UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

aura

AURA CENTRE FOR DOCTORAL TRAINING

RESEARCH PROPOSALS

Indicative proposals listed by research theme:

- Big marine data and metocean

  Biological activity; marine & offshore wind personnel traffic; metocean forecasting; seafloor mapping; smart seabed sensor networks.

- Environmental interactions, seabed dynamics and benthic habitat

  Acoustic impact on marine life; cable risks; extreme events; monopile decommissioning; natural hazards; seafloor structure.

- Logistics, safety, risk and human factors

  Workload analysis in operations & maintenance and construction; remote safety training for technicians; control and mitigation of fatigue under shift systems; comparison of logistics for fixed vs floating OSW.

- Low carbon transitions and community benefits

  Offshore wind and smart grid development; societal impact of offshore wind; economics of offshore wind developments; aquaculture in windfarm zones.

- Next generation materials and manufacturing

  Assistive assembly and manufacture; blade design and manufacture; bulk additive component production; reconfigurable manufacturing; self-healing surface coatings.

- Operations and remote autonomous monitoring

  Blade structural health; floating turbines control; hydrophone systems for marine mammals; internal turbine inspection; position monitoring with GNSS.

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NERC SCIENCE OF THE ENVIRONMENT

Theme: Big marine data and metocean

Project: AI empowered wind turbine health self-diagnosing system using sensor network.

Supervisory Team:
Lead: Dr Yongqiang Cheng (Faculty of Science and Engineering, University of Hull), **email: Y.Cheng@hull.ac.uk**
Dr Nina Dethlefs (Computer Science, University of Hull)
Dr Qin Qin (Acoustics Research Centre, University of Hull)
Dr Prosanta Gope (Computer Science, University of Hull)

Project Description
The blades of wind turbine are in various lengths, materials, shapes and sizes, even their natural frequencies are not constant. Precise modelling of the wind turbine including their blades reflecting their internal structures changes, damages, imperfections of movement proves to be challenging. In this project, we steering away from the conventional methods of wind turbine health monitoring, but to study the feasibility of a novel low cost data driven response oriented (DDRO) method for real time wind turbine health reporting. In DDRO, a customised sensor emitting a selected range of waveforms propagating through the material of the wind turbine body. They will demonstrate various resonant/vibrating features, detected from a number of sensors that are mounted in far end of the structures and blades. In the meanwhile, periodical laser beams are deployed on the sensors to align them in precise positions and also detect deformation of the structure. Empowered by the latest big data analysis algorithms, the signature of each wind turbine will be learnt through fusion of these data. By consistently monitoring these signatures, any deformation, damages, defects of the blades will be immediately revealed in real time and possibility their degree of severity.

Project: Smart low-cost listening networks for monitoring offshore hazards and impacts on marine mammals (2 x PhDs)

Supervisory Team:
Lead - Professor Nick Wright (Turing Fellow – School of Engineering, Newcastle University), **email: nick.wright@ncl.ac.uk**
Jeff Neasham (Senior Lecturer in Engineering, Newcastle University)
Dr Per Berggren (Senior Lecturer – School of Natural & Environmental Sciences, Newcastle University)
Professor Peter Talling (Geography, Durham University)
Dr Matthieu Cartigny (Research Fellow in Geography, Durham University)
Dr Michael Clare (National Oceanography Centre)
Professor Dan Parsons (Director - Energy & Environment Institute, University of Hull)
Dr Rob Dorrell (Research Fellow in FoSE, University of Hull)
Professor John C Murray (Robotics & Autonomous Systems, University of Hull)
Dr Steve Simmons (Research Associate in Geography & Geology, University of Hull)

Project Description
We seek to make a major step-change in monitoring hazards and the environmental impacts caused by offshore installations. This will be done by developing and demonstrating novel low-cost, smart-sensor systems that form widespread and long-term listening networks. These low-cost and energy efficient (passive) sensors comprise hydrophones. Such a low-cost network has unusually widespread applications, such as monitoring hazards to offshore

structures, and their impacts on marine mammals. Similar systems can be used to monitor gas leaks from underwater pipelines or Carbon Capture and Storage (CCS) facilities. The first PhD project will help to design and test these low-cost hydrophone systems, and explore the best strategies for recovering data without a need for expensive vessels. These novel listening networks will then be used to address a series of major environmental issues, including those associated with offshore wind energy infrastructure. A second PhD will optimise strategies to identify the hydrophone signals of different processes with large acoustic datasets, such as via machine learning (e.g. signals of marine mammals, hazardous sediment flows etc). This PhD will thus allow smart sensors to process data on board, to minimise data volumes, and thus allow efficient data transfer.

Theme: Environmental interactions, seabed dynamics and benthic habitat

Project: The impact of windfarm associated noise on commercially important benthic invertebrates

Supervisory Team:
Dr Thomas Breithaupt (Sensory ecologist, University of Hull), **email: T.Breithaupt@hull.ac.uk**
Dr Krysia Mazik (Benthic ecologist, University of Hull)
Dr Silvana Birchenough (Principal ecologist, Marine Climate Change Centre, Cefas)
Dr Nathan Merchant (Principal scientist, Noise and Bioacoustics team, Cefas)

Project description:

The need for clean energy has triggered a rapid increase in offshore windfarm installations. Little is known about the associated environmental impact. Windfarm developments emit sound and vibrations during construction (e.g. by pile driving, drilling), operation and decommissioning. Our finding that crabs and mussels show behavioural and physiological responses to minute vibrations of the seafloor indicates high susceptibility to such acoustic disturbances. It is crucial to understand the chronic impacts on benthic populations so regulators can provide guidelines for their protection.

This project aims to understand the impact of wind farm associated noise on commercial species such as lobsters and mussels. Lobsters form the basis of the internationally important fishery of the Holderness coast. Mussels are considered candidates for windfarm based aquaculture but it is unclear whether the associated noise affects their growth. The project will include noise measurements in the field (in collaboration with operators) as well as controlled laboratory studies to investigate chronic effects on growth and fecundity. The student will gain experience in bioacoustical techniques as well as in physiological and behavioural assays and will profit from collaborations with windfarm operators and the centre for environment, fisheries and aquaculture science.

Project: The impacts of offshore wind farms on marine benthos: a question of scale?

Supervisory team:
Lead: Dr Bryony Caswell (Geology, University of Hull), **email: B.A.Caswell@hull.ac.uk**
Dr Krysia Mazik (Senior Benthic Ecologist – IECS, University of Hull)
Magnus Johnson (Senior Lecturer in Environmental Marine Science, University of Hull)

Project description:

Within Europe, offshore wind farms (OWFs) are causing widespread changes in marine environments, but a clear understanding of the ecological responses are lacking. The seafloor communities widely employed as indicators of such environmental change are naturally highly variable, and so require intensive, costly, sampling. Consequently, arbitrary spatial and temporal scales have been used in sampling programmes, producing data that cannot reliably detect OWF impacts. Further, the impact of OWFs on seafloor communities appears minor. However, the increasing scale and expansion of OWF developments (50-fold increase by 2050) means research is urgently needed to establish what the cumulative impacts might be.

Large volumes of published and unpublished benthic monitoring data exist, acquired from, mostly local, routine monitoring of offshore developments. By compiling this disparate data and using meta-analyses, supplemented by field sampling for 1-2 case study OWFs, we will investigate the impacts of OWFs on seafloor assemblages across larger spatial and temporal scales than previously attempted. Utilisation of this large volume of data will improve the power of the benthic signal of OWF impact. Operating in with external partners the project addresses the big data and environmental interactions themes.

Project: Integrated marine environmental assessment for offshore windfarm decommissioning

Supervisory Team:

Lead: Professor Mike Elliott (IECS, Department of Biological and Marine Sciences, University of Hull), **email: Mike.Elliott@hull.ac.uk**
Dr Daryl Burdon (IECS, Department of Biological and Marine Sciences, University of Hull)
Steve Barnard (IECS, Department of Biological and Marine Sciences, University of Hull)
External Advisors: Professor Richard Barnes (Hull Law School), Dr Simon Jude (Cranfield University), Dr Adrian Judd/Dr Andrew Gill (Cefas), Dr Becky Hitchin (Joint Nature Conservation Committee) and Ørsted.

Project description:

The potential environmental interactions of offshore wind farm developments have been a research focus at UHULL for many years[6,7], including the first analysis of the impacts of decommissioning using DAPSI(W)R(M) as a problem structuring framework and the 10-tenets for successful and sustainable environmental management[2,5]. Building on this interdisciplinary research, a recent NERC-funded project developed a novel decision support framework SPIDA (Screening Potential Impacts of Decommissioning Activities) that assessed environmental impacts of decommissioning oil and gas infrastructure[1], and which incorporated wider impacts on ecosystem services and societal benefits. This tool creates a multidisciplinary approach by linking the natural environmental, engineering, management and societal aspects with a flexible modular structure allowing adaptation for applying to the offshore renewables sector. The core of the proposed project is the innovative merging of SPIDA, the 10-tenets, the Bow-tie Risk Assessment/Risk Management framework, DAPSI(W)R(M) and the previously published hazard and risk typology[3] within the Cumulative Effects Assessment[4] and the recently-created Integrated Marine Management Systems Analysis approaches. It thereby involves a wide and experienced advisory team. Importantly, this project would be concurrent with the ESRC-funded PhD (White Rose DTP) starting at UHULL (September 2019) on the industrialisation and urbanisation of the North Sea.

Project: Modelling jack-up installation for offshore renewables

Supervisory Team:

Lead: Professor Charles Augarde (Professor of Civil Engineering, Durham University), **email: charles.augarde@durham.ac.uk**
Dr Will Coombs (Associate Professor in Computational Mechanics, Durham University)

Project Description:

Offshore renewable infrastructure, in particular wind turbine superstructures, are usually installed using Jack-up rigs which are floating vessels which carry extendable legs (usually steel frames) to convert them into a stable platform at any random location. The legs are founded on the seabed via “spudcan” foundations that can penetrate below seabed until sufficient bearing capacity is generated. Predicting the rate of and final depth of penetration is difficult as it depends on ground

conditions and the loading from the Jack-up. There have been accidents where Jack-ups have toppled over because one or more of the legs is unable to find suitable foundation.
The project aim will be to develop numerical models of Jack-up foundations interacting with the seabed in order to improve predictive capabilities for future projects. The numerical modelling will be based on a relative newcomer to the computational mechanics scene called the Material Point Method. This method has advantages over more traditional methods such as finite elements since it can capably model very large deformations, just as we would expect in the Jack-up problem. The project will build on existing work using this method and further development will require coding to be done by the student.

Project: Novel technology for monitoring, understanding and modelling processes of seabed scour

Supervisory Team:
Lead - Professor Peter Talling (Geography, Durham University), **email: peter.j.talling@durham.ac.uk**
Dr Matthieu Cartigny (Research Fellow in Geography, Durham University)
Professor Richard J Hardy (Geography, Durham University)
Professor Dan Parsons (Director - Energy & Environment Institute, University of Hull)
Dr Rob Dorrell (Research Fellow in FoSE, University of Hull)
Dr Steve Simmons (Research Associate in Geography & Geology, University of Hull)
Dr Miguel Morales Maqueda (Senior Lecturer in Oceanography, Newcastle University)
Dr Michael Clare (National Oceanography Centre)

Project Description:
This PhD will aim to monitor, and thus better understand and model, processes of seabed scour. It will first seek to develop new systems for time lapse bathymetric monitoring of scours and other features, such as using single-beam echo sounders on wave gliders, or time-lapse multibeam bathymetric surveys from surface vessels. This includes recently collected time lapse survey data from Canada and Monterey Canyon, offshore California. Second, the PhD will develop novel numerical models for predicting processes of seabed scour, both via grain-by grain detachment, and by deeper-seated liquefaction or wholesale failure of the seafloor. These models will be used to understand the main controls on seabed scour, including in the vicinity of offshore wind energy infrastructure.

Project: Modelling jack-up installation for offshore renewables

Supervisory Team:
Lead: Professor Charles Augarde (Professor of Civil Engineering, Durham University)
Dr Will Coombs (Associate Professor in Computational Mechanics, Durham University)

Project Description:
Offshore renewable infrastructure, in particular wind turbine superstructures, are usually installed using Jack-up rigs which are floating vessels which carry extendable legs (usually steel frames) to convert them into a stable platform at any random location. The legs are founded on the seabed via "spudcan" foundations that can penetrate below seabed until sufficient bearing capacity is generated. Predicting the rate of and final depth of penetration is difficult as it depends on ground conditions and the loading from the Jack-up. There have been accidents where Jack-ups have toppled over because one or more of the legs is unable to find suitable foundation.

The project aim will be to develop numerical models of Jack-up foundations interacting with the seabed in order to improve predictive capabilities for future projects. The numerical modelling will be based on a relative newcomer to the computational mechanics scene called the Material Point Method. This method has advantages over more traditional methods such as finite elements since it can capably model very large deformations, just as we would expect in the Jack-up problem. The project will build on existing work using this method and further development will require coding to be done by the student.

Project: Feasibility of advanced computational electromagnetic modelling of the influence of wind turbines on radar

Supervisory team:

Lead – Professor Jon Trevelyan (Dept of Engineering, Durham University), **email: jon.trevelyan@durham.ac.uk**
Dr Panos Gourgiotis (Assistant Professor of Engineering, Durham University)

Project Description

The effect of wind turbines, and wind farms, causing interference to radar systems is of concern for industry sectors such as maritime navigation and air traffic control. The presence of large, rotating structures makes it difficult to identify small targets. The effects can be determined experimentally, but this is expensive in the field and it is also desirable to have some predictive capability through accurate and efficient modelling tools.

The difficulty with modelling the radar scattering is that turbines are "electrically large" structures, spanning hundreds of wavelengths. The faster methods, based on optics and theory of diffraction, involve approximations and assumptions. Conversely, the accurate analysis methods such as Method of Moments become cumbersome, requiring very large models and long run times.

In Durham we have made advances in high-frequency wave scattering algorithms based on the boundary element method (BEM), which is similar to the Method of Moments. We have also made improvements to the Fast Multipole Method that have accelerated similar computations in elasticity. In this project, you will assess the feasibility of combining these numerical methods to produce accurate radar scattering solutions for wind turbines in an efficient manner.

Project: The variability of glacial sediment packages in the North Sea

Supervisory team:

Lead – Dr Stephen Livingstone (Physical Geography, University of Sheffield), **email: S.J.Livingstone@Sheffield.ac.uk**
Professor Chris Clark (Geography, University of Sheffield)

Project Description

During the last ice age, and with lower sea levels, the British and Scandinavian ice sheets advanced over the North Sea and built up a grounded ice mass of up to a km thickness. Its mass and flow profoundly altered the subsea geology on the basin, for example building the relief of the Dogger Bank and depositing a complex sequence of glacial sediments including clays laid down in ice dammed lakes. Such complexity poses a challenge to the optimal placement of offshore engineering structures.

We will apply knowledge of ice marginal glacial landsystems from elsewhere in the world (e.g. Antarctica, Greenland, Iceland) as an analogue to model the geotechnical variability of sediment packages across the North Sea. Glacial landsystems often comprise a variety of glacigenic deposits with different mechanical properties, including subglacial tills, flow deposits, glaciolacustrine sediments and glaciofluvial sediments. The model will be anchored in reality using existing geophysical survey and borehole data in the North Sea to map 3D glacigenic sediment packages. This could include manual mapping of sediment packages, investigation of borehole sediment properties and/ or the development of novel techniques to automate the identification and classification of sediment properties from these data.

Project: Assessment of echolocating cetacean (porpoise and dolphin) occurrence and behaviour in offshore development sites using a novel passive acoustic monitoring system (1-2 PhDs)

Supervisory Team:
Lead: Dr Per Berggren (School of Natural & Environmental Sciences, Newcastle University), **email: per.berggren@ncl.ac.uk**
Professor Nick Wright (School of Engineering, Newcastle University)
Jeff Neasham (School of Engineering, Newcastle)

Project Description
Newcastle University is currently developing a novel low-cost acoustically networked passive acoustic monitoring system (nanoPAM, Fig. 1) which will revolutionise assessment of potential environmental impacts from offshore installations. NanoPAM is a complete system incorporating new hardware, software and analyses tools for recording and processing high (20-160kHz) frequency sounds produced by animals and human activities. NanoPAMs transmit processed data back to shore, eliminating data loss and allowing assessment of echolocating cetaceans and noise in the deployment area with near real time spatial and temporal tracking of the sound producing sources through the network. Additional sensors may be incorporated into the system to allow further environmental monitoring. The first PhD project will conduct full scale deployments of nanoPAM to test its performance against other commercially available PAM systems. It will further conduct an assessment of porpoise and dolphin occurrence and behaviour in an offshore energy development site to assess potential impact from different anthropogenic activities. This PhD project is suitable for a marine science student with background in recording and analysis of sounds to investigate animal ecology and behaviour. A second PhD project, suitable for a student with engineering, maths or computer science background, will focus on developing analysis tools to process data supplied by a deployed nanoPAM network. This project will include working with very large data sets and applying machine learning methods to achieve both spatial and temporal efficient analyses. The project will also look at optimising data collection, storage and transfer, both in hard and software applications to further develop the nanoPAM system. It is anticipated that these two PhD projects will work in parallel to create interdisciplinary research incorporating marine science, engineering and technology.

Project: The impacts of offshore wind farms on marine benthos: a question of scale?

Supervisory team:

Lead: Bryony Caswell (University of Hull), **email: B.A.Caswell@hull.ac.uk**
Krysia Mazik (University of Hull, IECS)
Andrew Gill (Centre for Environment Fisheries & Aquaculture Science)
Keith Cooper (Centre for Environment Fisheries & Aquaculture Science)
Magnus Johnson (University of Hull)

Project description:
Within Europe offshore wind farms (OWFs) are causing widespread changes in marine environments, but a clear understanding of the ecological responses are lacking. The seafloor communities widely employed as indicators of such environmental change are naturally highly variable, and so require intensive, costly, sampling. Consequently, arbitrary spatial and temporal scales have been used in sampling programmes, producing data that cannot reliably detect OWF impacts. Further, the impact of OWFs on seafloor communities appears minor. However, the increasing scale and expansion of OWF developments (50-fold increase by 2050) means research is urgently needed to establish what the cumulative impacts might be.

Large volumes of published and unpublished benthic monitoring data exist, acquired from, mostly local, routine monitoring of offshore developments. By compiling this disparate data and using meta-analyses, supplemented by field sampling for 1-2 case study OWFs, we will investigate the impacts of OWFs on seafloor assemblages across larger spatial and temporal scales than previously attempted. Utilisation of this large volume of data will improve the power of the benthic signal of OWF impact. Operating in partnership with Cefas, OWF developers (e.g. Siemans, Turner ICENI) the project addresses the big data and environmental interactions themes.

Section: Low carbon transitions and community benefits

Project: The aural impact of wind farms on fish: testing frequency sensitivity in the marine soundscape

Supervisory Team:
Lead: Professor Michael Fagan (PI, Department of Engineering, University of Hull),
email: **M.J.Fagan@hull.ac.uk**
Dr Magnus Johnson (Co-I, Department of Biology and Marine Science, University of Hull)
Professor David Bond (Co-I, Department of Geography, Geology and Environment, University of Hull)
Dr Tom Webb (External Co-I, Department of Animal and Plant Sciences, University of Sheffield)
Oliver Crimmen (Project partner, Senior Fish Curator, Natural History Museum, London)
Katherine Pearson Maslenikov (Project partner, Fish Collections Manager, Burke Museum, Seattle)

Project description:

Fish have a vibration reception system for far field signals consisting of calcareous otoliths in the head that vibrate in response to sound waves in water. The difference in movement between fishes' bodies and their much denser otoliths stimulates mechanoreceptors, which convey both acoustic and directional information. Pilot studies at Hull have demonstrated that the response of otoliths is more complex than previously understood, with different regions of the otolith responding to different frequencies. Although behavioural and physiological responses of fish to sound have been investigated, for many species (deep-sea, large and rare taxa) including some that inhabit the sites of offshore wind installations, very little is known. World-class otolith collections held at Hull and our partner museums permit a novel evaluation of changing sensitivities to increasing anthropogenic noise pollution. We will characterise otoliths using microCT, providing high resolution data on shape (Figure 1) and material density variations, and measure that variation in material properties. Otolith response will then be modelled with the same advanced engineering techniques used to design the turbine blades and towers. Our study of otoliths will reveal the dominant sounds that are ecologically relevant to fish, and help understand the impact of offshore wind on fish communities.

Project: Offshore Wind Energy in Chemical Manufacturing by Electrolysis – ePTA & Hydrogen
Low Carbon Transitions and Community Benefits – Economics of Offshore Wind Developments

Supervisory Team:
Lead: Dr Jay D Wadhawan (Chem Eng, University of Hull), email: J.Wadhawan@hull.ac.uk
Dr Nathan Lawrence (Chem Eng, University of Hull)
Professor Stephen Kelly (Chem, University of Hull)

Project Description:
This project will demonstrate proof-of-principle for the efficient and cost-effective storage of the intermittent electrical power from Offshore Wind Farms as chemical energy products.
We will examine the technical, environmental and economic feasibility of producing hydrogen *via* water electrolysis, with co-generation of both oxygen and purified terephthalic acid (ePTA) used to produce the recyclable plastic PET (polyethyleneterephthalate).
Around 13 Mte *p.a.* of terephthalic acid are manufactured by the oxidation of *para*-xylene using oxygen (15-30 atm) in acetic acid between 175–225 ^{o}C using a cobalt-manganese-bromide catalyst, in the BP AMOCO process. We will replace these with lower cost, more environmentally friendly reaction conditions through the use of OSW electricity as a 'reagent' to produce ePTA. We will apply electrosynthesis in innovative approaches to:

(1) study *para*-xylene electrooxidation using environmentally friendly solvents,
(2) optimise 'green' hydrogen production, storage and utilisation as a low-carbon power source,
(3) remove the toxic catalyst (AMOCO process) and requirement for expensive, corrosion-resistant titanium reactors,
(4) optimise the reaction using intermittent electricity from OSW farms,
(5) demonstrate technical, economical and environmental feasibility (against the counterfactual).

Commercial and industrial pathways to take this methodology forward will be developed in conjunction with BP during the project.

Project: Offshore Wind, Work and the Digital Frontier: What Kind of Green Economy and for Whom?

Supervisory Team:

Lead: Professor Gavin Bridge (Geography, Durham University), **email:** **g.j.bridge@durham.ac.uk**
Dr Sarah Knuth (Geography, Durham University)

Project Description

As offshore wind emerges as a crucial resource frontier and industry for 21st century economies, it confronts an essential, yet underexamined paradox. Like other advanced cleantech sectors today, offshore wind has attracted a wave of digital innovation and would-be technological disruption: schemes for drone monitoring, machine learning and other 'Internet of things' interventions to boost wind farms' economic productivity and spin off new support industries. Such economic development visions have likewise enticed regional and national governments as they work to imagine and promote a green economy, in the United Kingdom and beyond. Yet wind developers face competing mandates. Notably, as offshore wind industries and infrastructure locate in deindustrialised cities and along disinvested coasts, governments and developers have framed wind projects as a locus of working class job creation and regional revitalisation – local jobs largely absent from the high-tech imaginaries above. These competing priorities for labour-saving technological innovation (with jobs for the highly-educated few) and broad-based 'green collar' job generation demand further investigation. Fundamentally, they offer a window into profound questions facing a green economy, geographies of work within it and the nature of its resource-economic frontier: what *kind* of economy will it be, and for whom?

Theme: Next generation materials and manufacturing

Project: Laser interactions with composite materials for wind turbine blade manufacture

Supervisory Team:
Lead: Dr Howard V Snelling (Dept of Physics and Mathematics, University of Hull), **email: H.V.Snelling@hull.ac.uk**
Dr Ali Adawi (Dept of Physics and Mathematics, University of Hull)
Dr Jason Lee (Research & Development Director, Rofin-Sinar UK Ltd)

Project Description:
Composite materials offer many advantages for the manufacture of stiff, high strength, lightweight structures and so are ideal for use in wind turbine blade manufacture. However, techniques for drilling and cutting that do not compromise the strength of the part still require development. In addition, methods to texture surfaces, for aerodynamic purposes or for adhesive bonding to other parts, are underdeveloped. Tailored laser interactions with the bulk of the material, or just the surface, offer solutions to these problems. This project will explore in detail how laser light is absorbed in the matrix and fibres, and how this results in different mechanisms for machining. We will be working with a local laser manufacturer (Rofin-Sinar UK Ltd) to align our experiments and models to their latest developments in sources. Novel laser pulses in time and wavelength will be modelled and experiments performed to corroborate these calculations. A microscopic view will be taken to account for the fact that this is a complex optical problem since the fibres are sub-wavelength in diameter and embedded in a dielectric. We have already seen experimentally that this gives energy coupling effects associated with the polarisation of the laser beam.

Project: From textile waste to advanced carbon materials for wind turbine blade manufacturing

Supervisory Team:
Lead: Dr Dmitriy Kuvshinov (Chem Eng, University of Hull), **email: D.Kuvshinov@hull.ac.uk**
Dr Olga Efremova (Chem, University of Hull)

Project description

Due to high tensile and compression strength, low weight, and resistance to corrosion, carbon reinforced composites (CRC) are normally placed within a typical turbine blade as the 'spar', the primary load bearing component of a blade. In this project we will explore utilisation of textile waste as a row material for nano-carbon filaments production and their consequent application as a filler for CRC.

The novelty of the project will come from combining of two modern techniques in the area of nanomaterials manufacturing: (i) TCVD technology will be used to produce versatile nanostructured carbon filaments from waste textiles. (ii) The carbon filaments will be than processed by electrospinning technique to produce nano/microfibrous CRCs. Specifically, we will investigate the effect of the chemical nature of the textile material and processing conditions on both the morphology of the nanocarbons obtained and the mechanical characteristics of the resultant CRCs.

In summary, this project will address both **the cost efficiency of bulk blade material production** and **low carbon transitions**, by reduction of the overall carbon footprint from textile and wind turbine manufacture industries. It will also **benefit communities and environment** by **optimised waste management** leading to decreasing of landfill plastic waste and microplastic pollution of oceans.

Project: Development of novel adaptive materials and intelligent structures for wind turbine blades

Supervisory Team:

Lead: Professor Jiawei Mi (Department of Engineering, University of Hull), Materials design, manufacture and characterisation, **email: J.Mi@hull.ac.uk**
Professor Simon D Guest (Department of Engineering, University of Cambridge); Structural mechanics, Head of Civil Engineering
Dr Bing Wang (Department of Engineering, University of Cambridge); Composite design and manufacture
Professor Michael Fagan (Department of Engineering, University of Hull); Biological engineering and finite element modelling

Project Description:

The aerodynamic loading on wind turbine blades is highly variable and sometimes fluctuates rapidly, caused by gusts, wind shear, turbulence, yawed operation etc. Such unwanted aerodynamic forces can be reduced significantly by controlling the pitch of the entire blade, however the inertia of large blades restricts the speed at which such pitch control can occur. As a result research has recently focused on the development of adaptive trailing edge devices with 'morphing' capabilities to manage these rapidly fluctuating loads.

We propose to develop novel adaptive materials and intelligent structures to tackle such problems. We will develop novel morphing composite materials and embed piezoelectric patches to form the key element of the blade's trailing edge to provide highly responsive, compliant morphing structures. Such structures will be able to adapt more quickly to the change of aerodynamic loading, increasing wind turbine stability and energy generation efficiency. We will also explore the integration of lattice or bone-type light-weight open structures within the blade trailing edge, with variable anisotropic properties, to further control and optimise the morphing capability. The research will provide novel materials and new design strategies for the design and manufacture of next generation 'smart' wind turbine blades for offshore wind industry.

Project: Load mitigation smart rotor control for offshore wind turbines

Supervisory Team:

Lead: Professor Ron J Patton (Control and Intelligent Systems Engineering, University of Hull), **email: R.J.Patton@hull.ac.uk**
Professor Jim Gilbert (Eng, University of Hull)

Project Description:

Large offshore wind turbine (OWT) blades and towers are subject to significant unbalanced structural loading caused by complex wind flow and imbalance due to wind shear, tower shadow, yaw misalignment. A well-known approach to load mitigation is individual pitch control (IPC) used to minimise rotor and tower bending forces. Interest is increasing in more advanced load control strategies with built-in intelligent actuators located directly in the blades, referred to as "smart rotor control". A new concept of *trailing edge flaps* on turbine blades proposed in [1] can achieve efficient fatigue load reduction by changing local blade force distributions. The idea suggests a significant advantage over IPC as only small masses will be regulated and not the total blade mass. This O&M PhD project is based on a previous IPC study [2], modifying the open-source NREL 5MW OWT software, focusing on enhancing sustainable operation of OWTs, based on the "smart rotor" concept.

[1] Barlas, T, & Van Kuik, G., (2007), "State of the art and perspectives of smart rotor control for wind turbines." *J. of Physics: Conference Series.* 75.

[2] Liu, Y, Patton, R & Lan, J. (2018), "Fault-tolerant Individual Pitch Control using Adaptive Sliding Mode Observer." IFAC-PapersOnLine 51.24, 1127-1132.

Project: Strain sensors for structural health monitoring of the turbine blades.

Supervisory Team:
Lead Supervisor - Dr Natasha Shirshova (Assistant Professor of Engineering, Durham University), email: natasha.shirshova@durham.ac.uk
Dr Claudio Balocco (Associate Professor of Engineering, Durham University)

Project Description

Various techniques are available for the structural health monitoring (SHM) of wind turbine blades but most of them are still at the prototype stage. This means that for most of the time, the state of the wind turbine blades is still assessed using physical inspection, which could be especially problematic for offshore wind farms. The issues associated with many of the existing systems are not just limited active feedback, but also incorporation of the SHM system into the turbine blades themselves - whether during or post manufacturing of the blades. Given that most of the turbine blades in use are manufactured from fibre-reinforced composite materials, it is logical to use SHM systems based on polymers compatible with the matrix used in the composite materials, i.e. thermosets. The main aim of the project is to develop a system that can be used as a strain sensor and apply on the new as well as blades which are already in use. The system in question should not only be electrically conductive but also flexible enough to allow it to withstand the relatively high deformations experienced by blades.

Project: High Performance Current Sensing for Wind Turbine Reliability

Supervisory Team:
Lead - Dr Alton Horsfall (Associate Professor in Electrical Engineering, Durham University), **email: alton.b.horsfall@durham.ac.uk**
Dr Christopher Crabtree (Associate Professor of Engineering, Durham University)

Project Description

The development of high performance current monitoring sensors will enable the behaviour of the power modules in wind turbines to be assessed in real time. This will allow the identification of power losses in the power system due to component wear out, unbalanced loading and individual device heating. The current waveforms will also be critical in the identification of early stage fault development and reliability issues within the electrical system, as well as enabling studies into the effect of wind gusts on the power generation system.

The project will develop the graphene based sensor and a route to integration of the supporting electronics to form a single chip. This chip will be installed into a high performance solid-state-transformer (SST) system that mimics the power converter in a wind turbine and allow investigations into turbine behaviour. The SST will also enable investigations into the development of these sensors for high frequency power converters, such as those being developed using wide bandgap semiconductors, such as silicon carbide. Reliability testing of the power conversion system will be undertaken using a range of highly accelerated test strategies, as well as using data from real turbines to simulate a range of wind conditions.

Project: Optimisation of the internal structure of wind turbine blades

Supervisor:
Lead: Dr Stefano Giani (Assistant Professor of Engineering Durham University), **email: stefano.giani@durham.ac.uk**
Dr Will Coombs (Associate Professor in Computational Mechanics, Durham University)

Project Description:
Modern wind turbine blades are large structures, with complex geometries and they are subjected to a large number of aerodynamic loading cases and design constraints. Many new wind farms are under construction and many more are planned for the future. In this context, the efficiency and reliability of wind turbine blades are paramount. The topic of this project is to study ways to optimise the structural design of the blades to reduce their weight and increase their reliability. Structural optimisation techniques are frequently used as part of the design process for many applications, but the numerous design constraints that wind turbine blades are subjected makes it a hard problem. Also, the newest designs involve composite materials, which add an extra layer of complexity to the problem but also new ways to optimise the design. Composite materials are characterised by a mesoscopic structure that can be highly customised opening the door to optimisation methods. This project will deliver novel numerical techniques that allow engineers to better design wind turbine blades. In the scope of this project, the methods are applied to blade designs and the results of the optimisation process are analysed and assessed.

Project: Next Generation High Temperature Superconducting Generators for Floating Wind Turbine

Supervisory Team:
Lead – Dr Guang-Jin Li (Electrical Engineering, University of Sheffield), **email: g.li@sheffield.ac.uk**
Professor Dave Stone (Electrical Engineering, University of Sheffield)

Project description
The current generator technologies used in offshore wind are mainly permanent magnet machines, doubly fed induction machines, rotor wound field machines. They all use copper wires for windings. Such machines have limited efficiency and are generally bulky due to relatively low torque/power density, which will make the nacelle larger and heavier and also increase the mechanical requirement for the tower. This is undesirable for offshore wind, particularly for next generation floating wind turbines. Therefore, this project will look at developing high torque/power density and high efficiency next generation high temperature superconducting generators for floating wind turbine. One example of such machines can be seen in Figure 1. The superconducting windings (armature and or field windings) will have zero losses and also have superb current carrying capability, leading to significantly higher torque/power density compared to their copper counterparts. So the generator size can be dramatically reduced, making not only the nacelle but also the entire tower lighter and more stable. The ultimate goal of this PhD project is to reduce the levelised cost of offshore wind energy, and therefore improve the acceptance of general public of such technology.

Project: Physics-based modelling for decision making in offshore infrastructure

Supervisory team:
Lead – Dr Robert Barthorpe (Department of Mechanical Engineering, University of Sheffield), **email: r.j.barthorpe@sheffield.ac.uk**

Project description
A core problem in the offshore wind industry arises from the need to make high-stakes decisions on turbine operation under uncertainty. Given the trend towards building larger farms in more hostile and remote environments continues, these challenges are set to grow as the industry matures. One of the key challenges in assessing the health of a structure is the difficulty associated with gathering experimental data from the structure in its damaged state. One way to overcome this problem may be to turn to numerical modelling to address gaps in our knowledge of the structure. However, numerical modelling raises challenges of its own, with the big question being how ones goes about establishing the credibility of the model predictions. This project will focus on the development and demonstration of a framework for offshore infrastructure health assessment with a particular focus on the development of uncertainty analysis tools for physics-based modelling. The project forms part of the broader notion of building 'digital twins' of individual turbines within an offshore wind farm.

The aim of this project is to develop methods for combining the analysis of uncertainties from subsystem models and components into system level model predictions; and subsequently combining these with experimental data-based to enable informed decision making under uncertainty. This will involve the student learning state-of-the-art techniques for quantifying uncertainty from both models and data; and for combining methods from machine learning and numerical model validation within the proposed framework. A core element will be in developing numerical models of how structural damage will progress within subsystems and developing and conducting test programmes targeted at the validation of such models. To do so, the project will take advantage of the facilities for dynamic testing under realistic environmental conditions that are available at the Laboratory for Verification and Validation (www.lvv.ac.uk), and will build from small scale testing conducted within the LVV to application to real world case studies.

Project: Bulk additive component production

Supervisory team:
Lead: Professor Steve Jones (Chief Technology Officer - Nuclear AMRC, University of Sheffield)
email: p.osborne@sheffield.ac.uk
Dr Pete Osborne (Senior Technical Fellow - AMRC, University of Sheffield)

Project description:
Large wind turbine components such as the hub casting, and bed plate are high value items with a high degree of complexity. Traditional manufacturing of such components involves the fabrication of these parts from a combination of machined forged or cast near net shape parts or machining directly from bar, billet or plate. Within the industry there are a number of trends and drivers for such components, which include:

- Integration of many parts into single component
- Reduced lead times
- Reduced reliance on single source supply – e.g. Casting houses, large forgings
- Lightweight materials – competing materials CFPR, Aluminium, Titanium
- Reduced waste – improved material usage ratios.

Additive Manufacturing (AM) technologies provide a potential solution to address many of these challenges and over the last 8 to 10 years a number of competing AM technologies have emerged which could be used to manufacture such components. These are often, though not exclusively, based on metal wire feedstock combined with a high energy heat source such as; laser, electron beam, plasma or arc, depositing molten material on to a substrate, manufacturing components in a layer by layer manner.

There are differing views within the industry as to the strengths and weaknesses of some of these competing technologies often confounded by aspirational sales information provided by the system suppliers. Some of the known concerns around the use of some of these systems include: deposition rates, build accuracy, microstructure, mechanical properties and residual stress. There will also be trade-offs in terms of the costs, flexibility of the platform, complexity of the components and post-processing requirements. This project will investigate the use of these techniques with the offshore wind sector as a means of replacing the traditional forged and cast approaches.

Project: Self-healing surface coating

Supervisory team:
Lead: Dr Stefan Lea (Research Engineer - AMRC Composite Centre, University of Sheffield) **email: p.osborne@sheffield.ac.uk**
Dr Clara Frias (Research Engineer - AMRC Composite Centre, University of Sheffield)

Project description:
Offshore wind farms require regular maintenance – typically 2-4 times a year depending on the location of the farms and the weather that they experience. Each visit requires the deployment of an access vessel and its associated personnel with a typical cost in the region of £10k per day even before the addition of spare or replacement parts. Damage to the various surface coatings applied to a wind turbine to protect against the environment can have significant costs associated with its repair.

Rain erosion is currently the leading source of damage to offshore wind turbine blades and is caused by rain and wind hitting the blades. Over time, this erosion breaks down the protective coatings attached to the blades, exposing and eventually compromising the blade's structure.

Solving this problem is a significant issue for both turbine manufacturers and operators as they look to improve a blade's operational life to match the 25-year active service life of the turbines.

Self-healing coatings therefore are of significant interest to the industry, to increase the maintenance intervals between repair and replacement of elements of the turbine. This project will investigate new and improved self-healing surface coatings for a range of wind turbine components with the intention of reducing or removing the significant cost of repair and reducing the risk that operators face when carrying out these repairs in offshore locations.

Prevention of erosion and wear will also help to ensure that the turbines are also able to operate at peak rated capacity throughout their operating life.

Project: Modular/reconfigurable blade design and manufacture

Supervisory team:
Lead: Dr Tristan Shelley (Research Engineer - AMRC Composite Centre, University of Sheffield) **email p.osborne@sheffield.ac.uk**

Project description:
The mould production of the tooling associated with composite components for the offshore wind industry is a complex problem due to the huge variation in the demands of processes, production volumes, materials and tolerances. With the upsurge in the production of large volume composite components to meet the demands of growth for the sector, there is a requirement to investigate new blade and tooling designs, which facilitate increased productivity and save costs. In addition, as the size of turbines increases along with the resultant increases in blade size to boost generation capability there is greater pressure on the available land for production facilities and increased complexity associated with transport of the finished blades and so modular construction is increasing desirable to meet these evolving needs.
This project will look at the options available for modular and reconfigurable construction within the industry and provide recommendations for future design with a focus on the manufacturability of the designs.

Assistive assembly and manufacture of turbine blades

Supervisory team:
Lead: Dr Kevin Kerrigan (Research Engineer - AMRC Composite Centre, University of Sheffield) email: p.osborne@sheffield.ac.uk
Dr Peter Osborne (Senior Technical Fellow – Advance Materials Research Centre, University of Sheffield)

Project Description:
Laying up of fibreglass Non-Crimp Fabrics (NCF) on to the mould tool is a manual process which currently requires a significant number of operators (5 or more) who are required to trim and position the pre-cut materials use a combination of rules, simple laser measurement devices and even chalk lines to position the plies. This process is therefore both time consuming and suffers from a potential lack of repeatability. Due to the size of the blades and relatively low build volumes full automation is unlikely to be cost effective.

This process can potentially be improved by using a laser projection system (LAP laser projection) or similar that project where the plies need to be placed, saving time and potentially improving repeatability, some laser projectors can also complete scans of the surface to recognise ply orientations and record quality data. This project will investigate the potential of a range of assistive techniques, which will aid the human workforce in both the trimming, positioning and validation of the NCF material within the mould tools used to form the blades with the goal of improving efficiency and reducing variation in the end product.

Theme: Operations and Remote Autonomous Monitoring

Project: DIAS: Data-driven Intelligent Alarm System

Supervisory Team:
Lead: Professor Papadopoulos (Faculty of Science and Engineering, University of Hull), **email Y.I.Papadopoulos@hull.ac.uk**
Sohag Kabir (Computer Science, University of Hull)
Professor Jim Gilbert (Engineering, University of Hull)

Project description:

We propose to develop an advanced alarm processing system using data analytics and machine learning. The system will be able to filter false alarms, synthesise low level alarms and localise faults from a plethora of low level indications. Sensors in wind farms monitor equipment or environmental conditions. Using them, abnormal behaviours are detected and alarms are generated. This is vital for safety and efficiency, but a huge number of nuisance alarms typically makes the process of fault localisation difficult. This is confusing operators, reduces efficiency of maintenance and increases costs, a problem that DIAS will address.

DIAS will be undertaken within the Dependable Intelligent Systems group in collaboration with Engineering staff. We pioneer internationally methods and tools for design of dependable systems. Tools include HiP-HOPS and Safety Designer, the latter together with ESI-ITI GmbH. We lead new AI algorithms which imitate the hunting behaviour of Penguins, and have shown that they apply to the safety of autonomous cars. The BBC has run an article on "Hungry Penguins Keep Car Code Safe". Our tools have been taken up by several major automotive and other corporations.

Project: In-situ monitoring of the pressure on wind turbine blades by self-powering nanocomposite base sensor

Supervisory Team:
Dr Mehdi Keshavarz-Hedayati (Assistant Professor in Engineering, Durham University)
Professor Dagou Zeze (Engineering, Durham University)
Dr Majid Bastankhah (Engineering, Durham University)

Project Description

One of the main challenges in offshore wind energy is high costs of maintenance and inspection. This necessities novel techniques to provide real-time monitoring of wind turbine health and performance. Pressure distributions over wind turbine blades can provide essential information such as their inflow conditions, power efficiency and noise generation. Traditional pressure taps are the most common tools to quantify pressure distribution over turbine blade aerofoils. However, due to the destructive nature of this technique along with the lack of spatial and temporal resolutions, their use is mostly limited to laboratory research and not in utility-scale wind turbines. To tackle this limitation, we aim to design and develop a new class of pressure sensors based on nanotechnology. Within this multidisciplinary project, pressure variation over turbine blades can be quantified by measuring optically the spatial distribution of nanoparticles. The resulting sensor can be attached as a plaster to the surface of the blades while operates with stray light (self-powered) and allow in-site and real-time monitoring of pressure measurements. The realization of this innovative concept could revolutionize the monitoring process of the wind turbine blades, reduce operation costs and ultimately improve the offshore wind turbines efficiency.

Project: Optimisation under uncertainty of Operation and Maintenance of Large-scale Offshore Wind Farms

Supervisory team:
Lead Supervisor - Dr Behzad Kazemtabrizi (Assistant Professor of Electrical Engineering, Durham University), **email: behzad.kazemtabrizi@durham.ac.uk**
Dr Christopher Crabtree (Associate Professor in Wind Energy Systems, Durham University)

Project Description

The UK's share of offshore wind energy has been steadily increasing in recent years. There are already plans for developing large-scale offshore wind farms with capacities exceeding 1 GW. There is however still a degree of uncertainty over how to best maintain and operate the wind farms to remain cost competitive with conventional generation technologies. For example, larger turbines located farther offshore will be more difficult to access, and the operator might not always possess sufficient information to make the most economical decision relating to maintaining their assets. The aim of this research is to develop new methods for optimising operation and maintenance regimes for larger offshore wind farms when facing such drastic uncertainties in the available actionable information. The successful candidate will implement daily maintenance routines in from of stochastic decision problems, which will be optimised whilst taking into account an acceptable level of operability and reliability for the wind farm. They will join a thriving team of researchers at both PhD and Post-Doctoral levels already involved in relevant research projects. The outcome of this project will inform decision-making processes for years to come for efficient operation and maintenance of larger offshore wind farms paving the way for future developments.

Project: Autonomous Drones for Wide-Area Survey and Inspection in support of Offshore Wind Energy

Supervisory Team:
Lead: Professor Toby Breckon (Computer Science, Durham University), **email: toby.breckon@durham.ac.uk**
Dr Peter Matthews (Assistant Professor in Design Informatics, Durham University

Project description:
The future road-map for unmanned aerial vehicles (UAV, "drones") will encompass the use of a range of sensing options for conventional aerial sensing and surveillance tasks such as terrain mapping, site inspection, object detection and on-board sense/avoid capabilities.
Current work explores such techniques as a low cost approach to the 3D mapping and inspection of complex engineering installations (both offshore and in-land), wide-area search and real-time in-flight visualization (video mosaicking). Ongoing work on stereo vision within this context recovers the 3D depth as an input to the guidance system of the platform or an input to downstream detection or mapping applications.
Whilst the accessibility of UAV to civil/domestic user increases, the use of advanced sensing options is less well explored within the context of offshore wind energy. Sensor capabilities, algorithm reliability and on/off board processing options present a range of design considerations for any given application task. All are similarly constrained by size of the airborne platform against desired altitude of flight and flight duration in addition to the conventional aspects of Size, Weight and Power (SWaP) SWaP considerations for deployed sensing solutions across ground surveillance, automotive and aerial are a key area of research focus for the Durham research team.

Project: Wind Turbine Power Converter Reliability

Supervisory team:
Lead: Dr Christopher Crabtree (Associate Professor of Engineering, Durham University), **email: c.j.crabtree@durham.ac.uk**
Dr Mahmoud Shahbazi (Assistant Professor of Engineering, Durham University)

Project Description
Wind turbine power converters have significantly worse reliability than similar converters in other operational environments. The cost of energy from wind has strong dependence on system reliability and the move to offshore wind has compounded the challenges, making power converter reliability a key industry target for improvement.
Power converter reliability is dominated by power module failures, often driven by thermal cycling due to constantly changing operational loads. Work at Durham has demonstrated that lifetime estimates are highly dependent on wind input data quality and mechanical drive train dynamics. However, real time simulation is complex, especially when modelling thermal cycles within converter switching patterns, and thermal monitoring within operational wind turbine power converters is impractical. Instead, a better understanding of the links between wind input, converter loading and lifetime estimates could be developed to provide a proxy measurement of consumed lifetime and risk of failure without the need for costly and impractical device monitoring.
This PhD will use simulation and experiment to investigate how wind characteristics affect converter loading and lifetime. The contribution to knowledge will be in developing approaches to link wind conditions and lifetime estimates to allow operators to assess the risks of unpredicted failure.

Project: Advanced data analysis using machine learning tools and deep network architectures

Supervisory team:
Dr Nikolaos Dervilis (Mechanical Engineering, University of Sheffield), **email: n.dervilis@sheffield.ac.uk**
Prof Keith Worden (Mechanical Engineering, University of Sheffield)

Project description
As offshore wind turbines are entering a new technological era; more sensing systems are adopted which results to a geometrical increase of high sampling data. This project aims to promptly process the massive collection of data and automatically provide advanced data features that are rich in information. Artificial Intelligence tools like deep learning architectures shall be investigated spanning from deep neural networks to Bayesian deep networks like Gaussians Processes (GPs). The aim is to provide online, fast and sparse processing of huge amounts of data in order to deliver intelligent data understanding across wind turbine fleets and farms (e.g. informative structural health diagnosis systems (SHM)) under various operating and environmental conditions.

Project: Silicon Carbide (SiC)-based power electronics converters for wind generators

Supervisory team:

Lead – Dr Milijana Odavic (Senior Lecturer in Power Electronics Systems, University of Sheffield)

email: m.odavic@sheffield.ac.uk

Dr Antonio Griffo (Electrical Engineering, University of Sheffield),

Project description:

In wind turbines, power electronic converters provide the interface between the variable speed generator and the fixed frequency AC grid. The majority of current wind turbine converters use 690V two-level converters based on 1.7kV Si-IGBTs.

Recent advances in semiconductor manufacturing have made SiC devices commercially available. SiC MOSFETs promise benefits in terms of lower losses, higher efficiency, lower sensitivity to temperature, and potentially higher operating voltages.

This project will investigate the use of SiC Mosfet for wind-turbine converters, analyse converter topologies and connection voltages and provide methodologies for optimal design solutions in ac-connected offshore wind turbines.

Aims and Objectives
1. To develop a system-level approach to the design optimization of a wind turbine design and identify benefits of IGBT to SiC technology in wind turbine converters.
2. To identify the choices in of operating voltages and converter topology (two- and multi-level) that may deliver an optimised full-system solution for inverters for offshore wind applications.
3. To investigate the technical barriers to the application of SiC-MOSFET modules in MW scale wind-turbine converters.
4. To investigate solutions to one or more of the technical barriers
5. Design, prototype and test novel converter designs

Project: Condition monitoring and lifetime prognosis of wind electrical generators bearings

Supervisory team:
Lead – Dr Antonio Griffo (Electrical Engineering, University of Sheffield) email: a.griffo@sheffield.ac.uk
Dr Guang-Jin Li (Senior Lecturer - Electrical Engineering, University of Sheffield)

Project description:
Reliability and availability are two key requirements in many industrial applications. In the offshore wind power generation, any downtime caused by faults or maintenance results in significant loss of revenues. With the aim of reducing faults and increasing availability, there has been a recent upsurge of interest in real-time monitoring of machine health during its lifetime.
The aims are not only to avoid the risk of catastrophic failures but also to replace costly periodic routine maintenance with condition-based maintenance to be performed only when the remaining useful life (RUL) decreases below a predefined threshold.
The project will investigate novel methodologies for condition monitoring and prognosis of the remaining life of bearings in electrical machines. Based on emerging methodologies for signal processing, sensor fusion and machine learning, the project will develop novel detection methods for bearing faults that combine the available mechanical and electrical signals. It is expected that the approach developed will result in significant improvement in sensitivity to the detection of progressive degradation and incipient faults.

Project: Incorporation of Energy storage into offshore wind farms for load levelling and energy security

Supervisory team:
Lead – Professor D. A. Stone (Electrical Engineering, University of Sheffield),
email: .a.stone@sheffield.ac.uk

Project description:
The project will examine the use of energy storage in off-shore wind farms to provide a more continuous power flow from the farm to the grid. The integration of differing energy storage technologies will facilitate long and short-term storage for the turbines / farm as a whole, and ease the intermittency of supply for the grid. The project will also include an investigation as to the return on investment for incorporation of energy storage, and provision of services to the grid through the wind farm grid connection. An investigation as to the potential for incorporating the energy storage as part of the floating structure will also be examined in terms of storage lifetime and maintenance requirements. This project is highly relevant to both government policy and the 'green' agenda.

Project: Developing a digital twin for offshore wind turbines

Supervisory team:

Lead – Professor David Wagg (Professor of Nonlinear Dynamics, University of Sheffield), **email: david.wagg@sheffield.ac.uk**

Dr Nikolaos Dervilis (Mechanical Engineering, University of Sheffield)

Project Description

There is an urgent need to grow the offshore wind contribution to UK power supply, as global targets on reducing emissions mean that the UK is committed to increasingly relying on renewable and nuclear energy to provide power. However, the levelised cost of offshore wind power remains high [1], particularly maintenance & operational costs in addition to which design life estimates of wind farm ageing are difficult to calculate [2]. As a result, there is clearly a pressing need to improve design life estimates and operational life management in the offshore wind sector. In this PhD the concept of a virtualised digital twin will be developed.

A digital twin is a fusion of models and data, with the twin relationship holding throughout the entire structural life cycle, from design, through operation, to end of life. The digital twin must be so representative of its physical counterpart that it can serve as a proxy for important design/operation decisions. This can only be achieved by fusing together physics-based models with an uncertainty analysis of the dynamics, test results, measured data and design criteria to provide a step change in design/operation confidence. The idea of creating a digital twin to achieve an improved design process is shown in the figure, where in (a) the current situation is shown schematically for a design process without a digital twin. In this scenario, not all the information available, such as different types of model output, recorded data, historical data, user feedback etc., are necessarily used in the design process. If it is used, it may not be fully coordinated in a systematic way that targets the specific design objectives. In the figure (2) we show the idea of a digital twin, where all models and data are linked and synchronized using a workflow. The process of developing this idea for wind energy forms the core thematic research areas of this project.

Project: Self-adaptive Model Order Reduction Models for Large Nonlinear Finite Element Models

Supervisory team:

Lead – Dr Charles Lord (Mechanical Engineering, University of Sheffield), **email: c.lord@sheffield.ac.uk**
Dr Jem Rongong (Senior Lecturer - Mechanical Engineering, University of Sheffield)

Project Description: Model order reduction is a process by which mathematical models are reduced in the number of degrees of freedom to simplify the numerical expense while at the same time still maintaining the rich content of the model. Several model order reduction techniques already exist, but are generally limited to a particular dominant mode or set of modes. These models are further limited by their bias toward linear representations which do not lend their usefulness or efficiency to nonlinearities. For structures, such as those comprised of thin components (e.g. wind turbine blades), this is particularly important due to their inherent nonlinearities. The proposed research here is the development of a self-adaptive reduced order model. The novelty lies in two main parts: (i) in the ability of the reduced order model being self-adaptive switching between which model and the coupling of models to account for extended complex mode shapes (mixed bending and torsion) and (ii) that it can be used and directed to localised areas and does not have to contain global information or accountability. From an industrial standpoint, reduced order models are used frequently. Currently, there is little standardisation or agreement on how, when, and to what extent a reduced order model should be utilised; the decision gate usually comes from 'trial and error'. As part of this research, it would be expected that the self-adaptivity of the model would define these guidelines.