyd (GL), has now presented a simulation tool with which not only the O&M costs can be determined with a good approximation to reality but which can also be used to model the many parameters of an O&M concept. A few years ago, the British consulting firm Garrad Hassan and GL had each developed their own simulations; following the acquisition of the British firm by GL, these were combined to form the "O2M Plus" package.

O2M Plus. The model allows consideration of weather windows, vessel size, staffing options, availability of spares and wave climate.

The program sequences of the tool are quite complex. "All of the possible combinations of the various parameters are modelled," emphasises Project Manager Wilhelm Heckmann. The actual computing work is done in Bristol, UK. "For one complete pass of the program, the colleagues in Bristol need one or two whole days of pure computing time."

Judgement Reserved until the End

This long period for computer simulation results from the large number of possible variants. Many decisions have to be made at the beginning. It all starts with the O&M strategy: Should it be defect-driven, or perhaps interval- or condition-based? "We then have to consider very customer-specific requirements," says Heckmann. "For instance, should helicopter service be allowed or not? Is there a fixed service platform in the OWF? How many crews are deployed? What ships? What are the weather conditions in the region under consideration? And much, much more." Early definitions tend to have major effects on later decisions and options. Although it is possible to try out changes at the touch of a button once the program has completed its run, this is only feasible if the basic data has been included in the current run. If strategic decisions are revised, the program has to be started all over again.

As a matter of principle, all variants are always tried out in their entirety. The tool does not discard any options prematurely just because they have turned out to be suboptimal in a previous step. Take the harbour issue, for example: even if the decision for a particular harbour is shown to be optimal, all other harbour variants are still considered in the subsequent steps. In the example mentioned above, stationing the crew on the North Sea island turned out to be the best solution – a surprising result in view of the tidal dependence. In the next computing run with all variables, this could then change again, as Wilhelm Heckmann points out. For this reason, it is vital to perform a holistic analysis of the O&M concept. □ JI

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Photo: alpha ventus/Jan Oelker

certification

Certification of wind farms, turbines and their components is state-of-the-art and a must around the world. GL Renewables Certification offers project and type certification.

Photo: iStockphoto

Riding out the Gridlock

The rapid expansion of wind energy is putting a severe strain on the electricity distribution networks. Wind turbines have to stay grid-compatible

There are dates you never forget – like 14 August 2003. Shortly after 4 p.m., the electricity grid in the U.S. northeast and the adjoining Canadian province of Ontario collapsed entirely. The blackout, which went down in history as one of the most extensive ever to occur in the U.S.A., cut off the power to 50 million people.

As is true for many countries around the world, the energy supply in the United States is faced with a major transformation. Wind energy is increasingly beginning to replace the conventional power generation technologies, with the installed wind power capacity already exceeding 40 gigawatts.

The utilisation of wind energy requires that wind turbines operate in a grid-compatible manner and that they are able to deal with grid faults. GL Renewables Certification has now revised its "GL Wind Technical Note 065" on the grid compatibility of electrical power genera-

ABSTRACT

- The requirements regarding the grid compatibility of wind turbines in the U.S.A. are high
- GL Renewables Certification has formulated the necessary guidelines

Energy Supply.
In the U.S., the installed wind power capacity already exceeds 40 GW.

tion systems – which includes wind turbines – and adapted its technical requirements to reflect the needs of the North American market. The design criteria, tests and certifications can therefore be applied to 60-hertz technology.

Balancing the Grid

"Even if widespread grid failures such as the 2003 blackout are absolute rarities, the grid operator must be able to rely on the wind turbines to get the grid up and humming again in the event of a problem," says grid expert Tobias Gehlhaar of GL Renewables Certification. "The grid operators keep generation capacity in reserve to prevent a blackout. And if a grid fault does arise, the wind turbines must carry on running – called riding through the low-voltage fault – and must supply power to stabilise the grid during the fault and again after the fault".

UWIG. The group provides a forum for critical analysis of wind technology for utility applications and informs on the status of wind technology and deployment.

To keep a grid operating robustly, the dispatchers in the grid control centres have to keep the system frequency within a narrow band. In normal cases, it is sufficient to connect or disconnect electrical consumers, hence balancing out the operational parameters. It must be possible to control wind farms to meet the grid requirements – i.e. reduce their output when the frequency is too high.

Both external and internal factors can upset the balance. If the grid should happen to collapse, modern wind turbines must remain online and able to deliver active current immediately, which was not a requirement in previous years. "Some grid operators also require that the turbines be able to deliver reactive power," says Gehlhaar.

The requirements set by the various grid operators with respect to the grid compatibility of wind turbines tend to differ in terms of the details. This turns the certification of wind turbines in the United States into an extremely demanding task. "The situation in the U.S.A. is certainly complicated," agrees Charlie Smith, CEO of the Utility Wind Integration Group (UWIG). This interest group says that there are as many as 178 grid operators in the U.S.A. Requirements for the grid technology have thus far only been formulated in FERC (Federal Energy Regulatory Commission) Order 661-A for the low-voltage grid. At the National Environment Research Council (NERC), a task force is working on a grid code for the transmission lines. In the estimation of the UWIG, it could take years before this project is completed.

Calculated Short-Circuit

Nevertheless, it is possible to proceed without a uniform national grid code. GL Renewables Certification offers type certification for wind turbines as well as project certification for wind farms worldwide as a system service. "For this, we need the precise grid code for that special region," GL expert Gehlhaar points out.

The service offering of GL also includes the validation of software models. In the American wind energy industry, this usually involves the simulation of a grid failure, with a subsequent test of the turbine's grid compatibility. With a mobile "fault ride-through" test container of GL Garrad Hassan America, these simulations can be checked in the field with a "real emergency". A short-circuit is produced on purpose, which in reality would be equivalent to a grid fault. The turbine then runs under no-load conditions and must withstand this situation without difficulty. According to Gehlhaar, clear-cut criteria have been set. "We look at the final result. The plant must not go into overspeed and fall down". □ JI

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The Answer is Blowing in the Wake

GL Garrad Hassan develops "Bladed" wake meandering model while GL Renewables Certification improves the Guideline's approach to wake assessment

GL Renewables Certification and GL Garrad Hassan were two of the nine partners in the EU FP7 research project TOPFARM that comprised the development of software and control schemes to take account of wind farm wake impacts on turbine power output and loads. Results covering the Bladed wake meandering model validation and a comparison to common IEC-standard design approaches were presented at the scientific poster session of EWEA 2011 in Brussels.

The research was motivated by the fact that wind turbine wakes significantly affect the downstream wind field, decreasing performance and increasing dynamic loads for downstream turbines. This influence is particularly significant in offshore wind farms, where the number of turbines is typically large and the ambient turbulence low. Consequently, the need arose to improve wake induced wind field modelling.

Within the EU research project TOPFARM, the wake model developed and calibrated by Risø DTU has been improved. This dynamic wake meandering (DWM) model has been implemented in the wind turbine load simulation software Bladed. Load validation of the Bladed DWM model against two load measurements has been performed. Quantitatively good agreements with the load measurements have been found and GL Garrad Hassan is proud to state that the Bladed DWM model improves the account of load impact from wind turbine wake influences.

One main question governing the analysis of offshore wind farms is whether the existing methods are conser-

ABSTRACT

- Underestimated in the past, the effects of wakes on downwind turbines are now studied in depth
- GH Bladed, GL's load simulation software, now features a powerful wake modelling tool

Photo: Madsen

Computation. Half wake with EllipSys3D.

Photo: sinit/photocase.com

Blades. **The project addresses the optimisation of wind farm topology and control strategies.**

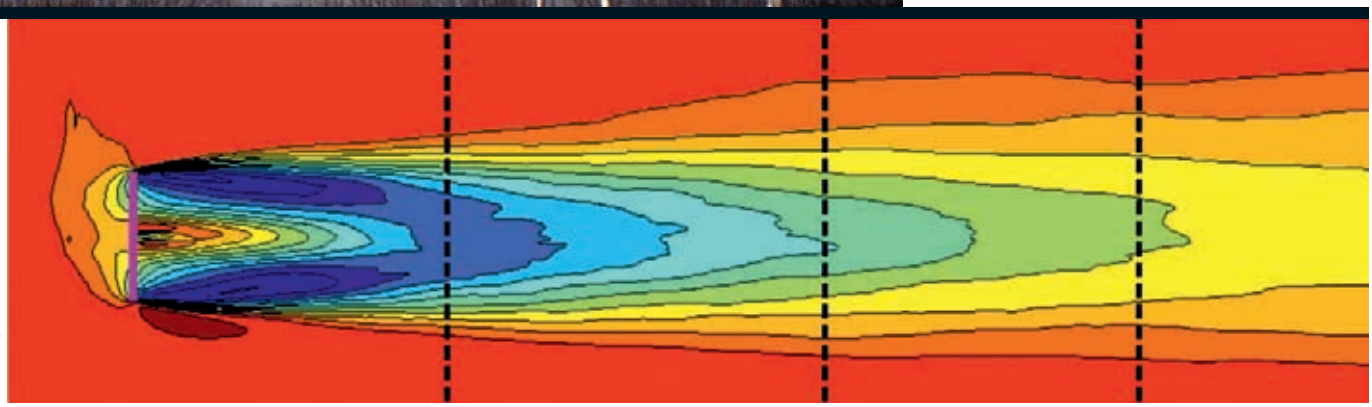

Photo: Risø DTU

Turbulence. **ACL wake simulation.**

vative and how much room exists for optimisation. These aspects were addressed by further research that was performed in the field of turbine design and certification approaches.

Further Developments

Wake-induced fatigue loading was studied by using the Bladed DWM model. The results were then compared to the recommendation of the IEC 61400-1 standard to account for wake-load impact. The IEC 61400-1 approach is commonly used by the industry for design and certification purposes to predict wake-affected wind turbine loading. The fatigue load comparisons of the Bladed DWM model with the IEC-Standard approach suggested that the IEC approach is conservative at low turbine spacing but may underpredict wake loads for spacing larger than five rotor diameters at low ambient turbulence.

GL Garrad Hassan is currently implementing the Bladed DWM model in the full commercial version of Bladed and aims to release it as part of version 4.2. GL Renewables Certification is actively using the research findings from TOPFARM to further develop its Guideline for the Certification of Wind Turbines. □ **BS**

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MORE INFORMATION.

"Unsteady Navier-Stokes Simulations of a Rotor Operating in Wake", by Frederik Zahle, Helge A. Madsen, Niels N. Sørensen.

Customised Quality

A wind turbine is made up of many different components. Only if the quality of all the parts is certified can the profitability of the whole installation be safeguarded

ABSTRACT

- Certification of wind turbine components reduces the losses resulting from outage
- GL Renewables Certification provides customised solutions for the specific requirements

The U.S.A., China, Germany and Spain are the great wind energy nations of our time. When travelling through these countries, one is always impressed by the sight of whirling rotors in large wind farms – interrupted here and there by stationary turbines. The technical availability of a modern wind turbine lies at over 95 per cent, but failures of vital components, such as the gearboxes, bearings, rotor blades or generators, are responsible for losses amounting to billions of dollars worldwide. Only a turning turbine earns money for its operator. The outage of a three-megawatt plant alone will lead to expenses of several thousand dollars through loss of income – for every day of downtime. And if delivery of the replacement components is delayed, the costs including de- and reinstallation, the repair itself, transport and crane logistics can easily exceed the hundred-thousand-dollar threshold.

Moreover, the total costs arising from the outage of a turbine have risen in recent years with the growing size of the plants. This makes the quality of the components obtained from the supply chain all the more important. Certification of the components, as provided by GL Renewables Certification, therefore constitutes the state of the art and has become a "must" everywhere in the world. "The objective of component certification is more than to confirm that the component for a wind turbine has been designed, documented and manufactured in conformity with design assumptions, specific standards and technical requirements," explains Axel Dombrowski, Head of Department Machinery Components and Electrical Engineering at GL Renewables Certification. "You could also put it like this," he continues, "the certification of a component is performed analogously to the type certification of a wind turbine and hence equally important to the certification of the whole wind turbine. It is based on the new Guideline for the Certification of Wind Turbines, Edition 2010, which we revised last year."

Four Modules

For a long time now, GL has been certifying the most strongly loaded components: rotor blades and gearboxes, and also generators and towers. To an increasing extent, the turbine manufacturers and equipment suppliers are also enquiring about the certification of other components: rotor hubs, main shafts, frames, main bearings, brakes and couplings, pitch systems, transformers, lifting devices and converters.

Component certification is made up of the following modules:

- An assessment of the design – design assessment (DA). Here it is necessary not only to examine compliance with the applicable standards of GL but also with other codes. A particular challenge lies in the

Photo: iStockphoto/asterix0597

Wind Turbine. **Rotor blades and gearboxes are the most strongly loaded components.**

application of realistic load spectra. "As a rule, we have to arrive at a tailor-made solution for each customer," says Dombrowski.

- An Evaluation of the manufacturing and installation processes – here the so-called IPE (Implementation of design requirements in Production and Erection) is examined. While the design assessment is more or less all about "paperwork", the specific operational procedures are in the focus of the expert in charge who monitors the entire production process and installation activities for the IPE. "Of course, the expert will pay special attention to the critical manufacturing process (CMP)," Dombrowski adds.
- An internal QM system – an important role in safeguarding the quality is played by the quality management system of the manufacturer or supplier. The internal QM system is also included in the component certification.
- The testing of the prototype – this forms the keystone for the entire certification procedure.

It is only the final assessment of all the requirements that leads to the requested certificate. "As you can see," Axel Dombrowski sums up, "there are a number of different demands to be met. We want to find solutions tailored to the specific needs of our customers." JI

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news in brief

Celebration. **Andreas Schroeter (GL), Nimish Shah (Suzlon), Pekka Paasivaara (GL), Christian Nath (GL), Mike Wöbbeking (GL), Dr Rüdiger Kortenkamp (Suzlon) (from l. to r.).**

Suzlon A Trustful Partnership: Suzlon Energy Ltd. and GL Renewables Certification Have Been Cooperating for Ten Years

brussels 50 type certificates, 100 statements of compliance and 350 certification reports had been issued by GL Renewables Certification (GL) to Suzlon Energy Ltd. in the past decade. At EWEA 2011 in Brussels, Belgium, both companies celebrated their successful collaboration and look forward to their future cooperation.

"This marks an important milestone in our long-standing relationship with GL Renewables Certification. It is our constant endeavour to deliver innovative, robust wind power solutions that deliver maximum value to our customers. Through GL's exceedingly high standards we have been able to continuously raise the bar," says Tulsi R. Tanti, Chairman of Suzlon. Pekka Paasivaara, Member of the Executive Board of GL, explains: "We are delighted to look back on this ten-year cooperation with Suzlon. All along, we have shared our common sense of quality standards and successfully concluded our joint state-of-the-art projects. We are honoured to have such a trustful partnership and now, we are looking forward to the next ten years of intensive, fruitful cooperation."

The first type certificate for Suzlon's wind turbine types S33 300kW and 350kW was handed over in February 2001. The latest Suzlon wind turbine, the S9x in the 2MW+ range, is under certification at the moment. Over the years, 51 GL engineers were involved in Suzlon's global projects.

The type certificate confirms that a wind turbine complies with the requirements of the GL Guideline for the Certification of Wind Turbines regarding design, prototype measurements and exemplary manufacturing evaluation.

GL Garrad Hassan Simulation Software Evaluates Risks

peterborough GL Garrad Hassan's new Power Market Analysis services utilise state-of-the-art simulation software to evaluate the short and long-term risks to renewable development projects associated with external influences. These include assessing the impacts of energy curtailment, policy changes, and infrastructural development, and quantifying the financial ramifications that they have for a specific site or project.

The new services support investors and developers of renewable energy projects in North America at all stages of the project lifecycle. The Power Market Analysis services complement GL Garrad Hassan's existing independent engineering portfolio which has helped to make possible 45 per cent of all U.S. and 39 per cent of all Canadian wind farms.

As wind power has matured and the volume of projects connected to the grid has risen, there are an increasing number of geographical areas where projects experience curtailment issues. Accounting for the risk related to reduced opportunity for energy delivery, and the corresponding revenue loss, is now an essential factor in determining the value of a proposed site for project development. It also forms a key element of any technical due diligence process associated with a project.

Once a project is developed, the opportunity for its extension, as well as its long-term financial viability, can be impacted by factors such as future grid limitations, decisions affecting the design of future energy markets, and changing government policy in relation to renewable energy as part of the broader energy mix.

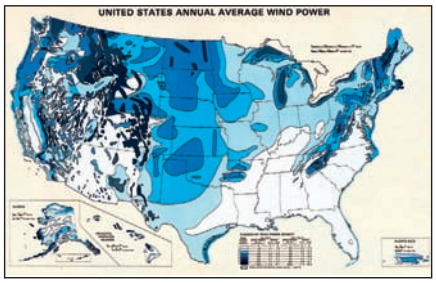

Photo: US EIA

Track Record. **45 per cent of U.S. wind farms have been delivered by GL Garrad Hassan.**

Rules for certification and construction. Our latest brochures, rules and guidelines are available on request. Order forms are available on the Internet: www.gl-group.com > Rules & Guidelines

Honour. GL Garrad Hassan's Cathy Syme has been awarded for her activities.

Award Woman of the Year 2010

san diego Cathy Syme, Senior Manager in the Operations and Asset Management Group of GL Garrad Hassan, U.S.A., was honoured by the San Diego Chapter of Women of Wind Energy (WoWE) as Woman of the Year. Ms Syme is responsible for technical due diligence for assigned projects in the U.S. Her responsibilities include programme management and technical support for GL Garrad Hassan projects related to wind turbine service and operations monitoring, technical due diligence relating to the realisation of new projects, and project engineering support for equity investor and finance clients.

The Women of Wind Energy San Diego Steering Committee said: "Our winner is an outstanding representative and model for all women in the wind industry. She has more than 14 years' experience in the wind industry where she has developed widely recognised expertise in the field of operations, finance and asset management. She was involved in many "firsts" in the wind industry earning the respect and admiration of both men and women in wind..."

New Zealand Conference Down Under

wellington International renewable energy experts met at the New Zealand Wind Energy Conference 2011, held in Wellington in April. GL Garrad Hassan contributed four presentations. Mathias Steck, Vice President GL Garrad Hassan Asia, gave a speech on the Asian wind market and showed the developments of countries like China, India and South Korea. He ended with an analysis and outlook for the wind energy business in New Zealand.

Graham White, GL Garrad Hassan Regional Manager Pacific, discussed the characterising turbine availability and showed that there are many uses and many definitions. Philip Wong Too, GL Garrad Hassan New Zealand, spoke about remote sensing. He highlighted best practice recommendations and practical uses of formal energy assessments.

In addition, William Thorp, GL Garrad Hassan New Zealand, spoke about "Wind Energy in the Pacific Islands – An Engineering Sabbatical" and showed what the energy problems are in that area, what is being done to solve the energy problems and how organisations can become involved.

Photo: NZWEA

Event. The conference was organised by the New Zealand Wind Energy Association.

Photo: Prinses Amaliawindpark

Offshore. Rapid growth on the Dutch shelf.

Netherlands Getting Closer to the Client

heerenveen GL Garrad Hassan is now registered in the Netherlands as a B.V. (Dutch limited company). The name of the new entity is "GL Garrad Hassan Nederland B.V.". The renewables consultancy has offices in Heerenveen, Leiden and Sint Maarten to accommodate the demand for consulting, design, project management services and training courses for renewable energy projects.

The Netherlands has emerged as an evolving market for renewable energies with particular emphasis on offshore wind energy. GL Garrad Hassan's Country Manager Netherlands, Ben Hendriks, calls the official registration an important step for the company: "We are now much closer to our Dutch clients and can offer our services without any restrictions." The Netherlands represents one of the most active regions in Europe in offshore wind developments. The developments on the Dutch shelf are expected to grow rapidly in the coming years. "Further, we aim at catering for the large group of Dutch marine contractors in the offshore wind industry. Our staff here in the Netherlands can now support stakeholders at all stages of wind projects by providing services and support locally," says Hendriks.

dates at a glance

Conferences & Fairs

MAY

22. – 25.05.2011
AWEA WINDPOWER 2011
Anaheim, USA

California. One of the fastest-growing trade shows in the U.S.

JUNE

08. – 10.6.2011
INTERSOLAR
Munich, Germany

Munich. International hub for solar energy.

15. – 16.06.2011
Offshore Wind China
Shanghai, China

Shanghai. Greatest offshore event in Asia.

15. – 17.06.2011
ICCI International Energy and Environment Fair & Conference
Istanbul, Turkey

29. – 30.06.2011
RenewableUK Offshore Wind
Liverpool, UK

Offshore. Experts meet in Liverpool.

AUGUST

31.08. – 02.09.2011
Brazil Windpower 2011
Rio de Janeiro, Brazil

Latin America. Huge wind resources.

SEPTEMBER

05. – 09.09.2011
26th PV Solar Energy Conference and Exhibition
Hamburg, Germany

Hamburg. Europe's top event in photovoltaic solar energy.

05. – 09.09.2011
EWTEC 2011
Southampton, UK

Southampton. Focusing on wave and tidal energy.

IMPRINT

energize renewables, issue no. 02/2011, May 2011 **Frequency** energize renewables is published four times a year **Published by** Germanischer Lloyd SE, Hamburg **Editorial Director** Dr Olaf Mager (OM), Corporate Communications **Managing Editor** Steffi Gößling (SG) **Authors of this issue** Justine Hackney (JH), Patrick Henn (PH), Jörn Iken (JI), Nora Luttmer (NL), Bruce McMichael (BMM), Bridget McEwen (BME), John McAskill (JM) **Cover photo** Wilhelm Heckmann **Design and production** printprojekt, Schulterblatt 58, 20357 Hamburg, Germany **Layout** Lohrengel Mediendesign **Translations** Andreas Kühner **Prepress** Lohrengel Mediendesign **Printed by** Media Cologne Kommunikationsmedien GmbH, Luxemburger Straße 96, 50354 Hürth, Germany

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Photos: alphaventus/ Matthias Ibeler; Solar Promotion GmbH; GE Wind Energy; Falense

GL Garrad Hassan

Training Courses – Dates 2011

Introduction to Meteorology
16 June Hamburg, Germany
30 Sept. Copenhagen, Denmark

Wind Farm Design
20 June Casablanca, Morocco
22 June Dublin, Ireland
25 July Johannesburg, S. Africa

Introduction to WindFarmer
21 June Casablanca, Morocco
23 June Dublin, Ireland
26 July Johannesburg, S. Africa

Offshore Wind Energy
21 June Hamburg, Germany
7 July Leiden, Netherlands
20 July London, England
27 Sept. Paris, France

Offshore Electrical Systems
21 July London, England

Wind Farm Projects and Investment Risk
30 Aug. Rio de Janeiro, Brazil
28–29 Sept. Copenhagen, Denmark

Turbine Technology
7–8 Sept. Bristol, England
12–13 Oct. Tokyo, Japan

For more information on these courses, see:
www.gl-garradhassan.com/en/Training.php

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