12th PRIMaRE CONFERENCE 2025
2nd & 3rd July 2025
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Booklet of Abstracts

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RTide: A machine learning enabled implementation of Munk and Cartwright's Response method

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Conference Theme: 1. Tidal/Ocean current energy

ABSTRACT: The prediction of water levels and currents is of importance to the design and operation of all marine renewables. This is particularly true for tidal energy where the resource is dependent on the ocean flows and water levels. It is also important for other offshore infrastructure, including the prediction of currents for scour calculations around monopiles and cables.

The conventional method of predicting currents based on data is Harmonic Analysis (HA). This approach works well for the prediction of astronomically driven water levels in areas where there is not strong interaction with bathymetry. However, in areas such as estuaries where there is non-linearity in the water levels, and even more so for the highly non-linear tidal currents we are interested in extracting energy from, the method struggles. In addition, HA requires relatively long time-series, which for tidal currents, are prohibitively expensive to collect.

The main alternative empirical approach is the Response Method developed by Munk & Cartwright (1966). This approach does not make the same limiting assumptions that limit Harmonic Analysis but it has never been widely used. The main reason for this was the expertise necessary to use the model. We have tackled this problem by embedding machine learning into the method which we have released as the open source package RTide (Monahan et al., 2025). By using a class of neural networks which is equivalent to the Volterra series used in the original formulation we preserve the key mathematical structure of the original approach. Further, a key attraction of the method is that it retains the physics of the original problem in its formulation greatly increasing the reliability of the approach.

Harmonic analysis will remain the "language of the tides" however we foresee the approach used in the RTide code as having significiant advantages for many marine renewable energy applications. These include:

(i) Prediction of strongly non-linear currents. For example, simply running RTide without any special configuration greatly outperforms HA when both are trained on 180 days of measured data at the Meygen site in the Inner Sound of the Pentland Firth.

(ii) Prediction from very short time series. Whilst it is location specific HA generally requires roughly five times as much data as RTide in order to make comparable predictions. This is valuable for field data collection as it greatly reduces the measurements required as well as for computational modelling where the run time is reduced. It is worth noting that HA can then be applied to a longer time series generated by RTide, preserving the interpretability of the harmonic constituents.

(iii) Inclusion of meterological and other inputs. It is straightforward to include other forcing in the Response Method which allows fast prediction of the impact of weather on flows and water levels to be rapidly computed. It is also possible to add other forcing, for instance whether a turbine is on or off.

ACKNOWLEDGEMENTS

TM is funded by the University of Oxford. TA is funded by the EPSRC CoTide Project (EP/X03903X/1)

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
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Effect of winglets on tidal turbine tip vortices

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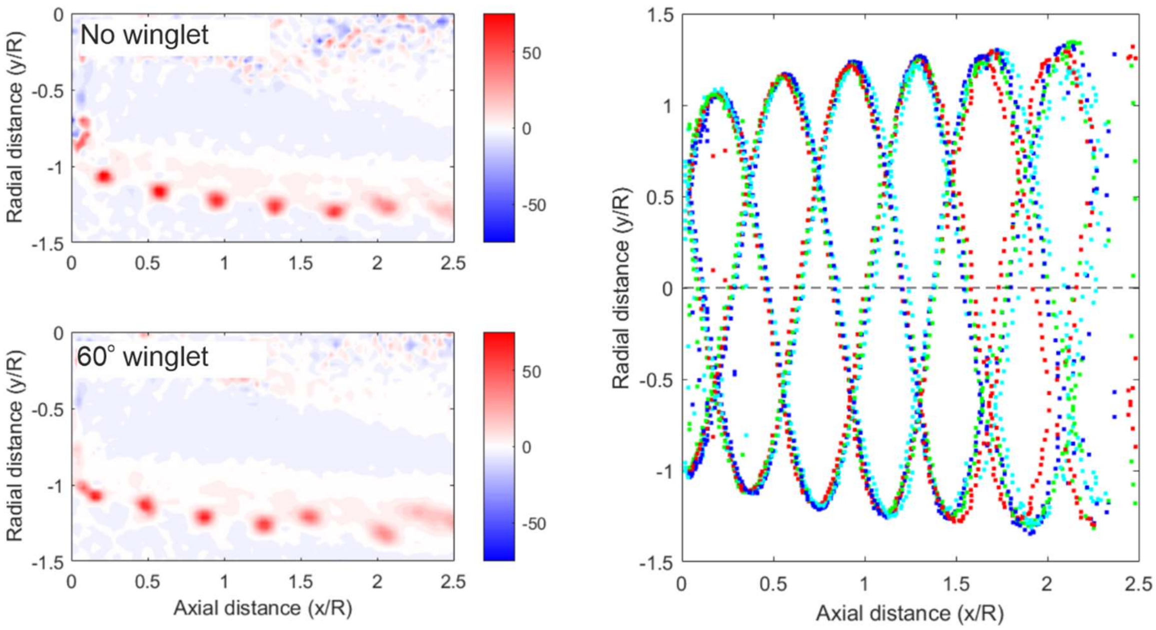
Conference Theme: 1. Tidal/Ocean current energy

ABSTRACT: Winglets are routinely used on aircraft to increase the lift generated by a wing of constrained span, and they may offer a similar benefit on tidal turbine blades. Winglets may also improve the efficiency of a turbine if they can be designed to reduce circumferential non-uniformity in the blade tip region, and therefore reduce the total rotor wake mixing loss. Previous work (Young et al, 2019, Olvera Trejaro, 2022) has shown efficiency benefits on model-scale rotors. Interestingly, a winglet pointing towards the suction side of the blade (as is conventional in aircraft) has been shown to increase thrust while providing no increase in power (i.e. reducing efficiency), while one pointing towards the pressure surface has been shown to offer efficiency benefits (i.e., increased power with little-to-no increase in thrust (Young et al, 2019)).

In this work, we investigate the effect of winglets on the tip vortex trajectory using data obtained from model-scale tests. The data is from phase-locked PIV taken with four different tip geometries: plain tip (no winglet), winglet on the pressure side at 90º, winglet on the suction side at 90º, and a winglet on the pressure side at 60º. Vorticitiy contours (Figure 1(a)) show that there are differences in the strength and trajectory of the tip vortex between the no winglet and 60º winglet case. The 60º winglet appears to generate a double vortex, which merges and then breaks down more quickly in the far wake. Figure 1(b) shows the trajectory of the tip vortex for all four designs (calculated using the Γ_2 criterion). It can be seen that the trajectories are very similar between the designs, until the far wake, where the vortices begin to break down and there is more scatter.



(a) Phase-averaged vorticity contours from downstream of the rotor for no winglet (upper) and 60° (lower) winglet showing differences in vortex structure and breakdown.

(b) Vortex Trajectory tracked using Gamma 2 criterion for the turbine with plain tips (red), suction-side winglets (blue), pressure side winglets (green) and 60° winglets (cyan).

Figure 1: Tip vortex trajectories for a model turbine with different winglet designs.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by the EPSRC, and MARINET2 Facility Access.

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
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Evaluation of passive flow control jets to reduce loads on tidal devices

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Conference Theme: 1. Tidal/Ocean current energy

ABSTRACT:

Incoming flow unsteadiness causes large fluctuations in thrust and torque on a tidal stream turbine. This represents a significant obstacle to commercial deployment as the fatigue loads on blades and drivetrain cause high turbine failure rates and increased costs for replacement parts and maintenance. Existing turbines can respond to low frequency variations in flow conditions (of the order of tens of seconds) by adjusting generator speed or pitching whole blades, but new technologies are needed for higher frequency fluctuations in torque and thrust.

Flow control devices can be used for this purpose and can be actively or passively controlled. This research proposes the use of a passively controlled mechanism that uses blowing and suction jets through a common passage within the blade to promote or surpress flow seperation and effectively change its camber, and thus achieves the desired level of alleviation. The spanwise spacing, diameter and chordwise positioning of the holes was varied in this study. Active flow control devices require a sensor-actuator loop to adjust the flow around the blade. Young et al. (2016) used a small scale turbine to show that serrated trips can reduce unsteady torque fluctuations by 50% and that trailing edge flaps can attenuate thrust fluctuations by up to 75%. However, the complexity of the actively controlled mechanisms and the limited spatial and temporal accuracy in measuring the flow field can make these devices challenging to control.

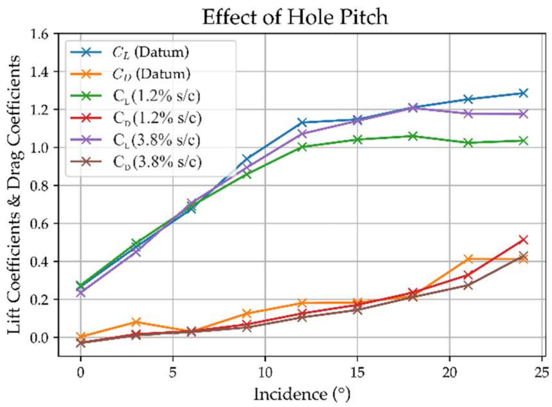

Figure 1: Effect of hole pitch on lift and drag for a hole of 1mm ϕ (equating to 0.43% c) and connection the pressure surface at 5% c to the suction surface at 2% c

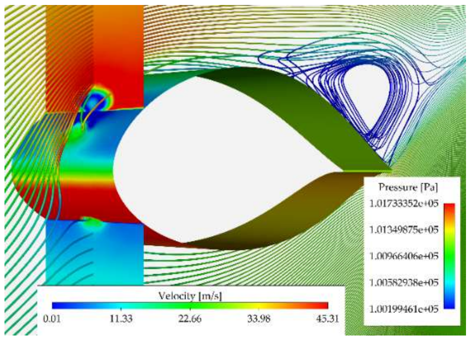

Figure 2: Wake induced vortices mixing the flow and promoting attachment

Experiments (Figure 1) and CFD (Figure 2) were used to assess the performance. The passage-based passive flow control method reduced the influence of incident flow angle on the torque and thrust. This is reflected by a reduction of sensitivity in lift and drag around the design incidence as seen in Figure 1. Over 6deg Cl now only varies by 5.8% compared to no-flow control where it varied by 7.7%. There is no significant compromises in drag around the design incidence. Furthermore, the desirable level of lift moderation can be controlled by changing the span-wise separation.

ACKNOWLEDGEMENTS

This research was based on the first author's Masters project, and was funded by an anonymous donor.

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Assessing the risk of collision between seals and an operating tidal turbine in the Pentland Firth, Scotland

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Conference Theme: 1. Tidal/Ocean current energy

ABSTRACT:

As the demand for renewable energy grows, locations proposed for marine renewable energy devices increasingly overlap with areas important for marine mammal habitats . The concerns around negative ecological impacts from tidal turbines derive primarily from the potential for fatal collisions between marine mammals and the moving parts of the turbine (i.e. blades). We quantified the number of encounters of seals within a meso-scale (10's of m) and micro-scale (<10 m) of an operational turbine in the Pentland Firth, Scotland, between May 2022 and June 2023, using two multibeam sonars. We characterised factors contributing to risk of collision and developed a decision-making framework to guide the evaluation of collision risk between the blades and seals. There were 704 seal encounters within meso-scale (10's of metres) of the turbine. Through rule-based automated analysis of the tracks, the majority (n = 665) were considered to be at a zero - low risk of collision, either because they were detected when the turbine was not operating, they were only detected downstream of the turbine, or they remained further than 10 m from the rotating blades. To further review, a decision tree incorporating parameters related to seal trajectory was developed to quantify the relative risk of collision for each track. This decision tree effectively ranked the risk of collision for each track based on a series of objective and repeatable questions. The uncertainty in the outcomes of tracks closer to the blades requires human subjective assessment of risk, guided by these questions and cross-referencing with the raw sonar data. Our analysis identified 10 tracks that likely passed through the rotor-swept area in the horizontal plane in the year of monitoring. These tracks represent a higher risk , though this cannot be taken as evidence that a collision occurred. The sonars provide accurate locations in the horizontal plane (XY), but very limited vertical information. This approach has the potential to be a valuable tool to guide regulators and developers when assessing the risk of collision between marine wildlife and tidal turbines as an approach to be used in other similar monitoring studies and support informed decision making for future tidal energy developments in deepening our understanding of collision risk.

ACKNOWLEDGEMENTS

The monitoring platform was developed with funds from the Natural Environment Research Council (Grant Nos. NE/R015007/1 and NE/R014639/1). Software development and data analysis were funded by the Scottish Government as part of the Marine Mammal Scientific Support Program (Grant No. MMSS/002/15). Umbilical cables to the turbine infrastructure were funded and developed by MeyGen. We thank SAE Renewables for technical assistance during deployment and data collection, and for providing metadata for this. In particular, we thank Fraser Johnson for all his support and guidance throughout the study.

Proving Tidal: Real-World Lessons from Installing Marine Energy Systems in Japan and Scotland

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Conference Theme: 1. Tidal/Ocean current energy

ABSTRACT:

This presentation will provide a practical, real-world account of what it takes to install and operate multi-megawatt tidal energy systems in diverse environments. Drawing on Proteus Marine Renewables' deployments in Japan and Scotland, we will share key insights into the challenges and lessons learned from delivering reliable marine energy under demanding conditions.

We will examine the AR1100 turbine, recently certified and connected to the grid in Japan, highlighting not only its operational performance but also the regulatory and logistical hurdles overcome during deployment. Insights from the earlier AR1500 installation at the MeyGen site in Scotland will also be shared, including lessons related to site preparation, environmental conditions, installation techniques, grid integration, and maintenance planning.

The session will conclude with a forward look at the AR3000—Proteus's next-generation, 3MW AR Series 2 turbine—designed for utility-scale rollout in Europe. This includes our Normandie Hydroliennes NH1 project in France's Raz Blanchard, which aims to deploy a 12MW array of four of Proteus 3MW tidal turbines in 2028, supported by €31 million in funding from the European Union's Innovation Fund.

By focusing on the practical realities of deploying tidal energy systems—from design to installation, operation, and decommissioning—this presentation aims to contribute to the research community's understanding of system-level challenges, performance outcomes, and the technological advancements needed to scale reliable ocean energy. Our Bristol based company has over 20 years of experience in marine technology and offshore operations, with more than 25 deployments worldwide and over 20 GWh of renewable energy generated to date. This track record demonstrates the real-world performance and long-term viability of tidal power systems.

We will also reflect on end-of-life planning, drawing from one of the sector's first complete install–operate–decommission project cycles. The session will highlight opportunities for continued research and collaboration, and the role Proteus plays in accelerating the marine energy sector—creating green jobs and supporting global energy transition goals through ocean-based solutions.

Figure: Proteus Marine Renewables' AR1100 recent deployment in Japan : 1.1MW turbine.

Acknowledgement

The author gratefully acknowledge the support of the European Union's Innovation Fund for the NH1 Raz Blanchard project.

Proceedings of PRIMaRE 2025
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Resolving the wakes of offshore wind infrastructure in density stratified tidal flows

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: To enable a global net zero future the next decade will see exponential growth of offshore wind renewable energy. This scale of development necessitates expansion into deeper, seasonally stratified, waters for the first time. Density stratification has a profound effect on the physical dynamics of the marine environment, where density gradients act to suppress vertical motion and can lead to large-scale coherent structures. These processes are vital for marine ecosystems through their control on material fluxes. However, there is a growing amount of evidence that turbulence introduced by tidal flows past offshore wind infrastructure can affect the water column structure and subsequent vertical transport processes (Dorrell et al., 2022), but there remains open questions regarding the fundamental nature of wakes in stratified flows and how these should be parameterised in oceanographic models capable of assessing both local and regional impacts of the industry.

To further our understanding we carry out the first direct numerical simulations of two-layer density stratified flows past simplified offshore wind infrastructure. The tidal flows are assumed uniform and free of turbulence, and the density profile takes a tanh form with two constant density regions separated by a pycnocline at the centre of the domain. To understand the impact of stratification strength on dynamics, we vary the density difference between the upper and lower regions (characterised by the background Richardson number, $\boldsymbol{Ri_d}$).

We find that stratification strength has a profound impact on infrastructure wakes. As stratification increases, a large recirculation region develops at the pycnocline, attached to the structure. As a result, the Karman Vortex is weakened, turbulence and drag are reduced, and large-scale mean-flow structures develop in the form of standing internal waves. The influence of structure-induced turbulence on the pycnocline is most pronounced at lower levels of stratification, where the pycnocline width in the wake continuously increases downstream. In contrast, while the absolute difference in pycnocline width is smaller at higher stratification levels, the effects are more spatially extensive. In addition, the conversion between turbulent kinetic energy and potential energy is larger at higher stratification levels, despite the lower drag coefficient, and the dominance of reversible processes (transport and internal waves). When stratification is strong, energy transport by internal wave propagation is of a similar proportion as that lost through irreversible mixing processes. The fate of energy transferred by these reversible processes will be important to consider when developing future mixing closures. Future work aims to upscale these results to realistic conditions and infrastructure designs to better inform oceanographic and ecosystem models capable of assessing the marine impact of offshore renewable energy.

Figure 1: Vortices in the wake of the flow past a model monopile, visualized by contours of swirl strength. Panels from left to right are increasing strengths of background density stratification.

ACKNOWLEDGEMENTS

C.J.L. was supported by an Early Career Fellowship funded by the Leverhulme Trust.

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Proceedings of PRIMaRE 2025
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Floating offshore wind pumps for pumped storage electricity generation in small islands

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: The aim of this research is to investigate the integration of floating wind pumps with pumped storage hydropower (PSH) for electrical power generation in small islands. Traditionally, remote areas and islands depend on imported fossil fuels for power generation but a recent shift towards hybrid power systems of renewable energies and diesel generators has been observed (Mustayen et al., 2022; Department of Environment, Food & Agriculture, 2023). With global efforts to achieve Net Zero Emissions by 2050 (IEA, 2024), countries are motivated to expand their investments in renewable energy innovation. Moreover, the global events since 2020 (the COVID-19 pandemic and major conflicts worldwide) highlight the need for energy independence (Bhattacharya & Bose, 2023; Bigerna et al., 2023). For small islands, high renewable energy penetration can be achieved using offshore wind resources (Martín-Betancor et al., 2024) but this depends on the wind resource's availability. Wind-driven PSH concepts have been demonstrated to have the potential to regulate fluctuations in wind energy supply (Abdelmagid & Siddig, 2025).

In this research, the potential for combining floating offshore wind turbines with the concept of PSH for an island location will be demonstrated. A schematic of the proposed technology is shown in Figure 1. A model has been developed to predict the system's behaviour under various operating conditions. GIS analysis is performed to determine suitable locations for the proposed system within the UK, and the model is applied to a case study to investigate the technical and economic feasibility of this energy generation approach.

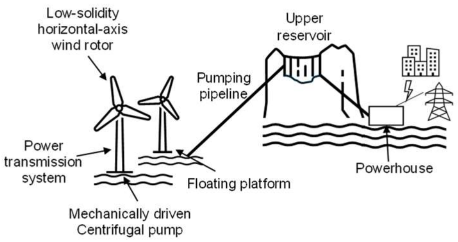

Figure 1: Schematic view of the proposed system

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by the Council for at Risk Academics (CARA) and the UK Government through the Swansea Bay City Deal.

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Proceedings of PRIMaRE 2025
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Hydrodynamical responses of a novel spar-type floating offshore wind turbine: experiments and modelling

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: This study focuses on modelling a novel concept of a spar-type floating wind turbine, designed specifically with ease of assembly and deployment from shallow ports in mind. The UltraMarine design can be assembled in the horizontal position and towed in that state out of the shallow port. Once at the deployment site, the turbine will be ballasted, to bring it to the vertical state and connect it to the mooring and electrical connections. The novel concept is tested first using 1:100 scaled prototype in the wave tank (Figure 1 (a)) at Kelvin Hydrodynamics Lab (KHL) and subsequent detailed modelling studies are performed in the state-of-art Marine Simulator [1, 2] at the National Decommissioning Centre (NDC) to predict the system's nonlinear dynamics behaviour for the feasibility study of deploying this novel floating turbine design.

The numerical model is first calibrated using the experimentally obtained RAOs for both horizontal and vertical orientations of the wind turbine, which results in good agreement between both. Next a set of experiments and simulations is conducted utilising the JONSWAP spectrum, where three sea states are considered with corresponding significant wave heights, H_S, and peak periods, T_P (1.5 m & 9.5 s, 10.4 m & 15.0 s, 18.0 m & 17.0 s). The calibrated model resulted in good agreement with experimental results, which are depicted in Figure 1 (b)-(d), that show results of exceedance observed in the experiment and the simulation for heave, pitch and roll responses. The results from experiments and simulation for heave and pitch responses follow each other very precisely in terms of absolute values and shapes of curves obtained. For roll responses, which are much lower due to the direction of waves chosen, it is possible to obtain the match in terms of magnitude of motions observed.

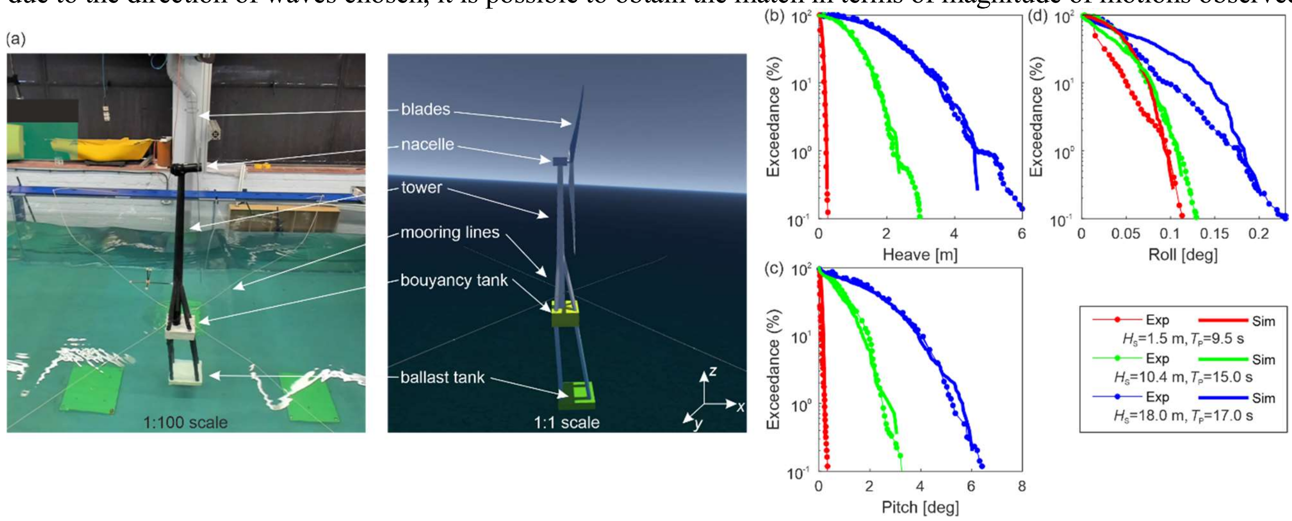

Figure 1: (a) Experimental wave tank test of a 1:100 scale prototype of UltraMarine spar type floating offshore wind turbine and corresponding 1:1 scale numerical model implemented in the Marine Simulator; (b)-(d) Comparison of heave, pitch and roll exceedance responses from the experiments and the numerical model for 3 sets of sea states with JONSWAP spectrum: $H_S = 1.5\ m$, $T_P = 9.5\ s$; $H_S = 10.4\ m$, $T_P = 15.0\ s$; $H_S = 18.0\ m$, $T_P = 17.0\ s$.

ACKNOWLEDGEMENTS

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On the Development of a Short Design Events Approach for Floating Wind Turbines

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: To predict design loads of floating wind turbines during extreme sea states, current design standards recommend simulating multiple irregular wave and turbulent wind time series of one to three hours in duration. In contrast, fixed offshore wind turbines are permitted to use a constrained wave approach with significantly shorter, 10-minute simulations—greatly reducing computational effort [1]. However, this approach is generally not suitable for floating turbines, as the largest wave event does not always correspond to the peak response.

Work on the development of a response-conditioned short-duration simulation method that offers an equivalent constrained wave strategy tailored for floating wind turbines and expanded to include the wind loading will be summarised following our recent publications [2] [3]. This recent work provided evidence for the application of the method to turbines in parked conditions using the numerical model OpenFAST for various floating platform types—including spar, semi-submersible, tension leg platform, and barge devices [2], and physical modelling of a semi-sub in operating conditions [3]. The application of the method to the WindCrete spar device, which will be used in upcoming physical experiments this summer will then be discussed.

Extreme responses such as platform pitch, nacelle accelerations, mooring line loads, and tower base bending moments will be compared across three approaches: long-duration irregular wave simulations, constrained response-conditioned events, and unconstrained response-conditioned events. The work to date suggests that the constrained short-duration series reliably produced extreme responses within −5% to +20% of those generated by the full-length simulations. However, caution is advised when using unconstrained series in cases where higher-order effects are significant—for instance, when surge or tower responses are driven by second-order wave loads.

1. ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by the EPSRC and the Supergen ORE hub.

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Finite element-based dynamic characterization of a Tension-Leg Floating Offshore Wind Turbine

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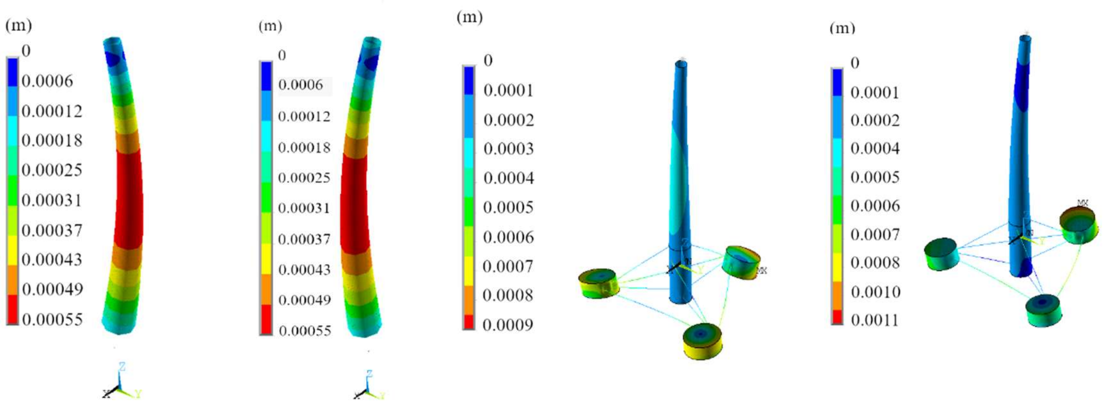
Conference Theme: 3. Offshore floating wind energy

ABSTRACT: The present study aims at identifying the key parameters influencing the dynamic response of floating offshore wind turbines (FOWTs), offering a broader perspective, useful for optimizing the design and reducing potential risks related to resonance phenomena (Lenci, 2023). In particular, the research focused on investigating the linear dynamic behavior of an optimized tension leg (TLP) FOWT, which support a 10 MW DTU reference wind turbine modified for offshore applications (Yu et al., 2015).

Modal analyses were performed on simplified and coupled Finite Element (FE) models, aiming to identify the key natural frequencies and mode shapes. In the simplified model, the tower is discretised through beam elements, providing a simplified representation of the system, allowing to reduce computational costs. The coupled model provided a more detailed geometric representation with shell (used for the tower and for the columns of the platform) and beam (used for the braces of the platform) elements.

The simplified model provided a comprehensive view of the global dynamic behavior. The most significant findings included the fore-aft and side-side bending modes of the tower. A deeper insight into the linear dynamics of the structure was given by the coupled model. Bending and torsional deformations of the pontoons and cross-braces were found to be associated with the natural bending modes of the tower, suggesting potential critical interactions. The two simulation methods led to similar vibration modes associated with the rigid motion of the platform, while a variation of 14% was highlighted for the first bending modes of the tower. Figure 1 shows the 1st bending modes (and their relative frequencies) related to the tower of both models.



(a) *(b)* *(c)* *(d)*

Figure 1: 1st bending modes of the models: a) Side-Side (0.986 Hz) and b) Fore-Aft (1.005 Hz) of the simplified model; c) Side-Side (1.121 Hz) and d) Fore-Aft (0.863 Hz) of the coupled model

ACKNOWLEDGEMENTS

The financial support of the PRIN 2022 project "NonlinEar Phenomena in floaTing offshore wind tUrbiNEs (NEPTUNE)", prot. 2022W7SKTL, is greatly acknowledged.

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Optimisation of a lazy wave dynamic power cable configuration using a surrogate model assisted genetic algorithm

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Conference Theme: Offshore floating wind energy

ABSTRACT: The dynamic power cable is a vital component of floating offshore wind systems, responsible for transmitting electrical energy from the turbine to the seabed while withstanding complex environmental loading. Optimal configuration design is essential to ensure cable reliability and minimise system cost. This study presents an optimisation framework that integrates a genetic algorithm (GA) with a surrogate model trained on numerical simulations conducted in OrcaFlex. The framework is applied to a case study involving a dynamic power cable connected to a semi-submersible floating offshore wind turbine in 200 m water depth. The optimisation seeks to maximise reliability—considering both survivability under extreme conditions and fatigue life—while minimising cost.

Previous studies, such as Rentschler et al. (2020), have applied evolutionary algorithms to optimise dynamic cable configurations but were limited by the high computational cost of full numerical evaluations. The use of surrogate models to support GAs has been proposed for mooring systems (e.g., Pillai et al., 2019); this work extends that approach to dynamic power cable design. The surrogate models predict key response metrics including maximum tension, minimum bend radius, and fatigue life, using training data generated under a 50-year storm for extreme response and a set of operational conditions for fatigue assessment.

The GA iteratively refines the configuration by varying the total cable length, the location of the buoyancy section, and the number of buoyancy modules. The optimisation is multi-objective, aiming to reduce cable length and tension while maximising fatigue life, subject to all required design constraints. The impact of varying objective weightings is also explored, highlighting trade-offs between competing design priorities.

The resulting optimised design satisfies all constraints and demonstrates the capability of the proposed framework to efficiently identify high-performing configurations. The integration of surrogate modelling significantly reduces computational time, making the method well-suited for early-stage design, sensitivity analysis, and broader system-level optimisation.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge that this work was undertaken at the University of Plymouth, UK, under the funding of an Engineering and Physical Sciences Research Council (EPSRC) Ph.D. studentship, grant number EP/T518153/1.

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Hydrodynamic Loads on Semi-submersible Floating Turbine Platform: Role of Orientation and Air-Water Interface

Nilotpal Dhar, Univrsity of Hull

Conference Theme: Offshore floating wind energy

Floating offshore wind turbines are essential to access the stronger and more consistent wind resources in deep-sea locations where installing traditional fixed-bottom foundations, such as monopiles, in deep water can be technically challenging and expensive. Floating platforms for wind turbines, conceptualised from the oil and gas industry, have scale, location, and loading vastly different from those in the oil and gas industry, leading to the development of a range of foundation types to meet the sector's requirements. Amongst them, semi-submersible platforms are structurally complex compared to other types, such as spar buoys, as these consist of multiple members connected by braces and pontoons, with the wind turbine connected to one of the members in the arrangement. Unlike onshore wind turbines, FOWT platforms are subjected to wave-current hydrodynamic loading, wave-induced diffraction and platform-induced radiation. Therefore, it is essential to account for this wide range of loading to optimise the platform design, material selection and construction at an optimal cost. However, the understanding of loading even under simplified conditions is poorly understood. So far, studies have focused on coupled aero-hydrodynamic studies to understand the motion of platforms, vortex-induced vibrations and loading to anchoring systems. The presence of multiple members with different length scales in a semi-submersible platform will influence the hydrodynamic loading. This will be further influenced by a change in the orientation of the platform, leading to non-symmetric flow and the presence of the air-water interface. This study numerically investigates the effect of the change in orientation and the air-water interface on total hydrodynamic drag, as well as the contribution of individual members towards total drag due to a unidirectional constant current of Reynolds number = 2900. A high fidelity Detached Eddy Simulation (DES) with Menter $k-\omega$ SST base model is adopted. The simulations are carried out using OpenFOAM, and a 1:600 model of the OC4 semi-submersible platform developed by NREL is used as the reference platform. The orientations considered are $0°$ (Figure1), at which the flow is symmetrical, and $10°, 30°, 50°, 70°, 90°$ and $110°$ orientations to the incoming current. Analysis of total drag coefficients ($\overline{C}_d$) showed that the highest $\overline{C}_d$ is at $30°$ and $90°$ orientations, whereas the lowest drag is at $10°$ orientation. The individual contributions of members at each orientation are presented in the Figure 2.

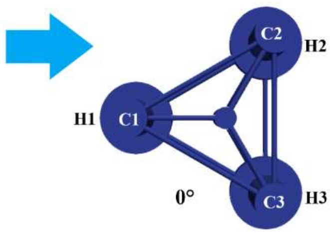

Figure 1 OC4 semi-submersible platform at 0° orientation with respect to the incoming current

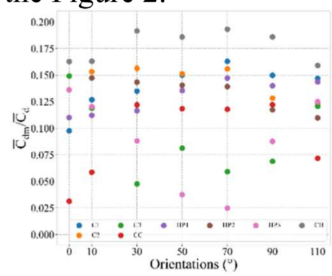

Figure 2 Individual contributions of all members of the OC4 semi-submersible platform across all orientations.

The variation of the contributions of individual members towards total drag with the change in orientation of the platform is attributed to the wake-wake and wake-structure interaction of individual members of the OC4 semi-sub. For instance, the contribution of the central cylinder (CC) is lowest at 0° due to it being within the wake of the C1; however, as the orientation changes, the wake effect reduces, leading to an increase in the contribution of the CC. Further, this also leads to non-symmetric and differential pressure distribution on individual members. Therefore, the shift in orientation results in non-uniform loading across the floating platform, which can affect the dynamic motion and stability of the platform. These findings can help not only in the design optimisation of the platform but also in identifying the optimal orientation of the platform in real time to reduce hydrodynamic loading, leading to the holistic development of the offshore wind sector.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by NREC NE/S014535/1, Early Career Fellowship funded by the Leverhulme Trust and ORE Catapult and EPSRC, grant number EP/S023763/1 with project reference 285298.

Quasi-impulsive reverse wave force on a vertical cylinder

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Conference Theme: Offshore floating wind energy

ABSTRACT: Steep wave breaking on vertical cylinder (a typical foundation supporting offshore wind turbines) will induce slam loads. Many questions on the important violent wave loading and the associated secondary load cycle still remain unanswered. We use laboratory experiments with unidirectional waves to investigate the fluid loading on vertical cylinders. We use a novel three-phase decomposition approach which allows us to separate different types of non-linearity. Our findings reveal the existence of an additional quasi-impulsive loading component that is associated with the secondary load cycle and occurs in the backwards direction against that of the incoming waves. This quasi-impulsive force occurs at the end of the secondary load cycle and close to the passage of the downward zero-crossing point of the undisturbed wave. Wavelet analysis showed that the impulsive force exhibits superficially similar behaviour to a typical wave-slamming event but in the reverse direction. To monitor the scattered wave field and extract run-up on the cylinder, we installed a four-camera synchronized video system and found a strong temporal correlation between the arrival time of the Type-II scattered wave onto the cylinder and the occurrence of this quasi-impulsive force. The temporal characteristics of this quasi-impulsive force can be approximated by the Goda wave impact model, taking the collision of the Type-II scattered waves at the rear stagnation point as the impact source [1].

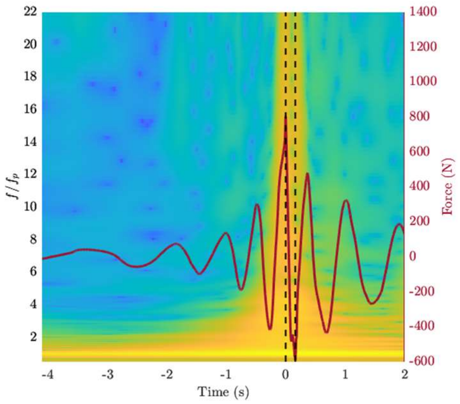

Figure 1: A demonstration of additional higher-frequency forces associated with secondary load cycle with wavelet analysis

ACKNOWLEDGEMENTS

This research is funded by the EPSRC grant EP/V050079/1. TT is also funded by the Eric and Wendy Schmidt AI in Science Postdoctoral Fellowship.

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Initial results when using unmanned vessels for tidal current survey

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: This paper involves a coastal survey with an autonomous vessel (ARCboat, see Figure 1) to collect turbulent flow data. The boat is fitted with a downward facing Nortek Signature VM 1000 ADCP. Currently no small autonomous vessels have been used for ADCP data collection of turbulence data offshore in tidal channels. The main objective of this work is to show that a small autonomous vessel can produce useful data when holding position. A series of experiments were carried out to test the vessel's capabilities under different environmental variables such as wave height, flow-rates (different speed and direction), depths and different types of seabed and sites. The second objective is to understand the physical characteristics in terms of velocity, Turbulent Kinetic energy (TKE) and Turbulence Intensity (TI) of the two sites at different times in the tidal cycle.

The two sites chosen were a shallow tidal estuary at Loughor Bridge, Wales, UK with visible turbulence created by the bridge pillars, the second was the META Warrior way tidal test site, Pembrokeshire, UK. At the time of the measurement, a barge was moored at the META site, and some measurements were taken in the wake of the barge. The vessel was controlled manually in both cases, with live feedback of the vessel GPS position available to the operator. Data was used to calculate velocity (Figure 2) and turbulence statistics through the water column using methods developed by Togneri (2021). Measurements are compared with data from a novel converging beam ADP which was deployed on the same site by Lake (2024).

Figure 1: The ARCboat unmanned vessel

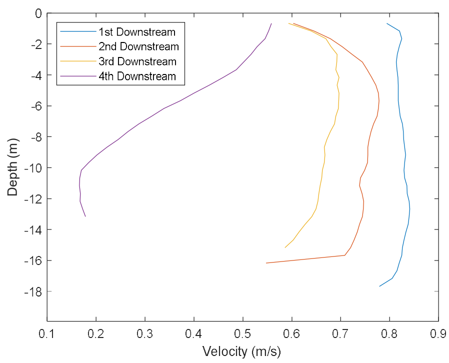

Figure 2: velocity results from holding position at four different locations and times.

ACKNOWLEDGEMENTS

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Fully Differentiable Fluid-Structure Interaction Solver for Wave Propulsion of a Flapping Foil

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Conference Theme: 2. Wave energy

ABSTRACT: Flapping foils are widely used for thrust generation in both aerodynamic and hydrodynamic applications, converting the kinetic energy of the surrounding fluids into thrust. (Xing and Yang, 2023). The resulting motion of a flapping foil thrust can be predicted through coupled fluid-structure interaction simulations. This study presents a fully differentiable fluid-structure interaction solver that leverages GPU acceleration for efficient computation of a flapping foil submerged within deep water waves in a 'one-fluid' framework using a finite element fluid solver. The solver incorporates gradient information to enable control and optimisation of the foil's thrust motion, which is adjustable through the application of automatic differentiation. The solver is considered to be a high-fidelity solver demonstrating both a fast and accurate computation that aids in providing a better understanding of how the thrust motion of the flapping foil is generated in response to propulsion of the incoming waves.

ACKNOWLEDGEMENTS

K. Tuv acknowledges the support from the EPSRC DTP scholarship. Dr L. Yang acknowledges the flexible grant from UK-MaRes Hub 'Wave Devouring Propulsion to Improve Vessel Efficiency'.

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Q-learning and the control of point absorber wave energy converter arrays

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ABSTRACT:

The work that is described here relates to the point absorber type of wave energy converter, although it may have applicability to other types of wave energy converters. The mechanical movement of the point absorber is translational, with changes in terms of velocity and direction. In addition, the characteristics of ocean waves change over time, and can present themselves as regular or irregular waves with different characteristics, such as amplitude and wave period. Furthermore, there can be changes in the wave energy converter caused by, for example, wear and tear or marine growth. The aim of the work presented here is to apply reinforcement learning as a control strategy, to minimize power oscillation whilst maximizing power generation. This study seeks to address these challenges, both in individual wave energy converters, and to make some progress towards evaluating reinforcement learning-based control strategies for arrays.

The performance of a reinforcement learning-based control system is evaluated, using a simulation of a point absorber. Similar simulation systems have already been described in the literature (Anderlini et al., 2016). The specific form of reinforcement learning used is called Q-learning, and it is recognised as a promising model-free control strategy. In the individual point absorber, Q-learning uses rewards, which, in the case of the wave energy converter, is power generated. The Q-learning agent takes actions, which can result in changes to the damping force acting through the power take-off (PTO) on to the wave energy converter. The PTO employs load force damping, and so the level of damping is proportional to the power produced.

During the last year, work has been undertaken on applying Q-learning strategies to more than one wave energy converter. The simulation model has been modified so that the two wave energy converters were coupled, using the method described by (Li & Belmont, 2014a) & (Li & Belmont, 2014b).

In this work, two strategies are used: 1) Each wave energy converter has its own agent. However, the reward signals are a composite of both local and array-wide rewards. 2) Using a single agent, with a much extended tabular Q-learning approach, states and actions for the two devices are implemented from the single table. There is evidence that, for larger arrays, the limitations of tabular Q-learning may be reached. With multi-agent Q-learning, it maybe possible to observe phenomena such as cooperative behaviour, whereby an agent will locally reduce power generation should it result in an overall gain in power.

ACKNOWLEDGEMENTS

I would like to thank the Engineering and Physical Sciences Research Council for funding.

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Rigid and flexible floating plates for wave energy extraction

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Conference Theme: 2. Wave energy

ABSTRACT: We present recent advancements in the hydrodynamic modelling of wave energy converters (WECs), specifically those composed of floating plates deployed in open-sea environments. There has been a growing body of research focused on the hydrodynamic analysis of floating plates for applications in wave energy conversion (WEC), floating solar power, and sea ice dynamics. Prior studies have explored a range of configurations, from piezoelectric plates, to arrays of elastic plates, rectangular structures in constrained environments, and porous and compound bodies. A recurring theme is the use of simplified or idealised geometries to enable analytical or semi-analytical treatment, often limiting applicability to real-world ORE platforms with complex structural layouts (for an exhaustive presentation of previous models see Michele et al., 2024, and references therein). We address these limitations by presenting a theoretical and experimental investigation of the hydrodynamic performance of a rigid floating rectangular platform, equipped with localised vertical power take-off (PTO) cables. The hydrodynamic behaviour of the proposed system is modelled using Green's theorem in conjunction with a free-surface Green's function to solve for the wave interactions. The motion of the plates is predicted by decomposing the system into rigid natural modes of oscillation. Initially, we focus on the case of a single rectangular plate, which is validated with available experimental data. Then we extend our analysis to more complex configurations, including arrays of plates. In this extended study, we investigate how different factors—such as plate geometry, the direction of incident waves, and the power take-off (PTO) coefficient—affect the dynamic response of the platform and the efficiency of energy absorption. Finally, we discuss the role of elasticity in enhancing power production, especially in contrast to the performance of rigid plates.

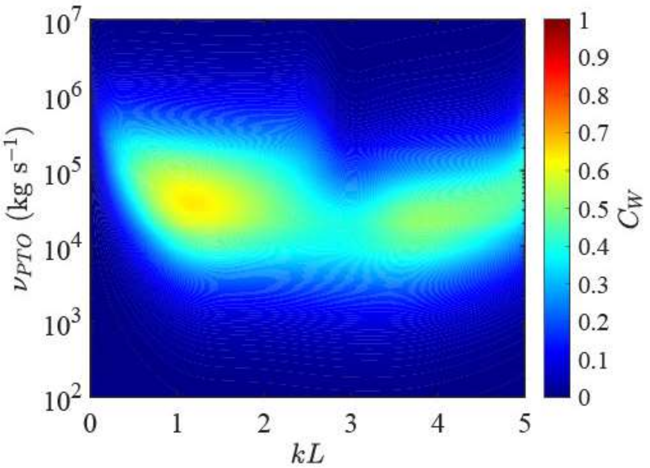

Figure 1: Capture width (CW) of a 10 m x 10 m plate with an internal 5m x 5m moonpool, for varying power take-off (PTO) damping.

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Numerical investigation of wave devouring propulsion for stabilisation of floating wind platforms using hydrofoils

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Conference Theme: 4. Hybrid renewable energy floating platforms

ABSTRACT: In response to the global climate crisis driven by greenhouse gas emissions and non-renewable energy sources, floating offshore wind turbines have emerged as a promising solution and gained increasing attention from both industry and academia due to their suitability for deep-water environment. However, the high cost of mooring systems for platform stabilisation poses a significant financial challenge, indicating the need for novel stabilisation approaches through optimised designs and advanced techniques.

Inspired by the movement of birds and fish, foil-shaped structures can generate thrust through flapping motion. When submerged in waves, a hydrofoil undergoes heave and pitch motion, achieving the conversion of wave energy into forward propulsion (Xing & Liang, 2023), a process known as wave devouring propulsion (WDP). WDP technology has shown great potential as an alternative propulsion method for powing ships (Chan et al., 2024). Additionally, the thrust generated by hydrofoils in waves, combined with their dynamic motion characteristics, contributes to motion control and stabilisation, making them a promising solution for stabilising floating offshore platforms (Xing et al., 2025).

This study numerically investigates the dynamic response of a floating platform equipped with a submerged hydrofoil, focusing on its effectiveness in reducing platform motion. The results indicate a significant improvement in stability compared to a conventional floating platform without hydrofoils, highlighting the feasibility of incorporating WDP technology into offshore wind applications. These findings offer valuable insights into the development of cost-effective and sustainable stabilisation methods for next-generation floating wind platforms.

ACKNOWLEDGEMENTS

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Nature Inclusive Offshore Wind JIP

Conference Theme: 5. Economic, environmental, social, and policy aspects of marine renewable energy

Arup have joined forces with leading industry players in a pioneering Joint Industry Project to put Nature Inclusivity at the core of offshore wind farm design. This initiative goes beyond minimising harm – it aims to create positive, measurable biodiversity gains across a wind farm's entire lifecycle, from planning to decommissioning. By integrating nature-positive design principles, this project will help set a new industry standard, ensuring offshore wind development enhances ecosystems while driving the renewable energy transition.

1. Overview:

- Wood Thilsted, Arup, COWI, NIRAS, Parkwind and Ørsted are collaborating on a revolutionary JIP focused on Nature Inclusivity in offshore wind farms.
    - Founding members include Wood Thilsted, Arup, COWI and NIRAS.
    - Parkwind has joined as a steering group member.
    - Ørsted expected to join as a member imminently.
- The project aims to redefine wind farm design to create measurable, positive impacts on biodiversity, moving beyond harm minimisation to ecosystem regeneration.

2. The Need for Nature Inclusive Design:

- While offshore wind is crucial to the global energy transition, it must not come at the expense of natural environments.
- Regulatory frameworks are increasingly prioritising environmental performance (e.g., in the Netherlands, Denmark and UK with nature recovery and Biodiversity Net Gain policies).
- Nature Inclusive solutions will help meet these emerging standards while contributing to climate resilience and ecosystem recovery.

3. Comprehensive Lifecycle Approach:

- The JIP will explore how Nature Inclusivity can be integrated across all phases of wind farm development: planning, construction, operation and decommissioning.
- The scope includes offshore turbines and substations, all offshore areas, cabling and protection measures, targeting holistic environmental benefits.
- The initiative will harness innovative design and operational practices to enhance marine and coastal ecosystems.

4. Open Invitation for Participation:

- The success of this initiative depends on broad industry participation, leveraging diverse expertise to create stronger, scalable solutions.
- Companies and institutions interested in shaping the future of sustainable offshore wind are invited to join, hence presenting this opportunity to the PRIMaRE event.
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Climate and environmental considerations for green hydrogen from Offshore Renewable Energy (ORE)

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Conference Theme: 5. Economic, environmental, social, and policy aspects of marine renewable energy

ABSTRACT:

Presentation only – no separate paper.

Aims and objectives:

This presentation examines the climatic and environmental concerns of coupling green hydrogen with ORE and compares onshore and offshore hydrogen production.

The UK consumes 700,000 te of grey H_2 annually (Policy_Exchange; Simakov, 2024), emitting 8 Mte.CO_2e/y (The_Oxford_Institute_for_Energy_Studies, 2024**)**. The existing hydrogen industry is firstly a priority for decarbonization. Replacing this with green hydrogen requires ~9 GW of offshore wind and storage to ensure demand is met from an intermittent supply.

The coupling of ORE and green hydrogen seems highly probable, the ORE Catapult have launched a Cost Reduction Monitoring Framework, similar to that conducted for offshore wind. The UK aims for 50 GW of offshore wind and 5 GW of electrolyser capacity by 2030. The CCC in the 7th carbon budget forecast the UK requirement for offshore wind at 88 GW by 2040, with the economy consuming and 800,000 te H_2/y from electrolysis (CCC, 2025). Direct hydrogen production could reduce grid connection costs. NESO estimate a cost of £112 billion for onshore transmission upgrades to connect and transmit all the planned expansion of offshore wind (National_Grid_ESO, 2024)**.**

This study identifies environmental considerations for regulators assessing ORE-hydrogen projects.

Methodology:

A comparative study based on an extensive literature review, assessing climate and environmental impacts, and comparing renewable energy applications for emissions reduction.

Findings / Current work position:

Key findings so far:

- Hydrogen acts as an indirect GHG (GWP_{100}=11**)** (Warwick, 2022)**.** Its high leakage rate should be included in environmental assessments.
- The power grid must be balanced in real time with natural gas taking much of this duty, this can lead to:
    - Green hydrogen may divert renewable power from other sectors, potentially increasing overall emissions, “robbing Peter to pay Paul”.
    - Prioritizing green H_2 with new renewables deprives other economy sectors with higher emissions. i.e. is green hydrogen the best ‘bang for the buck’ for climate? (Statista, 2023) (ACWA_Saudi_Arabia, 2025)

- Electrolysis demands large water volumes. The stoichiometric balance is 9 l/kg H_2 of pure water. Tap water requires de-ionising, with a typical industry requirement of 18 l/kg H_2. 100-1,000MW scale electrolysers will require water cooling, with a water consumption on a city scale, equivalent to 100,000 people (Statista, 2022) (IRENA, 2023).
- Offshore hydrogen production impacts marine ecosystems through HV cable EMF emissions (National_Grid, ND), entanglement hazard in dynamic cables and mooring lines, artificial reef effects, and habitat fragmentation from pipelines (Taormina et al., 2018). Pipelines may mitigate some impacts compared to HV cables (limited to 500MW), as one pipeline can transport several GWs of green hydrogen production (The_Oxford_Institute_for_Energy_Studies; Patonia, 2023) (Spyroudi, 2019).
- Hydrogen transport options include ammonia (NH_3) and methanol (CH_3OH), both are under active consideration for replacement marine fuels (DNV, 2020) (DNV; Brinks, 2020). Ammonia is the basis for fertilizer, essential to global wellbeing. NH_3 is highly toxic to human health and marine life, and releases NOx, while CH_3OH emits CO_2 but is much less hazardous to health.
- ORE can provide environmental benefits, restricting fishing and enhancing local biodiversity with the inclusion of new habitat, which may support surrounding marine ecosystems.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by Funding Body – UKRI Reference 2590893

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Improving the Accessibility of Offshore Wind Infrastructure

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Conference Theme: 5. Economic, environmental, social, and policy aspects of marine renewable energy

ABSTRACT: As offshore wind farms move further offshore and to more challenging locations, sites such as the West of Orkney Wind Farm experience poor accessibility rates due to strong wind speeds and high wave heights, particularly during the winter months. This PhD project aims to improve the accessibility of wind farms by extending weather windows for safe crew transfer to allow technicians to carry out necessary operations. The research aims to investigate improving weather forecasts, advancing crew transfer technologies and considering the comfort of offshore crews.

A first step in the project was to identify industry perceptions of the challenges faced in moving wind farms offshore to challenging sites. To do this, we conducted interviews with industry experts, focused primarily on metocean challenges and technological issues related to crew transfer. Interviewees were identified using LinkedIn networks and by attending conferences. The interview data was analysed using thematic analysis.

Provisional results have highlighted a reliance on modelled data and the need for more live, in-situ data to improve forecasts whilst balancing the cost of the equipment and the installation. Improving crew transfer methods to allow for harsher sea states to extend weather windows and enhancing crew comfort to reduce seasickness were common themes.

Improved communication between metocean and operational teams was identified as a priority. Metocean specialists wish operational professionals had a better understanding of weather models, while operational professionals want simplified decision-making tools that do not require in-depth knowledge of weather systems and models. Interviewees also highlighted the potential roles of AI in generating forecasts and drones use in turbine inspections, particularly in blade inspection where currently rope access teams are being phased out. Lastly, a difference of opinion was uncovered relating to the use of offshore platforms as accommodation blocks instead of using service operational vessels and using smaller crew transfer vessels to transfer people from the platform to the wind turbine generators.

While not directly related to improving the accessibility of offshore wind farms, reducing the need for humans to go offshore through improvements in turbine reliability, pre-commissioning planning and maintenance routines could reduce the need for these offshore crews, minimizing risks and operational costs. The resulting increase in capital cost is likely to be outweighed by lower operational costs and risks.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by EPSRC and Offshore Wind Power Limited.

Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
Bristol, UK | July 2-3 2025

Quantification and attribution of uncertainty in wind power modelling

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Conference Theme: 5. Economic, environmental, social, and policy aspects of marine renewable energy

ABSTRACT:

The expansion of offshore wind power is vital for meeting the UK's net zero targets. Wind power modelling has become an essential tool to inform planning of new wind farms, repowering of existing ones, the assessment of windpower generation under weather conditions not historically experienced yet, or to create synthetic datasets to provide inputs into multi-source power systems modelling.

Wind power model predictions are conditional on a range of uncertain assumptions and input data. Previous studies have focused on investigating the influence of year-on-year climate variability on wind power predictions, particularly when only a short time-period can be used to perform a stress test; others investigated the impact of errors in windspeed data or in their manipulation within the model to extrapolate windspeed to the turbine' hub-heigt (e.g. Staffell and Pfenninger 2016; Yang et al. 2024). However, recent work has suggested that the distribution of wind farms and/or the type of wind turbine installed can have comparably large impacts on windpower statistics (e.g. Giddings et al. 2024; Norman and et. 2024). In this study we investigate, to our knowledge for the first time, all these sources of uncertainty and variability at the same time, so to assess their relative importance in controlling the overall uncertainty in model outputs.

To this end, we use Global Sensitivity Analysis (Pianosi et al. 2016) approach to provide a consistent assessment of the sensitivity of several output metrics capturing mean power generation, length of wind droughts and power generation surplus. We apply our analysis at all existing and planned offshore and onshore sites across Great Britain, using both historical windspeed reanalysis data as well as future climate projections, so to explore the spatial pattern of uncertainties and sensitivities under both present and future climate. Insights from the GSA can help modellers prioritise future efforts for uncertainty reduction and model improvement, and can help decision-makers to grow their understanding of the model's scope of validity and limitations, hence making a more appropriate and justified use of model outputs for informing large investment decisions.

ACKNOWLEDGEMENTS

This work is funded under the DAFNI Centre of Excellence for Resilient Infrastructure Analysis within the UKRI Building a Secure and Resilient World program, with grant number ST/Y003713/1.

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Uncertainty measurements of laboratory tests used in geotechnical design

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Inter- and intralaboratory tests are extremely useful in understanding and quantifying random errors and bias, repeatability and reproducibility limits, and uncertainties in laboratory test data. Such information allows for better understanding and comparison of test data from different geotechnical laboratories and improves the choice of design parameters. To quantify test data as well as the statistically acceptable data range(s), the Structural Soils Limited (SSL) laboratories have been participating in intralaboratory and interlaboratory (proficiency) schemes for the last 10 years. More recently, we have concentrated on the quantification of the uncertainties associated with advanced soil tests, such as constant-rate-of-strain (CRS) consolidation, direct simple shear (DSS), and resonant column (RC) and bender element (BE) measurements of shear modulus.

Soil parameters derived from replicate tests on identical or nearly identical reconstituted soil specimens are statistically analysed following standard tests methods, e.g. ASTM E1601-19. Data analysis provides estimates of repeatability (within-laboratory) and reproducibility (between-laboratories) standard deviations, i.e. s_r and S_R, the corresponding repeatability and reproducibility limits, i.e. r and R, and finally the standard and expanded data uncertainties, i.e. u and U. The discussion is focused particularly on DSS, RC and BE tests.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by funding agency Innovate UK. The project presented in this paper is supported by Structural Soils Limited and University of Bristol.

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
Bristol, UK | July 2-3 2025

Wet storage of floating wind turbines

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Conference Theme: 6. Offshore site characterisation and support infrastructure

Many governments have a number of ambitious targets to increase electricity generation by renewable energy in order to achieve Net Zero by 2050. To meet these targets, the requirement for new wind farms in deeper waters has led to increasing interest in the opportunities of floating offshore wind (FOW). Existing Floating Offshore Wind projects are small scale demonstrator projects. Future commercial scale projects with a generation capacity of 1GW could result in novel and more significant impacts on construction schedules.

Management of wet storage sites – Floating Offshore Wind introduces new potential impact areas in coastal waters where turbines might be temporarily moored during construction or maintenance.
Offshore wind farms have not directly impacted inshore vessel traffic, ship anchorages, port approaches, and coastal aerodromes. The use of wet storage imposes new potential impacts on the maritime industry.

A reoccurring theme for construction and installation is the concern over wet storage requirements for FOWFs. Environmental Impact Assessments (EIAs) for OWF have typically comprised of three components: the array area, the offshore export cable route, and the onshore export cable route to the substation. However, wet storage (which is principally a concept that is useful for construction logistics), involves the temporary storage of either partially or fully constructed floating offshore wind turbines in port or coastal waters.

It is expected that many substructures may be wet stored simultaneously during the construction of a commercial-scale project. Whilst it is feasible that major maintenance campaigns or even construction could occur at wet storage sites, tow to shore, the size of Floating Offshore Wind Turbines, depth of water and current capabilities of large crane vessels likely make this impractical. Given that wet storage sites are likely to be essential to construction strategies for commercial-scale Floating Wind Farms, their potential impacts could be significant. However, this assessment of wet storage is constrained by the uncertainties as to where such sites would be located and therefore prevents a full assessment.

Multi-Rotor Wind Turbines: a Scalable Path to Lower Cost and Greener Energy?

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: The wind turbine industry faces mounting challenges in material usage and disposal, as well as in meeting the growing demands of the renewable energy market. Scaling up single-rotor wind turbines presents significant challenges, including the manufacturing, testing, transportation, operation, and maintenance of blades exceeding 100 meters in length. As these challenges grow, rising capital and operational costs (CapEx, OpEx) may offset the energy gains of larger rotors, making their impact on levelised cost of energy (LCoE) uncertain. Multi-rotor wind turbines (MRWTs) show great promise in reducing LCoE through their advantageous scaling laws [1]. Their smaller individual rotors enable the use of more sustainable materials and streamlined operations and maintenance (O&M), addressing both economic and environmental shortcomings of single-rotor designs. Despite the potential for MRWTs to address these issues, the concept is still in the early stages of validation, with little empirical data supporting their reported advantages. Most notably, there is a distinct lack of comprehensive coupled aero-servo-elastic design studies assessing and iterating upon the design of multi-rotor systems.

This work aims to evaluate the economic viability and environmental impact (EI) of MRWTs – generating designs through bi-objective optimisation and utilising aeroelastic modelling software to comprehensively assess performance. The authors intend to present results from analysis of pre-defined MRWT designs using the novel software, as well as the results of design optimization studies aimed at generating a library of reference rotors for use in future MRWT design studies. The implementation of this design library in multi-rotor models, and a procedure for interpolating blade designs for rapid generation of custom models will also be presented.

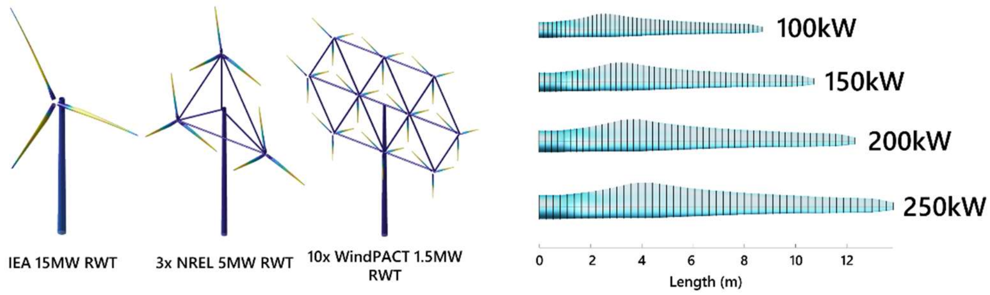

Figure 3: Illustration of multi-rotor comparison study using existing reference wind turbines, alongside sample of the custom rotor design library.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the following organisations for their support throughout this project: (i) The funding of the Wind Blades Research Hub (WBRH), a joint collaboration between the University of Bristol and ORE Catapult, for contributing to the early development of **ATOM** (ii) EPSRC Doctoral Training Partnership (DTP) Studentship awarded to A. Sheik Hassan (iii) The Bristol Composites Institute at the University of Bristol.

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Towards Smarter Wind Turbine Blade Production with Advanced Sensing and Real-Time Modelling

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: The race to net-zero depends heavily on the offshore wind industry, necessitating 27 times scale-up of today's operations (GLOBAL WIND REPORT 2024, 2024; *GWEC's Offshore Wind Hub*, n.d.). Commercial trends are pushing production capacity and blade lengths beyond limits to meet escalating energy demands. However, blade defects will increasingly undermine such efforts by reducing turbine performance, increasing delays and downtime, and costing millions of euros in repairs per turbine overall (Mikindani et al., 2024). The most strategic intervention lies within the vacuum infusion manufacturing process, where defect mitigation is possible to ensure maximum reliability out in the field. By leveraging state-of-the-art process control technologies, such as in-line sensing and automation, the infusion must be monitored and steered towards the defect-free manufacture of wind turbine blades.

The enormous scale of offshore wind turbine blades and the high spatial resolution of sensors needed for flow front detection makes current sensing methods infeasible. A smarter choice and configuration of in-mould sensors allows the fitting of a Darcy flow model to the measured data. In doing so, it is possible to determine the underlying material properties and its variations. These variations significantly impact the flow of resin in the mould and if left uncontrolled, can result in dry spot defects. An efficient procedure based on Latin hypercube sampling and nonlinear least squares regression detects, quantifies and accounts for variations in the prediction of flow front position; in milliseconds and up to three metres away from any one sensor. The real time flow front information provided is essential for guiding process control towards first-time-right manufacture.

A practical solution is proposed that maximises the information obtained from the fewest possible sensors, making it for the first time applicable to large-scale serial production processes. The added resilience to processing and material variations will help to ensure defect-free production of wind turbine blades for reduced downtime in-service required to reach net-zero.

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101058054 (TURBO). This includes funds from UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee [grant numbers 10037822, 10042318 and 10044756] as part of the topic ID HORIZON-CL4-2021-TWIN-TRANSITION-01-02.

Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or UKRI. The European Union or UKRI cannot be held responsible for them.

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
Bristol, UK | July 2-3 2025

A Novel Machine Learning Model to Fast Predict Nonlinear Wave Forces on Monopile-Type Offshore Wind Turbines

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Conference Theme: Offshore wind energy

ABSTRACT: Offshore wind turbines encounter harsh environmental loads that critically influence their design, particularly due to complex wave-structure interactions and strongly nonlinear wave forces under severe conditions. To address this challenge, we present a fast and accurate model for predicting nonlinear wave forces on offshore wind turbine foundations. Our approach uses a "Stokes-type" force formulation (Chen et al., 2018) that approximates the higher force harmonics by correlating them to the linear force time series raised to an appropriate power, modulated by amplitude and phase coefficients. A machine learning model, specifically the Gaussian Process (GP) model, expands the database of these coefficients established through our experimental tests to predict a wider range of wave regimes (Tang et al., 2024). Thus, we have developed a novel predictive framework, the Stokes-Gaussian Process (Stokes-GP) model. Figure 1(a) illustrates the flowchart of the Stokes-GP model, and Figure 1(b) demonstrates its precision in predicting experimental results. Notably, the linear force consistently underestimates the peak force value in severe wave conditions, highlighting the critical importance of accounting for nonlinear forces. This comparison effectively demonstrates the model's efficiency in accurately forecasting nonlinear force.

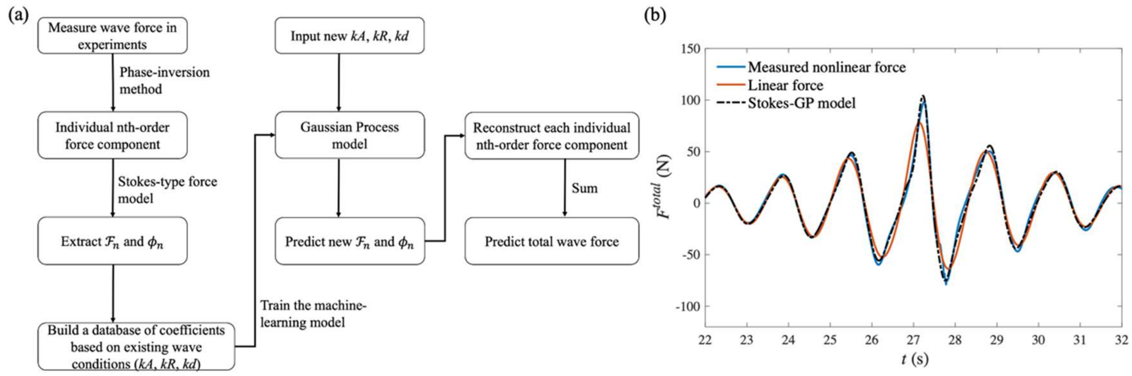

Figure 1: (a) Flowchart of the Stokes-GP model and (b) Predicted nonlinear force from the Stokes-GP model compared to the nonlinear force measured in experimental tests and its linear force with peak wave period (T_P = 1.64 s), peak wave amplitude (A = 0.11 m, is half the sum of the crest-focused wave crest and the trough-focused wave trough magnitude), water depth (d = 0.5 m) and cylinder radius (R = 0.125 m).

This model will be released as open-access. Predictions for a wave regime are completed within a few seconds, enabling comprehensive design evaluations during the planning phase and supporting real-time monitoring. Comparative analyses with experimental data confirm the model's high fidelity in reproducing complex wave forces. Ultimately, the Stokes-GP model represents a transformative tool for optimising the design, safety, and sustainability of offshore wind structures, directly contributing to the broader objectives of enhancing renewable energy infrastructure and supporting net-zero transition initiatives.

ACKNOWLEDGEMENTS

The research presented in this paper is supported by EPSRC grant EP/V050079/1.

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Scale Modelling and Validation of Inverse Catenary Formation of Embedded Tethers

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT: As floating offshore wind expands into deeper waters, anchoring solutions must adapt to complex seabed conditions and mooring loads. JAVELIN is an innovative anchoring technology, offering a low-footprint, high-capacity solution suited to multi-directional mooring loads and geologically constrained offshore sites.

The primary challenge of the JAVELIN anchor is to support laterally loaded mooring systems (catenary and taut/semi-taut) with a vertically drilled and installed anchor. The tether system allows JAVELIN to verticalise lateral loads and enables application to an increased range of geological profiles, including those with significant depth of superficial soils at the seabed surface. Additionally, the frictional interaction between tether and soil reduces the mooring load transferred to the anchor, allowing for potentially reduced conservatism in the JAVELIN anchor design.

Numerical models of the tether system were built based on DNV recommended practices for analysing embedded mooring lines in fluke and plate anchor systems, and further studies from the literature. An in-house scale testing campaign was designed to validate the numerical models, and to study the tether system under a range of load conditions. Procedures for measuring inverse catenary profile, characterising tether performance, and monitoring and maintaining consistent geotechnical conditions were developed. The testing campaign involved a number of stages and methodology improvements. As testing increased in scale, the full JAVELIN anchor system was integrated.

Figure 1: Tether 1:30 scale test rig

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by the Department for Energy Security and Net Zero (DESNZ) SENSEwind workpackage 12. The project presented in this paper is supported by Blackfish Engineering and University of Bristol.

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Offshore Electric Vessel Charging: An Engineering Opportunity

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT:

As offshore wind farms continue to grow in size and complexity, the costs of their operations and maintenance are having an increasingly significant impact on project LCOE. This is particularly true for floating offshore projects, which are predicted to have ~37% of lifetime costs coming from O&M activities **(The Crown Estate, 2025)**. One contributing factor for this is that farms are being built further and further offshore and fuel costs alone are becoming a significant player in project costs. To minimise both the costs and emissions associated with O&M activities, the industry is moving towards hybridising/electrifying the fleet of vessels required for maintenance. However, this presents an immediate challenge - as the farms are moving further offshore how will an electric vessel be able to make the journey? Range anxiety is a very real issue but there is a solution.

Typically, electric vessels are charged in port where there are calm conditions and making connections is straight forward. However, being able to charge on site directly from wind turbines or offshore substations would halve the required distance capability of electric vessels and alleviate much of the concern over their range capability. Charging offshore does present a number of significant engineering challenges to enable a safe, reliable connection that can be achieved in a range of sea conditions. Despite this, Blackfish and its partners have developed an automated system that can overcome those challenges and have demonstrated system viability through a number of trials.

This presentation will walk through the various stages of the project, from concepting to the sea trials that took place last year. There will be a focus on the methodology used and journey taken to innovate this novel technology, and how challenges inherent to the problem were overcome to enable us to seize the opportunity for cost and emission reduction.

Figure 1: Photo from the trial of the first-generation vessel charging system.

ACKNOWLEDGEMENTS

The authors are grateful for the collaboration with Charge Offshore, MJR Power and Automation, Tidal Transit and Parkwind on this project.

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Enhancing Nearshore Wind Estimation with Wave Buoy Data: A UK Southwest Coastal Study

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Accurate nearshore wind data is crucial for offshore wind resource assessment, wave system partitioning, and structural load predictions. Traditional empirical methods (Shimura et al., 2022; Voermans et al., 2020) estimate wind characteristics from wave buoy measurements but struggle in nearshore regions due to complex bathymetry and nonlinear interactions. This study develops a machine learning (ML) approach using wave spectra, depth and coastline to estimate nearshore wind, addressing the limitations of empirical models.

Wave data from six UK coastal Datawell Directional Waverider buoys (2017–2021) were paired with onshore meteorological stations for training. The test dataset (2023) was used for evaluation. Model inputs included the "First Five" (E_f, a_1, b_1, a_2, b_2), depth-related parameterisations (E_k, kd) and site-specific directional fetch. A deep neural network (DNN) was developed with two hidden layers (128, 64 neurons) using ReLU activation and trained with an 80:20 data split. The Adam optimizer was used with a learning rate scheduler and early stopping.

The model performance was assessed by comparing the results with measuremtn in the test dataset (2023). The empirical method provides a baseline (MAE: 2.485 m/s for wind speed, 54.849° for wind direction). Introducing directional information (a_1, b_1, a_2, b_2) improves wind speed estimation (MAE reduced by 20%). Directional fetch parameter enhances accuracy further, while fetch and kd inclusion yields the best results (MAE: 1.267 m/s for wind speed, 35.526° for wind direction). Figure 4 windroses indicate that the model effectively captures prevailing wind distributions.

This study demonstrates the feasibility of ML-based wind estimation from wave spectra, depth and coastline data, achieving significant accuracy improvements over empirical methods. The consideration of wave dispersion relation and fetch was critical in nearshore environments. Future work will extend this framework to additional sites and compare results with satellite SAR data.

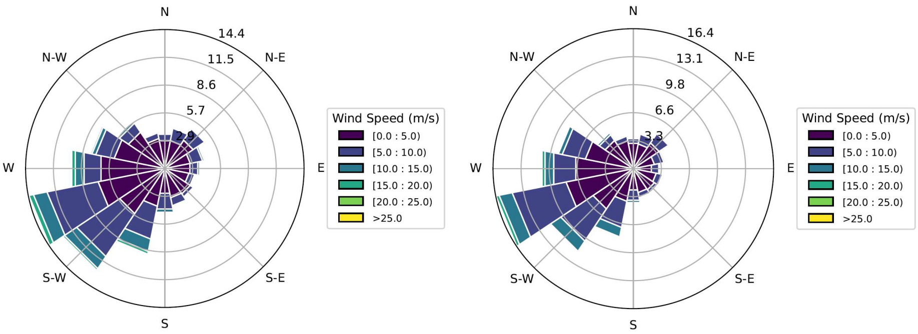

Figure 4 Windrose of six buoys in 2023. Left: Measured. Right: Modelled.

ACKNOWLEDGEMENTS

The authors acknowledge that this work was funded as part of the Engineering and Physical Sciences Research Council (EPSRC) project 'Supergen ORE Hub' [EP/S000747/1].

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Proceedings of PRIMaRE 2025
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Advanced Machine Learning PCPT Interpretation in Offshore Geotechnical Investigations

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Piezocone Penetration Testing (PCPT) is the preferred technique for evaluating ground conditions in offshore geotechnical engineering. However, the large and often complex datasets generated by PCPT testing pose challenges for traditional analysis methods, which often rely on substantial engineering judgement. This study presents an integrated methodology leveraging both supervised and unsupervised machine learning (ML) algorithms to analyse PCPT data to rapidly define stratigraphic boundaries, characterise soil properties, and develop predictive models which can be readily utilised by engineers to develop reliable engineering design parameters. PCPT parameters with strong correlations to soil properties were identified and selected as model inputs. The profiles were preprocessed using data cleaning techniques based on empirical correlations and anomaly detection methods. Depth-independent clustering algorithms, such as k-means, were applied to differentiate soil types, while hierarchical methods, such as agglomerative clustering, were used to identify geological layers by incorporating depth continuity constraints. The model results were validated against robust layering datasets, which incorporated offshore field descriptions, PCPT profiles, and geotechnical laboratory test results. Through development of this workflow, the authors demonstrate the potential of the integration of ML to aid geotechnical interpretation workflows aimed at PCPT data interpretation, thus offering a systematic approach that can significantly benefit the vast scopes of offshore geotechnics.

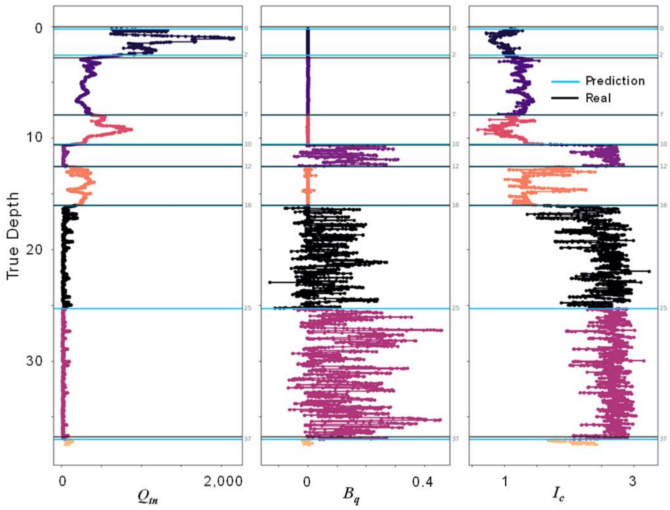

Figure 1: PCPT profile showing Qtn (Normalized tip resistance), Bq (Normalized porer pressure ratio) and Ic (Soil behaviour type index) from Roberston (2016) respectively. The blue lines are the layer boundaries predicted by the algorithm, while the black lines indicate layer boundaries determined by analyzing data from PCPT and onshore geotechnical lab testing. The different colours indicate different geological layers predicted by the algorithm.

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A Critical Appraisal of P–Y Models for Anchors in Weak Rocks for Marine Renewable Energy Applications

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Marine renewable energy devices need to be secured to the seabed using substantial anchors that must resist significant lateral loads. Accurate prediction of anchor behaviour under lateral loading is essential for ensuring both the safety and cost-effectiveness of mooring systems. This paper critically evaluates several p-y model formulations either specifically developed for or potentially applicable to weak rocks. The goal is to identify the most versatile and accurate models for predicting the lateral behaviour of anchors embedded in this type of geomaterial. Selected p-y models are firstly summarized, then suggestions for adjusting their parameter to better capture the typical response of weak rocks are advanced. Suitability and performance of each model is assessed by comparing with field test data from multiple sites and featuring different anchor geometries. The results demonstrate that traditional p-y models can be effectively applied in weak rocks through straightforward parameter adjustments. These adaptations enable more accurate and practical application in engineering practice. Based on the findings, specific recommendations are provided for selecting and optimizing p-y models tailored to the design of anchoring systems for marine renewable energy mooring applications.

Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
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ROBOCONE: Design development and testing of a novel robotic site investigation tool for enhancing geotechnical design of offshore renewables

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: The rapid expansion of offshore wind energy to meet net-zero targets by 2050 necessitates a significant reduction in typical project timelines (HMG, 2022). One of the most time-intensive phases is the pre-construction site investigation, where soil samples are collected and transported onshore for laboratory analysis. Streamlining this process through alternative in-situ probing and testing techniques can accelerate design by providing critical soil parameters much earlier in the project lifecycle.

Recent advancements in robotic and sensing technologies offer the potential to enhance site investigations, supporting a 'whole-life' design approach for offshore renewable structures (Gourvenec, 2020). The ROBOCONE device, introduced at PRIMaRE 2023 and 2024, is an innovative robotic tool designed to replicate the stress and strain histories experienced by soil elements surrounding geotechnical structures as demonstrated in Figure 1. Mounted behind a standard CPT cone, its cylindrical 'p-y module' moves laterally—up to 25% of the cone diameter—to measure the soil's p-y response. This data improves the design of seabed foundations for offshore renewables, including monopiles, caissons, and anchors for floating structures.

The developed design of the ROBOCONE p-y module, along with results from large-scale testing and their application to offshore renewable foundation design is presented here.

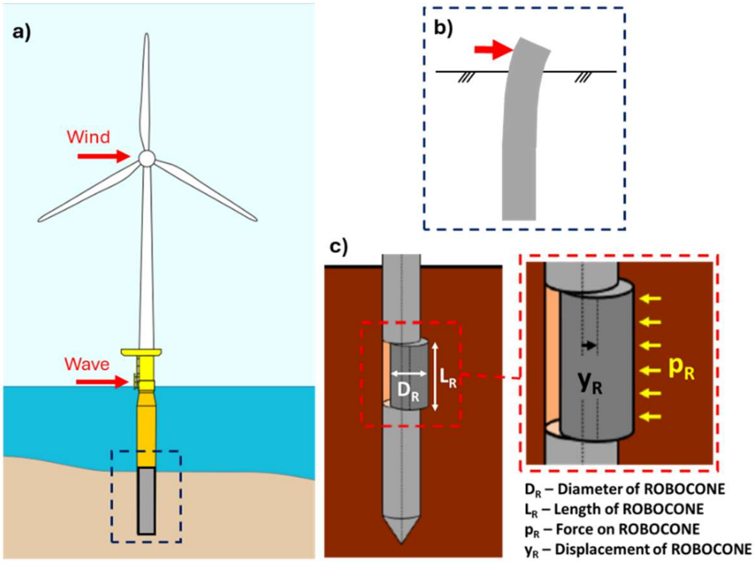

Figure 1: Typical loading on a) an offshore wind turbine structure and its b) monopile foundation which can be replicated using the c) ROBOCONE: p-y module

ACKNOWLEDGEMENTS

The authors acknowledge financial support from the EPSRC (Ref: EP/W006235/1).

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Physics-informed and data-driven modelling of WECs – current activities at Uppsala University

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Conference Theme: 2. Wave energy

ABSTRACT: Accurate prediction of dynamics and reliability of wave energy converters in realistic ocean conditions still presents significant challenges. Computational fluid dynamics (CFD) models can provide accurate predictions, but remain infeasible due to their computational costs. Low-fidelity models can assess system responses in larger ranges of scenarios, but rely on crude simplifications for system dynamics and wave-structure interaction. Finally, experimental campaigns are indispensable for validation and training purposes, but come with significant complexities and costs. Recent progress at Uppsala University involves methods to bridge the gap between high and low fidelity models, using machine learning (ML) techniques and experimental data from dry tests, wave tanks, and offshore campaigns. Stavropoulou et al. (2025) equipped a low-fidelity linear potential flow model for a wave farm with a long short-term memory (LSTM) neural network and trained it using experimental wave tank data, thereby improving its ability to make accurate predictions for the wave farm dynamics. Validated high-fidelity CFD models based on both mesh-based OpenFOAM and particle-based DualSPHysics have been developed for single and arrays of wave energy devices (Tagliafierro et al., 2025). Surrogate models based on Gaussian process regression coupled with a LSTM have been shown to predict extreme loads well, and convolutional neural networks have been developed to map wave height to line force prediction as a survivability strategy. Current work continues this approach, combining CFD models with dry test data using ML (Dupuis et al., 2025), predicting wave farm performance in unseen array layouts, and advancing modelling capabilities for wave energy systems.

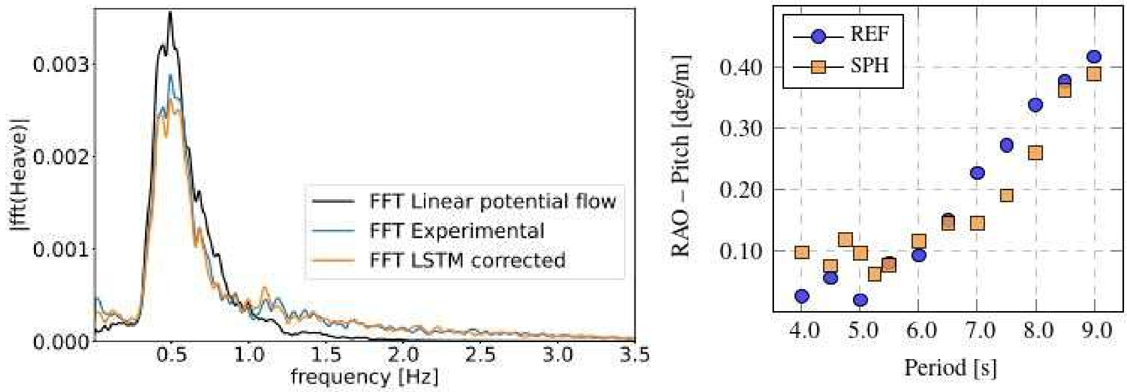

Figure 1: Left) Equipping the low-fidelity model with LSTM and training it with experimental data significantly improves its ability to predict wave farm dynamics in unseen conditions (Stavropoulou et al., 2025). Right) A DualSPHysics model has been developed for a DeepCWind platform combined with three WaveStar WECs, and validated with experimental data (Tagliafierro et al., 2025).

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by eSSENCE, EU Horizon, and the Swedish Research Council.

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Ocean-Based Instrumentation Power Assessment for Node Zero in the Northwest Atlantic Region

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Conference Theme: 6. Offshore site characterisation and support infrastructure

"Node Zero" is the first of a global network of next-generation wave-powered data collection buoys and Marine Autonomous Systems hubs being developed by UK and Canadian companies at the leading edge of the next ocean technology revolution. The limits to onboard power and solar charging on offshore buoys restrict the deployment of advanced sensors, recharging underwater and surface vehicles, data processing and communications systems, which are necessary to extend mission durations and eliminate vessel intervention, thereby reducing associated carbon emissions, for ocean observation in offshore locations. Utilizing renewable energy from ocean waves to provide power at sea for ocean observation activities offers a solution with lower operational costs and a significant reduction in carbon emissions, while enabling the expansion of mission durations and capabilities.

Wave energy resource assessment is crucial for the effective deployment of wave energy converters (WECs). This assessment involves a comprehensive understanding of wave characteristics, including spatial and temporal variations, which significantly influence energy generation potential. This research applies a methodology to assess wave energy resources and estimate the annual energy yield of Node Zero WEC using time-series wave data and a capture width function, with a specific focus on two locations: Halifax, Nova Scotia, and the Gulf of Maine. The approach is based on best practices and technical guidelines defined in the international standards IEC TS 62600-100:2022 and IEC TS 62600-101:2015.

A comprehensive assessment of wave energy resources in the Northwest Atlantic was conducted, with a particular focus on two key regions: the coast of Halifax, Nova Scotia, and the Gulf of Maine. Data were collected from six wave buoys—three deployed near Halifax and three within the Gulf of Maine—to evaluate the spatial and temporal variability of wave energy potential. The analysis encompassed parameters such as significant wave height, energy period, and wave power density over a multi-year time frame, enabling a detailed characterization of the regional wave climate.

This work presents a resource assessment framework developed to support the design of reliable, off-grid power systems for ocean-based instrumentation packages. The framework integrates inputs from multiple renewable energy sources—including wave energy converters (WECs) and photovoltaic (PV) systems—along with performance characteristics such as WEC power conversion workflows (PCW) and PV specifications. By modeling the temporal variability of these resources in conjunction with power demand profiles, the framework determines the required battery storage capacity to sustain continuous, baseload operation. This tool is particularly relevant for applications where persistent, autonomous power is critical, such as offshore wind resource assessments utilizing LIDAR, ocean monitoring stations, and other remote sensing and data acquisition systems deployed at sea. Moreover, the framework enables rapid, site-specific evaluation of energy system configurations to ensure operational reliability under varying environmental conditions. The results contribute to an enhanced regional understanding of marine renewable energy resources and support strategic planning for future deployments in Atlantic Canada and the northeastern United States.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support provided by funding UKRI Innovate UK, UK-Canada Ocean Collaborative R&D Grant Number 10108979.

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Laboratory Characterisation of Thermal Properties of Binary Mixtures and Its Impact on Submarine Cable Design

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: The integrity and performance of submarine cables during installation and throughout their service life cycle are crucial to the offshore renewable energy sector. Accurate ampacity (current-carrying capacity) assessments are essential for optimising the design of high-voltage (HV) submarine electrical cables, extending their operational lifespan, and reducing maintenance costs. The actual power transmission capability of these HV cables is primarily constrained by the maximum allowable core temperatures, commonly quoted as 90°C, beyond which insulation degradation begins (Dix et al., 2017). This internal temperature depends critically on the thermal properties of both the cable and the surrounding burial medium. The heterogeneous soil mixtures and conditions induced by settlement in the marine environments should be considered in the HV cables design, particularly given the extended distances spanning several kilometres Although the mechanical behaviour of binary mixtures have been studied, demonstrating the influence of fine contents on their mechanical responses (Belkhatir et al., 2013), limited study has addressed the thermal environment around offshore HV cables (Worzyk, 2009). Consequently, current design practices often adopt the assumptions of homogeneous thermal conditions governed solely by conduction.

To address the gap, the present study systematically investigates the thermal properties of binary sand mixtures. A series of thermal conductivity tests was conducted using a custom-designed multi-needle system, capable of capturing both spatial and directional variations in thermal behaviour as shown in Figure 5. Figure 5 also illustrates the testing programme by series of the post-jetting conditions of sand column. The sand column consists of layered Leighton Buzzard sand and silt, initially arranged from top to bottom, which reveres as several jetting progresses through the column. This configuration enabled a comprehensive evaluation of how stratification and heterogeneity influence soil thermal conductivity. The results provide valuable insights for optimization of design and operation of submarine cables in real-world application.

Figure 5: Testing setup and programme

ACKNOWLEDGEMENTS

The first author is grateful for the financial support provided by the University of Bristol and China Scholarship Council (No. 202206380059). Technical support by Gary Martin of the University of Bristol is thanked gratefully.

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Numerical modelling of laterally loaded pile foundations installed in weak rocks

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Floating offshore wind structures present unique geotechnical challenges, particularly in the design of anchor piles that must withstand significant lateral loading in variable seabed conditions to ensure long-term stability and performance. As offshore wind energy development expands into deeper waters and new regions, weak and hard rocks are increasingly encountered at foundation level, each posing distinct engineering challenges. Weak rocks are prone to destructuring and gapping under load, while hard rocks present high driving resistance, making pile installation complex and difficult to execute. The in-situ strength and stiffness characteristics of these rocks critically influence the choice of foundation type and installation method, and in turn affects the rock-foundation interaction mechanisms and the foundation's serviceability and ultimate capacity. This research investigates how installation effects can be captured explicitly in three-dimensional (3D) finite element (FE) modelling of impact driven and drilled-and-grouted pile foundations in weak rocks through describing layers of materials adjacent to pile shafts and beneath pile bases with distinct properties. A general modelling framework is presented and illustrative examples given, drawing on reported studies of laterally loaded driven piles in low-to-medium density chalk and drilled piles in weathered carbonated rocks. Detailed PLAXIS 3D FE analyses incorporating routine constitutive models arenpresented and the results benchmarked against field pile data and external FE test experiments, with further analysis using more advanced constitutive models and an additional set of piles currently underway. Four components of local rock reaction will be derived based on the PISA design framework for sands and clays, including the distributed lateral load and moment along pile shafts, as well as shear and moment at the pile base. These reaction components will be directly linked to rock's mechanical parameters and pile geometries, enabling further development of one-dimensional (1D) beam-spring model for efficient modelling and practical design of lateral loaded piles in rock strata.

ACKNOWLEDGEMENTS

The authors are grateful to the ALPACA and Wind Support Campaign teams for providing valuable field data. The work also benefited from technical insights shared by colleagues at the University of Bristol.

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A new design of Oscillating Water Column wave energy device with high broad-banded efficiency

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Conference Theme: 2. Wave energy

ABSTRACT: An Oscillating Water Column (OWC) device exploits the rise and fall of ocean waves to drive the flow of a fluid within an internal chamber via a submerged opening (see, for example, Evans (1978)). The air enclosed above the internal free surface is pumped back and forth through a Wells turbine through which power is taken. The principal underpinning the success of the OWC is resonance: its frequency is set by the mass of the fluid in the internal chamber and the hydrostatic spring restoring force provided by the oscillating internal free surface. Evans & Porter (1995) showed how a simple two-dimensional model of shore-mounted OWC could extract 100% of the incoming wave energy at a single resonant frequency dependent on the size and shape of the rectangular internal chamber.

In this abstract we outline the early theoretical developments of a new design of shore-mounted OWC in which the internal chamber is comprised of an annular half U-bend which is segmented into a number of narrow annular channels each independently connecting the ocean to its own internal free surface (see Fig. 1(a)). On account of the channels having different lengths, the OWC now has multiple resonant frequencies, the largest/smallest of which are associated with the shortest/longest channels.

The problem is formulated using the linearised theory of water waves and the complexity of the structured half U-bend is simplified using a continuum model which assumes sufficiently large number of sufficiently narrow channels. The mathematical boundary-value problem is reduced to an integral equation whose solution is approximated by a standard spectral method leading to numerical solutions. The efficiency of power capture is provided by two independent calculations, used to confirm the accuracy of the numerical method. Preliminary results (see Fig 1(b)) show how it is possible to capture nearly 100% of the incoming wave energy over a wide range of frequencies set by the OWC design parameters.

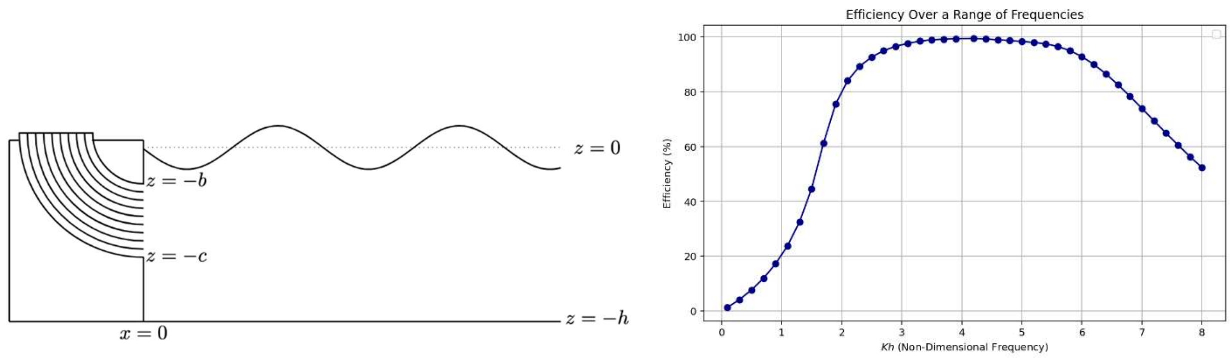

Figure 1: (a) Schematic of a structured OWC device and (b) an example of the efficiency as a function of dimensionless frequency parameter, Kh.

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
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The Robocone rotational Tool for Advanced Characterisation of the underground

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: The rapid growth of the wind energy sector, a key component of international efforts to achieve Net Zero, highlights the need for advancements in geotechnical site investigation. Offshore wind construction requires precise geotechnical data to design safe, reliable foundations. While economies advocate for more marine wind infrastructure, the challenges of site investigation in increasingly remote, hostile marine environments become apparent. Within geotechnics, the use of robotic technologies can be exploited to improve site investigation. The ROBOCONE – being developed at the University of Bristol, in collaboration with the University of Southampton and the Trinity College Dublin – aims to integrate robotics with traditional CPT apparatus to facilitate accurate, immediate, affordable in-situ investigation practices [1]. Presently, the ROBOCONE has three distinct modules (Figure 1a), each applying a respective mechanical loading, mobilising the following responses resembling pile loading scenarios: the lateral p-y module, the vertical t_{rz}-z module, and the torsional $t_{r\theta}$-θ module.

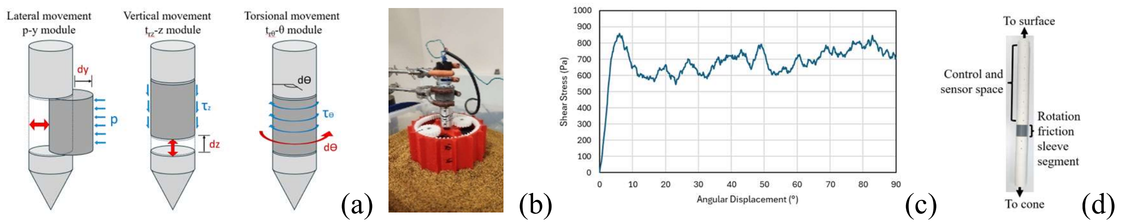

Figure 1: (a) Schematic overview of the ROBOCONE modules, (b) Large scale trθ-θ prototype, (c) example of preliminary results, (d) Small scale trθ-θ prototype.

The ROBOCONE's rotational module, $t_{r\theta}$-θ, imposes continuous rotation of a cone element, aiming to determine both shear strength and stiffness, and their evolution with infinite increasing torsional strain. Critically, residual properties can be determinable from in-situ tests, representing possible worst case parameters for safe but efficient geotechnical design. The module aims to be miniaturised to a 54mm diameter, so that it can be deployable on a standard CPT rod. Large scale prototyping, at 138mm diameter, has been completed (Figure 1b), with evolutions of shear strength against increasing rotation plotted through calibration of motor power-speed characteristics against torques that were post-processed to shear stresses (Figure 1c). A CPT compatible 54mm system (Figure 1d) is being designed and tested, with improvements to the system's robustness, sensor resolution and control. Overall, the ROBOCONE project is developing three new robotic tools to enable advanced geotechnical characterization. Designed to be implemented alongside traditional apparatus - the CPT - the tools aim to allow in-situ testing capabilities well beyond current site investigation practices, allowing rapid, reliable data acquisition in even the remotest offshore environments.

ACKNOWLEDGEMENTS

The authors would like to acknowledge financial support from the EPSRC (Ref: EP/W006235/1) and SFI (Ref: 21/EPSRC/3787).

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
Bristol, UK | July 2-3 2025

Integrated model for Floating Offshore Wind Turbine

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Conference Theme: 3. Offshore floating wind energy

ABSTRACT:

Offshore wind energy has become increasingly attractive to researchers as a valuable energy source, particularly through the use of floating offshore wind turbines (FOWTs). Investigating FOWTs numerically is significantly more cost-effective than conducting experimental model testing. Traditionally, studies on FOWTs have focused on their individual components, examining the aerodynamic performance of the turbine and the hydrodynamic behavior of the platform separately. However, analyzing these components in isolation overlooks the complex interactions between the floating platform and the turbine's motion, which can limit the overall effectiveness of the analysis. Therefore, a fully coupled analysis is essential to evaluate FOWT performance under combined wave and wind forces, integrating both aerodynamic and hydrodynamic factors. Many existing fully coupled methods rely on simplified models, which may overlook nonlinear hydrodynamic effects and unsteady aerodynamic loads. This oversight can adversely affect stability predictions, particularly under extreme conditions.

This project aims to develop a fully coupled, high-fidelity numerical model to accurately capture the aero-hydro-elastic response of FOWTs, with a specific focus on tower-base loads and structural deformation. A partitioned simulation strategy is employed using the ParaSiF framework, which integrates OpenFOAM for high-resolution aerodynamic analysis and OpenFAST for simulating the dynamics of floating platforms and mooring forces. To reduce computational costs while ensuring accuracy, aerodynamic loads are modeled using the Unsteady Actuator Line Method (UALM) in the initial phase, followed by the Elastic Actuator Line Method (EALM) in OpenFOAM. These methods provide an enhanced representation of blade loading without the need for fully resolved blade Computational Fluid Dynamics (CFD). In addition, to enhance realism, nonlinear hydrodynamic coefficients will be imported into the OpenFAST to improve the fidelity of platform motion predictions under combined wave and wind loading. and for modelling the tower structure, which plays a critical role in load transfer, a Computational Solid Mechanics (CSM) approach will be used.

A key challenge in this study is balancing computational efficiency with model accuracy. High-fidelity CFD and fully nonlinear hydrodynamics can be computationally expensive, so the approach taken here prioritizes high accuracy in aerodynamic loads (using UALM and EALM), efficiency in hydrodynamic modelling (using potential flow), and realistic tower dynamics (using a solid mechanics solver). By leveraging this multi-fidelity, modular approach, the model enables more accurate prediction of aerodynamic forces and tower structural response, advancing current methods for simulating FOWT behavior under combined wind and wave loading.

ACKNOWLEDGEMENTS

This PhD project is supported by the Offshore Renewable Energy Catapult and the School of Engineering, Computing and Mathematics (SoECaM) of the University of Plymouth.

Large Deformation Finite Element Analysis for the Installation of Offshore Embedded Foundations

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Large deformation problems are frequently encountered in offshore site characterisation with cone penetration (CPT), T-bar, ball or other penetrometers, and the installation of a wide range of shallow to deep foundations. Advanced numerical analysis offers significant insights into soil resistances under large strain shearing and the underlying soil-structure interaction mechanisms. Among other established or emerging numerical methods, the Coupled Eulerian-Lagrangian (CEL) method is widely recognised as an effective and robust approach for modelling large-deformation problems involving quasi-static and dynamic loading. However, the conventional CEL method is largely limited to total stress analysis, restricting its ability in capturing coupled hydro-mechanical behaviour of saturated soils. This ongoing doctoral study explores a coupled hydro-mechanical CEL approach for modelling cone penetration and driven pile installation problems in sands. Predictions of cone resistance profiles were made with a conventional Mohr-Coulomb model and more advanced soil constitutive models and then validated against centrifuge experiment results. Cone penetration resistances in dense dilatant fine sand were found to depend critically on the advancing rate, with resistances increasing substantially as the response transitions from partially drained to fully undrained conditions. Further parametric studies were undertaken to investigates the effects of model size, mesh configuration and boundary condition on the accuracy and efficiency of large-deformation modelling. The coupled CEL method has significant potential for improving the theoretical understanding and industrial practice of the installation of offshore embedded foundations.

ACKNOWLEDGEMENTS

The first Author thanks the financial support from the University of Bristol through a Global Challenge Doctoral Scholarship. Professors George Mylonakis of the University of Bristol and Yinghui Tian of the University of Melbourne are thanked for their helpful discussions and kind support.

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
Bristol, UK | July 2-3 2025

Synergy of tidal power and flood alleviation in UK estuaries

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Conference Theme: 1. Tidal/Ocean current energy

Project objectives and goals: Many UK estuaries present both tidal power potential and significant risk of coastal flooding, which is being exacerbated by climate induced sea-level rise. This project investigates the potential synergy between tidal power generation (through turbine arrays or barrages) and flood prevention through surge barriers by exploring the integration of renewable energy production with flood protection.

The research aims to undertake: Desk study to review overlap between literature and UK datasets covering tides and surges in estuaries, tidal power potential, flooding and sea-level rise.

Case study future-scenario modelling of the River Itchen mixed-use scheme using field data on tidal elevations and with flood prevention under long term future climate change & sea-level scenarios.

Techno-economic feasibility assessment of such multi-use schemes, enhanced with bathymetric data, tidal measurements and recent cost estimates.

Description of method and results: Hydrographic and official data layers were combined to identify areas of high flood risk and population density as potential sites for tidal power installations around the UK. Bathymetric data from the S-100 trial [Admiralty,2024] was used to calculate the depth of the estuaries such that the cross-sectional area of a potential barrage may be derived.

As a case study, a hypothetical barrage was simulated in the River Itchen. Tidal elevation data from Southampton Port [Admiralty,2024] was used to model a tidal barrage operating in ebb flow generation. A time-stepping loop waits until sufficient head difference is reached before generating electricity until the basin level and the sea-level are equal, all based on a fixed discharge coefficient [Soton Met, 2024]. Following identification of generation periods, power is estimated with a time-stepping calculation [Pugh, D.T.,1993].

Initial results indicate a modest annual potential of 3.5 GWh, accounting for the entire electrical demand of Southampton 033B LSOA which has 1200 electrical meters [GOV.UK,2024]. Complexities, including sluicing, holding and generating, were then introduced. Additionally, variations in tidal range, river flow, storm surges and sea level rise were also accounted for, with the aim of applying machine learning techniques to optimise the predictive operation of tidal barrages.

The time stepping model was effective in modelling the Solent's complex tidal dynamics, including its double high-water phenomenon, with the developed methods robustly applicable for other estuaries with similar characteristics.

Acknowledgements

Funding from 2023/24 SMMI HEIF fund, supported by Energy and Climate Change Division.

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Proceedings of PRIMaRE 2025
12TH PRIMARE CONFERENCE
Bristol, UK | July 2-3 2025

ROBOCONE t-z module: A Novel In-Situ Testing Tool for Offshore Pile Foundations under Axial Loading

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Conference Theme: 6. Offshore site characterisation and support infrastructure

ABSTRACT: Offshore wind energy is expected to play a central role in global decarbonisation strategies, particularly in deep waters where higher-capacity turbines and jacket foundations are increasingly adopted. For water depths exceeding 30 metres, jacket structures are favoured for their stability under large overturning moments from wind and wave loads. These moments are primarily transferred to the seabed through axial loads on pile foundations, which are subject to long-term cyclic loading (Alamo et al., 2018). Such loading can degrade pile capacity and stiffness over time, leading to changes in axial load-transfer mechanisms and potential structural tilting, representing a critical concern for foundation performance.To support more efficient offshore site characterisation and reduce dependence on slow, laboratory-based cyclic loading tests, a novel robotic in-situ testing device called ROBOCONE t-z module is under development (El Hajjar et al., 2024). This tool is designed to expedite the geotechnical investigation process by enabling direct field measurement of soil-structure interaction parameters.A key innovation within the system is the t-z vertical module, developed to measure t-z reaction curves by simulating the kinematic behaviour of an axially loaded pile. The module performs controlled vertical displacements within the soil, capturing axial load-displacement relationships representative of real pile loading conditions. It is also designed to be integrated behind a standard Cone Penetrometer, enabling efficient offshore deployment using existing CPT infrastructure. The ROBOCONE system represents a significant step toward faster, more accurate offshore site investigations, supporting the safe and cost-effective development of future offshore wind infrastructure.

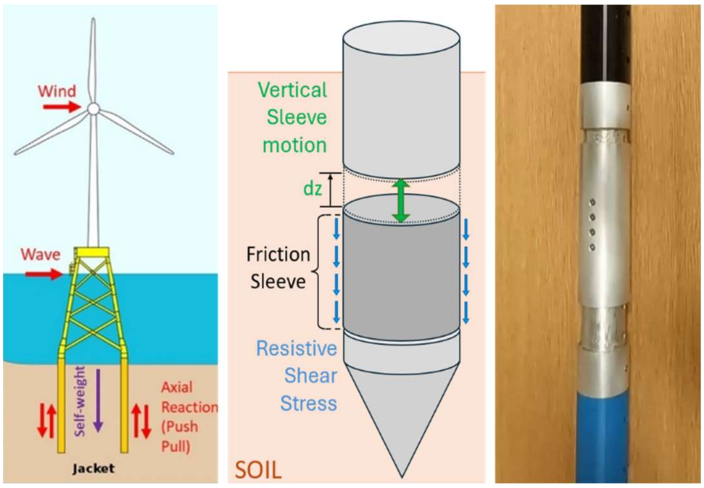

Figure: Typical loading conditions on an offshore wind turbine supported by a jacket foundation, with the ROBOCONE t-z vertical module replicating axial loading experienced by pile foundations.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support from the EPSRC (Ref: EP/W006235/1) and SFI (Ref: 21/EPSRC/3787).

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