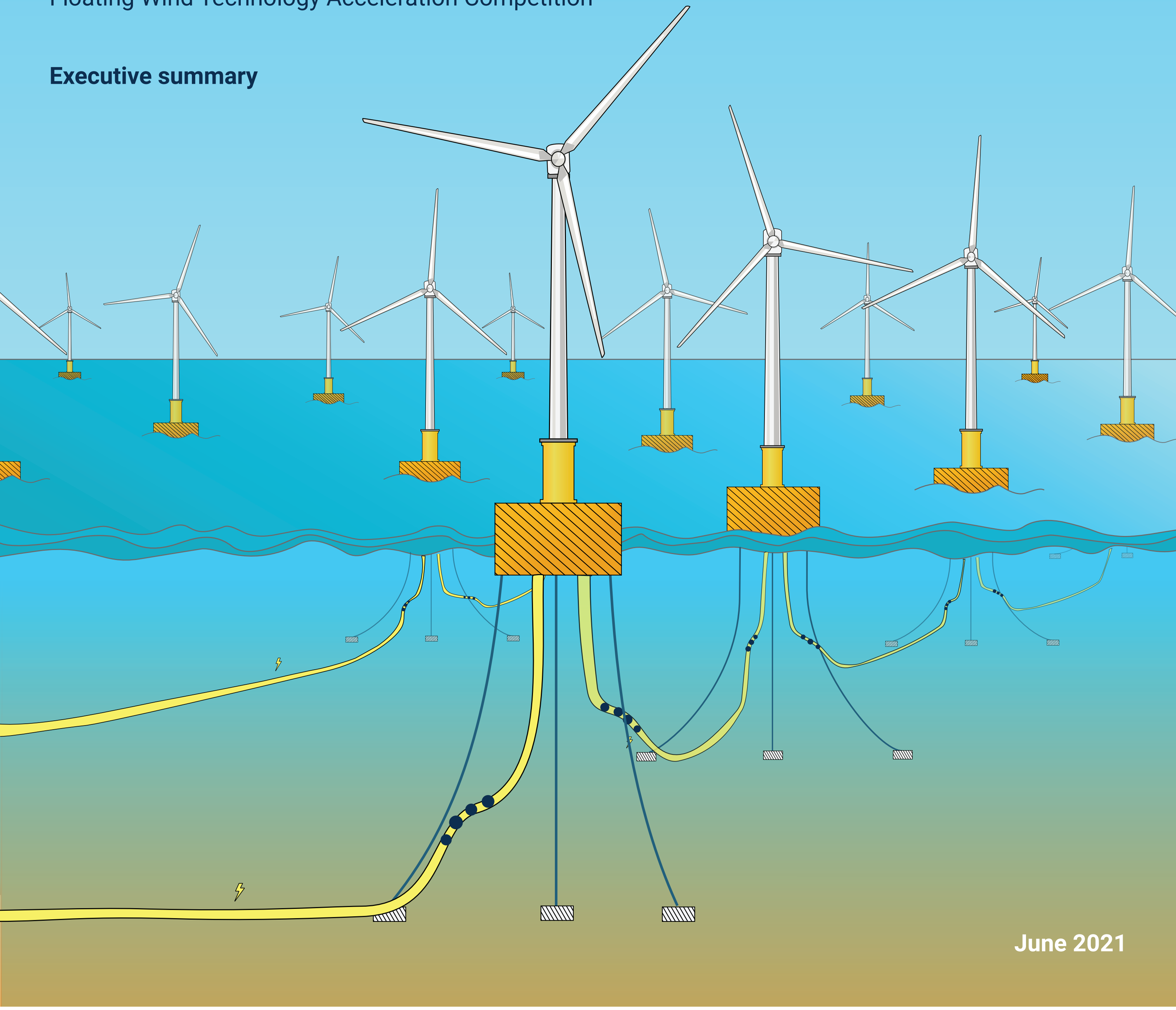
CARBON TRUST

Mooring Line Dampener – Intelligent Mooring System (IMS)

Floating Wind Technology Acceleration Competition

Executive summary



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Executive Summary

Conventional mooring designs for Floating Offshore Wind Turbines (FOWT) rely on adaptations from the oil and gas sector that can meet the required integrity and safety margins but lead to CAPEX intensive designs. The capital cost of moorings is driven by extreme (peak load) conditions, whilst the revenue is generated under normal operating conditions. If peak loads can be mitigated, the cost of mooring systems and associated structural elements, as well as deployment and installation costs, can be significantly reduced.

Intelligent Moorings Limited is developing a mooring load reduction damper - the Intelligent Mooring System (IMS). The IMS has now been developed to TRL5 and seeks to become the new future standard in mooring line load reduction for large floating platforms, targeting the growing floating wind market. Whilst essential innovative aspects have been proven in previous projects, this project has facilitated further development of the innovation to prepare for commercialisation in the offshore wind energy sector.

The IMS reduces peak loads on the platform by extending in length and increasing stiffness through the wave cycle

The IMS has a unique approach to mooring damping, a braided sleeve with pressure based active control and no mechanical moving parts. The system fundamentals could be described as a Hydraulic Muscle – a large diameter braided sleeve encapsulated hydraulic reservoir, actively controlled in operation or with intelligent load threshold responses. This working principle gives the IMS a characteristic nonlinear load extension profile, i.e. it is compliant (soft load response) at the beginning of the extension and becomes increasingly stiffer with increasing tension. This profile, together with the load hysteresis leads to the load reduction in the mooring line. Active control of the device’s load-extension characteristics in operation means the response of the mooring system can be optimized for the lowest loads possible, consistent with required position keeping criteria in a range of environmental conditions, improving efficiency and energy capture. Analytical performance assessments for floating wind mooring integration of the IMS, have demonstrated considerable mooring load reductions of up to 40% in the peak line tension compared to a Polyester rope/chain system in dynamic simulations.

The ability to change the load-extension curve in operation also allows tuning of the mooring system, potentially reducing platform motions through variable pre-tension. In addition to excellent load reduction performance, the IMS can be tuned dynamically in operation in response to wind and wave conditions, as well as allowing multiple pre-configured responses to loading thresholds. The IMS achieves load reduction and the mooring properties can be varied whilst in operation without replacing the mooring system.

With reduced loads there are associated cost reduction benefits in neighbouring sub-systems, e.g. anchoring and platforms, as well as in the costs associated with installation and O&M.

Research Questions

The aim of the project was to take an IMS prototype design and develop the technology to meet Floating Offshore Wind requirements through collaboration with industry. The project determined optimum specifications for an IMS unit for Floating Wind requirements, built a scaled IMS unit to these specifications and validated the performance through testing on the University of Exeter DMaC facility. Following the project, the outcomes support a full scale prototype test on a floating platform.

Research Undertaken

Modelling and design configuration of hydraulic and physical parameters for IMS installation was undertaken in order to refine the coupled hydrodynamic modelling of the IMS in FOW mooring configurations. Engineering interfaces and load requirements were established and design parameters for the IMS configuration were confirmed through numerical modelling to inform prospective installation at the East Pickard Bay demonstration site as a representative deployment site. Characterisation studies were conducted to suitably configure the mooring design for IMS field deployment and quantify the load reduction potential offered by the IMS device.

Design specifications for the IMS unit were generated based on FOW requirements. To increase longevity and reduce risk a material change was made to the braided sleeve design by selecting a proven mooring line fibre (Dyneema® DM20) for the braid construction. The pressure control function was redesigned so that the IMS internal pressure is controlled by an internal accumulator instead of relying on an external pressure reservoir. Performance characterisation testing and accelerated reliability and field load testing were successfully undertaken on the University of Exeter's DMaC facility with representative loads.

IMS Mooring Dampers on Test at the University of Exeter DMaC Test Facility

Key Findings

- Successful testing of the IMS at 1:3 (Froude Scale) to FOW requirements
- Successful test campaign demonstrating representative loads for FOW requirements
- Increase in tensile performance of 47% in IMS design from the previous prototype
- Dyneema® DM20 successfully constructed into a braided configuration
- Internal accumulator design proven, reducing system complexity
- TRL advanced from TRL 4 to TRL 5 by validating the technology based on available information of the relevant environment

Future Work

After the successful completion of this project, a range of future work and actions have been identified. The performance characterisation curves of the IMS can be used in conjunction with FOW models available to developers for individual deployment sites. This will demonstrate the effectiveness of the IMS and allow evaluation of the expected peak load reduction when including the IMS in specific FOW mooring systems. In practice, the IMS configuration will be such that it provides the required strength to withstand extreme environmental conditions and operational loads whilst providing necessary compliance to reduce the platform loads. The site- and platform-specific loads will be determined by conducting analysis similar to that described in the baseline studies undertaken in the project. For IMS configurations providing the necessary strength, further simulations will be conducted using variable stiffness profiles available from physical testing to compare the loads and motions of the platform to identify the most suitable configuration for the turbine and site, considering peak loads, operational loads and mooring footprint/length. To further develop the technology following the conclusion of this project a contract with the Marine Energy Engineering Centre of Excellence (MEECE) has been agreed to deploy the IMS at the Marine Energy Test Area (META) test site in Pembrokeshire with support from the ORE Catapult. The trial is scheduled to deploy in mid-2021. This sea trial of the IMS triple unit design, as demonstrated at DMaC, will provide an opportunity to advance the technology to TRL 6, through proving in an operational environment and highlighting any issues with O&M of the system.

Alongside the META deployment, product scale up engineering will continue in parallel with certification planning. Further sea trials of the IMS are planned at full scale with contracts scheduled to be confirmed in 2021.