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9.

Wave energy converters: The application of particle swarm optimisation to hyperparameter tuning of reinforcement learning based control systems.

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Reinforcement learning is a promising model-free control strategy to optimise power generated by wave energy converters in different sea states and with changing system dynamics. However, ensuring convergence to optimal state relies heavily on the selection of hyperparameters which are not learnt. Manually tuning hyperparameters can be very time consuming and potentially unreliable. This paper suggests employing particle swarm optimization for tuning the hyperparameters in reinforcement learning for controlling a point absorber wave energy converter. Particles are assigned to 5 hyperparameters associated with a Q-learning controller. Simulation results show that the optimised hyperparameters result in increased energy generation derived from the wave energy converter model. Particle swarm optimisation also helps to better understand the range of optimal hyperparameter values and their sensitivity. The findings have significant implications for the deployment of reinforcement learning-based control systems in wave energy converters.

10.

Cost Model for Levelised Cost of Hydrogen from a Floating offshore wind farm (FLOW) in the Celtic Sea.

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Abstract Title : Cost Model for Levelised Cost of Hydrogen from a Floating offshore wind farm (FLOW) in the Celtic Sea.

The UK Government has set an ambitious goal of 5GW of installed electrolyser capacity by 2030 (BEIS, 2021). The path to achieve this goal is not yet explicitly defined, and the UK Government has identified the need to better understand the "archetypes" for green hydrogen production, transport, compression, and storage (DESNZ, 2023). The UK's power grid is transitioning to net zero, with a target of 2035 proposed by the Climate Change Committee (CCC) (CCC, 2020). The UK has great expectations for future power to be delivered from offshore wind (OSW), with a target of 50 GW installed capacity by 2030 (BEIS, 2022) and the CCC describing OSW as the future "backbone" of the grid. The OSW aspiration includes FLOW. Scotwind leases include > 19 GW of FLOW (Offshore_Wind_Scotland, Not Dated), and The Crown Estate is leasing seabed real-estate for 4.5 GW of FLOW in 2024 (The_Crown_Estate, 2023). As the UK economy decarbonises, many sectors will transition from fossil fuels to electrification. The forecast for UK electrical power consumption is a doubling by 2050 (CCC, 2020). The direct (or indirect) coupling of OSW with electrolysers seems probable (McKay, 2022).

A design concept is presented that addresses the archetypes the UK government identifies as needing clarity, with a focus on the Celtic Sea. The concept comprises 8 x 510 MW FLOWS, with dynamic cables to an offshore substation. Power is then directed to shore via conventional HV AC cables. Onshore facilities include an electrolyser of capacity matched to the FLOW, and compression. The concept assumes a large industrial offtaker, with a constant demand of > 16 tonne.H₂/hr. This is a significant mass of H₂, and one that would require >900 MWe continuous power to supply, nearly 20% of the UK Government's 2030 5GW electrolyser target. The variable nature of wind necessitates hydrogen storage to guarantee continuous supply. The Royal Society identifies salt caverns as being the most likely storage media for large volume hydrogen supply (Royal_Society, 2023). The UK has experience storing both methane and hydrogen in salt caverns. The British Geological Society has identified the halite (salt) deposits within the UK, which include deposits

beneath the Celtic Sea (Williams et al., 2022). Therefore, the concept also includes an offshore pipeline to a salt cavern storage platform.

The levelised cost of hydrogen delivered by the concept is assessed with sensitivities for the Discount Rate, electrolyser efficiency, and Capex costs of electrolyser stacks and the floating structures. The volume of hydrogen in the store is presented; results suggest an annual seasonal hydrogen generation variation. The impact of using imported grid power to top-up the electrolyser capacity during periods of low or no power generation is assessed. The CO₂ intensity of hydrogen derived from a mix of power from the OSW and grid is also presented.

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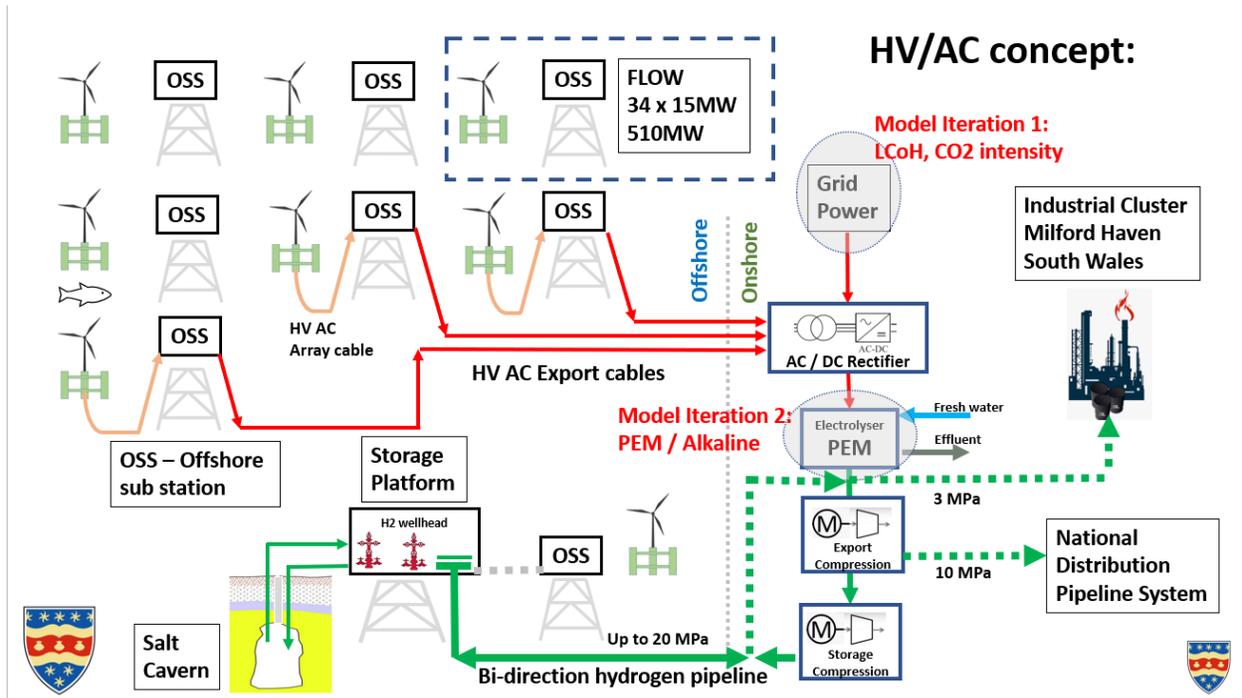
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11.

Remote River Energy System: Engineering considerations from a field trial

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Reflections on the design, build and operation of a 3 meter diameter tidal turbine in a tidal estuary in Pembrokeshire in January 2024. The device is 3 meters in diameter and is positioned below a floating barge. The test site at Warrior Way on the Cleddau river is part of the Marine Energy Test Area (META) a project run by Marine Energy Wales.

The turbine is open source, including technical reports and SolidWorks drawings [1]. It is based on a design concept that has been previously reported [2].

Six separate records of velocity were taken, four seabed mounted ADCP units, one ADCP downwards pointing on the barge and an ADV, which was recording at 10Hz and synchronized with the turbine performance data. The primary performance measurement was four pairs of strain gauges measuring blade root bending moments in thrust and torque directions. These were then used to obtain the usual power and thrust co-efficients.

This paper focuses on the mechanical and operational issues of the deployment.

Our turbine is designed to operate in remote communities and has a purely mechanical system offshore. The power take off is a water pump and this was a source of issues throughout the test. Test filling of the system revealed that the sliding seal in the front of the turbine had failed since the previous test 12 months ago. We have also learnt that this system is difficult to align and keep the pump shaft straight through the whole rotation.

Shaft misalignment was also an issue. The root cause of this was the design strategy, and this was made more difficult by the wet running polymer bearings.

Overall, a successful test was conducted with several hours of operational results.

[1] <https://zenodo.org/doi/10.5281/zenodo.8082024>

[2] <https://doi.org/10.1680/jener.21.00101>

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13.

A study of solid solvers selection for fluid-solid interaction (FSI): Dam break on elastic obstacle

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With the increasing development and utilization of wave energy at sea, in order to improve the efficiency of wave energy conversion and the survival performance of the device, the wave energy conversion device has gradually shifted from the traditional rigid structure to the flexible structure. According to the components of wave energy conversion devices, flexible materials are mainly used in three aspects: flexible wave energy acquisition components, flexible energy conversion components, and flexible device subcomponents. Flexible devices have a wider energy acquisition bandwidth than rigid devices of the same size, and they respond better to small wave conditions, with higher reliability and survival performance. However, such devices are currently in the laboratory research and development stage, and the complexity of flexible material selection and numerical simulation techniques affects their large-scale maritime and commercialization. Some open-source CFD tools are used to do the simulation of fluid-solid interaction (FSI). OpenFOAM is the mostly used software to simulating the fluid phase of FSI. As for solid solvers, there are two mostly used solid solvers for calculating the structure deformation. In order to compare these two solid solvers for more complex simulation, we take classic case - dam break on elastic wall to do the comparison. On the above basis, a more suitable solid solver can be chosen for flexible WECs simulation.

14.

Remote River Energy System: Instrumentation and measurements from a field trial

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In early 2024, a 3 meter diameter tidal turbine was tested off of a floating barge at a test area in Pembrokeshire. A quarter scale version of this device was previously tested at the same location in 2023. The test site is located at Warrior Way on the River Cleddau, and forms part of the Marine Energy Test Area (META) which is a project of Marine Energy Wales. The turbine under test was a two bladed device based on an original design concept reported at [1], with the blade geometry based on the geometry described in [2]. The design used was made publicly available at [3] after the initial 2023 build. The turbine used a recirculating hydraulic pump with water as the working fluid, supplied from a reservoir on the deck of the barge. The water pumped by the turbine was returned to the reservoir container via an instrumentation rail comprised with pressure sensors, flow meter, electronically controlled and monitored throttle valve and an orifice plate – the latter being used as a proxy for electrical generation or other mechanical work. The system was also equipped with strain gauges in the mounting adapters between the hub and each blade. This contribution will summarise the operational behaviour of the turbine, along with some of the difficulties encountered and limitations of the available data. Device performance is then compared to expectations from previous lab testing and the results of the three bladed rotor tested at IFREMER [2]. The authors are grateful for funding from the Swansea Bay City Deal and ERDF through the Welsh Government European Funding Office (WEFO).

[1] <https://dx.doi.org/10.1680/jener.21.00101> [2]
<https://dx.doi.org/10.1016/j.renene.2013.12.036> [3]
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16.

Offshore substation construction and installation methods

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Substations are required for offshore renewable energy development far from shore. Various options are available for offshore electrical substations, namely fixed, floating, and subsea. This presentation will consider the construction, ocean voyage, and offshore installation of different types of offshore substations. There are HVDC (high voltage direct current) and HVAC substations.

As the offshore wind turbine industry continues to develop and grow, the capabilities of established port facilities need to be assessed as to their ability to support the expanding construction and installation requirements for offshore substations. This presentation reviews projected changes to port facilities that may be required to support the substation required for the offshore wind industry. Understanding the infrastructure needs of the offshore renewable industry will help to identify the port-related requirements.

Separate shipyards are required for substructure construction and fit-out of the substations. Marshalling ports are required for mooring components, subsea cables and maintenance. Large areas are required for the laydown of mooring equipment, inter array cables, turbine blades and nacelles. The capabilities of established shipyard facilities to support floating wind farms are assessed by evaluation of size of substructures, height of wind turbine with regards to the cranes for fitting of blades, distance to offshore site and offshore installation vessel characteristics.

The presentation will consider the requirements for floating substations, concerning floating wind farms far from shore.

The presentation will consider installation vessel requirements for offshore substations. This includes crane vessels, tugs, and heavy transport vessels. Cable lay vessels will be considered for medium voltage inter array cables and high voltage export cables.

17.

Experimental design and prototype tests of novel floating solar platforms

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The global climate crisis, caused by the overuse of traditional energy sources, has encouraged research for renewable energy innovations. At the forefront of this quest, Floating Photovoltaic (FPV) technology is rapidly advancing and drawing increasing attention from academia and industry.[1] Floating solar platforms represent an ingenious resolution to land scarcity, enabling energy production across expansive aquatic terrains without seizing valuable terrestrial ecosystems.[2] FPV systems are categorized based on their deployment locale, which includes inshore, nearshore, and offshore, presenting varying degrees of complexity. Recently, inshore FPV has achieved commercial viability. However, the erratic situation of marine climates presents formidable challenges for nearshore and offshore applications, where those environmental loads may have unpredictable effects to solar panels.[3] In addressing these challenges, this research utilises the wave tank at Cranfield University to undertake experimental designs and prototype tests, paving the way for scientifically sound and practically feasible floating solar platform structures for nearshore and offshore usage. The present research is driven by the vision of multifunctional floating solar platforms—efficient in energy capture and durable against the fluid forces of waves. The testing floating platform prototypes are mainly divided into single-body and multiple-body platforms, each with its unique architecture and engineering complexities. The single-body platform is engineered for simplicity and cost-effectiveness, aiming to provide a stable and robust structure with a minimalistic design.

In contrast, the multiple-body platform explores the concept of modularity and distributed loading, which could offer enhanced stability and scalability. Furthermore, floating breakwaters are integrated with the FPV to study their potential to protect the delicate solar systems. This research applies an array of sensors to measure the hydrodynamic parameters, including pitch angle, heave motion, excitation frequency, and mooring system tension. These measurements are critical for theoretical analysis and are essential to the iterative optimization process. This work's goal is to go beyond mere functional feasibility and work toward commercial sustainability in the FPV field. This research will enhance the understanding of FPV technology's hydrodynamic and mooring responses to contribute to the global renewable energy landscape. By harnessing solar energy atop the undulating waves, this work endeavours to light a path toward an era where environmental stewardship and energy production coalesce. The presentation will dig into the

experimental results analysis of prototypes and offer insights into their potentials for promoting the FPV industry.

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18.

Energy system modelling of floating offshore wind farm combined with hydrogen production

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The Python for Power System Analysis tool is used to optimize hydrogen production capacity using electricity from a 600 MW wind farm situated 60 km from shore. Whereas the rated capacity of the wind farm is fixed, the rated capacities of the subsea cable connection, electrolyser system, and hydrogen storage are optimized by the model based on several input parameters. Amongst those are the subsea cable connection Capex, electrolyser system Capex as well as auxiliary equipment (platform, desalination), and hydrogen storage Capex. The electrolyser system is based on reversible Solid Oxide Cells (rSOC) and, for a slightly higher Capex than for electrolyser mode alone, can therefore be run reversibly to provide electricity from stored hydrogen.

It is considered that a regional onshore demand must be met. In addition to the electricity produced from the wind farm or using hydrogen, electricity can be taken from the grid to provide for that demand but needs to be paid for. Furthermore, excess electricity can be sent to the grid and revenue perceived.

This kind of study has been presented in [1] and will be published in [2]. Improvements have been made in [2] on several aspects of the study presented in [1], that is, refined costing of the offshore components necessary for hydrogen production, varying efficiency with power input or output, the addition of heat storage, as well as a modification of the parameters of the sensitivity study.

In those two studies, past day-ahead hourly or daily electricity prices were used from the years 2017, 2021, and 2022 to put a monetary value on electricity received from or provided to the grid. For hydrogen not converted into electricity, a constant price was applied for the duration of a year. This was carried out for four different values, namely 2 £, 4 £, 6 £, and 8 £. All simulations were run for the duration of year.

To further improve the energy system modelling and accuracy of recommendations based on the optimization, this time, rather than running the simulation for one year only, the simulation is run for the total project duration of 25 years. A different wind speed profile is used for every year, as well as the price paid for electricity. In addition to that, whereas the previous studies only investigated offshore hydrogen production, the same simulation is run for the case where the hydrogen production is happening onshore.

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19.

A combined experimental and computational study of floating solar farm

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Floating photovoltaic (FPV) technology is regarded as an environmentally friendly and cost-effective solution. It can aid in reducing water surface evaporation, achieving sustainable water resource supply, promoting clean energy production, and mitigating greenhouse gas emissions [1]. FPV power plants involve installing solar panels on floating structures typically located in reservoirs or ponds, and in recent years offshore systems have also gained significant attention. Although Floating Photovoltaic (FPV) applications are predominantly limited to freshwater bodies, considering that oceans encompass approximately 70% of the Earth's surface and represent a vast, largely untapped renewable energy source, the natural progression of FPV applications is expected to extend from nearshore to offshore locations [3]. Designing an ocean photovoltaic system involves addressing the challenges presented by the harsh marine environment, including ensuring that the floaters can withstand the occasional but severe wave loads. Due to its relatively recent conceptualization, there are currently only a few demonstration projects deployed globally [2]. Considering the multifaceted aspects and complexities of the matter, this research starts from nearshore floating solar farms. This project started by designing and crafting a prototype modular float with a solar panel. The whole structure is composed of a floater to provide buoyancy, the solar panel, and superstructure to fit the solar panel. The monomer structure serves as the foundational element for the multi-body structure, following a modularised design approach. Ensuring the stability and reliability of the monomer is essential before proceeding with additional multi-body connections and structural design. Experiments serve as a method to validate the feasibility of the structure and provide valuable data to inform desktop-based models, as their results are generally considered reliable. However, experiments are often limited by the facilities size and may not fulfil requirements for large-scale projects. It motivated us to devise a remedy of computational simulation approaches. Simulations can be adapted to a variety of different design requirements, but the results need to be validated thoroughly. For the aforementioned purposes, this work carried out experiments in the wave tank of Cranfield University, considering different wave height and frequency conditions. Various sensors were used to monitor the force applied on the mooring lines and heave/pitch motions of the floating structure. The CFD simulation was performed using the STAR-CCM+ software, and the simulation data was compared with the experimental data. Simulation settings were investigated to derive a reasonable approach to model the experiments. The results differences between experiment and simulations are less than 10%. Accurate simulation

settings can be used in the subsequent design of multi-body structures and multi-body connections, such as joint forces and multi-body structure response.

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20.

Resource Assessment of the Queen's Marine Laboratory Tidal Test Site

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The commercialisation of tidal energy converters (TEC's) requires technology de-risking to attract investor support increase installed capacity and reduce cost through economies of scale. The commercial wind energy sector has demonstrated a pathway to achieving this through standardisation and certification of technology and resources assessment. This presentation will provide a case study considering the standards for the resource assessment for tidal energy converters using seabed mounted acoustic doppler profiler (ADP) site measurements.

The Strangford Narrows is a circa 9 km long channel connecting 150 km² Strangford Lough to the Irish Sea. The channel has a general axis lying at 330 degrees relative to North and experiences flows in excess of 4.5 m/s and water depths up to 59 m. The currents are dominated by semidiurnal tides. The Strangford Narrows was the location of the first multi-megawatt grid connected tidal energy device, MCT 1.2MW Seagen which was installed in 2008 and operated until 2018. The Queen's Marine Laboratory operates a tidal test site less than 2km from the Seagen site and has conducted field trials of multiple tidal stream technologies as shown in Figure 1.



Figure 1 QML Tidal Test Site Technology Deployment Timeline

The ADP was deployed in ~18m mean sea level (MSL) at 54°22'52.98"N 5°33'24.24"W for a period of 45 days. The harmonic analysis of tidal velocities used 35 tidal constituents capturing 97.2% of the variance. The depth averaged 1 year forecast from the date of deployment found velocities exceeded 1m/s >70% of the time with peak depth average velocity at 2.5m/s. When considering a resource assessment with knowledge of the TEC performance the annual energy production (AEP) maybe calculated. An example turbine previously published with performance curves can be used to demonstrate this providing a conservative AEP estimate of 84.6 MWh/yr for a 50kW rated turbine (at 2.75m/s flow).

The case-study continues to demonstrate the other values in such a resource assessment data set for validation of numerical models, site access and future avenues of resource analysis research.

21.

Numerical Modelling Study on Arrays of Wave Energy Converters in Real Sea-states

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The world's oceans are an abundant source of clean renewable energy. It is estimated that the total theoretical global wave energy potential is approximately 32,000 TWh/yr. Presently, this energy resource is severely underutilised. As of 2019, only 2.31 MW of electricity was generated from wave energy converter (WEC) installations. The marine renewable sector requires significant advancement and expansion for the implementation of WECs as a contributing clean energy technology. There have been a vast number of WEC devices designed and patented, however, few meet the commercial requirements of energy conversion efficiency.

Recent research at Dalian University of Technology has shown that the coupling of an Oscillating Water Column (OWC) WEC with an intelligently designed reflector wall in the form of a parabolic breakwater can concentrate the incident wave energy to a point location, yielding greatly augmented device conversion efficiencies (Mayon et al., 2023; Mayon et al., 2021). The next stage in the development of this concentrator-harvester concept WEC is to examine the performance of an array of WECs coupled with the parabolic wall. In this study, we numerically examine the performance of two arrays consisting of three and five component OWCs deployed in the concave opening of a parabolic reflector wall. Initially, we describe the heuristic manner by which the array layouts are designed. We then compare the energy harvesting and hydrodynamic efficiency of both array configurations. Many published studies only investigate the behaviour of WECs in regular incident wave conditions. The study investigates the performance of the arrays in regular incident wave conditions and in a randomly generated sea-state, simulating the actual sea-state environment in which these devices are deployed. The results obtained from simulations investigating the performance of the array coupled with the wall in the regular and irregular wave conditions are compared with corresponding arrays in open-seas conditions. The presence of the parabolic reflecting wall is shown to provide a beneficial effect to the array energy harvest, and consequently the array efficiency. The research also demonstrates that the regular wave assumption results in a significant overestimation of the OWC array performance compared with irregular wave conditions which transpire in actual sea-states. Furthermore, few numerical studies include

the influence of air compressibility when investigating the behaviour of OWC WECs. Some previous research works have suggested that the effects of air compressibility can be neglected at reduced scale investigations. In this study, we demonstrate that this model simplification should be treated with caution and cannot be applied in all instances. By comparing compressible and incompressible numerical models we show the crucial effects of air compressibility in the OWC chamber which should be considered in numerical modelling investigations.

22.

Marine growth predictions are important for accurately modelling the behaviour of dynamic power cables for FLOW, but little guidance exists on how to do this.

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Marine growth predictions are important for accurately modelling the behaviour of dynamic power cables for floating offshore wind, but little guidance exists on how to do this. Most projects appear to be adopting NORSOK / DNV guidance which was originally recommended for waters north of 59deg North - i.e. north of Copenhagen. The recommended design values are being applied to projects across the globe in oceans and seas far removed from the Baltic Sea and Norwegian coastline.

This presentation will summarise the available literature on the settlement and hydrodynamic properties of different types of marine growth together with some project examples of observed settlement.

23.

Comparative Analysis of Offshore Wind Turbine Force Calculation Methods

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With the increasing deployment of offshore wind power in the UK (Department for Energy Security and Net Zero, 2023), accurate determination of forces acting on turbine structures is crucial. This study compares the traditional Morison equation (1950) with the more recently developed Stokes-type modelling equations (Chen et al, 2018) and the industry-standard program OpenFAST (OpenFAST 2024) for calculating hydrodynamic forces on turbine structures.

This study evaluates the effectiveness of different methods for calculating hydrodynamic forces on offshore wind turbines based on three key criteria:

1. Usability: Assessment of the ease of operation for both academic and industry users with limited prior knowledge of the program.
2. Accuracy: Comparison of the calculated forces with laboratory data to determine each program's precision in predicting various scenarios of real-world conditions.
3. Data comprehensiveness: Evaluation of the extent of data provided by each method.

Preliminary results indicate that the Stokes-type modelling equations offer high accuracy and ease of use, albeit with lower comprehensiveness. While having some demand for prior mathematical knowledge, the Morison equation provides reasonably accurate results and comprehensive data. OpenFAST, whilst the most comprehensive, instead maintains a high knowledge barrier that makes it less accessible to those new to the program.

This research highlights the potential of the Stokes-type modelling program for widespread adoption in both academia and industry. However, further investigation is needed to determine its predictive capabilities across a broader range of scenarios.

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24.

Using simulation to reduce uncertainty in the wet towing of full-scale 15 MW floating offshore wind turbines

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The delivery of floating offshore wind turbines (FOWTs) from assembly ports to wind farm sites will be a key step in the installation and commissioning of these wind farms. One method for delivery is wet towing, a process that typically requires just tugs and anchor handling vessels, potentially bringing significant cost savings compared to the use of the heavy lift vessels more traditionally associated with offshore wind installation. Floating turbines are tall structures with relatively high centres of gravity, and parameters such as metocean conditions, tow arrangement, vessel engine settings, and platform type can have a significant influence on behaviour during towing. In addition, these parameters will also influence vessel fuel usage, carbon emissions, towline tension, towing duration, and weather limits. At present, this represents a significant source of uncertainty for developers planning farm installations, as there is very little practical experience with the towing of full-scale turbines from ports to farms.

Tools such as simulation are therefore required to reduce the uncertainty surrounding full-scale towing operations so that more robust installation plans can be developed. This talk presents a methodology for reducing uncertainty in FOWT tow operations using the Dynamic Positioning Ship Simulator in the Maritime Simulation Laboratory at Plymouth University. This tool permits real time simulation of full-scale offshore operations, enabling rapid experimentation in a safe virtual environment. Here, it has been used to investigate the towing of the IEA 15 MW turbine on the VoltornUS semisubmersible platform in a variety of wind speeds, angles, and sea states, using an Anchor Handling Tug Supply (AHTS) vessel. An overview of the modelling and experimental procedures is provided, and methods for interpreting the results are discussed in the context of optimising towing routes between Portland Harbour, in Dorset, to a theoretical 1 GW farm site in the Celtic Sea, over the course of a year. This focusses on the implications for operation scheduling and the potential variance in deployment timescales, economic costs, and carbon footprint.

25.

Agent-based simulations of the installation of 4.5 GW of floating offshore wind capacity in the Celtic Sea, UK

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Round 5 of the Crown Estate's offshore wind leasing programme aims to establish up to 4.5 GW of floating wind power in the Celtic Sea, split between 3 project development areas (PDAs) of roughly equal size. Achieving this will require the manufacture, assembly, deployment, and commissioning of hundreds of turbines, as well as hundreds of kilometres of mooring lines and electrical cabling. Combined with the highly ambitious timescales for offshore wind deployment over the next decade, this is likely to result in significant pressure on ports, infrastructure, and installation vessels. In the absence of appropriate planning, preparation, and strategic investment, this pressure could result in significant capacity bottlenecks, potentially increasing costs and delaying the installation timescales for a much needed low carbon and secure energy source.

This talk overviews an agent-based approach for technoeconomic simulations of the installation of floating offshore wind farms, and presents a case study into the installation of 4.5 GW of capacity across the 3 PDAs in the Celtic Sea. The tool enables users to define multiple farms of different capacities and array layouts, as well as manufacturing and assembly parameters, port strategies, and installation fleets. Deployment of these farms, either in sequence or simultaneously, is then simulated using historical metocean data to account for weather windows and limits. Agents, in the form of factories, assemblers, and vessels, execute operations and interact with one another to accomplish the goal of installing and commissioning their specified wind farms, including substations and export cabling. This ultimately provides time histories and equipment utilisations for the installation process, enabling timescales, costs, and carbon footprints to be calculated for different scenarios and strategies. Results from the case study are used to discuss potential implications for the deployment of floating offshore wind power in the Celtic Sea and to demonstrate how this type of modelling can assist with strategic planning.

26.

Enhancing Design and Operation Optimisation of Tidal Range Schemes

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Over 190 countries, including the United Kingdom (UK) and European Union (EU), have committed to the net zero emission targets to alleviate climate change. Reaching this target requires a transition from polluting fossil-fuel energy to renewable energy. While a significant amount of electricity can be generated by wind and solar energy, they are intermittent and not predictable. Dispatchable renewable energy sources and energy storage facilities are required to balance the supply and demand. Tidal range energy, a type of marine energy, has the potential for this task because of its predictability and dispatchability. Tidal range schemes (TRSs), such as barrages or lagoons, create artificial head differences across the structures aided by tides which are predictable to a high level of accuracy. The head differences then drive the turbines to generate electricity. This process can be manipulated by controlling the operation of the turbines. Pumping can be used at high and low waters to increase energy production and provide energy storage. Ideally, pumping is used when electricity is in low demand and electricity is generated when electricity is in high demand. The UK has vast tidal energy resources (25 GW theoretically). Yet, TRS developments are hindered by their large initial investment cost and significant environmental and ecological impact on their adjacent coastal areas. This research optimised several TRSs in the UK with a 0D-model with a Genetic Algorithm. The objective functions were (i) total annual energy generation; and (ii) revenue obtained from selling the electricity. The importance of optimising revenue is two-fold: (i) it maximises the monetary return of TRSs, and (ii) viewing revenue as a surrogate of electricity demand, generating electricity when prices are high is equivalent to generating electricity when demands are high. This research tested the potential of West Somerset Lagoon, North Wales Lagoon and Swansea Bay Lagoon developments as shown in Figure 1. The electricity price data used in revenue optimisation were based on the System Sell Price (SSP) of the national grid for year 2018. Tidal data at the lagoons were obtained from a Continental Shelf Model developed with the two-dimensional TELEMAC hydro-dynamic solver suite for year 2018. Flexible optimisation, in which optimised energy or revenue is evaluated for each tide, was used. Pumping was included for all three TRS sites. Results showed that revenue optimisation gives TRS operations that generate higher revenue compared to energy optimisation. For example, the revenue-optimised North Wales Lagoon with pumping gave a revenue of £ 333.1 million, which is greater than the energy-optimised revenue (£ 322.2 million). Revenue optimisation also shifts the energy generation to a period of higher demand as shown in Figure 2. This research demonstrates the potential

for TRSs for energy storage and the advantage of using revenue as the objective function as a surrogate of electricity demand.



Figure 1. Locations of West Somerset Lagoon, Swansea Bay Lagoon and North Wales Lagoon.

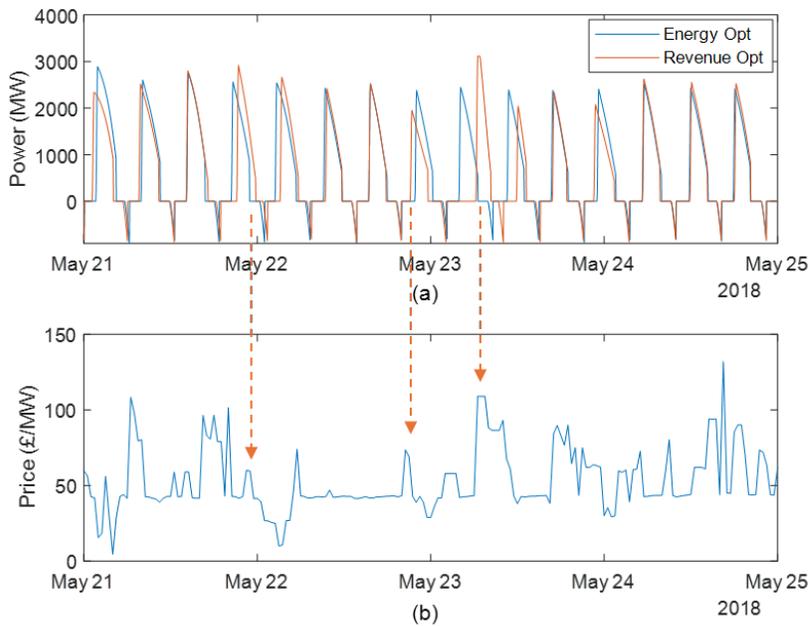


Figure 2. (a) Power output from energy and revenue optimisations of West Somerset Lagoon with pumping; and (b) the Electricity Price. Arrows indicate the shift of the power generation periods corresponding to higher prices.

27.

Evidencing vessel activity through the offshore wind life-cycle using open source information

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It is now possible to identify and analyse the activity of the different vessels involved in historical and current marine renewables projects on a potentially global basis using openly available sources of information. When combined with some expert knowledge on the roles of the vessels concerned this can give valuable contextual information to those involved in modelling proposed operations and can enhance the understanding of those new to the practicalities of marine projects. This presentation uses open source data such as archived Automated Identification System (AIS) data and Notices to Mariners to tell the story of an offshore wind farm from initial survey through to the start of operations and will highlight some of the challenges and opportunities relating to this approach.

28.

An Experimental Study of the Effect of Winglets on the Performance of a Tidal Turbine

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An experimental study using a scale 3-bladed horizontal axis tidal turbine. An oil-based paint flow visualisation coupled to blade thrust and torque measurements helped to identify the mechanism behind the phenomenon affecting the performance of winglets facing the suction side of a turbine blade. The results show that on average a winglet facing downstream decreases the power coefficient 1-2% and increases the thrust coefficient up to 6% for tip speed ratios 5.0-7.0. On the other hand, a symmetrically mirrored winglet facing upstream increased the power coefficient by 1-2%, and the thrust coefficient by 3-4%. Winglets have the potential to provide a meaningful increase in power capture at minimal additional capital cost without increasing rotor diameters. Further work to optimize pressure-side winglets should be conducted.

29.

Computational Fluid Dynamics simulation for an array of Floating Photovoltaics in waves

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Due to its renewable nature and cost-effectiveness, solar energy is the preferred choice in many applications. However, setting up ground-mounted solar farms can be impractical due to the lack of available land. For example, a 1MW PV farm can take approximately 15000 m² of land (Cuce et al. 2022). The shortage and expensive nature of land-based photovoltaics have thus raised needs and interest for viable alternatives such as floating solar to be developed.

A comprehensive Computational Fluid Dynamics (CFD) model has been developed for an array of Floating Photovoltaics (FPVs) using the opensource CFD software, OpenFOAM. This model uses interFoam coupled with the waves2Foam toolbox for wave generation and absorption. The model incorporates multiple coupled bodies (Wu 2106) and mooring lines to accurately simulate the complex hydrodynamic interactions between waves and the FPV array. The opensource nature of the developed code will facilitate future research and advancements in the field.

The study covers an analysis of wave propagation through the FPV array. Spatial and temporal discretization studies along with sensitivity to solution schemes, have been conducted to determine the optimal setup for accurate wave transmission modelling. Numerical results have then been validated against experimental data.

To quantify the hydrodynamic response of each solar unit within the FPV array in a nondimensionalised format, Response Amplitude Operators (RAOs) have been considered. This analysis aims to provide insights into the motions of individual FPV units, wave diffraction and transmission patterns, and the loads exerted on the structures and mooring lines. The influence of coupling and mooring on the overall hydrodynamic behaviour of the FPV array has also been investigated.

This work contributes to the advancement of floating solar technologies. The findings will support the FPV development through the analysis of key parameters such as fatigue and safety factor, enabling the creation of sustainable and resilient PV-based floating energy systems.

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30.

Development of Swift Anchor for Rock Seabeds, and its Applications

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The Swift Rock anchor, designed and built by SCHOTTEL Marine Technologies (SMT), was designed for challenging geotechnical and metocean environments to anchor floating marine energy systems. The system was originally designed for tidal energy sites, where rock sea beds are common due to scour from high speed flows. Additionally, high yield tidal energy sites have small slack water windows and so rapid installation is imperative to minimise time on site.

As the floating wind market has developed, the technology has been further developed to expand into this market. The opportunity to quickly and cost-effectively install in scoured and/or rock sea beds would open up many new development opportunities for the wind industry, as many sites are currently thought unsuitable due to the presence of rock on the seabed and the expense of current rock anchoring technology.

This presentation will demonstrate the development of the rock anchor technology and it's applicability to different floating renewable applications. The field applications of the technology will be presented, plus ongoing land trials designed to demonstrate the limits of operability of the anchor.

31.

Accelerating Offshore Wind Development in Indonesia: A Case Study of South Sulawesi

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With the global urgency to combat climate change and achieve net-zero emissions, the role of renewable energy sources, particularly offshore wind, has become increasingly vital. Indonesia, as the largest archipelagic nation in the world, holds great promise for offshore wind energy development. South Sulawesi, renowned for its existing onshore wind power plant, presents a prime location for the expansion of wind energy infrastructure. As the nation strives to meet its ambitious climate goals, tapping into the offshore wind potential in South Sulawesi is imperative.

This study focuses on identifying suitable offshore locations, considering wind resources alongside environmental constraints. The optimal wind farm capacity is determined, taking into account observed grid management issues from existing onshore generation portfolios and load profiles. Simulation of varying installed capacities into the grid balance is employed. Half-hourly estimated offshore generation data from wind resource data for a reference turbine is scaled up with an increasing number of deployed turbines. Subsequently, this modelled offshore generation time series is integrated with measured demand and onshore generation data to assess its contribution to demand and potential grid management issues, including potential curtailment.

Analysis reveals significant potential for offshore wind projects in South Sulawesi to bolster the renewable energy transition. By addressing technical challenges such as intermittency and grid integration, a stable and reliable energy supply can be ensured. Thorough site assessments and environmental impact studies help identify suitable locations that maximise energy generation while minimising adverse effects on the environment and maritime activities.

In conclusion, offshore wind development in Indonesia, particularly in regions like South Sulawesi, presents a significant opportunity to accelerate the transition towards a sustainable energy future. This study provides a case example by addressing technical challenges (supply, demand, intermittency) and reviewing site suitability. Studies of this

type can enable Indonesia to understand the opportunities and constraints better so that the offshore wind potential can be harnessed effectively. Ultimately this will support the achievement of climate objectives while fostering economic growth and energy security.

32.

Thermal Boundary Layer around a Partially Buried Pipe in the Seabed

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As the offshore renewables sector continues to increase, so must the infrastructure to support it. RenewableUK predict that by 2030 over 60,00 km of array cables, which connect offshore wind energy to the substation, are expected to be laid on the sea floor. Furthermore, the U.S Naval Institute estimate over 30,000 km of sea floor pipelines are in active use, with the Nord Stream alone being 1,000 km. With the staggering amount of submarine cables and pipelines, either on the sea floor or partially buried, it is crucial to understand the transfer of heat from these structures to the rest of the fluid domain.

In a similar fashion to the viscous boundary layer, there exists a thermal boundary layer adjacent to the circumference of the pipe. It is within this region that a majority of the heat exchange occurs and so an understanding of the thermal boundary layer is absolutely necessary. An analytical model of the problem is derived which predicts the structure and behaviour of the thermal boundary layer. This is then verified and visualised using numerical techniques. Four cases are investigated concerning the burial of the pipe/cable: no burial (i.e resting on the sea floor), a quarter buried, half buried, and 3 quarter buried. These four cases represent various situations, and heat flux values in each case are found and compared, which can be used in the industry.

It is found that due to the influence of oscillating flow, that the Keulegan-Carpenter number plays a significant role on the thermal boundary layer, altering the structure depending on its magnitude. In all cases, in a region around the top of the pipe, the temperature is confined to an inner boundary layer due to the convective terms. In contrast, in the direction of oscillation there forms a jet like situation, where the temperature is transported into the outer domain. This model is applicable to any works in which there is a long circular cylinder buried in a plane boundary; most notably are the aforementioned array cables from offshore wind.

33.

BlueBox: A cloud native, MRE optimised, IoT service

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The collection, management, and exploitation of data from the ocean can both benefit from and be a benefit to the development of marine renewable energy (MRE) converters. Leveraging MRE technologies to power remote sensing platforms will extend their range and capabilities. Standardization of data communication and processing in the marine environment can reduce the cost and complexity of MRE converter development and operation. The processing and transmission of data at sea may be modelled as an “internet of things” (IoT) application. The “thing” is any offshore device which can collect and process data in-situ, while the “internet” represents the medium for transmitting data between the thing and the user. IoT is differentiated from other internet-based communication paradigms by the constraints on the system. These constraints are typically limited energy budgets and computing power, intermittent and low-bandwidth connectivity, and limited physical access. Marine energy converters and remote ocean sensing platforms share many of the same constraints which IoT was designed to overcome. While land based IoT applications are already well served by a wide selection of hardware and software components, the needs of offshore IoT applications are not well served. The “BlueBox” project, funded by the Sustainable Energy Authority of Ireland, is overcoming barriers to entry for applying IoT technologies to offshore sensing by developing “Ocean IoT” (OIoT) hardware and software solutions. As the project ends, we report upon the progress made on features such as modular, offshore-focussed hardware, configuration and control of peripherals (such as sensors and actuators), duplex transmission of data over the internet and satellite network, and the cloud native web-interface and data analysis service.

34.

On the design of a small scale tethered tidal turbine for field experiment

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Tidal energy has several advantages over other renewable energy sources. Tidal currents are predictable, so both the amount of energy and when it will be available are known in advance. This is not the case with other renewable energy sources, such as wave or wind power, which are random in nature. Most of the current research into tidal energy devices is carried out under laboratory conditions, which are usually limited in size and scope. There are a limited number of utility scale demonstration tidal turbines installed in real-world environments (e.g. at sea and in an estuary) due to the high cost of implementation, installation and site accessibility. The Renewable Marine Energy Laboratory is a natural laboratory located on the east coast of the Strait of Messina (southern Italy). This location has been known since antiquity for its strong currents generated by the different sea levels of the Ionian and Tyrrhenian Seas. In addition, a frequent channel wind blowing from Sicily towards Calabria generates waves with significant heights between 0.20 and 0.80 m, in excellent Froude similarity with the waves generated by the most violent storms in the seas. The paper presents the study carried out to characterise the current regime at the site and the subsequent analyses carried out to design and realise the fully operational tethered turbine. The turbine model is the GEMSTAR (Coiro et al, 2020), which consists of two counter-rotating horizontal axis turbines supported by a floating submerged structure. A flexible mooring cable connects the floating support to the seabed, allowing the system to rotate freely and adjust to the changing direction of the current. The rotors are approximately 1.9m in diameter and each turbine is designed for a rated power of 700W at a current speed of 1.0m/s. Two BLCD motors were adapted to act as generators and therefore required full characterization when acting as generators. The rotor blades were manufactured using additive manufacturing and tested by applying a static load with the same configuration as the load produced by the current at maximum speed. There are several objectives of the experiment that will be described in the paper: to test the self-orientation capability of GEMSTAR and the control system used to avoid cable twisting; to assess the survivability of the system in the most severe storms; to monitor the performance degradation during a long deployment due to biofouling accretion; to create a digital twin for fault detection.

36.

Flow characterisation inside a scour hole of a monopile foundation

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Scour is to the local movement of sediments around subsea structures, which is well recognised as an engineering issue that may lead to foundation instability. The local scour bathymetry of an isolated monopile foundation has been reported to depend on local current and wave conditions, as well as the sediments in the marine environment. Many studies have documented the development of scour holes under certain ocean conditions with specific sediments, represented by changes in scour depth over time. In a relatively equilibrium state, it has been found that sand and clay sediments may lead to relatively high scour depth, while cobbles may only result in shallow scour depth. However, less well-documented is the flow characteristics inside a scour hole. This study aims to quantify the flow characteristics and dynamics inside different scour bathymetries, representing the fully developed scour holes of a monopile foundation. The outcomes should be useful in guiding the scour protection of offshore monopile foundations, which are widely used in the offshore wind industry.

37.

Learning based control for wave energy conversion

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As one of the most promising renewable energy resources, ocean wave energy has not been widely commercialized compared to wind energy and solar energy due to its high Levelized Cost of Electricity (LCoE). It has been long recognized that wave energy converter (WEC) control can increase the capture width ratio and enhance the robustness of the WEC against extreme sea states. However, some rigid-body WECs have high nonlinearities and soft-body WECs such as Dielectric Elastomer Generators (DEGs)/Dielectric Fluid Generators (DFGs) can barely be precisely modelled. To tackle these challenges, this paper aims to propose an optimal control scheme that has less dependence on the dynamical model by introducing deep reinforcement learning into the foundation of a non-causal optimal control strategy. The gain parameters are adjusted adaptively in real time to account for an increasing understanding of this scheme on the WEC behaviour and the incoming wave. Furthermore, by systematically contrasting outcomes obtained with various prediction time steps, this investigation aims to pinpoint the most effective prediction strategy for optimizing energy capture efficiency. In light of the unique characteristics of WECs, we have introduced a reinforcement learning methodology to augment the non-causal controller based on Double Deep Q Network (DDQN). After subjecting our approach to rigorous simulation tests using the collected dataset, we have achieved energy conversion results that outperform traditional control methods. Furthermore, we conducted a comparative analysis of the control effects stemming from different prediction time steps. Our findings unequivocally demonstrate that longer-term predictions, specifically, those involving three steps at 0.03 seconds and five steps at 0.05 seconds, significantly outperform the results obtained from shorter-term predictions, such as one step at 0.01 seconds. This indicates that extending the prediction horizon has a profound impact on improving the controller's efficacy. Additionally, it's noteworthy that even though a five step prediction has a negligible effect on the ultimate total energy output, it does alleviate the training burden on the reinforcement learning agent. This observation suggests that the increased predictive horizon enhances the controller's performance, consequently lightening the workload for the reinforcement learning agent.

38.

Estimating Wind Using Wave Buoy Measurement: A case study in the Celtic Sea

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In offshore wind energy development, precise wind data acquisition is pivotal for site assessment, operation, and safety. Traditional methods like LiDAR, though accurate, are costly, while satellite data often lacks the required resolution. This study presents an alternative approach using wave buoys, which are cost-effective and easily deployable in large numbers due to their compact size. Focusing on a case study in the Celtic Sea, the research investigates the feasibility of estimating wind conditions based on wave buoy measurements, particularly looking at the high-frequency portion of the wave spectrum known as wind-sea. The analysis employs measured wave and wind data from a site that presents both types of measurements, albeit at slightly different locations. The study finds that wave buoy data, through tailored modelling, can indeed serve as a reliable source for estimating wind speed and direction. The derived U10 wind parameter shows promising results, outperforming interpolated data from ERA5, especially in calmer conditions. When compared with ERA5, the modelled wind speeds are more accurate, with an RMSE of 2.7 m/s, and wind direction estimates are within an RMSE of 26 degrees, indicating substantial potential for wave buoys in wind energy assessments.

39.

Experimental study of multi-degree-of-freedom wave energy converter equipped with mechanical-motion-rectifier power-take-off system in wave tank

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To achieve sustainable reuse of offshore platforms, a novel multi-degree-of-freedom wave energy converter (SMD-WEC) is proposed to provide renewable energy. A mechanical power take-off (PTO) system based on the mechanical motion rectifier (MMR) technique is developed, which converts bidirectional oscillations of the energy harvesting buoy into unidirectional rotations of the gearbox shaft. As a crucial step towards technical proof before sea trials, the scaled SMD-WEC prototype is manufactured and experimentally evaluated in a large wave tank. The full-process measurement is performed on both single- and multi-DOF prototypes, which quantitatively identifies the kinetic and power state at each stage of energy transfer from wave to wire. The parametric oscillation phenomenon is observed, indicating the presence of nonlinear dynamic instability in multi-DOF WECs. The advantages of releasing multiple DOFs of the WEC device are evaluated.

40.

Hydrodynamic Efficiency of U-OWC WEC Through Geometric Investigation: A Design Formulation Approach

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Among various wave energy conversion systems, fixed Oscillating Water Column (OWC) Wave Energy Converters (WECs) are well-documented and widely studied as a classic solution. These systems can be effectively integrated into breakwaters to enhance their economic viability. However, despite their widespread use, a comprehensive codification of the design principles for these systems is still lacking. In this context, this study explores the hydrodynamic efficiency of U-shaped OWC structures through physical model experiments and a re-analysis of existing literature data, systematically varying geometrical parameters to understand their impact. In addition to investigating the influence of geometrical variations, the study explores the effect of wave steepness on the efficiency of the wave energy converter. It also determines the natural frequency of U-OWC structures, critical for tuning the system to local wave conditions and optimizing the capture width ratio. Several design formulations are derived based on experimental measurements and a dataset compiled in this study, incorporating information from literature sources. To analyse the data, two complementary approaches are employed: multiple linear regression and decision tree regression. The multiple linear regression method yields a straightforward formula for designing U-OWC structures, simplifying the design process. Conversely, the decision tree method utilizes a trained machine learning model file, enhancing prediction precision. Comparison of predicted and measured capture width ratio (CWR) values using multiple linear regression (Fig. 1-a) and decision tree regression methods (Fig. 1-b) are shown below. The results obtained from these findings illustrate a notable level of accuracy when compared to actual data. These models exhibit robust estimation capabilities across a spectrum of input variables, providing a comprehensive framework for designing and enhancing U-OWC structures. This contributes significantly to our understanding of U-OWC system behaviour and offers a pathway for developing more efficient and sustainable wave energy conversion solutions and designs.

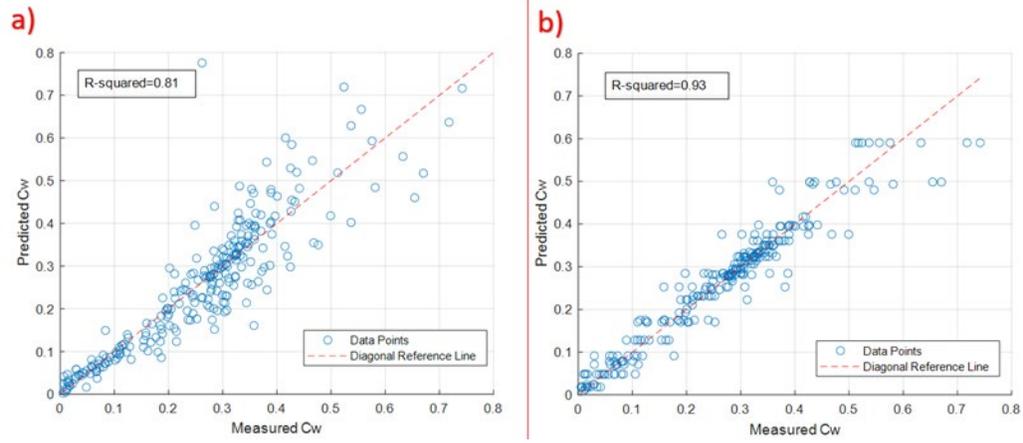


Figure 1: Comparison of predicted and measured CWR values using a) multiple linear regression and b) decision tree regression method.

42.

Preliminary study of a pivoting two-body offshore WEC device with a motion rectifier system

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The exploitation of wave energy, although potentially very interesting for the significant amount of available resource, presents some issues to be solved to develop efficient, reliable and commercially viable wave energy conversion devices. In this paper a wave actuated body WEC (Wave Energy Conversion) device is taken under consideration proposing a preliminary analysis of both the WEC device configuration and of the Power Take-Off (PTO) system implementation. Several concepts have been proposed in literature with the aim to exploit wave power; a general review of several different technologies and their working principles can be found for example in [1], [2].

The patented system considered in this study is composed by two floating bodies linked through a hinged connection. The relative oscillating rotational motion between the two bodies, generated by the wave actions, is transferred to a mechanical system comprising a motion rectifier. The device currently under investigation represents a development of an onshore pivoting device (whose initial development phase is described in [3],[4]), with the main aim not only to improve the PTO behavior but also to deploy it offshore.

One of the bodies (the pivoted buoy) is left free to rotate under the waves action while the motion of the other body is reduced as much as possible using a tension leg mooring system, trying, in this way, to maximize the relative motion. The aim of the rectifier system is the conversion of the two-way wave generated oscillations into a one-way rotational motion which is then used to actuate a standard rotating electric generator. The rectification is obtained using a kinematic chain comprising a set of coupled bevel gears mounted on a shaft using one way bearings allowing the transmission of torque only in one direction of rotation. A flywheel will also be used to further reduce the oscillations of the output rotational speed. The advantage of this approach is related to the regularization of the output motion and torque transferred to the generator: such regularized operating conditions positively affect the generator behavior through a reduction of the amplitude oscillations of electrical voltage and current, thereby increasing efficiency and improving power quality.

The development of the project will involve two phases. During the first phase, a dry test bench will be developed and used for the study and the optimization of the PTO behavior as is commonly done in literature (see, for example in [5]). Then a full-scale demonstrator

model of a 3 kW WEC system rated at the same power of dry test bench, will be tested in wave tank.

The paper describes the initial development study and numerical modelling of the proposed WEC configuration as well as the preliminary analyses for the preparation of the two described test phases.

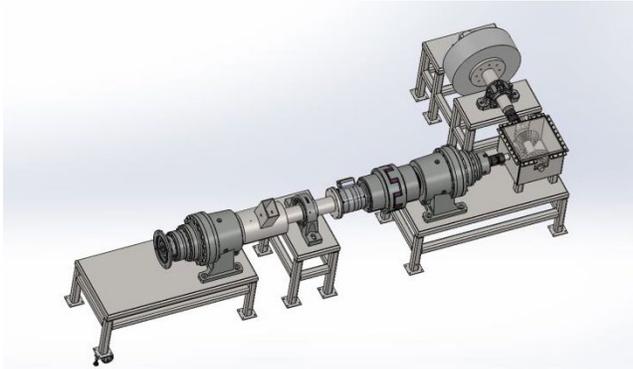


Figure 1. 3D cad view of a dry test bench for a WEC PTO system with rotational motion rectification.

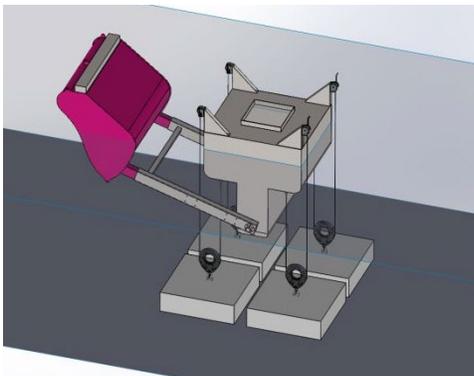


Figure 2. 3D cad view of a wave tank test model for a pivoting offshore WEC system.

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43.

Prediction of tidal current energy resource from sparse data

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Future sites for in-stream tidal energy device deployment are likely to extend beyond the well known sites currently considered. Although complex models of flow velocity at new sites are possible in both 2D and 3D, these are technically challenging and time consuming to implement due to their requirement for significant quantities of data and careful calibration. A new method presented here shows that predictions of velocity time series and therefore power availability can be carried out using surprisingly sparse estimates of flow velocity. Suitable data sources include tidal diamonds or flow vectors on navigation charts, flow data from a tidal current atlas, or short term in-situ measurements using drones, drogues or vessels. This study shows specifically how peak flood and ebb velocities from spring and neap tides can provide sufficient information to establish M2, S2, fortnightly, and residual current contributions. From this the tidal velocity and power time series can be constructed, and the tidal power potential at a site can be quantified. The approach may prove particularly useful when carrying out initial site appraisal.

44.

Optimising Floating Wind Turbine Layouts with Wake Modelling and Reinforcement Learning

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The adoption of climate change policies by global governments has significantly accelerated the development of renewable and clean energy technologies since the Paris Agreement in 2015. Wind energy converters, in particular, have rapidly evolved to maximise energy extraction. With 80% of offshore wind resources located at depths greater than 60m, beyond the reach of fixed-bottom turbines, the focus is increasingly on floating offshore wind technologies. This shift towards larger turbines and rotor diameters introduces complex interactions with environmental variables, which traditional simulation methods struggle to model accurately and efficiently. These complexities challenge the effectiveness of conventional design approaches, underscoring the need for innovative solutions. Our research aims to explore the application of machine learning techniques to predict and optimise the layouts of floating offshore wind farms, considering specific turbine characteristics and geographical constraints. To achieve this, we integrate a Gaussian velocity model with a Crespo-Hernandez wake turbulence model to simulate wake effects and velocity deficits. The resulting data is fed into an Artificial Neural Network (ANN), which efficiently models turbine wakes with significantly reduced computational demands. This ANN wake model is used in conjunction with a reinforcement learning model, based on local and global blockage, to map the effects on array power production caused by differing turbine wakes. This approach allows us to identify the most efficient turbine arrangements, maximising energy yield and reducing wake-induced losses. By employing these models, this research will enhance our ability to design optimal layouts for floating wind farms, leading to more sustainable energy solutions that support global renewable energy targets and promote environmental stewardship. Our findings could also provide actionable insights for the wind energy sector, potentially influencing future designs and policies by demonstrating the viability and benefits of advanced computational approaches in large-scale renewable energy projects.

45.

Observation of ocean current structure using coastal acoustic tomography

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This research topic concerns the application of acoustic tomography to three-dimensional current observed. Flow velocity modeling, signal processing, and experimental measurements were carried out and informed. Three acoustic gauging stations were used to observe the 3-D flow field at a confluence connecting two rivers in a reservoir. Reciprocal acoustic signals were transmitted simultaneously between each pair of stations. Despiking method and analysis for acoustic data was proposed and conducted to improve the accuracy of observed flow. In this study "Observation of Ocean Current Structure Using Coastal Acoustic Tomography," we meticulously documented the flow patterns across different depth layers. Observing these patterns is crucial for understanding and predicting marine dynamic behaviors, particularly in the context of developing and utilizing marine renewable energy. We verified the feasibility of the method through reservoir experiments, and in subsequent ocean acoustical experiments, by leveraging precise ocean current data, we can optimize the layout and operation of marine energy facilities, such as tidal and wave energy power stations, whose efficiency largely depends on a thorough understanding of the marine dynamic environment. Therefore, this research not only provides fundamental data essential for marine science but also offers practical references for the field of marine renewable energy, particularly in potential applications for facility design and energy efficiency enhancement.

48.

Wave Devouring Propulsion for Stabilisation of Offshore Renewable Energy Structures

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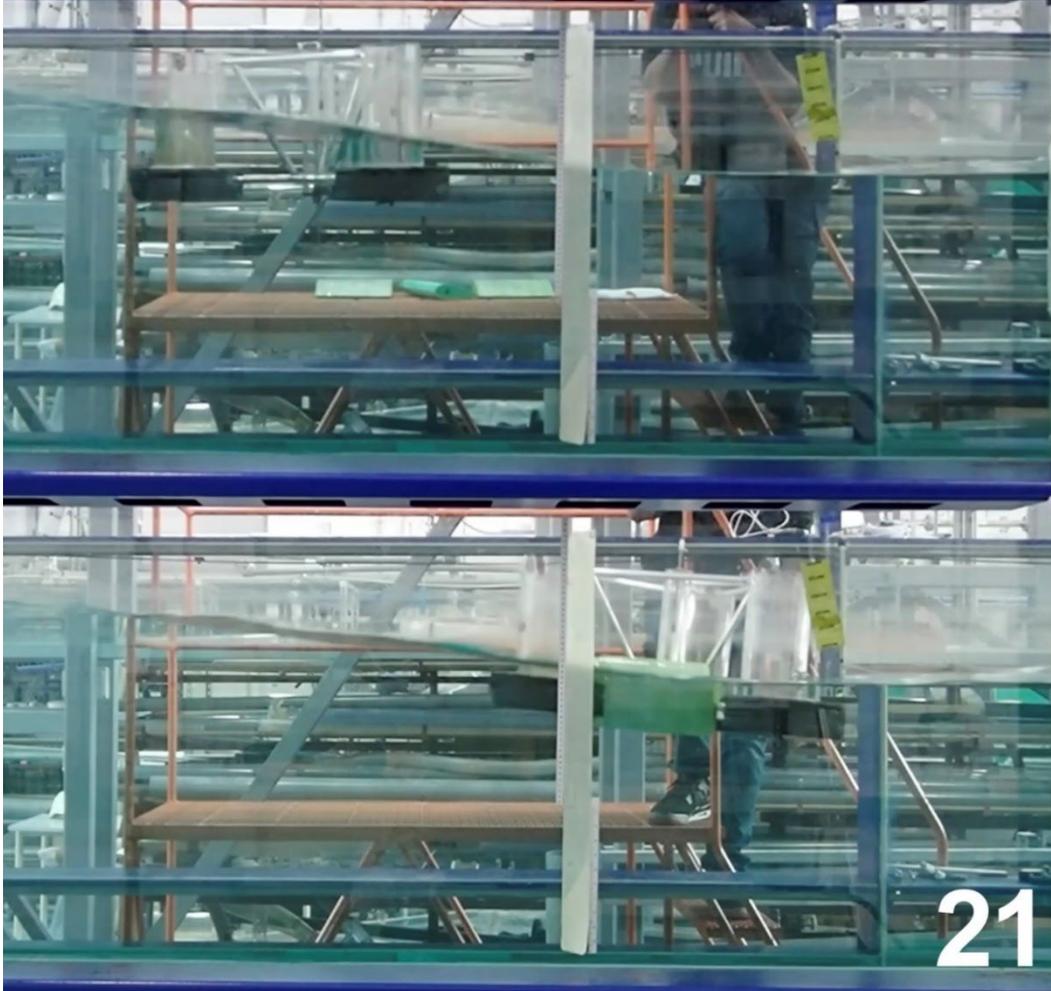
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The concept of a foil-shaped structure, deriving inspiration from the natural mechanisms of birds and fish, has been identified as capable of generating forward thrust through its flapping behaviour. When submerged, a hydrofoil can exhibit both heaving and pitching responses under wave conditions, named as wave devouring propulsion (WDP) [1]. This leads to the creation of a jet-like wake, wherein the hydrofoil experiences thrust due to the higher velocity of flow in the wake compared to the ambient or oncoming flow. Foil attachment to ship hull could generate green thrust in waves, significantly reducing fuel costs [2]. However, the incorporation of WDP technology into offshore platforms is still an emerging field, offering fertile ground for future research and innovation in marine propulsion systems.

This research focuses on the optimal design and method of attaching a submerged hydrofoil to an offshore platform to enhance stabilisation. The flapping hydrofoil, exhibiting a hybrid motion combining heave and pitch, is engineered to convert incoming wave energy [3,4]. It generates thrust that can balance with the drift forces from waves.

In this study, a NACA0030-type hydrofoil was positioned between the platform model. Comprehensive analyses were conducted to evaluate the free-floating platform's response to regular waves, with a focus on the attached hydrofoil. The results indicate that the hydrofoil significantly reduces the surge motion and drifting speed of the platform, affirming its effectiveness in enhancing stabilisation.



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49.

Dynamic response of a shallow-draft floating wind turbine concept

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This study presents a comprehensive analysis of a novel shallow-draft Floating Offshore Wind Turbine (FOWT) concept, designed by T-Omega Wind, which promises to revolutionize wind energy harvesting in deep and harsh sea waters. The research, conducted at the National Decommissioning Centre, University of Aberdeen, and the Kelvin Hydrodynamics Laboratory, University of Strathclyde, delves into the nonlinear dynamics of the FOWT under various sea wave excitations. The primary focus is on evaluating the system's heave and pitch displacements.

The FOWT's innovative design features a lightweight structure with 80% less structural steel than conventional models, supported by four stiff interconnected floats. This design not only allows the system to glide over sea waves but also incorporates a single mooring line to facilitate a weathervane effect, significantly reducing mooring costs. The system's capacity is 10 MW, and its high natural frequency is conducive to operation in harsh marine environments. Simulations using a real-time multiphysics Marine Simulator [1] integrated with the Algoryx Hydrodynamics module have been performed to predict the system's behaviour. These simulations are validated against experimental results from a 1:60 scaled prototype tested in a state-of-the-art water tank facility [2].

The dynamic responses of the system are quantified through Response Amplitude Operators (RAOs), with phase planes, Poincaré sections, and FFT analysis employed to identify resonant frequencies and system response periodicity. The study identifies optimal operating conditions for energy harvesting and confirms the system's dynamical behaviour, even under 'High Sea State' conditions. Experimental studies corroborate the simulation results, demonstrating the system's reliability and resilience. The findings reveal that the FOWT concept can float over steep high waves and is economically viable in deep water. The calibrated model provides an ad hoc damping expression that accurately predicts system dynamics for 'High' and 'Low' Sea States. The study concludes by proposing analytical expressions for RAO responses and offering validated damping parameters, which confirm the Marine Simulator as an effective tool for predicting FOWT dynamic responses with reduced computation time.

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50.

Investigation of the Non-Linear Wave Loading of a Point Absorber Wave Energy Converter

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Keywords: point absorber, wave energy converter, non-linear wave loading, OpenFOAM, numerical wave tank, heave response, capture width ratio, power take-off

Abstract:

Point absorber wave energy converters (WECs) have garnered significant attention due to their versatile integration with existing coastal energy and engineering applications, such as wind turbine foundations, breakwaters, and floating coastal structures (Gharechae et al., 2024; Waskito et al., 2024). However, the optimisation of these devices remains underutilised in practice due to the high computational resource demands associated with computational fluid dynamics (CFD) software and the multifaceted complexity of analysing a high order of variables and parameters (Ding et al., 2024).

This study employs a fully validated three-dimensional numerical wave tank using the widely applied OpenFOAM CFD framework to investigate the effect of non-linear waves, including higher order harmonics on the heave response of a Point absorber device under focused waves. The waves2Foam open-source plugin for OpenFOAM is applied to accurately generate focused waves in the numerical wave tank, ensuring good agreement with physical experiments.

Iterative simulations, including alterations to dimensional parameters and linear spring damper settings of a Point absorber are made using a range of wave conditions, with varying wave period (T_p) and wave amplitude (A_o). The resulting table of simulation iterations widens the parameter space and thresholds for Point absorber devices, providing a valuable lookup table for cross-comparison of Point absorber geometry, in relation to heave response, capture width ratio (CWR), and power take-off (PTO). This study highlights the sensitivity of Point absorber devices to various wave conditions and harmonics, contributing to the optimisation of these devices for enhanced power output and performance (Yi et al., 2023).

The findings of this study will aid in the design and optimisation of Point absorber -WECs, facilitating their widespread deployment and integration with existing coastal structures, ultimately advancing the field of wave energy

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51.

Recent advancements on the design of flexible plate wave energy converters

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We present recent advancements on the hydrodynamic modelling and design of flexible plate wave energy converters.

Hydrodynamic and laboratory models are presented for submerged and floating elastic plates, considering the contribution of hydroelasticity and power take-off damping to extract energy from incident waves. A hydro-electromechanical model of a piezoelectric plate converter is presented within the framework of linearised potential flow theory, augmented with piezoelectric and circuit equations. In addition, an alternative hydrodynamic model for a floating elastic plate connected to dissipative power take-off system is investigated both mathematically and experimentally.

We show that the piezoelectric device has the potential to extract a sufficient amount of energy for low-power applications, whereas the floating elastic plate connected to traditional PTO system has increased resonant peaks as compared to a rigid plate of similar dimensions. Such resonant properties allow extraction of energy at larger bandwidths than previously thought.

Parametric analysis further investigates the effects of design properties, such as plate dimensions, thickness, PTO configuration, on the extracted wave energy. Preliminary investigations on the effect of a random wave field on wave power generation are also presented.

52.

Enhancing a Stokes-type Gaussian Process Predictive Model for Non-Linear Wave Loading on Offshore Wind Turbine Foundations

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Offshore wind turbine foundations are consistently exposed to harsh environmental loads, significantly influencing their design. Understanding the complex physics of wave-structure interactions is a significant challenge, especially the strongly non-linear wave loads that occur under severe conditions. To develop a fast and accurate model for predicting non-linear wave loading on offshore wind turbine foundations, we have adopted a ‘Stokes-type’ force model [1]. This model approximates the amplitude of higher harmonics of force by correlating these to the linear force time series raised to appropriate powers, modulated by amplitude and phase coefficients. We have reanalysed previous experimental data and conducted new experiments to expand the parameter space and establish a force coefficients database for engineering applications. A machine learning model, known as the Gaussian Process (GP) model, is utilised to interpolate this database and predict higher-order force coefficients, as detailed in [2]. The novel predictive model is named the Stokes-Gaussian Process (Stokes-GP) model. Figure 1 demonstrates the Stokes-GP model’s precision in predicting the latest experimental results conducted at the Dalian University of Technology, where it is evident that the linear force underestimates the peak force value in severe wave conditions, underscoring the critical importance of accounting for non-linear forces. The comparison effectively showcases the model’s efficiency in accurately forecasting non-linear force components. The experimental data previously compiled provided partial coverage of the scale range of the current and planned wind farms in [3]. To further refine the accuracy of the Stokes-GP model, it is essential to incorporate additional data. Our current research integrates computational fluid dynamics (CFD) models with the experimental tank test dataset. We have conducted several additional groups of scale tests, specifically targeting certain water depth-to-cylinder radius ratios, to fill the existing gaps in our dataset.

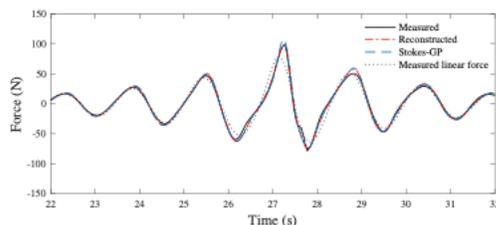


Figure 1: Comparative analysis of measured data from the experiment, reconstructed results from the Stokes-type force model, and predictions from the Stokes-GP model for cases with T (peak wave period) = 1.64 s, A_n (main crest amplitude) = 0.140 m, d (water depth) = 0.5 m.

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53.

ROBOCONE: Design development and testing of a new robotic site investigation tool to aid the geotechnical design of offshore renewables

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The acceleration of offshore wind deployment in order to meet future net zero energy targets by 2050 requires a compression of typical project timelines (HMG, 2022). The typically lengthy pre-construction, specifically the site investigation stage where soil samples are obtained and returned to shore for laboratory testing is a key phase in the project that could be streamlined. Alternative approaches utilising in-situ probes and testing techniques can speed up the design process by determining soil parameters required for design much earlier in the project cycle. These in-situ techniques combined with recent advances in both robotic and sensing technologies can be used to improve the quality of the site investigation stage, supporting a 'whole-life' design approach for offshore renewable structures (Gourvenec, 2020). The ROBOCONE device, whose initial design, testing and specification requirements were presented previously at PRIMaRE 2023 is an innovative robotic tool used to mimic stress and strain histories experienced by soil elements around real geotechnical structures, aiming to improve the efficiency and quality of offshore design. Situated behind a standard CPT cone, a cylindrical 'p-y module' of the ROBOCONE device translates horizontally up to 25% of the cone diameter to measure the soil's lateral p-y response. This measured response can be used to assist the design of seabed foundations for offshore renewables including monopiles, caissons, anchors for floating devices and many more. Here, developed design for the ROBOCONE p-y module is presented alongside larger scale testing results and their application to offshore renewable foundations.

54.

Improving Understanding of Real Ocean Waves and Their Impacts on Offshore Wind Turbine Foundations

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Offshore monopile structures are subject to extreme wave conditions. When these waves have been physically modelled, higher-order harmonic forces have been found to account for up to as much as 60% of the total hydrodynamic force exerted on test cylinders (Chen et al., 2018).

This study aims to identify fundamental wave properties that influence the proportion of the total hydrodynamic force that is non-linear as well as those that influence the impact and associated effects of a non-linear force from an incident wave on an offshore wind turbine foundation.

This study shows, using experimental data from tests conducted under severe wave conditions at DHI Denmark and the State Key Laboratory of Coastal and Offshore Engineering at Dalian University of Technology, China, the impact of different wave types and their non-linear force components on an offshore wind turbine foundation.

The data from the physical modelling was analysed using MATLAB. The total forces from the different wave types, including regular waves, uni-directional focused waves, bi-directional focused waves and multidirectional focused waves, have been split into their higher-order harmonic components using a phase-inversion decomposition method and a Fast Fourier Transform depending on the wave type. From these results, key wave properties have been identified as having an impact on the proportion of the total hydrodynamic force that comes from higher-order harmonics. It was also seen that regular waves have more of an impact on the offshore wind turbine foundation than comparable focused waves.

55.

Modelling of Floating Liquid Tank Subjected to Wave Effects Using FSI Techniques

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When a vessel navigates through open waters, it is subjected to the influence of ocean waves. Fluids contained within a tank onboard the vessel can shift and interact with the tank's walls. The movement of the free surface of the liquid is determined by the sloshing phenomenon. Combined with tank deformations and displacements, sloshing can cause tank deterioration. As part of marine renewable energies, floating systems, such as tidal or wind turbines, will be implemented. In this study, we examine a scenario in which a partially filled water tank is positioned on the ship's deck. Understanding the reciprocal influence between the tank walls and the liquid sloshing necessitates the consideration of fluid-structure interaction (FSI). To address this, we propose a simplified 2D model of a partially filled rectangular tank. This model combines a two-phase flow solver implemented in OpenFOAM, utilizing the finite volume method, with an elastic solid solver in FEniCS code, employing the finite element method. The preCICE coupling library facilitates the coupling of these two components, specifically tailored for FSI problems. To simulate the effects of ocean waves, a gravitational source term is integrated into both the fluid and structural models. Our findings indicate that the flexibility of the tank walls affects the amplitude of sloshing motions. The flexibility of the tank walls would influence how the fluids respond to external forces, ultimately affecting the amplitude and behavior of sloshing.

56.

Measuring waves and turbulence at a tidal stream demonstration site

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Accurate measurement of turbulence at tidal energy sites is an important concern to tidal energy converter (TEC) developers because of the importance of turbulence in driving fatigue on TEC components such as blades. A recent study by the authors has shown that it is possible to achieve better-than-conventional accuracy in removing the effects of wave action from acoustic Doppler current profiler (ADCP) estimates by combining two approaches: removal of wavelike spectral content from velocity records, and empirical orthogonal analysis to identify and extract statistical modes corresponding to wave action from a whole-record estimate of turbulent kinetic energy (TKE). The work presented here extends the earlier study by considering the relative effectiveness of the method on measurements taken at different locations within a tidal stream demonstration site. This allows us to demonstrate some aspects of the robustness of the method that were not possible to investigate with a single measurement location. In particular, we are able to show 1) that the method can be re-validated against independent wave measurements when the spatial separation between the ADCP and the wave instrument is greater than in the pilot study; and 2) that the method can be applied when the averaging period for ADCP measurements is shorter than recommended for achieving statistical stationarity of turbulent parameters.

57.

The Electric Seaway

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The Electric Seaway is a collaboration between industry and academia to deliver critical marine charging infrastructure. Ten sites along the south coast of England are targeted for integration into an electrical charging infrastructure supporting the region's ever-growing fleet of electric maritime vessels.

This network will offer a blueprint for future networks but also provide much-needed clarity for the whole supply chain. It will offer a standardised approach to e-charging in current and planned fully-marinated charging technology and help to overcome the major barrier of limited grid capacity, levelling up infrastructure provision.

The project has two primary work strands. First, the installation of the charger network, led by industry partners and secondly, the collection of environmental data and development of environmental intelligence.

At the half-way point of the wider project, two chargers have been installed, including in the Ocean Village, Southampton. A further 10 sites are in progress or are at the build-quotation stage.

UoP is leading the environmental data collection. Air quality (PM, CO₂, NO₂) and in-water potential difference sensors will allow the chargers' effects to be fully understood and will provide baseline data for environmental monitoring across the south west coastline. Here we present the general architecture of the network of sensors, which are connected via LoraWAN gateways. The sensors will send data to the Things Network servers for further analysis. The installation of the sensor network represents a first action in the creation of a long-term data set for environmental monitoring. Future stake-holder engagement activities will guide decision regarding data archiving and sharing.