Innovation Launchpad Network+

CASE STUDY

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Offshore Renewable Energy Catapult

The Challenge

This project addresses the urgent need to improve the reliability and cost-effectiveness of Floating Wind Turbines (FWTs) as a crucial element in achieving net-zero emissions. With the global shift towards a sustainable energy future, FWTs in deep waters are becoming increasingly significant. FWT support structures experience a harsh marine environment, with substantial uncertainties from the wind and wave loads. The current generic design standards, with their suggested partial safety factors, are inadequate in accurately accommodating these uncertainties. This often results in structures that are either over-engineered or under-engineered, leading to escalated costs and reduced reliability.

The Catapult challenge centred on a fundamental question:
how to design support structures that remain both safe and economically viable while operating under the significant uncertainties of the marine environment. To address this challenge, this project proposes the development of a reliability-based design optimisation framework.

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The project delivered a reliability-based design optimisation (RBDO) framework for floating wind turbine (FWT) support structures, integrating machine learning, stochastic simulation, reliability assessment and optimisation algorithms. By combining these methodologies, the framework enables the development of support structures that are both reliable and cost-effective, contributing to wider net-zero ambitions.

Key innovations included:

• Machine-learning model for environmental data processing: A neural-network-based model was created to process wind and wave datasets supplied by the Offshore Renewable Energy (ORE) Catapult. The workflow covered data normalisation, training/testing separation, network architecture definition, training optimisation and prediction. This enabled accurate modelling of wind and wave data.

• High-fidelity wave–structure interaction model
A high-fidelity wave–structure interaction model was developed using ANSYS AQWA to simulate realistic wave-induced responses of FWT support structures and generate dynamic hydrodynamic loads.

• Stochastic structural modelling
A stochastic finite-element model was established to capture the combined effects of environmental and gravitational loads. Stochastic variables were introduced to represent material and loading uncertainties, enabling the estimation of stress distributions and identifying critical structural regions.

• Reliability-based design optimisation framework
The RBDO framework automates the design iteration process by combining machine learning, stochastic analysis, reliability assessment and optimisation algorithms. It delivers optimised designs that meet a target reliability index while reducing material usage.
Project outputs included a peer-reviewed book chapter, Design Optimisation of Offshore Wind Turbine Support Structures (IntechOpen, November 2024), and a journal article currently in preparation.

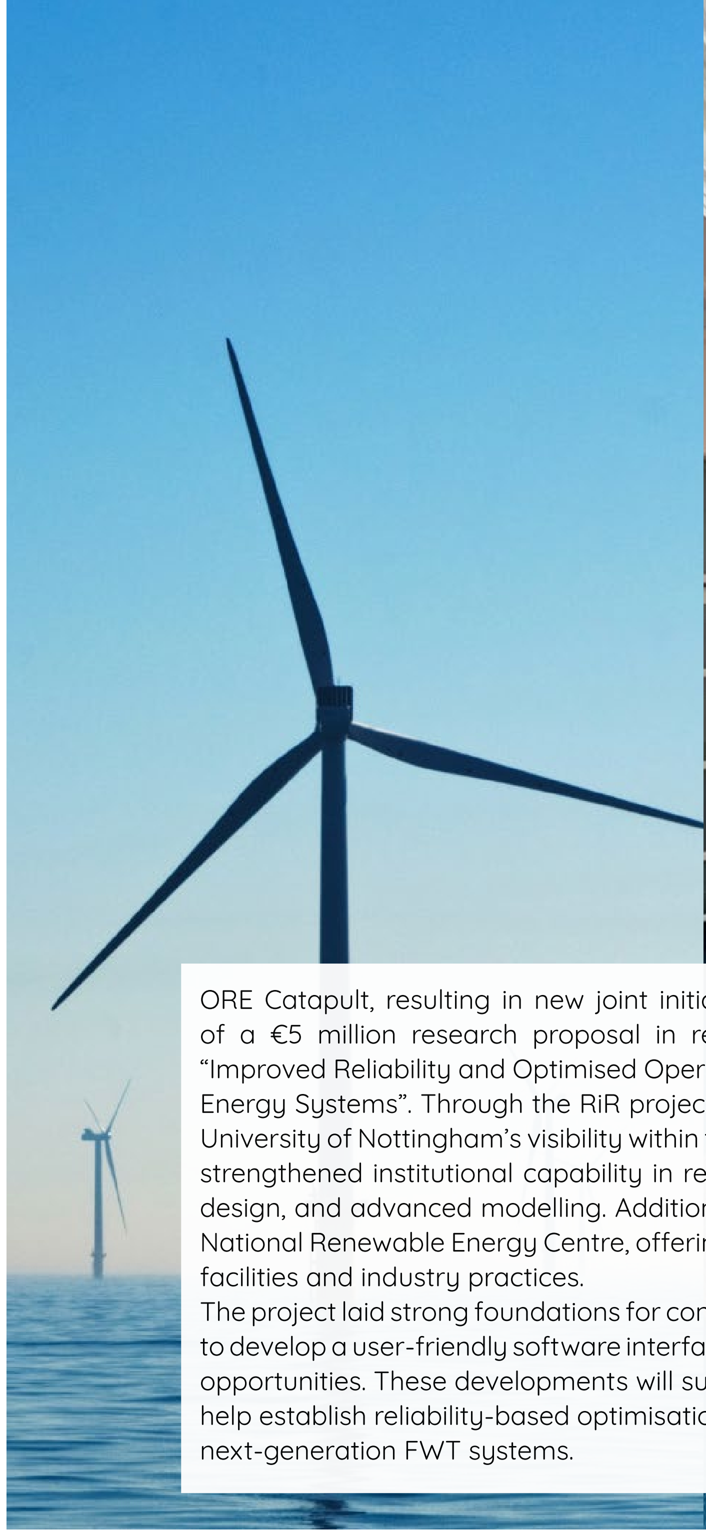
Result

The project delivered tangible research and engagement outcomes:

- Machine learning model capable of processing wind and wave data;
- Wave structure interaction model capable of simulating structural motion and assessing wave-induced loads on floating wind turbine support structures
- Stochastic structural model capable of predicting structural responses of floating wind turbine support structures subject to stochastic loads
- Reliability assessment model capable of evaluating the probability of failures of floating wind turbine support structures
- Reliability based design optimisation model capable of optimising the design and floating wind turbine support structures to meet the target reliability level with minimum cost
- The models have been applied to the IEA 15MW Offshore Wind Turbine on a semisubmersible floating platform.
- The research demonstrated that through reliability-based optimisation, support structure mass can be reduced by approximately 12% while meeting target reliability levels.
- Enhanced collaboration between the University of Nottingham and OREC, leading to continued discussions on future funding opportunities and the co-development of a €5 million research proposal in response to a Horizon Europe call on “Improved Reliability and Optimised Operations and Maintenance for Wind Energy Systems”.

Impact

The project has made a significant contribution to advancing reliability-centred design practices in the floating offshore wind sector. By developing and demonstrating a novel reliability-based design optimisation (RBDO) framework, the work has strengthened industry understanding of how uncertainty can be explicitly accounted for in the design of floating wind turbine (FWT) support structures. The research showed that support-structure mass can be reduced by around 12% while still achieving target reliability levels, providing clear evidence that reliability-based optimisation can deliver both economic and safety benefits. This shift represents a step change from traditional partial-safety-factor design approaches, which can lead to unnecessary conservatism and increased costs. The project has also deepened collaboration between the University of Nottingham and ORE Catapult, resulting in new joint initiatives, including co-development of a €5 million research proposal in response to the Horizon Call on “Improved Reliability and Optimised Operations and Maintenance for Wind Energy Systems”. Through the RiR project, the research has expanded the University of Nottingham’s visibility within the offshore wind community and strengthened institutional capability in reliability engineering, probabilistic design, and advanced modelling. Additionally, OREC hosted a visit to their National Renewable Energy Centre, offering valuable insight into real-world facilities and industry practices.
The project laid strong foundations for continued innovation, including plans to develop a user-friendly software interface and explore commercialisation opportunities. These developments will support future industry uptake and help establish reliability-based optimisation as a viable design pathway for next-generation FWT systems.



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“Working with ORE Catapult has been transformative. Their industrial expertise and access to real offshore datasets enabled us to develop a reliability-based optimisation framework that directly addresses the challenges faced by the floating wind sector. This collaboration has laid the foundation for long-term research, innovation and impact.”

OREC

“The collaboration with the University of Nottingham has been highly productive. The project delivered new tools and insights that can meaningfully improve the reliability and cost-effectiveness of floating wind support structures. It has strengthened our research partnership and opened up exciting pathways for future joint work.”

CATAPULT Offshore Renewable Energy

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