HOME Offshore

Holistic Operation and Maintenance for **Energy from Offshore Wind Farms**

Investigating how to de-risk offshore wind operations, reduce costs and make better use of assets through the applications of **Modelling and Data Science**, **Machine Learning**, **Advance Sensing** and **Robotics**.

Durham University · Heriot Watt University · Manchester 1824 The University of Manchester · University of Strathclyde Glasgow · Warwick The University of Warwick · UK Research and Innovation

Contents

Project Overview

In 2020 in the UK over 10% of electricity generated was being produced from offshore wind, enough to power 4.5 million homes. The cost of offshore wind has fallen by 50% over the last 5 years, and it is now one of the cheapest sources of electricity in the UK[1].

The present 10 GW of installed offshore capacity, could rise to as much as 80 GW in the coming decades. This however presents a challenge: operation and maintenance of offshore wind assets, is difficult, potentially dangerous and requires highly specialist skills which are in short supply.

The HOME Offshore project was funded by UK Research and Innovation to explore new technologies which de-risk offshore wind operations, reduce costs and make better use of existing assets. The project encompasses state of the art modelling and data science, machine learning, advanced sensing and robotics.

The project is a collaboration between the universities of Manchester, Durham, Warwick, Strathclyde and Heriot-Watt, as well as 16 partner companies and research organisations.

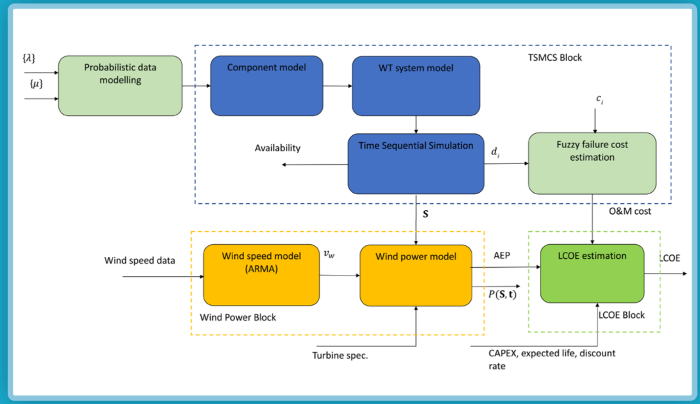
[1] RenewableUK: www.renewableuk.com/page/WindEnergy

THEME 1

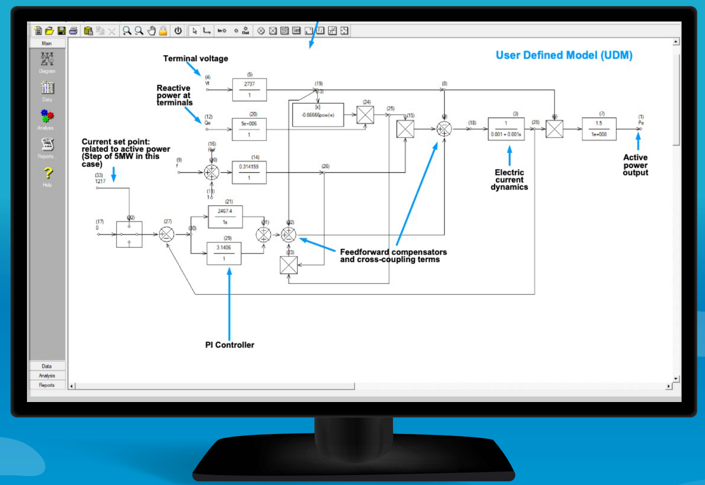
Models and Machine Learning

A major challenge for wind farms offshore is their sheer complexity and the number of different sub-specialisms involved.

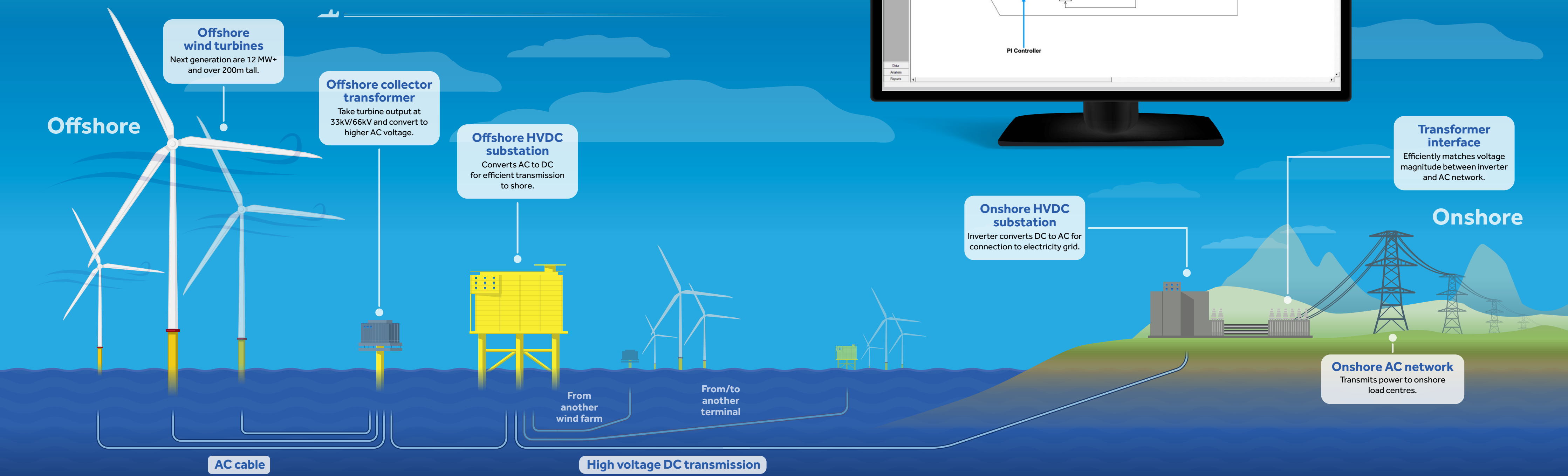
One work-stream in the project examined methods to try and bring these technology tribes together in a partnership between Manchester (Electrical Engineering and Computer Science), Durham and Strathclyde Universities. Methods were examined to try and combine advanced electrical models of the entire system from generator to shore with mechanical models (detailed aero-servo-hydro-elastic models) of the turbine and some of the effects of wind variation over the whole farm. This was combined with advanced machine learning algorithms to try and make sense of the vast amount of data generated. Failure statistics information was gathered to try and close gaps between different digital technologies and ways of representing farm operation.



Wind turbine reliability assessment tool to minimise cost of energy in future offshore wind farms.



Implementation of advanced 5MW benchmark electrical turbine model in commercial software to allow performance prediction and enhancement.

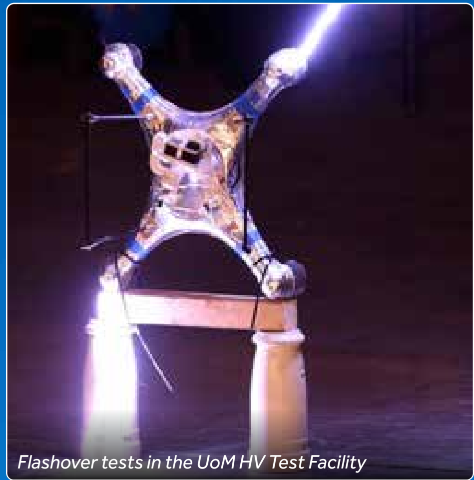


THEME 2

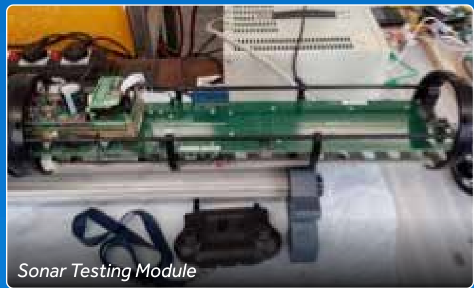
Robotics

Eliminating most human intervention – by using robots – can reduce risk and cost.

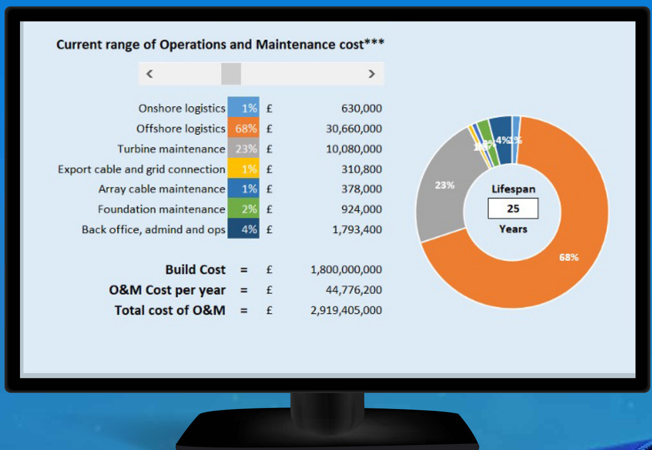
A skills shortage of technicians to undertake engineering tasks offshore also exists. Remote operations through robots and guided vehicles can provide an important solution to these problems. The project assessed the value of robots, beneath the waves assessing subsea structures such as cables, aerial robots to assess the state of turbines, and robots within the electrical structures (such as offshore substations). A challenging combination of communication, robot design, sensor and structural problems was investigated.



Flashover tests in the UoM HV Test Facility



Sonar Testing Module



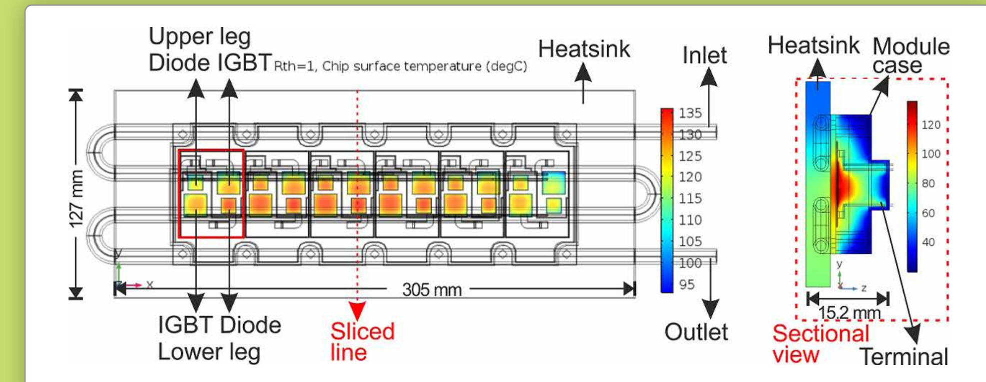
Robotic inspection costing tool.

THEME 3

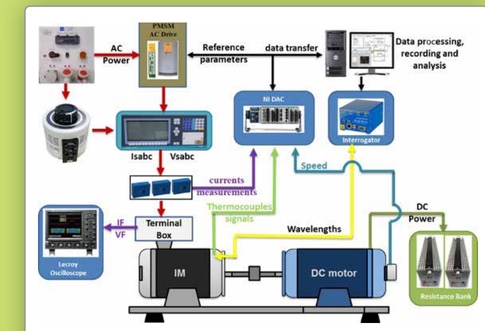
Advanced Sensing

A key to reducing operation costs is to find the problem early. This means the problem can be fixed before it becomes large.

This more predictive approach also reduces the maintenance intervention size, minimising the length of time people have to be sent offshore, and also the impact of the marine environment. This requires accurate and actionable data: many of the new sensing systems being developed have much better resolution both temporal and spatial. This better granularity allows smaller problems to be better perceived and dealt with earlier. They, coupled with a better understanding of system physics and machine learning, were explored to better predict failure.



Heat distribution in a power electronic module



Sensing test rig

Bio sonar cable testing in wave tank

Salford Quays Demo 2019

In 2019, the project demonstrated some of its technologies at an open day at Salford Quays and in the Lowry, along with our sister project the Robotics and Artificial Intelligence in Nuclear (RAIN) Research Hub.

Publications

The project has produced more than 50 scientific papers, with over 20 at journal level, as outputs.

PhD Project funded by the China Scholarship Council into Fibre Bragg Grating sensing, *Dr Sinisa Durovic, Prof Mike Barnes*

PhD Project funded by EPSRC / Energy Infrastructure Research Hub (in partnership with the Offshore Renewable Energy Catapult), *Prof Mike Barnes*

National Grid NIA project on Risk Based Maintenance for HVDC and STATCOMs, *Prof Mike Barnes*

Research to Innovator Award – AI for wind turbine diagnostics, *Dr Adrian Stetco*

EPSRC Supergen ORE Hub – Flexible Fund – Enhancing Control Capability of ORE Systems for Stress Management and Grid Support, *Prof Li Ran*

EPSRC Impact Acceleration Account and GE Renewable Energy – UAV Substation Monitoring, *Dr Simon Watson*

EPSRC Impact Acceleration Account – Proof of Concept, *Prof Bill Crowther*

Innovate UK, Multiplatform Inspection and Maintenance and Repair in Extreme Environments (MIMRee), *Dr Simon Watson*

PhD Studentship funded by the Indonesian Government Education Fund – 'FBG Sensing for Wind Turbine Generator Systems', 2020-2023, *Dr Sinisa Durovic, Prof Mike Barnes*

Direct in-service thermal monitoring for HVDC MMC converter power electronic modules – 8 month research project funded by the Offshore Renewable Energy Catapult Energy Infrastructure Hub, *Dr Sinisa Durovic, Prof Mike Barnes*

Research Conclusions

Models and Machine Learning

In this project underlying modelling technologies to represent the wind farm virtually were explored. Such techniques have become known as 'digital twins.' They allow improved use of data, test scenarios to be run, exploring improving operation and reducing downtime. Techniques examined links between meso-scale effects such as the wind landscape and the electrical connection array, and micro-scale effects such as individual wind turbine effects or component reliability. This range of modelling is challenging: offshore wind farms can stretch over tens of kilometres but to examine converter thermal performance sub-millimetre scales are required. To look at turbine reliability, time scales of years are necessary, to look at converter behaviour can require millisecond accuracy. Even with modern computers, the computation challenge is vast, and so some degree of simplification is required. Various cutting-edge methods have been trialled – for example embedding user knowledge and using artificial intelligence - with considerable success. But no single generally applicable solution for the whole wind farm has been found. Follow-on projects are taking the most promising methodologies developed further, for specific applications. For specific wind farm elements two mixed-physics reference turbine models at 5 MW and 10MW were formulated and used in tests to show how sensing could be simplified (for example extracting mechanical faults from electrical data). A model was constructed for commercial software and a manual created.

Robotics

In this project, the feasibility of using robotic platforms for the inspection of offshore windfarm assets was investigated. Three scenarios were considered; the external inspection of wind turbines using Unmanned Aerial Vehicles (UAVs), the internal inspection of HVDC substations using UAVs and the inspection of subsea cables using Autonomous Underwater Vehicles (AUVs). A techno-economic analysis of the use of UAVs for wind turbine inspections concluded that there was a clear cost saving to be made through the use of them over traditional manual inspection techniques. A specific use case of the inspection of live HVDC substations using UAVs focused on three aspects: the effects of high external EM fields, navigation in dark, GPS denied areas and the localisation of thermal hotspots. It was concluded that whilst UAVs will be affected by EM fields, these effects can be mitigated through shielding and the use of robust motor control strategies. Navigation can utilise the highly structured nature of the environment along with existing infrastructure such as QR codes to allow the use of low-cost sensors. The outputs of Lidar scans and thermal cameras can be fused to provide geospatial coordinates of thermal hotspots in real-time. For the inspection of subsea cables, a fusion prognostics algorithm utilizing historical data, failure mode analysis, in-situ data and Physics of Failure (PoF) modelling was implemented within a software tool to predict remaining useful life (RUL) of the cable in real-time. Data was generated using a new low frequency sonar technology which could be mounted to an AUV to enable in-situ analysis for subsea cable inspection.

Advanced Sensing

This project explored improved condition monitoring for wind turbine (WT) drive train and power electronic converter components, and wind farm subsea cables. This included the research of electro magnetically immune fibre optic sensing (FBG sensors) application for in-situ monitoring of operational features of key WT electro-mechanical power conversion components. Novel techniques were developed to allow advanced monitoring of a range of previously inaccessible or impractical measurands of diagnostic interest. These included distributed and multi-physical (thermo-mechanical) in-situ sensing of drivetrain bearings' operating stresses; distributed sensing of generator winding thermal hotspots; in-situ flux monitoring for diagnosing rotor magnets health in permanent magnet generators; distributed in-situ thermal sensing for wind turbine power electronic modules. The developed sensing techniques were demonstrated in small scale tests to allow effective monitoring and capture of in-situ diagnostic indices that can allow enhanced understanding and diagnosis of fault conditions. Furthermore, the application of machine and deep learning, and neural networks was studied to improve monitoring of operating conditions, such as heat-flux heath condition monitoring combined with deep learning for multi-device power electronics, and real-time neural network application for generator operating state prediction. It was shown that these methods have strong potential for improving the characterisation of fault features and their prognostic significance. Finally, the research performed on fusion prognostics of subsea cables has been demonstrated to enable predictive forecast on cable failure modes, including location and rates of degradation.

HOME Offshore

For further information about the project, please contact:

THEME 1

Models and Machine Learning

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THEME 2

Robotics

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Advanced Sensing

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