CIRCUIT

CATAPULT
Offshore Renewable Energy

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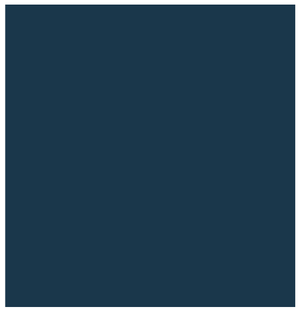
TRAILBLADERS

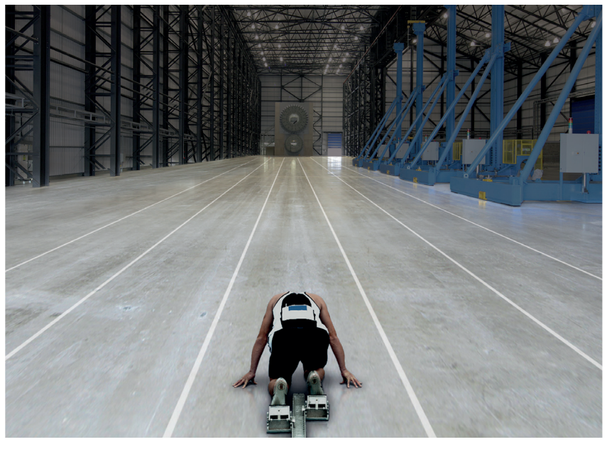
FEATURES

// Wind Blade Research Hub
New academic/industry collaboration

// Project Tag
Shedding new light on bird behaviour

// CHEG
Improving generator efficiency





THE 100M SPECIALISTS

The UK's open-access testing and research facilities for the next generation of offshore wind turbines

ORE Catapult operates a world-leading 100m blade test facility for product certification, verification and investigation purposes.

Department for Business, Energy & Industrial Strategy

EUROPEAN UNION Investing in Your Future
European Regional Development Fund 2007-13

CATAPULT Offshore Renewable Energy

WELCOME

Guest foreword - Dame Anne Glover, ORE Catapult Non-Executive Director & Vice Principal for External Affairs & Dean for Europe at the University of Aberdeen

Dame Anne Glover

The calibre of science, engineering and technology across Europe is truly inspiring. In sectors as diverse as automotive and life-sciences, materials and agriculture, ground-breaking discoveries are emerging that are redefining industries and our everyday lives.

Offshore renewables are no different, and the tremendous cost reduction in offshore wind is testament to both the inspiration and perspiration invested. However, maintaining such progress whilst staying ahead of global competition – not to mention social and political change - requires something extra.

There are two forms of innovation. The first is doing the same, but better. Changing how we do things to become more effective, more efficient. This tends to be reflected in gradual evolution and is no less valuable for it.

The second is where the greater leap of faith lies, for it is in the disruptive, the introduction of entirely new ways of doing things, not only imagining the unimaginable but achieving it.

This requires cultural change – it requires scientists to think entrepreneurial and businesses to think science. It requires highly effective communications and open minds to learn from others; it requires new people to break with old ways. It isn't comfortable, but it turns small companies into medium ones, medium ones into large ones. It is what inspires me as a scientist and what drives so much of the exciting research and development across our sectors.

CONTENTS

PAGE 6

PAGE 8

PAGE 11

Department for Business, Energy & Industrial Strategy

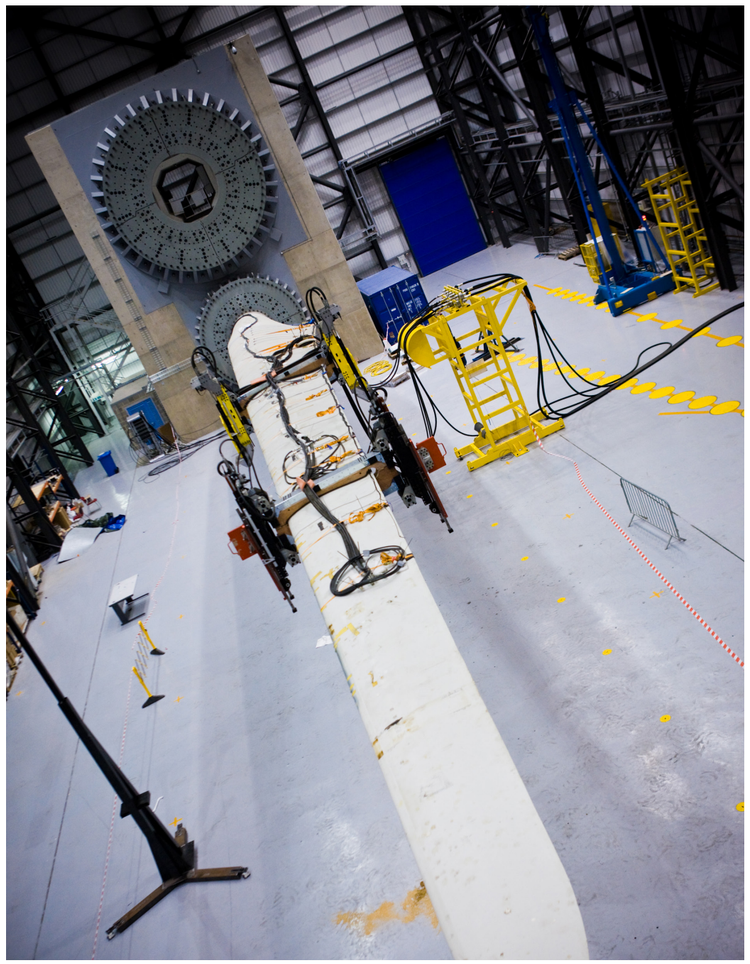
EUROPEAN UNION Investing in Your Future
European Regional Development Fund 2007-13

energy technologies institute

DemoWind Delivering cost reduction in offshore wind

WORKING TOGETHER TO UPSCALE TURBINE TECHNOLOGY

The future looks bright for offshore renewables, and it also looks big. 8MW offshore wind turbines are already being deployed in Round 3 projects, and the industry is now talking 10MW plus.



Indeed, DONG Energy's recent subsidy free offshore wind bid in Germany was largely based on the assumption that by 2025 13 to 15MW machines will be the norm. Bigger turbines mean bigger blades, with one of the longest in production, at 88-metres long, currently being tested at ORE Catapult's Blyth site. But how do you successfully upscale from 8 to 15MW? We believe strategic industry and academic partnerships hold the key.

Innovations in the design, materials and manufacture of offshore wind turbine blades can significantly lower the cost of offshore wind energy. It is an area of strategically important research and development: one in which ORE Catapult has a strong track record (see Page 6), and one in which we believe the UK can become a global leader. The Catapult sought a strategic academic partnership with one of the UK's leading universities to realise that vision – and the University of Bristol answered the call.

With world-leading composites expertise, over 150 researchers dedicated to everything from aerodynamics to blade design and materials use, and a strategic relationship with a leading equipment manufacturer, University of Bristol is the ideal partner with whom to take forward an industry-leading programme of strategic R&D into blade materials and manufacturing technology, blade integrity and design and performance.

The five year, £1.5 million Wind Blade Research Hub (WBRH) has kicked off the first phase of its programme of research, supported by a group of PhD and EngD students, a post-doctoral researcher, lecturer, and Professor Paul Weaver and Dr Alberto Pirrera (as Scientific Director and Senior Academic

image above
Composite materials

image left
ORE Catapult's blade test facility

of the WBRH respectively), working alongside the Catapult's blades research team. But the Hub is also looking to grow, to attract additional public and private investment as well as other industrial and academic partners who will help to influence and shape the research agenda.

"This unique opportunity to partner with the Catapult came at just the right time for us," explains Professor Weaver. "Our University has made a strategic commitment to grow all aspects of research associated with sustainability - we are home to the world-leading Cabot Institute, a flagship centre for all the ways we depend on and shape our planet – and participating in the WBRH enables us to pursue that strategy.

"The Hub will also enable us to develop the people and the elite technical skills that the industry needs. We hope that many of our postgraduate students will go on to forge careers in the industry, and that the University will have an impact in influencing the research agenda through journal papers, conference speakers etc. We want to build our academic reputation, with the Hub at the centre of a hive of industry and academic activity."

Paul McKeever, ORE Catapult's Head of Strategic Research, added: "The Hub model provides an excellent vehicle for translating academic output into applied research that is of real use and relevance to industry.

"We already have two significant blade manufacturing facilities in the UK – Siemens in Hull and MHI Vestas on the Isle of Wight – and we believe that the Hub can play an integral role in linking those facilities and their manufacturers back into the technical expertise, research activity and testing assets of the Hub's partners. Our vision is to establish the UK as a leading player in blade design, construction and manufacturing and attract further inward investment at the same time."

Bristol is also home to the High Value Manufacturing Catapult's National Composites Centre, an independent, open-access national centre delivering world-class innovation in the design and rapid manufacture of composites, making the choice of Bristol University an even more attractive proposition.

So what will success for the Hub look like? Dr Stephen Wyatt, ORE Catapult's Research & Disruptive Innovation Director, says it's a multi-partner, publicly and privately-funded centre for blades research excellence with its products and services being used by industry on a global scale. "Our ultimate goal is to design and manufacture more efficient blades that harness more energy from the wind. If we were able to develop, for example, a much lighter blade that may be more expensive to make, but which means you can build a much lighter turbine and therefore reduce capital expenditure and the cost of wind energy, then that would be a real achievement for the Hub."

It is expected that the WBRH will provide a blueprint for future industry/academic collaborations in areas such as electrical infrastructure, foundations and powertrains.

Paul Weaver

BLADE STUNNERS: NEXT-GENERATION WIND TURBINE BLADES

The experienced dockers at the Port of Blyth have seen it all over the years. But in early March, as the EEMS Duisburg carefully crawled its way up the river there, they were confronted with something new.

They were among the first people in the UK to witness the ship's unique cargo: an 88-metre Adwen wind turbine blade, one of the world's longest and most advanced. With its tip overhanging the 108-metre vessel's stern, its colossal scale was clear: this was a supreme feat of engineering.

As impressive as it looks now, in years to come blades of this size will be the new normal. As part of the XL Blade project, ORE Catapult is collaborating with wind industry leaders Adwen and LM Wind Power to assist in designing, validating and deploying two of the world's largest offshore wind turbine blades. This EU DemoWind-funded project isn't just about length for length's sake, though: the industry trend towards larger turbines with higher power outputs means that bigger blades are necessary if costs are to continue to fall.

The benefits of pushing the envelope can be seen in the Adwen blade's contribution to reducing the Levelised Cost of Energy (LCoE) through its lighter construction, and more predictable operational expenditure (OPEX) by means of its reliability-driven design.

The Duisburg was delivering the blade to our National Renewable Energy Centre in Blyth, where it will undergo a rigorous programme of testing in our 100m Blade Test facility. There, the project's other 88m blade – manufactured by LM Wind Power – will undergo a pioneering programme of dual-axis testing.

"Testing bi-axially isn't quite as simple as applying the single-axis test loads at the same time," explains ORE Catapult's Peter Greaves. "That would damage the blade more than in its service life, so we excite both axes at their resonant frequencies simultaneously. By doing this, the blade will experience load combinations that wouldn't occur in practice, because the two frequencies are very unlikely to be the exact same. That drives the tip of the blade in what we call a Lissajous curve.

"We analyse the fatigue that the blade will encounter in its service life, then feed that into an optimisation routine so that the test matches the service life damage over as much of the blade as possible. Once we run the fatigue tests, we then repeat the static tests so that we know the blade will handle the loads even at the end of its lifetime."

As well as reducing the time and costs of blade testing, this novel method – the brainchild of Peter, a Blades Structural Research Engineer at the Catapult – will subject the blade to loads and forces that are more representative of real-world operating conditions than the single-axis status quo.

image above
Adwen's 88-metre blade arriving at the Port of Blyth

image left
Levenmouth 7MW offshore wind demonstration turbine

Blyth and its state-of-the-art testing facilities are currently the centre of the Catapult's blade R&D work. But in future, large-scale research projects could utilise the 7MW Levenmouth turbine to develop and validate promising new blade add-ons aimed at reducing offshore wind's LCoE, and the operations and maintenance (O&M) costs around rotors.

O&M costs can represent between 16-23% of offshore wind LCoE, with rotor issues like structural integrity making up a significant chunk of that figure. Technologies that increase aerodynamic performance, reduce blade erosion, or strengthen the structure of the blade could all be retrofitted to the towering open-access turbine's 83.5m blades. It's estimated that combinations of these technologies could reduce LCoE by up to 4.7%.

Improving aerodynamic performance will have a positive impact on annual energy production (AEP), blade erosion protection has the potential to reduce O&M costs, and strengthening the structure of the blade could reduce blade failures by 50% while cutting maintenance costs.

"Our approach to industrial research and development, and the use of representative testing, brings benefits for equipment manufacturers, asset owners and investors," says Peter. "By focusing on technology innovation to reduce unplanned maintenance, increase availability and output, and reduce the time and costs of bringing new technologies to market, we're making big gains in the competitiveness of offshore renewables."

Peter Greaves

PROJECT TAG TO SHED NEW LIGHT ON LIFE AND FLIGHT OF BIRDS

Increasingly, there is more and more demand for information about the movement and lifestyle of our bird species – particularly as newer technology allows for the development of wind farms further offshore.

However, there is scope for further improving the tagging technology currently in use. The relatively short life of batteries, bulky size or susceptibility to poor weather or malfunction means obtaining information can be a time consuming, laborious and expensive process.

But a fledgling innovation challenge could transform that situation and help bring a new maturity to bird tagging technology, seeking solutions that are more robust, reliable and accurate than ever before.

Moray Offshore Windfarm (East) Ltd has partnered with ORE Catapult to launch the challenge, which is aimed at providing a greater level of insight into the lives of our bird species.

It is hoped that this information will contribute towards lowering the cost of offshore wind – and help to inform the location of new offshore wind farm sites in the right places.

Supported by Beatrice Offshore Windfarm Limited, Marine Scotland and Highlands and Islands Enterprise, the innovation challenge is aimed at developing a tagging technology that will initially be used to monitor the behaviour of a colony of greater black-backed gulls, with the intention of potentially adapting the technology for other species.

Vicky Coy, a project manager at ORE Catapult, said: "The greater black-backed gull is the ideal species to launch this innovation challenge with, as a colony is found in the Moray Firth area near a number

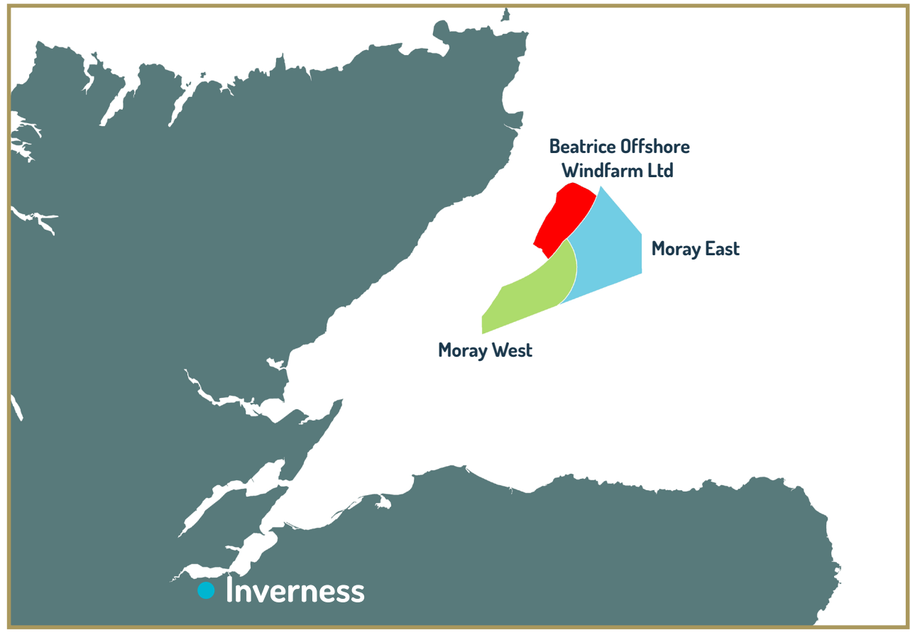


image above
Planned Moray Firth windfarm developments

image left
The Greater Black-Backed Gull

of planned wind farm developments. Our aim is to provide a mechanism for gathering real-world data in a way that works with the environment and preserves the species' natural behaviours as much as possible.

"With that in mind, the technology for the tagging should be as inconspicuous as possible for the birds, but like the colonies the developers want to track, it will have to be extremely resilient to the harsh weather conditions found around the UK's coastline."

Environmental monitoring is already a big part of any wind farm development onshore or offshore, but the reality is current techniques are expensive and not always representative of real-world conditions.

As such, a strong commercial market exists for those companies who develop the right solutions, Vicky added.

"For UK companies, the international reach of the right product to meet this innovation challenge goes beyond tracking birds' migratory paths.

"There are an ever increasing number of countries looking to develop wind farms, both on and offshore, so this represents a great opportunity to access a genuinely global marketplace, create new jobs and further bolster the UK's position at the forefront of the offshore renewables sector."

More reliable and robust technology will allow both developers and legislators a greater insight into coastal species' behaviour and, as such, will be an essential tool in informing the location and operation of developments across our coastlines.

Catarina Rei, Technical Lead on the project for EDP Renewables, who are developing Moray East, added: "Gathering this information is vital as it will help the offshore wind industry to develop proposals that maximise the delivery of clean energy without creating unacceptable impacts on our seabird populations. When planning for future offshore renewables it will help to refine even further what the 'sweet-spot' for wind farm placement looks like, finding the right balance between location, operational times and wind resource. This in turn will help to lower the cost of energy through lowering project risk, supporting decision making and ensuring high environmental standards.

"Finding the sweet spot is an essential part in helping this growing sector mature and support our move towards a more sustainable low-carbon future."

Vicky Coy

TIDAL-EC ADVANCES POWER TAKE-OFF IMPROVEMENTS

image above
1MW Powertrain test rig

Tidal Energy Converter Cost Reduction via Power Take-Off Optimisation (TIDAL-EC) is an EU funded FP7 project comprising seven partners. It was established to undertake research and development activities to substantially improve the economic competitiveness of tidal stream power generation. The project looked specifically at optimising a tidal energy converter's power take-off and permanent magnet generator technology for improved reliability, increased efficiency and reduced levelised cost of energy (LCoE).

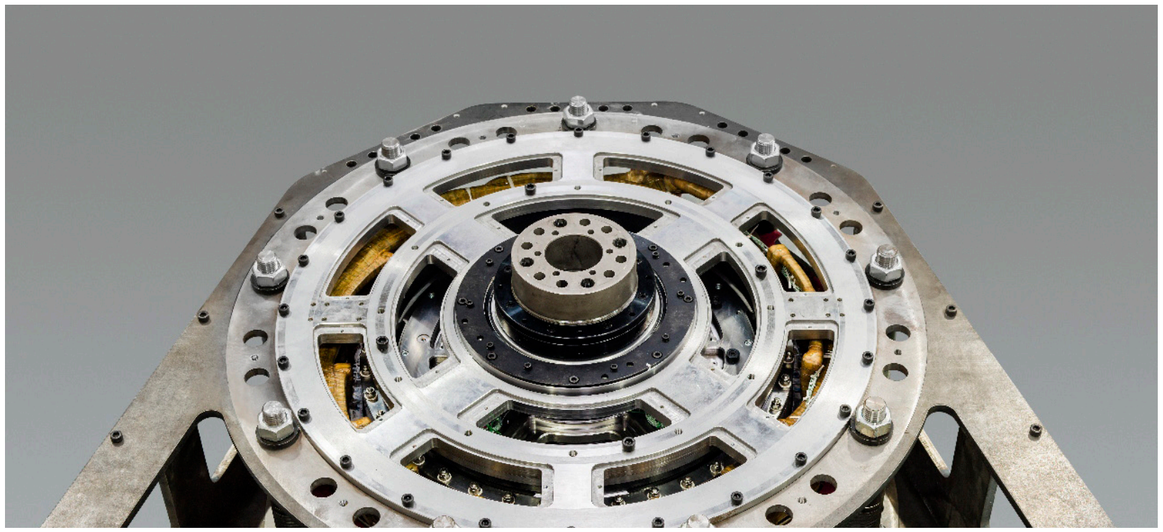
As part of the project, we collaborated with Dutch tidal developer Tocardo International to validate and optimise their T2 turbine. In order to test the device, our drivetrain experts were challenged to develop a 1MW powertrain test rig, including a bespoke tank for submerging the generator, as well as support the T2's testing programme.

Tocardo successfully conducted a full schedule of tests to validate and optimise the turbine's design, ultimately agreeing to demonstrate a 20-year, pre-commercial array at the European Marine Energy Centre's (EMEC) grid-connected tidal test site in Orkney, deploying eight T2 turbines.

TIDAL-EC has also enabled us to further develop our world-leading powertrain test facilities, adding the 1MW rig to our existing 3MW and 15MW facilities. This allows us to offer sub-megawatt powertrain and component testing to the UK and European tidal market and further support SME product development.

In addition, TIDAL-EC's outcomes include wider support for SME tidal developers in offering warranties and guarantees to end customers, enabling large-scale roll out of tidal energy across the EU.

COMPACT HIGH EFFICIENCY GENERATOR PROJECT (CHEG)



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PDD generator

Led by Sheffield-based SME Magnomatics, the Compact High Efficiency Generator (CHEG) project is an EU DemoWind-funded collaborative research and development programme aimed at driving down costs and increasing generator efficiency in large offshore wind turbines.

The project will deliver a 500kW Pseudo Direct Drive (PDD) generator based around Magnomatics' innovative magnetic gear technology, which replaces the traditional turbine generator and gearbox with a single magnetically geared permanent magnet generator (equivalent to a single stage gearbox and permanent magnet generator). By transmitting torque through a magnetic gear, the physical contact and need for lubrication required by traditional mechanical gearing is removed, eliminating the associated failure modes and increasing efficiency.

As gearboxes are one of the most common sources of component failure in offshore wind, PDD technology could have significant advantages in terms of reliability and lower maintenance costs when scaled up to the current size of offshore wind turbines. After completion of the current 500kW prototype, the project consortium will step forward to develop a new PDD drivetrain concept for large offshore wind turbines.

The PDD is more efficient than geared systems and competing direct-drive permanent magnet solutions due to the inherent efficiency of the magnetic gear and the large reduction in copper loss afforded by the reduced torque requirement of the generator. This translates to increased annual energy production. Further benefits in its compact and lightweight structure (it's smaller and lighter than competing technologies) will reduce transportation and installation costs and particularly benefit floating turbines.

ORE Catapult's research team has played a key role in the development, specification, and concept model review of the generator, while our testing team are developing a rigorous programme to prove and demonstrate the prototype's feasibility in our 3MW Drivetrain Test Facility.

The project team have established a potential 2.9% reduction in the levelised cost of energy (LCoE) using the model developed by the department for Business, Energy and Industrial Strategy (BEIS). This figure will be re-evaluated after prototype testing, as will the impact on energy output. Whichever way you look at it, these numbers combined with the reduced maintenance costs make the switch to PDD generators an attractive prospect.

PROJECT SNAPSHOTS

Knowledge | Collaboration | Innovation

CLOWT

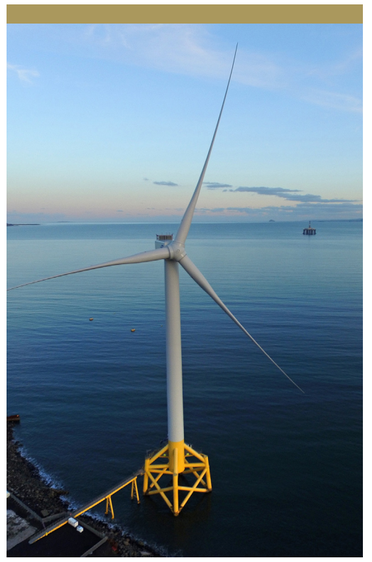
CLOWT (Clone of the Levenmouth Offshore Wind Turbine) is a project using data gathered from innovative sensor instrumentation to advance the industry's understanding of how large-megawatt turbines behave under the strains of real-world operation. Part funded by the Scottish Government, ORE Catapult has contracted SgurrEnergy for the procurement, installation and commissioning of a permanent load measurement campaign system to enable the development of a digital clone of the Levenmouth Demonstration Turbine. SgurrEnergy will manage the integration of successful SME instrumentation, with installation of all sensors due by July 2017. Following completion of installation and commissioning, a loads measurement will be conducted over a period of one year. Throughout the load measurements campaign, outputs will be used within ORE Catapult to develop the digital clone, progressing research activities and inspiring new projects.

CROWN

In response to the ongoing issue of monopile corrosion, and the mixed results of prevention methods to date, CROWN (Cost Reduction in Offshore Wind Now) has been established to investigate the effectiveness of thermally sprayed aluminium (TSA). Nine partners from the offshore wind industry have collaborated to assess the use of TSA at different stages of monopile construction, including lab and field experiments. ORE Catapult will provide the latter in our dry dock facility at Blyth, undertaking testing on 16 small scale piles coated with two variants of TSA, as well as conducting lifecycle cost modelling in order to compare with other methods of corrosion protection.

HD-MMC

The HD-MMC (High Definition Modular Multi-Level Converter) project has been established to create a more efficient and cost-effective method for power transmission from offshore wind substations to the grid, using sophisticated power conversion algorithms created by ORE Catapult. The project has successfully completed an important first phase, undertaking an experiment on a small-scale converter in order to verify digital simulations of the algorithm, proving that the HD-MMC approach is more efficient than existing methods. The next steps are to demonstrate the algorithm using measurements from the Levenmouth Demonstration Turbine, to build a realistic test environment, involving a grid emulation system, to generate specific voltage and current conditions. If successful, it will prove the viability of the HD-MMC algorithm for use in next generation turbines.



BOHEM

We're working with Glasgow based SME, Wideblue Ltd., on the BOHEM (Wind Turbine Blade Optical Health Monitoring) project which began in September 2016. BOHEM aims to deliver a low-cost, optimised camera sensor system built into wind turbine blades. The system is designed to monitor blade shape changes in all weather and operational circumstances. The data generated will be used to monitor individual blade health, allow early detection of any changes in performance, instruct more effective maintenance, and allow for better justification of life extensions.

SALE

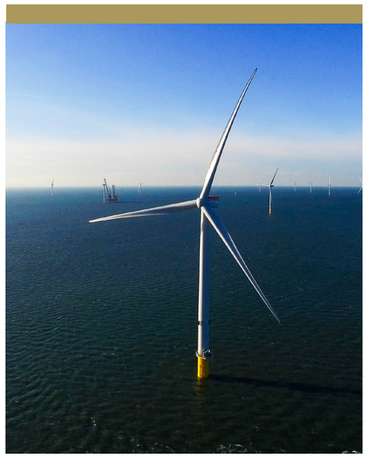
SALE (Simulation to enable Asset Life Extension of wind turbines) is an 18-month project partnership between ORE Catapult and Cambridge-based SME Ocean Array Systems (OAS) to validate software designed to improve wind farm control strategies. The project, funded by InnovateUK, will use data from LIDAR and the Levenmouth Demonstration Turbine to model the complex flow conditions at wind farms, and how they impact the performance and loading on the turbines. These tools inform wind farm operators about the unsteady loading experienced at a particular site. New control strategies enable them to reduce the adverse effects and increase the structural lifetime of wind farm components, potentially leading to as much as a 2.4%[1] reduction in the Levelised Cost of Energy (LCoE) of offshore wind.

[1] ORE Catapult's CRMF Report 2015.

SCORE2

SCORE2 is the second instalment of a £6million grant fund part financed by the European Regional Development Fund (ERDF) targeting SMEs that have the expertise and capability to support the offshore renewable energy supply chain, particularly those diversifying into offshore renewables from oil and gas. Delivered by OrbisEnergy and providing innovation challenges, advisory and testing services, SCORE2 is set to assist 200 SMEs over the three-year life of the project. As a partner of the project, ORE Catapult is providing advisory services, such as access to additional funding, as well as making its test facilities available for product development.

NEWS ROUND UP



Offshore Wind Innovation Hub highlights sector priorities

The Offshore Wind Innovation Hub (OWIH) launched its new website in May, creating a dedicated portal highlighting the UK's offshore wind innovation priorities and supply chain opportunities, and offering a comprehensive view of the funding landscape.

The website has been designed to act as an intersection for the industry and the public sector, providing both with evidence-based, validated information on the sector's priorities.

The Hub – and its first programme, the Offshore Wind Innovation Exchange (OWIX) – is backed by the Department for Business, Energy and Industrial Strategy (BEIS) and delivered jointly by ORE Catapult and Innovate UK's Knowledge Transfer Network.

"The OWIH will ensure that the UK's world-class technologies and services remain at the forefront of innovation and are promoted internationally, further growing the UK's leading global position in offshore wind," said Steve Wyatt, ORE Catapult's Research & Disruptive Innovation Director.

www.offshorewindinnovationhub.com

Open access to world-class test facilities up for grabs with MaRINET2 project

ORE Catapult has committed five state-of-the-art testing assets to MaRINET2, a €10.5m Horizon 2020 project which helps promising offshore renewables technology developers access a network of research facilities.

If successful in the application process, technology developers can benefit from discounted rates at the assets that ORE Catapult is committing to the project. They are: our 50m blade test facility, our 1MW drivetrain test rig, our high-voltage electrical and materials laboratories, and our marine and subsea testing docks.

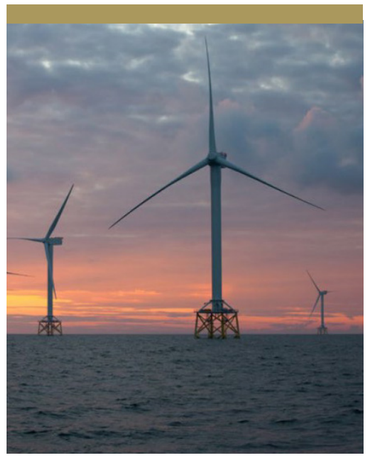
The first MaRINET project supported 178 technologies over a period of four-and-a-half years, and had a considerable and positive impact on their development. "We operate the largest concentration of open-access renewables testing facilities in the world, said James Battensby, ORE Catapult's Technical Bid Manager, "and we are pleased to be able to put them at the disposal of some of Europe's most innovative companies."

Catapult boosts capability with new rain erosion test rig

A new rain erosion test rig, which simulates the damage caused by the impact of water droplets on wind turbine blades, has been installed at our National Renewable Energy Centre in Blyth.

Supplied by R&D Test Systems A/S, and acquired with funds from Innovate UK, the rig enhances the Catapult's already-extensive blade testing capabilities. It allows our research and innovation team to provide deep engineering and technical analysis, and interpretation of test results for customers and research programmes – leading to a better understanding of rain erosion's impact on materials, repair applications and methodologies. "The procurement of the new rig was in direct response to a clear market need for this type of independent, open-access testing," said Stephen Robertson, ORE Catapult's Head of Business Development. "It will allow turbine and blade manufacturers and the supply chain to investigate and mitigate the effects of rain erosion on turbine blades, and to trial new types of materials and protective coatings."

Latest news and developments



SPARTA review gives insights into first full year of successful operations

The world's first offshore wind benchmarking platform has published the key insights from its first full year of operation.

The SPARTA (System Performance, Availability and Reliability Trend Analysis) joint industry project's first Portfolio Review shares insights from anonymised performance and maintenance data gathered from 93.7% of the installed capacity of UK operational offshore wind farms.

"SPARTA has demonstrated how crucial industry collaboration and benchmarking is in continuing to drive down costs and increase production," said Adrian Fox, Chair of the SPARTA steering group. "Industry members are now working to widen membership and reporting outside of the UK, enabling them to undertake deeper insight and analysis."

Offshore wind owner/operators not currently involved are invited to join SPARTA by contacting The Crown Estate or ORE Catapult.

Tocardo turbine success christens 1MW drive train test rig

Dutch tidal developer Tocardo completed a successful test of its T2 turbine at our new 1MW powertrain facility at the National Renewable Energy Centre in Blyth.

As well as giving Tocardo and its investors confidence that the T2 is ready to be deployed and start generating electricity, the test results will be used to validate and optimise the turbine's power output and design.

The new test rig, which was designed, built and commissioned by the Catapult, will be used for research and development, to validate the efficiency and reliability of new turbine designs, and for upscaling developer prototypes to multi-megawatt scale.

It was developed as part of Tidal EC, a European FP7 project on power take-off optimisation of tidal turbines. The rig provides a platform for companies to test sub-1MW devices in the UK, creating opportunities and benefits for the UK supply chain.

Regional marine developers to benefit from new Cornwall and Isles of Scilly programme

Almost £7m of European Regional Development Funding has been secured to develop Marine-*i*, a programme to support marine technology research, development and innovation in Cornwall and the Isles of Scilly.

As part of a wider £9.3m programme, Marine-*i* – a collaboration between the Universities of Exeter and Plymouth, The Cornwall College Group, Cornwall Marine Network, Cornwall Development Company and ORE Catapult – will bring together key infrastructure and expertise to enable innovation in the region's high-growth-potential marine sector.

"This funding provides a unique opportunity for businesses to enhance expertise and create jobs through collaboration and co-creation," said Project Manager Professor Lars Johanning. "Marine-*i* will strengthen business innovation and has been set up… to secure the continued growth of this sector."

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