Consolidated Abstracts / Summaries for the Supergen ORE Hub ECR Forum

1. Christelle Abadie, University of Cambridge

Lifetime performance of offshore wind turbine foundations

Offshore wind plays an important role in the transition to low carbon energy supply, and has developed rapidly over the past decade. Offshore wind turbines are massive structures (~600 tonnes), commonly supported by gigantic steel piles (~300 tonnes), called monopiles. Optimised and robust design of monopile foundations is central to the driving down of costs, and wider construction of Offshore wind farms, including larger turbines. Methods used by the industry for monopile design are mostly empirical, and devising rigorous models that accurately predict both high cycle fatigue and monotonic behaviours before and after cycling is an important challenge. This presentation will provide an overview of the development of a new constitutive model - HARM - aimed at capturing accumulated permanent deformation caused by repeated cyclic loads on the monopile foundation. More specifically, the talk will cover: (i) The development steps of the model, and how it relates to monopile behaviour under cyclic loading (ii) An illustration of how important accurate prediction of the monotonic behaviour is for cyclic loading design (iii) An example application of how the model could be used in industrial practice.

2. Mustafa Abdelrahman, University of Hull

Wave excitation force estimation and robust control approaches for a wave energy converter

My research deals with the design of 1) A robust control and 2) An unknown input observer-based estimator for the incoming Wave Excitation Force (WEF) of a Point Absorber Wave Energy Converter (PAWEC). Automatic control is considered to be a crucial element in the economic development of the wave energy conversion (WEC) technology aiming at 1) enhancing the power conversion efficiency, 2) improving the safety of the device and prevent damage due to the possible extreme sea states. My PhD thesis proposes a robust control strategy for a Single Degree-of-Freedom PAWEC using a combination of Sliding–Mode and Back-Stepping (SMBS) control approaches. The proposed controller is applied to a realistic PAWEC model of a Heaving Buoy WEC with a linear generator as a Power Take Off (PTO) mechanism. The SMBS is compared with two of the standard WEC control methods; the Resistive Loading (RL), and the approximate Complex conjugate (ACC). Under nominal model condition, the SMBS show a comparable performance to the ACC method regarding power conversion efficiency and PTO force limits and better than the RL method. By introducing some modelling mismatches, the SMBS shows a high degree of robust performance proving that it is insensitive to model discrepancies. In addition, my thesis presents two Observer-Based Unknown Input Estimation (OBUIE) methods to estimate the WEF, which is required for many WEC control methods, for example to calculate optimal reference velocity or position that maximize the absorbed energy. The first WEF estimator incorporates a Luenberger observer and a learning law to estimate the WEF. The learning rate can be tuned to capture the possible high-frequency contents of a WEF signal leading to accurate estimation in the whole range of WEF operating frequencies. The second WEF estimator is based on an augmented state structure and utilizes a generalized form of Leuenberger observer to estimate system states. Simulation results are obtained using Matlab and show the validity of the proposed WEF estimators under both nominal and perturbed model scenarios.

3. Fernando Alvarez-Borges, University of Southampton

Soil mechanics approach for shaft friction in offshore piles driven in chalk

The installation of jacket-supported aero-generators in the southern North Sea and the English Channel often involves piling in Chalk, a soft calcareous rock largely composed by micro-fossils. Pile driving crushes the material and forms a remoulded chalk interface around the pile. Resistance against pile uplift is mobilised by shearing of this interface, i.e. shaft friction, but little is known of its mechanical characteristics. Furthermore, piles often exhibit very low shaft friction values during driving and shortly after installation, which has led to design recommendations suspected of being overconservative. This said, a general notion exists that piles installed in dense chalks develop larger shaft capacities than piles driven in more porous chalks, and that this may be associated with the void ratio of the remoulded interface. Density-controlled strength is a fundamental feature of the mechanical behaviour of soils, and it may be reasonably expected that soil mechanics concepts are applicable to shaft friction mobilisation in offshore piles driven in chalk. A three-stage investigation is being carried out to examine this, encompassing (1) laboratory tests to determine if remoulded chalk may be characterised by critical state soil mechanics, (2) laboratory-based interface tests mimicking pile-chalk interaction to determine if interface friction complies with critical state concepts, and (3) scaled model tests coupled with micro-focus X-ray computed tomography (XCT) to compare theoretical predictions with actual pile response. Initial results show that the mechanical performance of remoulded chalk and of the pile-remoulded chalk interface may be adequately described using soil mechanics concepts, but that a-priori knowledge of in-situ interface density is required to carry out shaft friction predictions. Upcoming research on pile penetration processes using XCT are aimed at assessing in-situ pile-chalk interface densities from pile geometry, installation method and physical characteristics of the Chalk.

4. Anthony Blake, University of Southampton

Field tests to assess the installation and load capacity of screw piles geometries optimised for offshore wind turbine foundations

Offshore wind turbines in European waters are typically supported by large diameter monopiles installed through impact driving. Recently, concerns about the effects of pile driving noise on marine life has led to effective bans on offshore pile driving or the need to implement expensive mitigation measures. Screw piles are foundations which are screwed into the ground and as result have relatively low installation noise. They are widely adopted onshore and offer an attractive solution for supporting offshore wind turbines but will require significant geometric enhancement to meet the demands of the offshore environment. Hence, a collaborative research project between the University of Southampton (UoS), University of Dundee (UoD) and Durham University (DU) has been undertaken to assess the feasibility of screw piles as a foundation solution for offshore wind turbines. UoS in collaboration with the University of Western Australia (UWA) will conduct a series of field tests on screw piles with geometries optimised for supporting offshore wind turbines. The tests will serve to validate analytical and numerical techniques developed by and DU to predict the installation performance and load capacity of screw piles.

5. Shanshan Cheng, University of Plymouth

Shell structure design and assessment of a floating foundation for offshore wind turbines

As energy consumption increases globally and environmental issues threaten the quality of life, new sustainable ways of energy generation are actively being researched and promoted. Although offshore wind energy has demonstrated great potential, it needs to cut down cost significantly in order to be competitive with conventional energy types. Given the fact that the substructure and installation count for over 30% of the total investment costs of offshore floating wind turbines, it is essential to optimize the design and fabrication of the support structures in order to lower the cost. The aim of this work is to assess the structural design of a floating foundation for offshore wind turbines based on DNVGL and Eurocode in terms of economy and reliability. The wind loading is calculated using empirical equations, and the wave loading is obtained and verified using various methods including hand calculation, AQWA and flow 3D. It is found that the shell thickness could be reduced significantly by introducing the stiffeners (stringer or ring), which can decrease the weight of hull and lower the cost. While DNVGL and Eurocode yield similar design solutions if using plane shell structures, Eurocode significantly underestimates the buckling resistance of stiffened cylindrical shells.

6. Charlotte Cochrane, University of Edinburgh

Investigating the value to the UK economy of ocean energy: scenarios to 2050

Charlotte is currently a Research Associate in Marine Energy working on the Supergen ORE Hub project through the Policy and Innovation Group. She has a Master of Science in Global Energy Management with an Honours degree in French. Her MSc thesis focused on the application of a local wind powered electric vehicle distribution fleet serving Glasgow's retail centre with a view to lowering pollutant and congestion pressures on the area. Prior to starting at the Policy and Innovation Group Charlotte worked in energy and utilities consulting at a firm specialising in technology and innovation. Charlotte is particularly interested in the socioeconomic benefit afforded Scotland by marine energy opportunities.

7. Bin Guo, Cardiff University

Influence of different momentum sources on modelling tidal lagoons

Tidal lagoon has gained further interest in recent years because of the increasing demand for renewable energy and their potential in providing other benefits, such as coastal protection. An Open-Source hydro-environmental model, namely Telemac2D, has been refined to simulate tidal lagoons by modifying the momentum term as a part of this study. Swansea Bay lagoon was added into the model as an independent subdomain. The model without momentum was treated as the base model. Then two different momentum sources were used to maintain momentum conservation between subdomains in this study. The first momentum source used the average velocity of the water flow through turbine blade. The second momentum source used the average velocity at the end of diffusor. Result show that the momentum source calculated based on the water velocity of the turbine blade is higher than calculated based on water velocity of diffusor; the turbines wake expanded with the increase of momentum source, which has a significant influence on near-field flow patterns.

8. Jon Hardwick, University of Exeter

Assessing the integration of intermittent tidal energy into a renewable energy solution for a remote island community

The island of Ushant (French: Ouessant) off the coast of Brittany in North West France is a remote island community with a permanent population of approximately 850 people. The island is electrically isolated from the mainland and is developing a strategy for 100% renewable generation by 2030.

Ushant is currently powered by generators fuelled by millions of litres of diesel fuel per year imported from the mainland. In 2015 an 1100kW Sabella 'D10' tidal turbine was installed and connected to the island grid. During times of peak generation the turbine is sufficient to supply the majority of the island's electricity demand. Between 30 – 40% of the time however the tidal speed is less than $1ms^{-1}$, when only a fraction of the turbine's rated capacity is realised. The addition of solar PV and/or wind turbine installations on the island will reduce this intermittency and help to ensure a consistent and reliable supply.

The intrinsic variability of tidal and other renewable generation technologies means that the periods of peak generation are often unaligned with the times of peak demand. In order to provide a link between the times when spring tides provide plentiful tidal energy and times when demand is greatest, energy storage can be installed. This load levelling increases likelihood that tidal energy generated at off-peak times can be used on the grid at peak times, reducing the need to curtail generation. The island currently has 1 MW of battery storage with a 500kWh capacity installed.

In this study, the tidal resource is analysed and used to predict the electrical power that can be generated from the Sabella turbine. In addition, solar irradiation models and wind speed analysis are used to identify potential for other generation. The PVsyst software package is used to calculate the solar resource on the island utilising metrological data from several databases. A wind speed model is constructed from measured and re-analysis data. Of particular interest is the amount of synchronisation of the generation profiles from the technologies with the energy demand profile from the island.

Remote island communities may incur large benefits from installing a combination of renewable energy technologies to supply their electricity requirements. Isolated communities are often reliant on the import of fuel to supply generators which can result in a costly or intermittent supply. By installing a mixture of renewable technologies, isolated communities can be provided with a clean, reliable and cost effective electricity and/or heating supply. Many remote islands have the advantage of good tidal energy resource and the installation of tidal stream energy converters can be utilized to provide electricity for the island. The intrinsic variability of tidal energy however means that alternative generation methods will always be required. Installing a mix of technologies energy can reduce that intermittency and cut the amount of electricity required from backup supplies.

9. Magnus Harrold, University of Exeter

Intelligent mooring system for floating wind

Existing mooring systems for floating offshore wind turbines (FOWT) are based on proven designs from the oil and gas industry. While these designs can provide the necessary safety margins, it has been recognised that this is a high cost solution, with the mooring system accounting for as much as 10% of the FOWT. This is particularly problematic considering that the FOWT industry is striving to achieve cost-competitiveness. In this Innovate UK funded project, a hydraulic component is being developed to reduce loading in mooring lines, which will lower the requirements, and hence cost, of the mooring system and a number of other FOWT sub-systems. The component is referred to as the Intelligent Mooring System (IMS) and has a functionality akin to a shock absorber. Numerical modelling work performed in the project suggests that the IMS could reduce peak mooring loads by 18%, indicating a high level of feasibility. The IMS has been built at 1:3 scale and will soon undergo representative testing in a laboratory, which will aim to characterise the performance of the component and provide the physical evidence required to support the load reduction claims.

10. Siya Jin, University of Plymouth

Experimental and numerical studies of the wave structural interaction

Current post-doctoral research, for the Supergen ORE Hub, focuses on "Probabilistic design for offshore renewable energy (ORE) system to optimize operating efficiency and reliability". The study is to identify design load cases and demonstrate the impact of the probabilistic design approach in offshore renewable energy systems. Present design methods are inherited from the offshore oil and gas sector, where the design challenge is considerably different to ORE. ORE structures are designed to enhance motion responses in certain conditions, but suppress them in others to ensure survivability and reliability. Design conditions (responses and loads) result from combinations of environmental conditions and hydrodynamics of the structure, each of which are stochastic processes. By applying probabilistic design, the guideline for optimization of the ORE system will be proposed. This will feed into the larger research programme of the Supergen ORE hub, designed to maximize progress towards enabling transformation of the industry to future scale ORE.

Previous doctoral research focused on "Hydrodynamic and control optimization for a heaving point absorber wave energy converter", supervised by Prof. Ron Patton and Prof. James Gilbert (University of Hull). The study aims at discussing the non-linear effects on wave energy converter (WEC) performance and the application of control strategy on WEC. Compared with the conventional linear model, a non-linear model is proposed and validated by CFD and experimental data. The non-linear model shows great accordance with the CFD and physical data, indicating the significant viscosity effect on the WEC performance. Hence, joint tuning of the geometry and power take-off damping is involved to improve the power capture. Also, based on the non-linear model, control strategy is designed to further improve the conversion efficiency.

11. Yibo Liang, University of Strathclyde

Investigating the offshore wind turbine power generation in the U.S. - A case study in a life cycle perspective

Along with the continuing development in the offshore wind energy sector, the European offshore wind power grew from 0.3 Mtoe (million tonnes of oil equivalent) in 2005 to 2.8 Mtoe in 2014 and expected to reach at 11.7 Mtoe in 2020 [1]. Apart from EU, on the other side of the Atlantic, U.S. offshore wind has a technical resource potential of more than 2,000 GW of capacity, or 7,200 TWh of generation per year [2]. The state of New York has set of target of 2,400 MW of offshore wind to be built by 2030 [3]. There are numerous advantages for offshore wind energy, such as higher wind speed, greater applicable areas and easy for transport. However, the main challenge for offshore wind development is high capital and operating expenditures (CAPEX, OPEX). Unlike onshore wind development [4, 5], few studies about levelised cost of energy were carried out based on offshore wind sector, especially in the U.S. Due to the Merchant Marine Act of 1920 (Jones Act), it is difficult to import European mode directly to the U.S. Thus, the levelised cost of energy (LCOE) in the U.S. is worth to investigate based on the experience from European counties. Additionally, the present work employs a ten-year observation (2008 – 2017) of the wind speed at the New York State coastal area provided by the National Oceanic and Atmospheric Administration's National Data Buoy Center. Thus, the life cycle energy generation can be more realistic and the seasonal performance could also serve as a good guidance for maintenance work.

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12. Lilian Lieber, Queen's University Belfast

In pursuit of turbulence: anthropogenic wake generates a predictable foraging opportunity for top predators

A succinct overview of research outputs relating to the environmental interactions of marine renewables as part of the recently completed Powerkite project will be provided (device noise assessments, the use of ADCPs in assessing marine mammal site usage, and collision risk modelling and monitoring). With rapid growth in the offshore renewable energy sector, rethinking the fate of obsolete installations is timely. A broader perspective on the ecological implications of offshore installations is critical. For instance, through the introduction of a man-made structure into tidal seas, physical processes can be strongly modified. Notably on localised scales, strong currents interacting with installed structures can generate a wake with a complex three-dimensional coherent structure (von Kármán vortex street) in the lee of the installation. Set in a rare natural experiment, we quantified the relative use of an anthropogenically-generated wake by surface-feeding seabirds (Sternidae), using direct observation techniques including shore counts, UAV transects and active acoustics. The wake generates a predictable vortex street, thereby acting like a prey conveyor belt providing an unforeseen benefit. Finally, a brief introduction to the newly established Bryden Centre, a European Interreg project linking research across Northern Ireland, Scotland and the Republic of Ireland (and beyond) will be provided as it presents extensive scope for collaboration in the areas of marine renewables and bioenergy.

13. Yanhua Liu, University of Hull

Fault-tolerant individual pitch control for offshore wind turbines

My PhD focuses on applying fault tolerant control (FTC) techniques within load reduction strategies by individual pitch control (IPC) for offshore wind turbines. An important control challenge for wind turbines is to maximize the power capture whilst mitigating against structural loads at the same time. Furthermore, pitch actuator loss of effectiveness or sensor errors severely affect the quality of the IPC system and hence recovering the nominal load mitigation performance and power conversion efficiency using new advanced methods of robust FTC becomes significant.

During my PhD, a preview control system using model predictive control (MPC) with knowledge of future winds is proposed to achieve an impressive blade load reduction. Here, future effective wind characteristics are provided by a well-designed Gaussian process model. Moreover, a robust FTC system for three different pitch actuator incipient (component) faults is designed in two IPC system including PI and H infinity loop-shaping control systems. It gives some general insights into the unbalanced blade load and power deterioration in presence of pitch actuator incipient faults. It can be seen that the proposed sliding mode observer based FTC strategy can compensate the fault effects well and maintain the nominal asymmetrical load mitigation performance. Finally, due to the coupling between tower and blade loads, a multi-variable LQR-based IPC system is proposed to mitigate blade and tower loads together with sensor faults considering the uncertainties and measurement noise. An unknown input observer (UIO) system is proposed to achieve the estimation of sensor faults and thus the FTC compensation is implemented. The designed UIO is validated under three different pitch control cases and the performance of designed load reduction controller is compared in different faulty cases.

14. Ramon Lopez Jimenez, University of Hull

Impact of sediment transport processes over offshore windfarm sites

Wind farms need submarine equipment any other types of infrastructures for their operation. What are the consequences of different sediment transport processes on these submarine elements of wind farms? Power and communication cables can become inaccessible or damaged by these processes. Areas of erosion and deposition on the seafloor caused by these processes change in time. In the particular case of sand dunes and sandbanks, future areas of deposition and erosion change in a time frame from several months to years. We are improving our understanding of the causes and mechanisms of these seafloor processes. The more data we can collect from different sources on physical attributes of the seafloor, water currents and wind, the better we will develop predictive tools. The application of machine learning is a solution we are exploring for developing these predictive models on seafloor changes of wind farm areas.

15. Ed Mackay, University of Exeter

The use of porous materials for motion damping of floating offshore wind turbines

A key challenge for developing cost-competitive floating offshore wind is the design of stable platforms that keep the motions of the wind turbine within an acceptable range. The addition of porous structures to floating platforms has been proposed as a way of reducing platform motions without significantly increasing the size and cost of the platform. This talk will present the results of initial design studies of for floating platforms with porous elements. The talk will describe the development and validation of a novel multi-domain boundary element method (BEM) code for modelling floating porous structures. This work includes several innovations with wider application, including (1) development of a new fast and accurate method for calculating the free-surface Green function (a key step in all BEM codes), and (2) experimental validation of models for the pressure drop across a thin porous barrier in oscillatory flow. The BEM code has been validated against tank tests with porous cylinders with a solid inner column and is shown to be able to accurately predict the wave loads for varying porosity, cylinder diameters and wave conditions, including the nonlinear variation in force with wave amplitude. The initial design studies have considered the effect of adding a porous outer layer to the OC4 DeepCwind Semisubmersible. The inclusion of a porous layer causes a reduction in the wave excitation forces in surge, heave and pitch at higher frequencies and an increase at lower frequencies. However, the added mass and radiation damping in all three modes are increased significantly over all frequencies, resulting in a reduction in the motion RAOs.

16. James McNaughton, University of Oxford

Investigating constructive interference for multi-rotor tidal turbine systems

I have been involved in the offshore energy industry for almost a decade, particularly focussed on tidal stream energy. I completed my PhD at the University of Manchester on the topic of turbulence modelling of a full-scale tidal turbine using computational fluid dynamics. I performed steady and transient calculations of experimental and full-scale tidal turbines, as well as developed a new sliding-mesh method.

Post-PhD I worked for Alstom Ocean Energy, supporting the deployment of the 1MW DEEP-Gen IV turbine at EMEC and contributing to the design of the Oceanide turbine. My work focussed on performance and loads modelling, I was responsible for measuring the full-scale turbine's performance curve, validating this and loads with DNV-GL's Tidal Bladed BEMT, and using the information to improve design methodologies.

I then worked as a research engineer for EDF Energy, working on a variety of projects in the areas of floating wind, offshore wind asset management and marine energy. I conducted various offshore trials at Teesside Offshore Wind Farm related to anti-corrosion coatings and ROV inspections.

I am involved in the BSI committee for development of marine energy standards and am part of the recently formed IEC maintenance team for updating the technical standard for IEC TS 62600-200 - Power performance assessment of electricity producing tidal energy converters.

I returned to academia in March 2018. My current research focusses on constructive interference for multi-rotor tidal turbine systems. I am designing and testing experimental rotors in order to better understand the flow physics within close fences, and validate numerical tools for designing rotors for high local blockage ratios.

17. Agota Mockute, University of Hull

Suitability of wave loading models for OWT monopiles in very harsh seas

Monopile supports for offshore wind turbines are normally placed in shallow to intermediate waters where wave nonlinearities are high, and may prompt dangerous resonant amplifications of the structural response, known as springing and ringing. The use of linear and weakly nonlinear wave kinematics, i.e. Airy or Stokes theories, with the standard Morison equation as the hydrodynamic loading model, have been shown to omit the nonlinear amplifications which are associated with third or higher order loading components, requiring fully nonlinear wave kinematics. Therefore within the framework of this PhD work a higher-order Boundary Element Method for fully nonlinear gravity waves was advanced. Then a number of wave kinematics of increasing nonlinearity were used as input to three hydrodynamic loading models – Morison equation, slender-body and FNV theories – in order to assess which type of nonlinearities dominate and which combination is most appropriate for specific wave and cylinder conditions. Some of the key findings on fixed cylinder in regular waves indicate a stronger influence of wave kinematics in shallow water while the nonlinearities in hydrodynamic loading models were found to dominate in deeper water settings, as well as special attention drawn to the monotonic growth of the predicted loading with increasing steepness, which is not seen in the reported experimental values and was therefore leading to an increasing overprediction with higher steepness. The results in irregular seas, as well as the dynamic response of an offshore wind turbine still await.

18. Hannah Mullings, The University of Manchester

Efficient prediction of unsteady loading of turbine blades in turbulence

At the present time full scale tidal turbines are in use as part of an array in the Meygen Project [1]. Four turbines are currently installed and a further 49 are planned for installation beginning in 2019. As such there is a need for efficient methods to predict the long term loading that can cause fatigue of components. Turbine blades are particularly critical components as indicated by failures during trial deployments [2, 3] and the typically high safety factors [4] that lead to significant capital costs. Accurate assessment of the fatigue life of turbine blades requires prediction of the load spectra experienced over the wide range of quasi-steady conditions that can occur during operation. In our previous study, [5], the effect of scaling experimental load spectra from a measured turbulence level was shown to have a large impact on the equivalent fatigue loading. An understanding of loads experienced through computational simulation can be assessed by either using an unsteady Blade Element Momentum method (BEM) or through fully-resolved geometry computational fluid dynamics (CFD) models. The aim of this study is to investigate the use of a simplified method for predicting the spectra of unsteady blade loads based on the use of a synthetic turbulence method, accounting for turbine operating conditions and approximating loads in the high-frequency range informed by 2D CFD. The loading experienced by the blades due to turbulence distortion, tower shadow and various shear profiles within the flow field is also investigated. The predicted load spectra are evaluated relative to experimental measurements, Payne et al. in [6], for a 3-bladed 1.2 m diameter bed mounted turbine. The conditions experienced in the experimental case were replicated within the synthetic flow field predicting the overall shape and principal features of the blade load spectrum. The peak blade loading is to within 4% at the rotor frequency and the damage equivalent loads within 16%. Disparity of prediction in the high frequency range leads to an examination of the influence of blade-scale flow on time-varying blade performance. The relative velocity incoming to the blade is employed as input to CFD producing fluctuations in both lift and drag above a threshold frequency. Integration of these high-frequency blade loadings across the span improves the prediction of unsteady blade root bending moment which in turn improves the prediction of the damage equivalent loads to within around 13% of the experiments. This method is of similar accuracy to CFD but incurs considerably lower computational cost. Such understanding of different loading patterns is expected to enable development of standardised designs and improved overall system performance.

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19. Pablo Ouro, Cardiff University

Towards efficient large-eddy simulation of tidal turbine arrays: approaches to balance the computational expense

Tidal stream turbines operate in harsh marine environments that challenge their resilience due to unsteady loads caused by recurrent impact of oncoming turbulence, rough bottom surface and waves. Hence, to accurately represent the flow-structure interaction, these flow conditions need to be included and resolved in numerical models. As turbulence is an inherent feature of tidal flows, accurate eddy-resolving methods, such as Large-Eddy Simulation (LES), are required to accurately simulate tidal turbines understanding how their deployment in arrays within selected sea sites can be modified in order to maximise energy generation. The high computational cost of LES poses a huge challenge when modelling arrays of multiple tidal turbines, owed to the relatively fine grid resolutions required to resolve the broad spectrum of dominant flow scales. For this reason, LES requires using simplistic but accurate approaches to represent the turbines' rotor and support structure, whilst resolving the energetic scales dominating the flow field, such as tip vortices or wake meandering. The different methods available to efficiently and accurately simulate tidal turbines, e.g. immersed boundary and actuator line methods, will be introduced and their capabilities discussed. Finally, the future advances in this field will be also postulated.

20. Ajit Pillai, University of Exeter

Reliability Based Design Optimization – An Application to Mooring Systems

This work describes the development of a framework using reliability based multi-objective design optimization in order to aid in the design of a mooring system for offshore renewable energy devices. This framework couples numerical models of the mooring system and structural response to cost models in order for the genetic algorithm to effectively operate considering multiple objectives. The use of this multi-objective optimization approach allows multiple design objectives such as fatigue and the material cost to be minimized simultaneously using an automated mathematical approach. Through the application of this automated approach, a wider set of designs will be considered allowing the system designers to select a design which appropriately balances the trade-off between the competing objectives. In this work, a set of mooring designs that represent efficient solutions for the stipulated constraints are found and presented. The developed framework is applicable to other offshore technology subsystems allowing multi-objective optimization and reliability to be considered from the design stage in order to improve the design efficiency and aid the industry in using more systematic design approaches.

21. Alberto Rabaneda, University of Hull

The development of a satellite-enabled tool for offshore wind optimisation

The offshore wind industry has been searching for cheaper technologies capable to measure wind vectors on deep seas, such as floating LIDAR or satellites. The European project NORSEWInD created wind atlases from satellite measurements for the North, Irish and Baltic Seas. After that project, the creation of software to undertake wind resource assessments by satellites was aimed by a new project named WindRes. New software was created which merges knowledge from different fields, microwave remote sensing, satellite Earth Observation and wind resource assessment. The capabilities of the tool, and more important, the capabilities of satellites to match requirements by the wind industry were tested. In this initial analysis, advantages and disadvantages were identified as well as lack of knowledge. Two main points were concluded to need further research; the vertical extrapolation of wind vectors, and the creation of climatology from satellites measurements. Different extrapolation methods suggested in the literature were tested. These include methods to calculate aerodynamic surface roughness length and friction velocity, since both determine the logarithmic wind profile. After previous methodologies were found to mismatch in situ measurements, a new expression for z_0 was developed. New equations were reached by application of knowledge in oceanography and boundary layer meteorology.

22. Alma Rahat, University of Plymouth.

Intelligent Optimisation Methods.

Alma Rahat is a Lecturer in Computer Science at the University of Plymouth. He has a BEng in Electronic Engineering from the University of Southampton, and a PhD in Computer Science from the University of Exeter. He has been a product development engineer before starting his PhD, and has held post-doctoral research positions at the University of Exeter before starting his role in Plymouth. His research focus is in intelligent optimisation methods: combining data-driven (Bayesian) models, mathematical programming and evolutionary search, he aims to devise efficient and robust optimisation methods for NP-hard, computationally or financially expensive, and single- or multi-objective problems. He has particular interest in optimisation under uncertainty (in measurements and objective functions). His applied work includes computational fluid dynamic (CFD) simulation based engineering design, multi-objective routing design for wireless sensor mesh networks, and coal-combustion optimisation.

23. Edward Ransley, The University of Plymouth

Wave-structure-interaction using CFD

Numerical modelling of wave structure interaction problems using open-source CFD software, OpenFOAM. Applications include: offshore renewable energy devices, coastal structures and nonlinear wave kinematics. Heavily involved in the Collaborative Computational Project in Wave Structure Interaction (CCP-WSI) as well as high powered computing and software engineering initiatives.

24. Giovanni Rinaldi, University of Exeter

A (r)Evolutionary approach for the optimisation of offshore renewables O&M

Operation and maintenance (O&M) of offshore renewable devices is one of the major contributors to the final cost of the energy produced. As a consequence, support is needed in the decision-making process in order to achieve the safe and economic running of the project. At the University of Exeter, an integrated framework, constituted by a set of computational models, has been developed in order to achieve this objective and mitigate risks in the long term management of an offshore farm. This framework combines a characterisation tool, used to evaluate the key performance indicators of the offshore farm, with an optimisation model, based on genetic algorithms, for the automated and methodical improvement of the O&M strategy. As a result, a vast range of possible O&M assets are evaluated and compared, weaknesses and areas of improvement identified, and the viability of the project increased. The process of proposing corrective measures for the previously identified areas of amelioration is thus systematic and enhanced.

25. Fabian Schranz, University of Oxford

Capacity of driven piles in chalk (ALPACA Project)

Chalk is found in large parts of north-western Europe as a low-density porous, weak rock. Large numbers of engineering works (e.g. offshore wind turbines, bridges and ports) are founded on piles driven in chalk. Until now only little knowledge on axial and lateral behaviour of piles driven in chalk is available. This leads to high uncertainties for designers. With the ALPACA project further experimental data on pile behaviour driven in chalk will be gained. Therefore, axial and lateral tests on 36 driven piles are made, which are supported by advanced laboratory and in-situ testing. Advanced design guidance will be developed on basis of the new data.

26. Evdokia Tapoglou, University of Hull

Machine Learning in Wave Forecasting

Accurate predictions of waves with different lead times are necessary for a large scope of coastal and open ocean activities. A number of forecasting tools are widely available, corresponding to different sets of available sources (satellite images, meteorological data, physical modelling etc.). However, when compared with real data from buoys the reliability of the results vary depending on a number of parameters (lead-time, expected significant wave height, correlation with meteorological conditions, boundary conditions etc.). Moreover, the results can vary due to the grid size used by the forecasting model. These variations can have a large effect in the possibility of completion of the activity at hand. Wave height is the main parameter in deciding whether service vehicles can access a wind turbine safely. If the vehicle is mobilized, but the wave height then exceeds the safe limit, the journey is wasted. On the other hand, if the vehicle is not mobilized, and the wave height then does not exceed the limit, the opportunity to repair the turbine has been wasted.

The purpose of the present study is to identify ways of improving wave forecasting using machine learning methodologies and to compliment and compare them with traditional modelling techniques. Our work involves the use of Machine Learning (ML) models, such as Artificial Neural Networks (ANNs), to forecast waves using accurate, high resolution atmospheric and oceanic patterns data, such as tidal patterns, wind, atmospheric pressure and temperature data. Moreover, ML can be used to downscale multiple gridded forecasts to a wind farm level and further on to wind turbine level, in order to evaluate their accessibility in any given moment and determining if it is possible to perform the necessary maintenance during the required mobilization window. By comparing and complimenting already known methodologies to machine learning modelling results the uncertainty involved in significant wave height forecasting can be reduced, resulting in an informed and reliable sea-state forecast.

27. Neda Trifonova, University of Aberdeen

Ecosystem Models to Understand the Effect of Offshore Renewables on the Marine System

I am currently a research fellow at the University of Aberdeen, my principal supervisor is Professor Beth Scott. I completed my PhD in Computer Science during which I was working on developing dynamic Bayesian networks to investigate fish population dynamics throughout space and time and understand their interactions with fisheries and climate. My expertise is in the application of machine learning techniques such as Bayesian networks and I will be applying these approaches to investigate the effect of offshore renewables on the marine system. Specifically, ecosystem Bayesian models will be developed that capture relationships in the system and across spatial (ms to kms) and temporal scales (multiple years). In addition, model scenarios will be developed to investigate the effect of offshore renewables in combination with other anthropogenic factors such as fisheries exploitation and climate change. The ecosystem models will be able to assist the development of offshore devices and design to support the confident prediction of the environmental impact and provide information on the ecological benefits and trade-offs. Such information will ideally support the communication with other sectors and guide policy decisions and planning.

28. Chris Vogel, University of Oxford

Multi-scale offshore wind farm wake interactions

The UK benefits from a large wind resource due to its location in the north Atlantic Ocean, and wind energy currently represents a large and growing share of UK electricity generation. Development in the UK is increasingly focussed offshore, with almost £20bn being invested across the next five years. Across Europe, it is expected that 150GW of offshore wind capacity will be installed by 2030. The rapid growth in wind turbine size and the number of turbines within wind farms presents new challenges to the sector. The impact of wind turbine wakes on other turbines within wind farms is one of the key fluid-dynamic challenges that needs to be better understood in order to support meeting the dual aims of continued growth of the industry and reductions in cost of energy. Specifically, field data from existing offshore wind farms has shown that there is a significant performance drop for turbines operating in waked conditions, along with increased flow unsteadiness leading to fatigue damage of blades. Understanding the development and evolution of wind turbine wakes will enable better prediction of these effects leading to the potential for novel control algorithms for both new and existing wind farms and farm layouts to mitigate destructive wake interactions. Turbine-wake interactions are being studied through numerical simulation, which has shown that the interactions are differ depending on how much of the turbine is operating in wake conditions. Comparisons between detailed simulations and current engineering models for wake combination show that although existing models can work well under some flow and operation conditions, such agreement is very much case-specific and the models cannot be generalised reliably to the many cases that must be considered for large wind farms. In particular, these models do not capture the role of turbulence in wake evolution and combination. Work is ongoing to better understand these interactions and ultimately develop improved engineering models for offshore wind farms.

29. Andrew Want, Heriot-Watt University

A novel system for monitoring biofouling and testing antifouling and anticorrosion coatings in offshore renewable energy habitats

As part of UK governmental plans to decarbonise electricity generation, the seas around Scotland are being targeted for deployment of offshore renewable energy (ORE) devices, i.e. wave, tidal, and offshore wind technologies. The success of the ORE industry is dependent upon lowering the levilized cost of electricity generation through maximising energy capture and minimising down-time. A major concern to industries working at sea is marine biofouling – the settlement and growth of organisms on subsea structures. In the ORE sector, biofouling may affect device performance by increasing drag, accelerating corrosion, and adding weight to moorings and other infrastructure. Additional concerns exist regarding the accuracy of data buoys and sensors used to assess the hydrodynamic resource and device performance. The BioFREE project, part of a collaboration between Heriot-Watt University and the European Marine Energy Centre, has developed a novel monitoring and testing system for use in high-energy wave and tidal habitats. This system is allowing detailed characterisation of the biofouling communities from multiple locations in Orkney, as well as at international partner test sites. Results from these studies indicate that major fouling species differ between sites owing to hydrodynamic conditions, water depth, substrate type, and timing of deployment. Life stages of key fouling species often exhibit contrasting patterns of seasonality which may allow site-specific guidance to the industry regarding anti-fouling strategies. Deployment and maintenance of ORE devices and infrastructure may be scheduled to times when the settlement of fouling organisms will be minimal or their removal will be least costly. In addition, studies of the heave response of data buoys are providing quantifiable evidence of the consequences of fouling to sensor performance. This system is also providing a platform to test anti-fouling and anti-corrosion coatings applied to various materials used in component manufacture.

30. Benjamin Williamson, University of the Highlands and Islands

Multi-platform studies of the MeyGen tidal energy site – using UAVs to measure animal distributions and hydrodynamic features

The integration of seabed platforms, ship-based surveys and aerial surveys allows an understanding of animal use of marine renewable energy (MRE) sites. Top predators target these sites for foraging, where high flow speeds, upwelling or shear may enhance prey availability and foraging efficiency. We need to measure the distribution and behaviour of animals to understand and predict potential animal interactions with large-scale MRE arrays. Our studies have focused on the MeyGen tidal stream site in the Pentland Firth, UK. The FLOWBEC seabed platform was deployed to collect baseline measurements on hydrodynamics (ADCP & ADV), prey and turbulence (EK60), and predator-prey interactions (multibeam sonar). Temporal persistence of the FLOWBEC platform was complemented with spatial coverage from ship surveys, before and after turbines were installed, to measure hydrodynamics and turbine wake effects (ADCP), prey and turbulence (EK60), and surface detections of animals (observers and cameras). Unmanned Aerial Vehicles (UAV) imagery allows concurrent measurement of animal distributions and fine-scale hydrodynamic surface characteristics to investigate the behavioural associations between top-predator foraging and hydrodynamic features. UAVs can overcome the cost and therefore infrequency of vessel or aeroplane animal surveys which limit understanding of seasonal trends, and overcome the limitations of vantage point surveys which suffer from reduced detectability with increasing distance from the observer. Work is ongoing to develop algorithms for automated detection of animals and hydrodynamic features from UAV datasets. Together, the integration of these techniques is increasing our understanding of animal behaviour in tidal stream sites, and how this behaviour is changed around tidal stream turbines, to inform the environmentally-sustainable development of large-scale arrays.

31. Zhihua Xie, Cardiff University

Numerical study of turbulent multiphase flows

Multiphase flows where two or more fluids have interfacial surfaces are often found in environmental and industrial engineering applications. The objective of this study is to investigate the fluid dynamics of three-dimensional (3D) two- and three-phase multiphase flow problems, such as bubbles, droplets, liquid jet, falling liquid films, breaking waves and interfacial flows over rough surfaces. In this talk, two numerical codes (one for finite volume and the other for finite-element control-volume methods) for solving 3D Navier-Stokes equations with interface capturing are presented, and some numerical examples are shown to provide some insight into the physics and also to demonstrate the capability of the numerical tools developed.

32. Anna Young, University of Cambridge

Tidal turbines: Measuring, Modelling and Mitigating Unsteady Flow

Uncertainty over the lifespan of tidal turbines in the harsh marine environment means that components tend to be over-engineered, and maintenance schedules to be over-cautious; this drives up costs and deters investors. It is therefore imperative that the next generation of tidal turbines makes use of smarter design techniques which take into account the unsteady conditions experienced at sea. My work is largely in three areas: measuring the tidal channel flow itself, modelling the effect of unsteadiness on the turbine and improving turbine design to mitigate fatigue loads. I am currently interested in understanding the limitations of current models for fatigue estimation and in developing improved design tools for both steady and unsteady performance.

33. Donatella Zappalá, Durham University

Investigating wind turbine dynamic transient loads using contactless shaft torque measurements

The wind industry is showing increasing awareness about the importance of long-term direct shaft mechanical torque measurements to fully understand wind turbine (WT) dynamics, adopt proactive solutions for extreme load mitigation and enhance condition monitoring (CM) capabilities. Transient events, occurring during control actions or anomalous wind speed behaviour, cause high loads and can lead to unexpected torque reversals that can be harmful to wind turbine drive train components. Premature failures of gearbox bearings have been associated with overloading experienced by the drive train. Direct high frequency real-time measurements of wind turbine train loads can improve confidence in drive train design and allow the adoption of proactive solutions for extreme load mitigation. Mechanical torque measurements are also relevant for efficient CM during turbine operational life, and for condition-based diagnosis for reliable and safe operation. The potential of monitoring different WT drive train components using direct measurements of the shaft mechanical torque signal is significant, as it contains information on the mechanical response to wind before any generator effects. Although torsional effects are important, torque measurement on such a large, inaccessible machines is practically and logistically difficult, mainly because of the costly and intrusive specialised equipment currently available.

This paper presents the experimental investigation of a novel contactless, low cost torquemeter for shaft load and speed measurements, with a focus on tracking shaft dynamic transient conditions for use in a CM system. The adoption of the proposed technique would allow mechanical torque and speed measurement, and monitoring across the machine operational life. It relies on the instrumenting of the machine shaft with a set of two barcodes, one at each end of the shaft, and two optical sensors mounted on non-rotating supports. Experiments have been performed to emulate shaft dynamic transient loads experienced by a WT drive train, during anomalous wind speed fluctuations and control actions. The performance and accuracy of the proposed optical torque system have been experimentally demonstrated through comparison with reference measurements from an in-line, invasive torque transducer. Results obtained over a range of applied loads indicates good accuracy of the proposed contactless torquemeter, with average torque and speed root mean square error (RMSE) values of 0.53 Nm and 0.35 rpm, respectively. Unlike conventional measurement methods, the proposed barcode torquemeter does not require costly embedded sensors or shaft-mounted electronics. It can also be designed to be fitted, or retrofitted, on any WT shaft diameter and material without mechanical interference. Its implementation in the field would allow direct, cheap, real-time measurements of WT drive train loads. This overcomes the majority of problems currently limiting the industrial direct measurements of WT drive train loads for performance monitoring, control and CM purposes.

34. Siming Zheng, University of Plymouth

Coast/breakwater-integrated OWC: a theoretical model

Integrating wave energy converters into coastal structures such as breakwaters, seawalls or jetties not only offers benefits in terms of construction costs but also improves wave energy extraction. In this paper a novel theoretical model based on linear potential flow theory is developed to study the performance of an oscillating water column (OWC) integrated into a vertical structure in water of finite water depth. The model has three fundamental advantages relative to previous works: no thin-wall restriction (the thickness of the OWC chamber wall is considered), no singularities, and far fewer truncating terms in the eigen-function expansions. The OWC chamber is a vertical cylinder semi-embedded in the structure with a submerged, open bottom. As water waves impinge on the structure, the water column in the chamber oscillates and drives an air turbine installed at the chamber top to extract wave power. Using linear wave theory, the velocity potential in the water domain is decomposed into scattering and radiation potentials whose unknown coefficients are determined by the eigen-function matching method. Upon successful validation, the model is used to investigate the influence of the thickness of the chamber wall and the radius and submergence of the chamber on wave power absorption.