Supergen
Offshore Renewable Energy

Tackling the research challenges - Theme D: Sensing, control and electro-mechanics

Prof. Xiaowei Zhao
Supergen ORE Hub – Co-Director
University of Warwick

Prof. James M Gilbert
Supergen ORE Hub – Co-Director
University of Hull

Engineering and Physical Sciences Research Council

Research Theme D - Sensing, control and electro-mechanics

- D1: Control of ORE farms
- D2: Smart Sensor System Use
- D3: Drive Train Design
- D4: Power Electronic Conversion

D2: Smart Sensor System Use

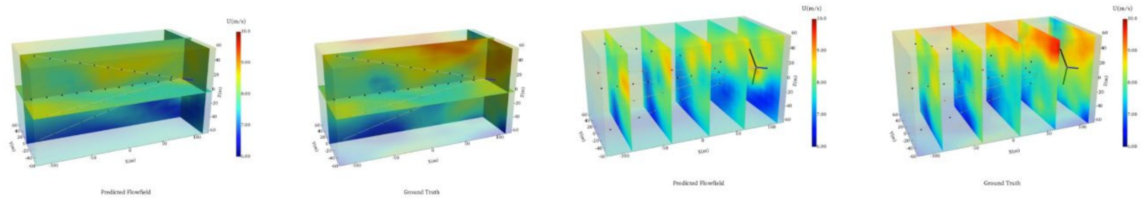
Core research and flexible funding projects

D2: Identify, evaluate and validate sensor technologies, data transmission, integration and interpretation systems to support improved control and management.

Spatiotemporal wind field prediction based on physics-informed deep learning

WARWICK

- A deep learning method: limited LIDAR data + physics
- Spatiotemporal prediction of wind field: full 3D dynamic wind field
- Perspective: wind turbine control; wind resource assessment; wind turbine monitoring; load/power forecasting.



University of Strathclyde Engineering

Smart Piezoelectric Metamaterials for Partial Discharge Monitoring

Rolan Mansour, Andrew Reid, James Windmill & Brian Stewart

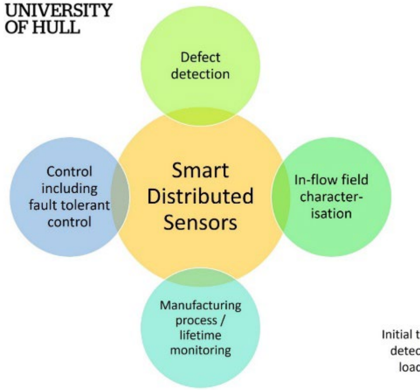
Department of Electronic & Electrical Engineering
Centre for Ultrasonic Engineering

CUE
CENTRE FOR ULTRASONIC ENGINEERING

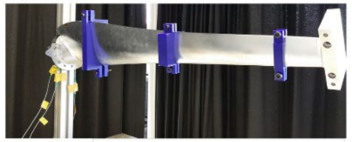
Flow measurement for accurate tidal turbine design

Anna Young, University of Bath

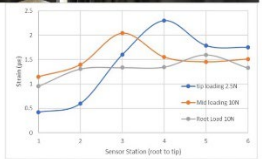
UNIVERSITY OF HULL



Tidal Turbine blade with 24 fibre optic strain sensors



Initial trials demonstrate detection of different loading conditions



Barnacle probe built and tested in lab and field

UNIVERSITY OF BATH

New probe head designed and tested in water tunnel

- Analog electronics optimised for tidal flows
- Excellent performance at very low speeds (0.2 m/s)
- Promising for wider uses (e.g. British Antarctic Survey)

Field tests at Strangford Lough

- Good agreement with Vector and superior frequency response

PROJECT AIMS & OBJECTIVES

- Design and manufacture a 3D printed piezoelectric sensor that provides acoustic emission information
- Evaluate the response of the new sensor(s) in laboratory partial discharge testing
- Compare this with existing acoustic and hybrid methods
- Report on the feasibility of using the new sensors to localize acoustic emissions from partial discharges in cables/cable connectors

D3: Drive Train Design

A hybrid and scalable digital twin for intelligent direct drive powertrain condition monitoring

D3: Conception, design and validation of novel drive trains for ORE devices including hydraulic drive and direct drive generators.

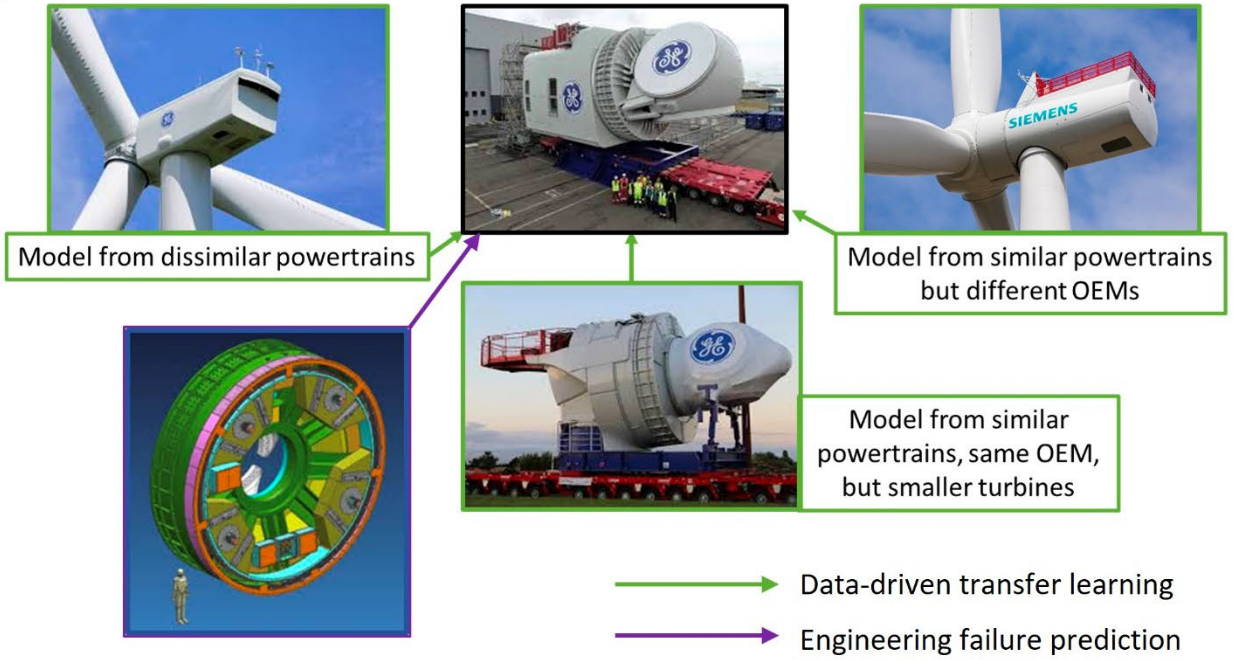
Supergen ORE Hub Flexible Fund Project: A hybrid and scalable digital twin for intelligent direct drive powertrain condition monitoring

Modern wind turbine powertrains are ***different*** and ***larger*** than our legacy offshore technology. As such, initially the prediction of failures will be harder.

This project is exploring the effectiveness of ***transfer learning*** to adapt and data-driven models from other turbines.

It also combines this with engineering models to predict failures.

We hope that brings additional value to legacy data from older turbines to be used newer turbines.



THE UNIVERSITY of EDINBURGH
alasdair.mcdonald@ed.ac.uk
cmckinn3@exseed.ed.ac.uk
University of Strathclyde Engineering
j.carroll@strath.ac.uk

D4: Power Electronic Conversion

Enhancing control capability of ORE systems for stress management and grid support

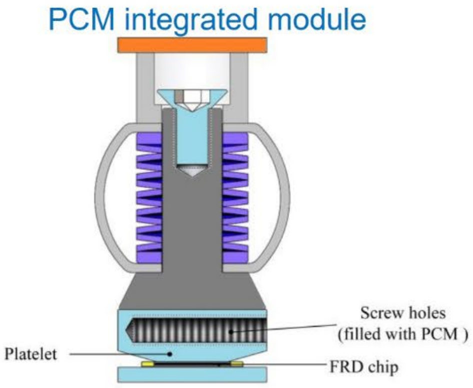
D4: Improving the power electronic converter in order to improve the system reliability and performance.

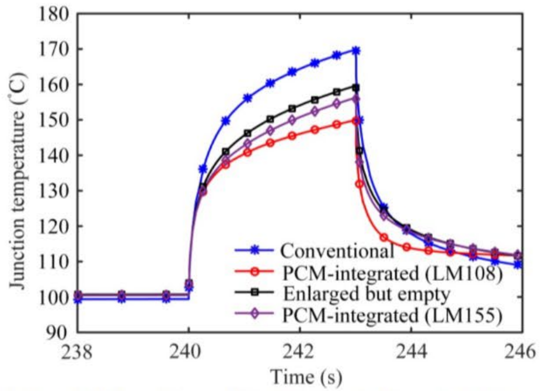
Supergen ORE Hub Flexible Fund

Enhancing Control Capability of ORE Systems for Stress Management and Grid Support

WARWICK
THE UNIVERSITY OF WARWICK

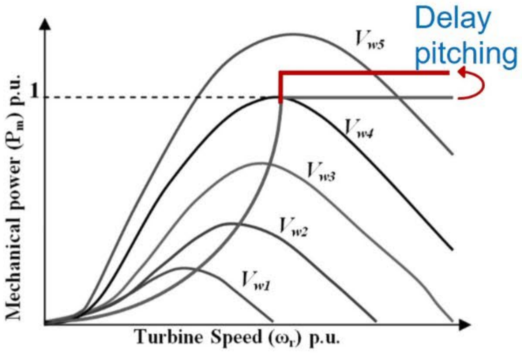
- **Grid Support:**
  - Grid inverters are unable to source large current during grid fault.
  - Integrate phase changing material (PCM) into semiconductor modules to enhance converter's short-term overload capability.
  - The converter can be overloaded to 2.4 p.u. for 3s .

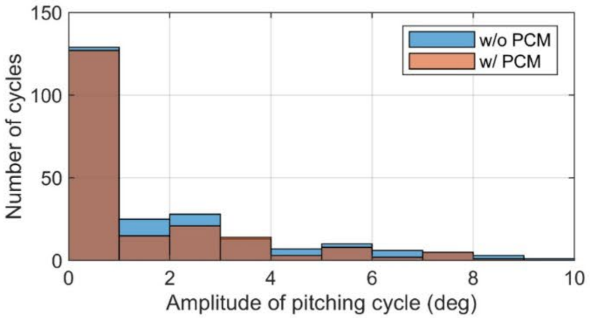




H. Ren, W. Shao, L. Ran, G. Hao, L, Zhou, P. Mawby, and H. Jiang, "A Phase Change Material Integrated Press Pack Power Module With Enhanced Overcurrent Capability for Grid Support—A Study on FRD," in *IEEE Trans. Industry Applications*, 2021

- **Stress Management:**
  - A coordinated stress management strategy is developed by a digital-twin method.
  - Using PCM to absorb the power loss during converter's short-term overload period.
  - The mechanical stress cycles of pitch system is reduced by 10%.





N. Iosifidis, Y. Zhong, B. Hu, B. Chen, L. Ran, S. Lakshminarayana, C. Jia, P. Mckeever, and C. Ng, "Reliability of Wind Turbine Power Modules using High-Resolution Wind Data Reconstruction: A Digital Twin Concept," in *ECCE*, 2021

Theme D: Early Career Researcher Projects (£5k)

- Wide-Bandgap-Enabled Dynamic Braking System for Grid Integration of Offshore Wind Farms. *Saeed Jahdi, University of Bristol*
- Structural health monitoring for wind turbine blades via graphene self-sensing adhesive layer joining fibre-reinforced plastics. *Maozhou Meng, University of Plymouth*
- Aeroelastic Modelling and Predictive Control of a 20-MW Offshore Wind Turbine. *Yinan Wang, University of Warwick*
- Innovative and cross-disciplinary wave energy research, aiming to develop a revolutionary Smart Control Algorithm (SCA). *Saishai Dai, University of Strathclyde*
- Innovative and cross-disciplinary wave energy research, aiming to develop a revolutionary Smart Control Algorithm (SCA). *Ian Laird, University of Bristol*
- Upgrade of Power_electronic Grid Emulator to Multi-Channel System and High Current Continuous Power Semiconductor Testor. *Paul Judge, University of Edinburgh*
- An investigation on the effect of early age cycling on grouted connections for offshore renewable energy support structures: a pilot study. *Nikolaos Tziavos, Aston University*
- Intelligent Fault-Tolerant Control of Offshore Wind Turbines via Deep Reinforcement Learning. *Hongyang Dong, Warwick university & Shuyue Li, University of Hull*
- Fibre Optic Sensors For Dynamic Cable Condition Monitoring In Floating Offshore Wind Turbines. *Kaushal Bhavasar, University of Hull*

Spatiotemporal wind field prediction based on physics-informed deep learning and LIDAR measurements

Prof Xiaowei Zhao and Dr Jincheng Zhang

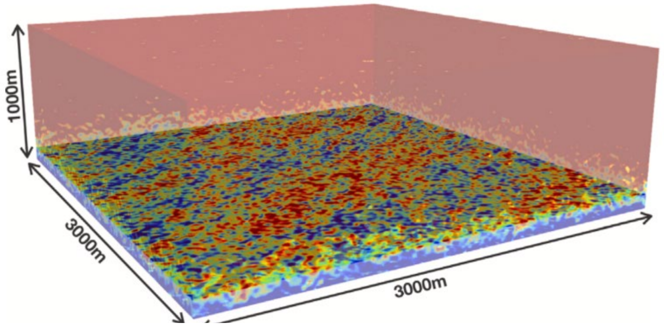
School of Engineering
University of Warwick
xiaowei.zhao@warwick.ac.uk
Jan 2022

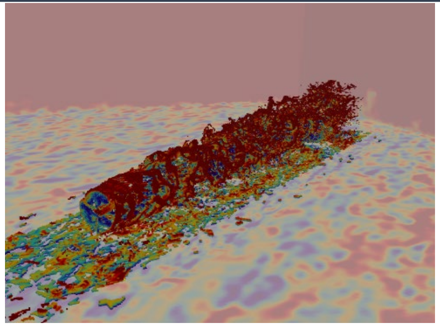
Spatiotemporal wind field prediction based on physics-informed deep learning and LIDAR measurements

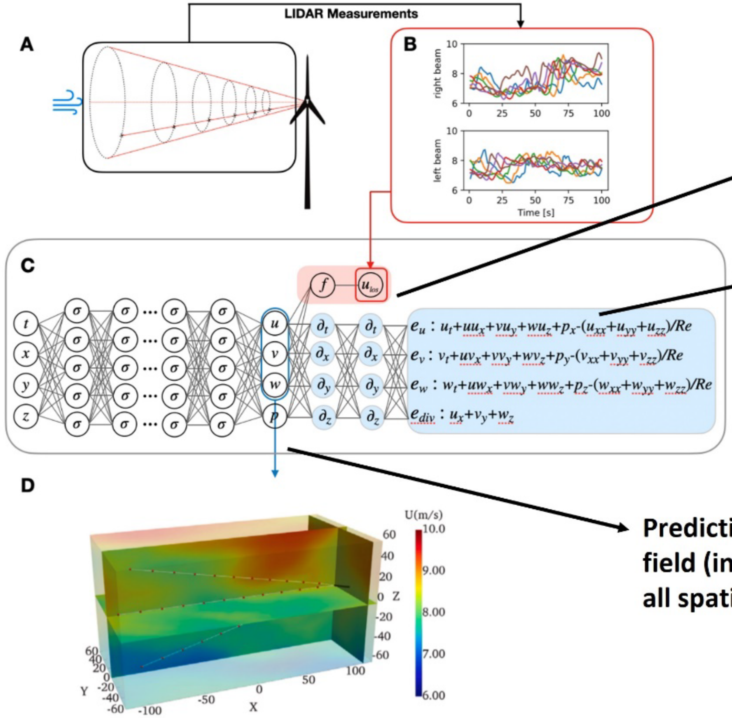
Background

- Spatiotemporal wind farm flow field
  - Freestream atmospheric boundary layer (ABL) flows
  - Wind turbine wakes

Offshore wind farm Horns Rev, Denmark (Photo: Christian Steiness).







Training data: LIDAR measurements

Flow physics governed by Navier–Stokes equations

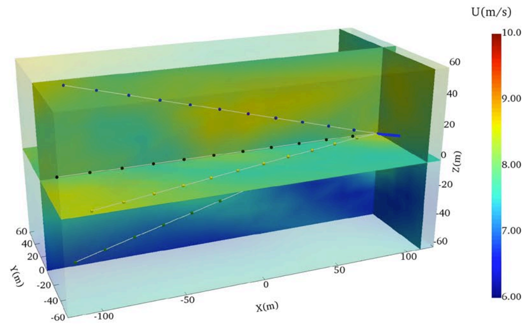
Prediction: spatiotemporal wind velocity field (including wind speed components in all spatial directions)

WARWICK

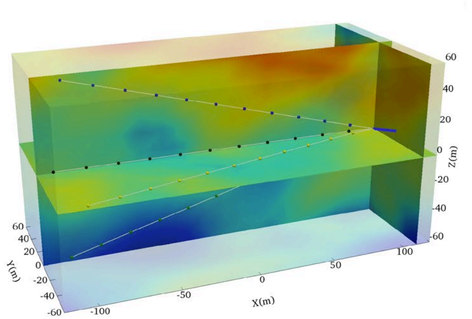
J Zhang, X Zhao, Three-dimensional spatiotemporal wind field reconstruction based on physics-informed deep learning, Applied Energy 288, 2021.

Spatiotemporal wind field prediction based on physics-informed deep learning

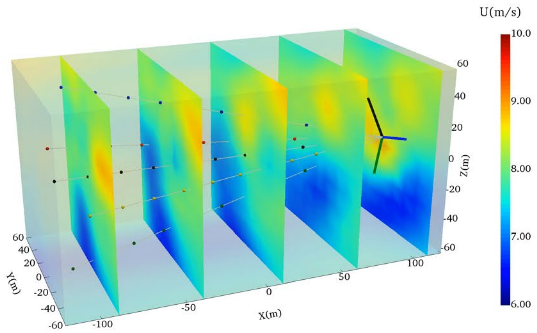
- **A deep learning method: wind prediction based on limited LIDAR data + high-fidelity flow model for the first time.**
- **Prediction of the full 3D dynamic wind field based on real-time measurements for the first time.**
- **Perspective: wind turbine monitoring and control; wind resource assessment; load/power forecasting.**



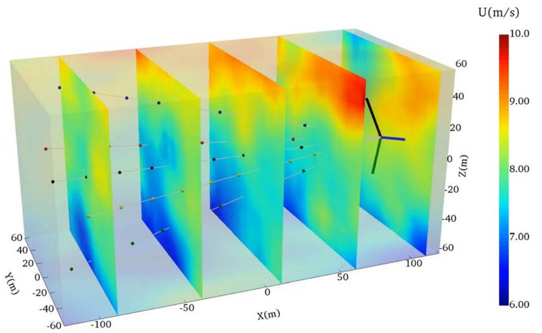
Predicted Flowfield



Ground Truth



Predicted Flowfield

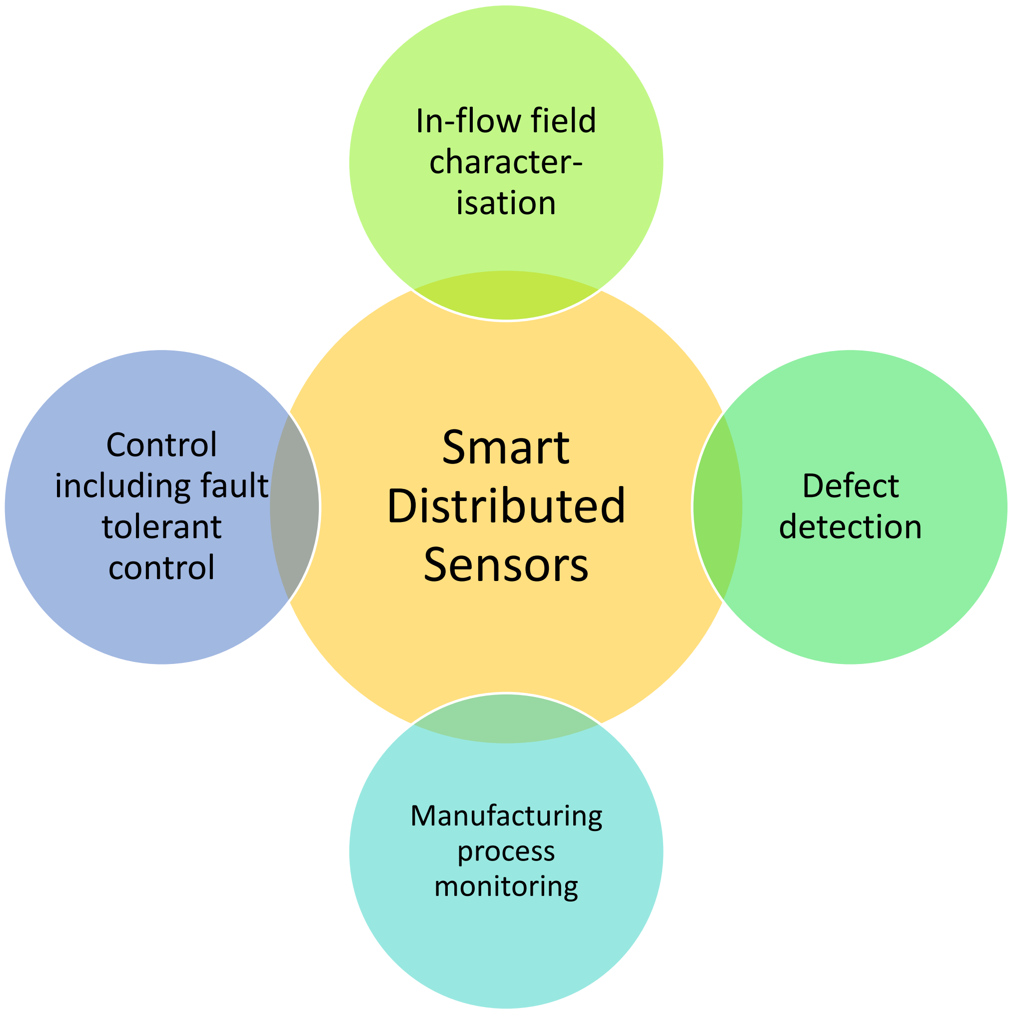


Ground Truth

J Zhang, X Zhao, Three-dimensional spatiotemporal wind field reconstruction based on physics-informed deep learning, Applied Energy 288, 2021.

Smart Distributed Sensors for ORE applications

UNIVERSITY OF HULL



Target devices

Wind and tidal turbine blades

Cables

Sensing challenges

Large, flexible structures

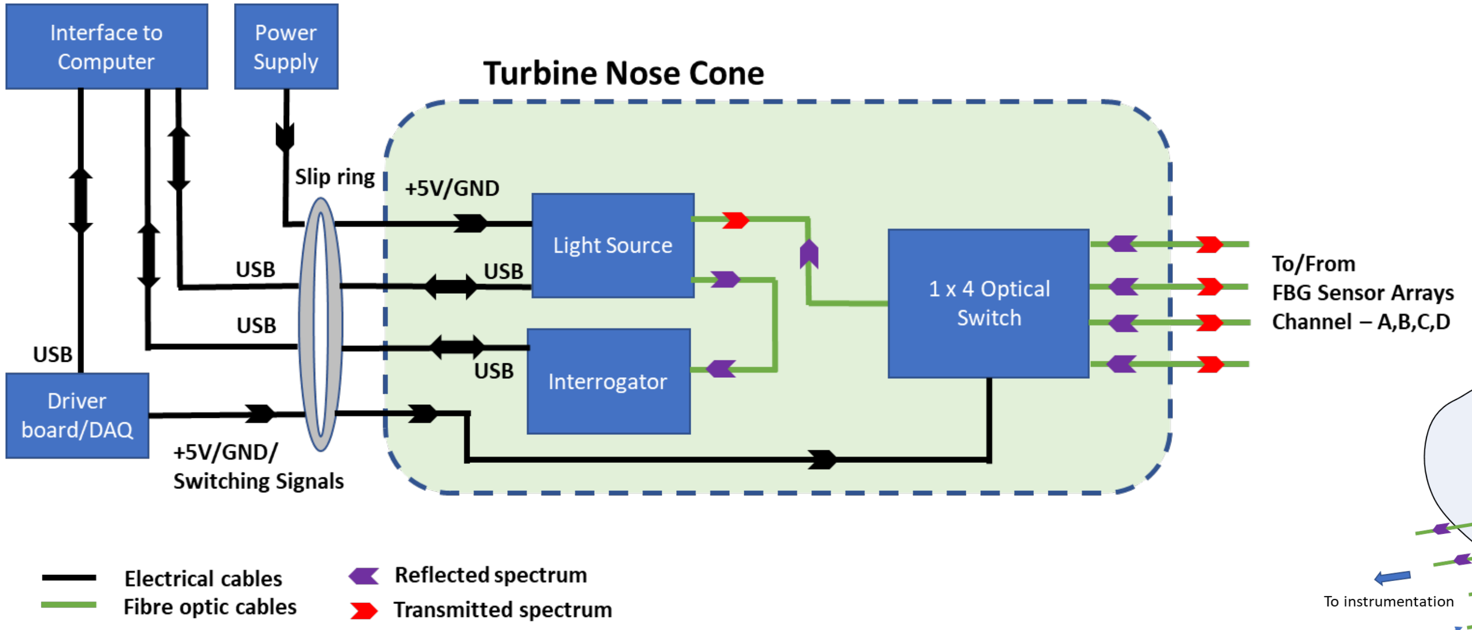
Complex loadings

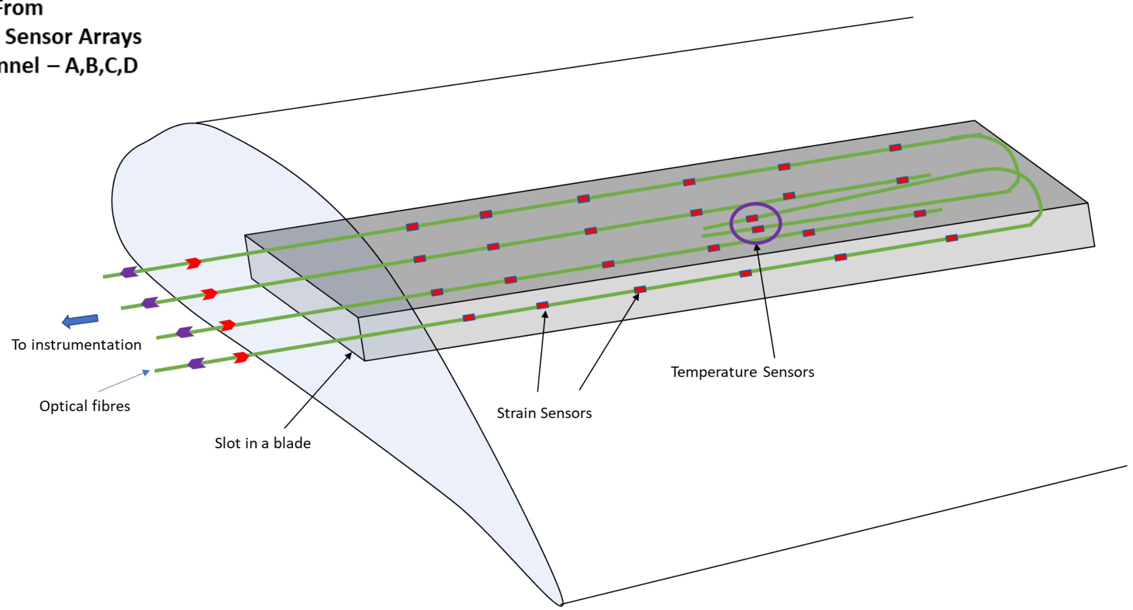
Multiple devices

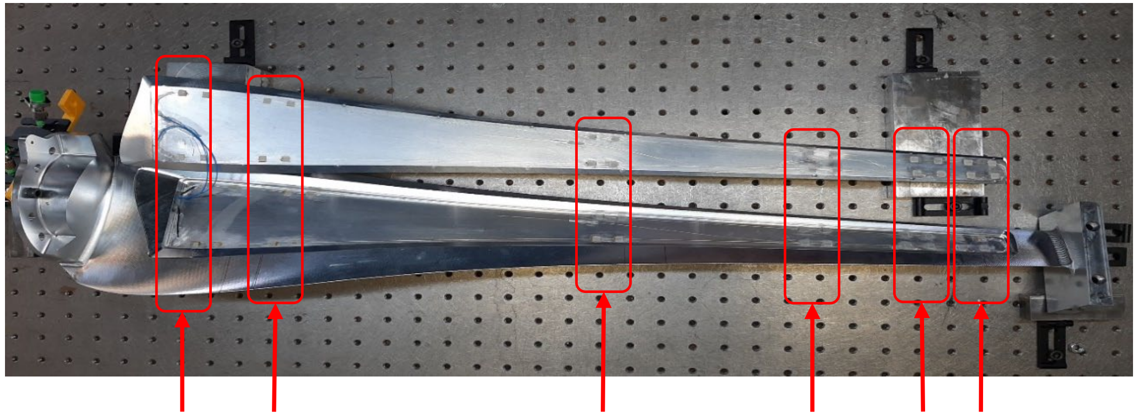
Harsh operating conditions

Fibre optic sensor system for in-flow load monitoring of tidal turbine

UNIVERSITY OF HULL







Position # 1 2 3 4 5 6

Theme D: Sensing, control and electro-mechanics

Flex-fund projects

Smart piezoelectric metamaterials for partial discharge monitoring

Dr Rolan Mansour, University of Strathclyde

Flow measurement for accurate tidal turbine design

Dr Anna Young, University of Bath

A hybrid and scalable digital twin for intelligent direct drive powertrain condition monitoring

Professor Alasdair McDonald, University of Edinburgh

Enhancing Control Capability of ORE Systems for Stress Management and Grid Support

Professor Li Ran, University of Warwick

Panel Discussion