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Offshore Wind Digital Twin Practice

- Data, Digital and Intelligent Condition Monitoring

Chunjiang Jia – Principal Engineer, Power Conversion

05.10.2023

Credit: Equinor Hywind Floating Offshore Wind Farm

Agenda

- ORE Catapult introduction
- Offshore wind digitalisation
- OREC digital twin practices
- Digital twin challenges

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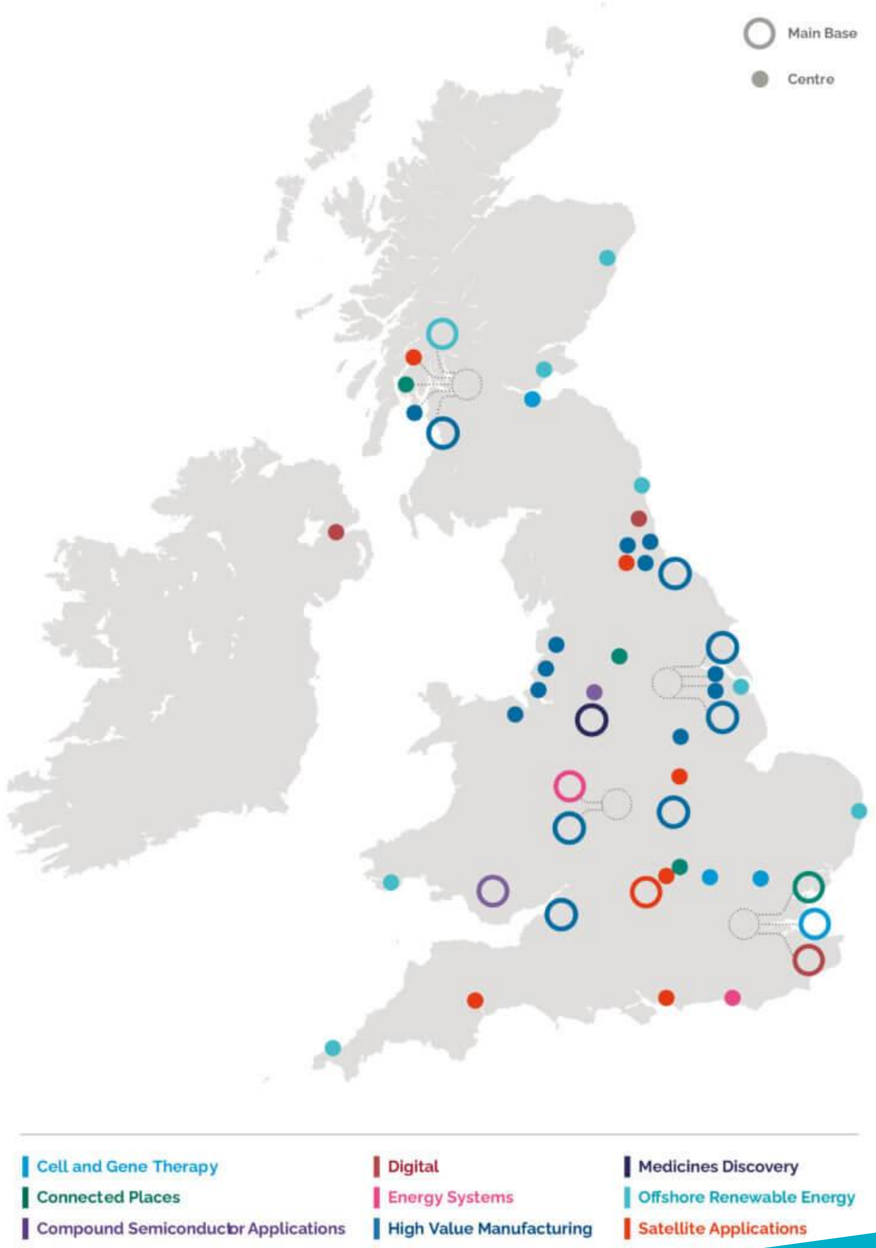
THE CATAPULT NETWORK – A NATIONAL CAPABILITY

- Network of 9 world-leading technology innovation centres
- Supporting businesses in transforming great ideas into valuable products and services
- Independent, not-for-profit
- Delivering impact across the UK economy, enabling businesses to thrive in global markets



UKRI Innovate UK

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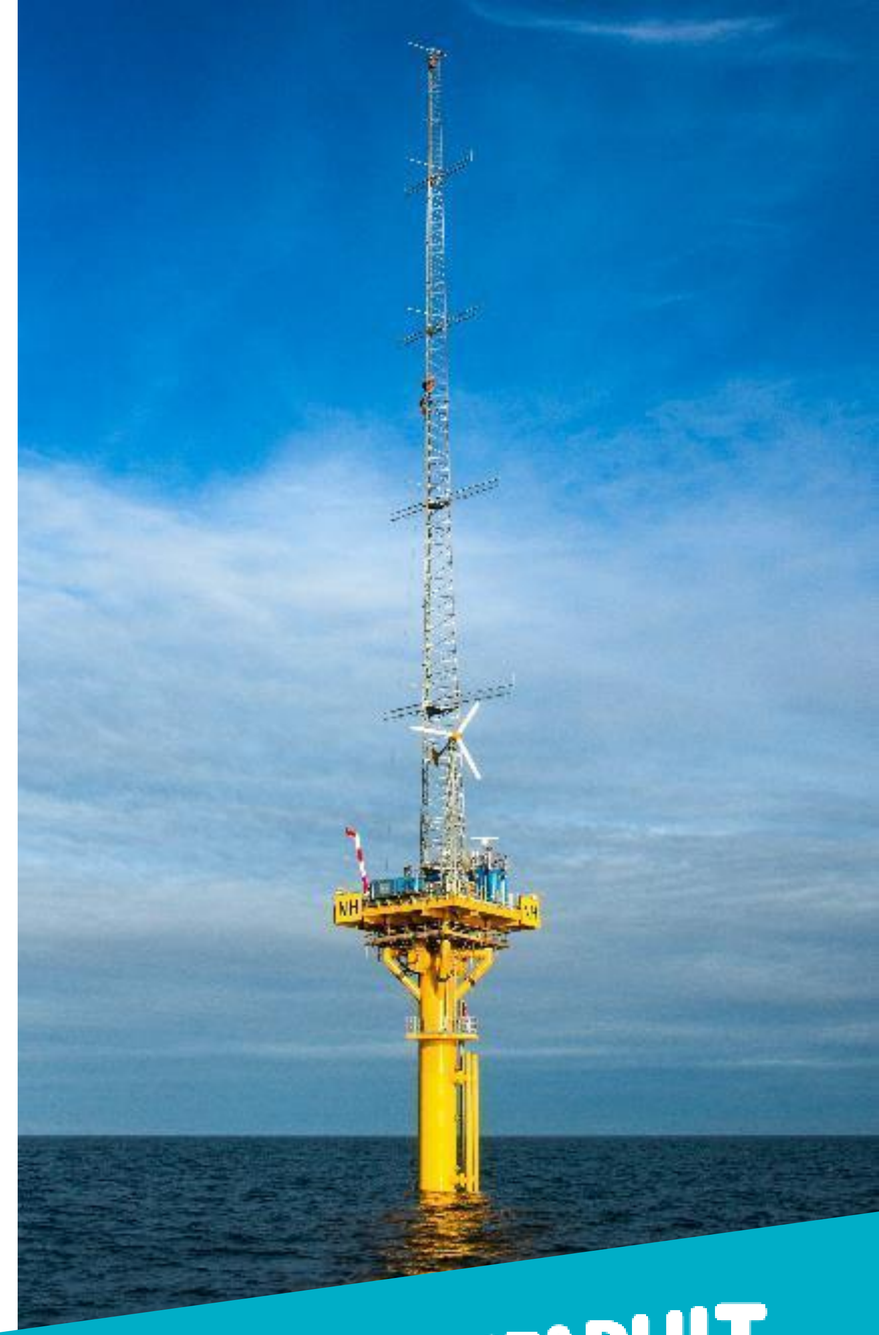
THE OFFSHORE RENEWABLE ENERGY CATAPULT

The UK's leading technology innovation and research centre for offshore renewable energy

Mission: to accelerate the creation & growth of UK companies in the offshore renewable energy sector

- Unique facilities, research & engineering capabilities
- Bringing together innovators, industry and academia
- Accelerating creation and growth of UK companies
- Reducing cost and risk in renewable technologies
- Growing UK economic value
- Enabling the transition to a low carbon economy



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THE OFFSHORE RENEWABLE ENERGY CATAPULT

- Over 250 engineering, research and sector experts
- World-leading test and demonstration facilities

8 UK Regional Centres

Aberdeen, Blyth, Fife, Glasgow, Hayle,
The Humber, Lowestoft, Pembroke Dock

3 UK Academic Research Hubs

Universities of Manchester
& Strathclyde – Electrical Infrastructure
University of Bristol – Blades
University of Sheffield & Warwick – Powertrains

International Research and Innovation Centre

Yantai, China

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WHAT WE DO – Accelerate Technology Developments

FULL SCALE TEST & VALIDATION

- Next generation Turbines & Balance of Plant
- Design validation and component testing

IMPROVE OPERATIONAL PERFORMANCE

- Better intervention techniques
- Operations & Maintenance
- Developer/owner solutions
- SMEs developing solutions
- Test & validate solutions

LEADING RESEARCH & DISRUPTIVE INNOVATION

- Evaluation and support for emerging technologies
- Floating wind, wave & tidal
- Energy networks and storage
- Under-pinning research
- Gateway to UK academia

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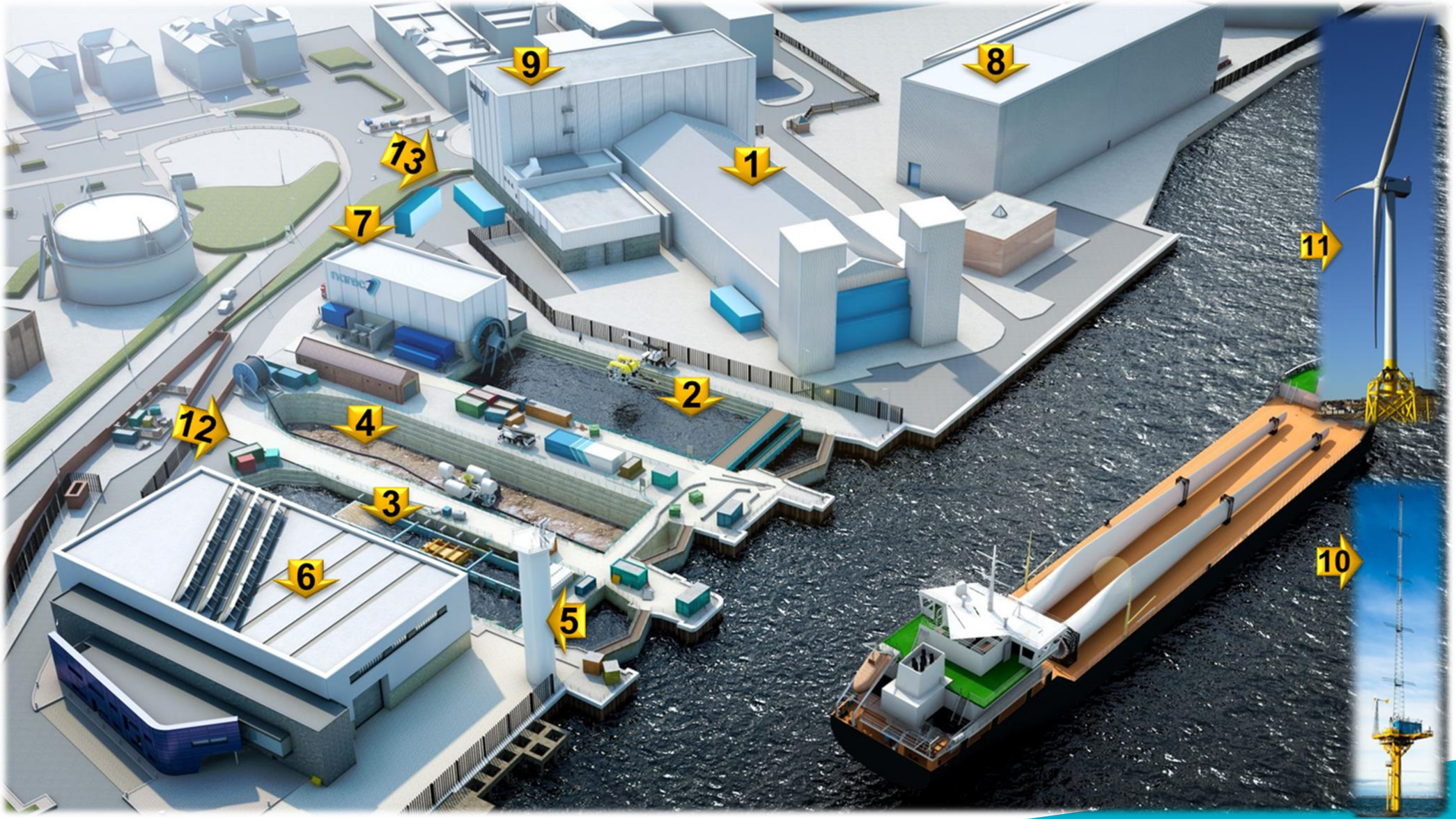
National Renewable Energy Centre - Blyth

1040 SMEs
supported
since 2013

705
Academic
collaborations
2013



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100m Blade Test Facility

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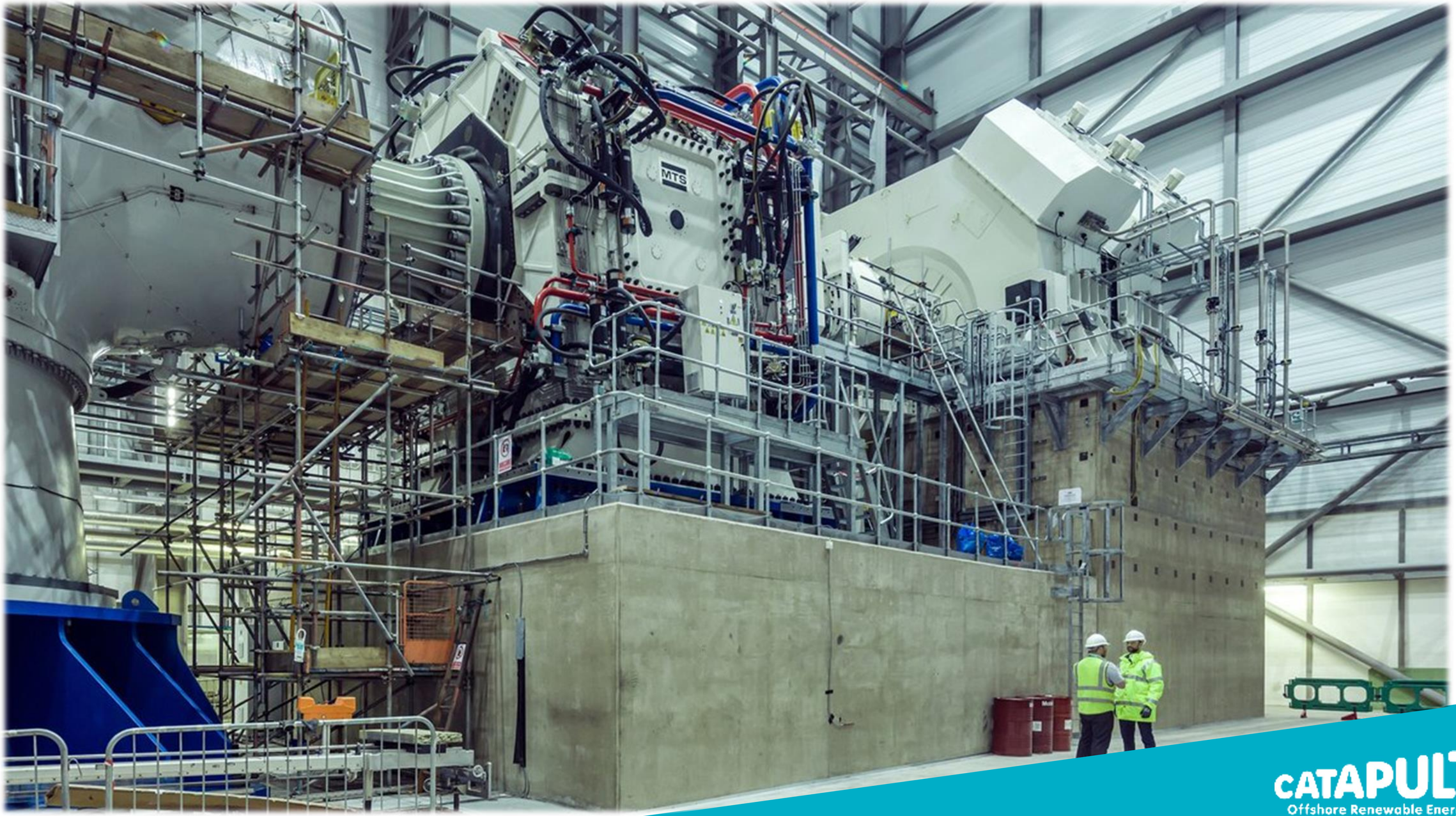
15MW Powertrain Test Facility



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3MW Tidal Turbine Test Facility

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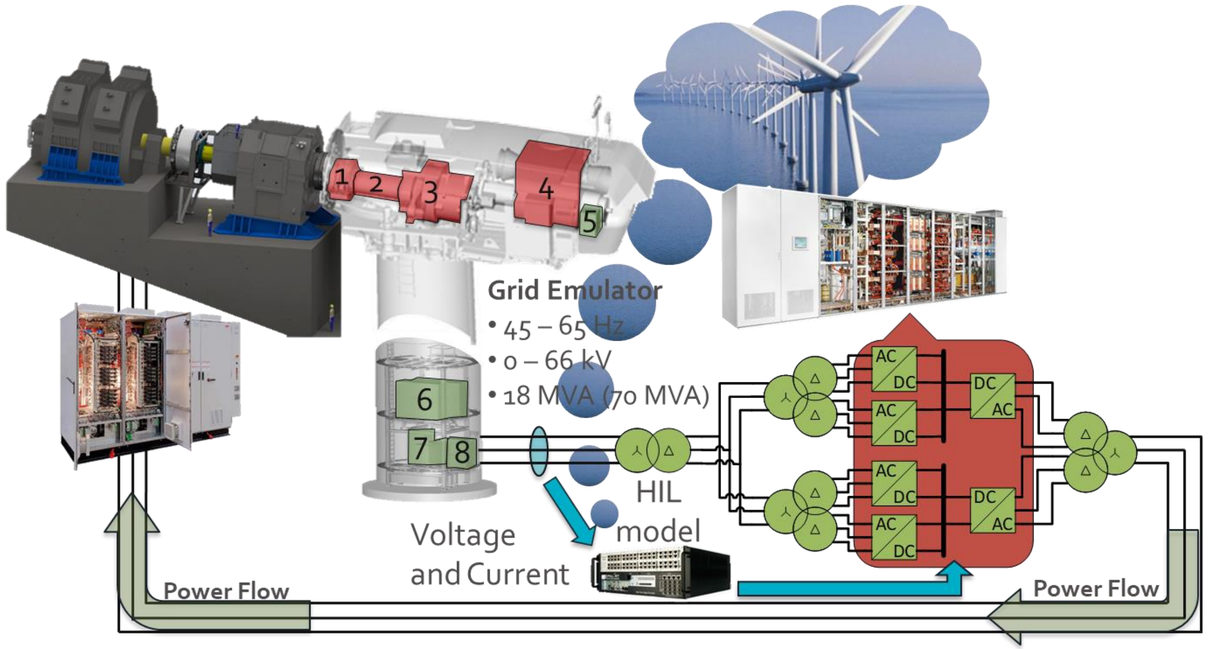
eGrid – an 18MVA Grid Emulator



Traditionally full-scale tests are run in the field which has several disadvantages:

- **Time Consuming** - planning permission required; standards tests take years to finish
- **Costly** - replacing broken parts and updating designs is difficult
- **Weather Dependant** - have to rely on wind conditions at site ⇒ limited repeatability

15MW test rig + eGrid:

- Main Bearing
- Drive Shaft
- Gearbox
- Generator
- Central Controller
- Power Converters
- Transformer
- Switch Gear

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Overview of Offshore Wind Digitalisation

Data

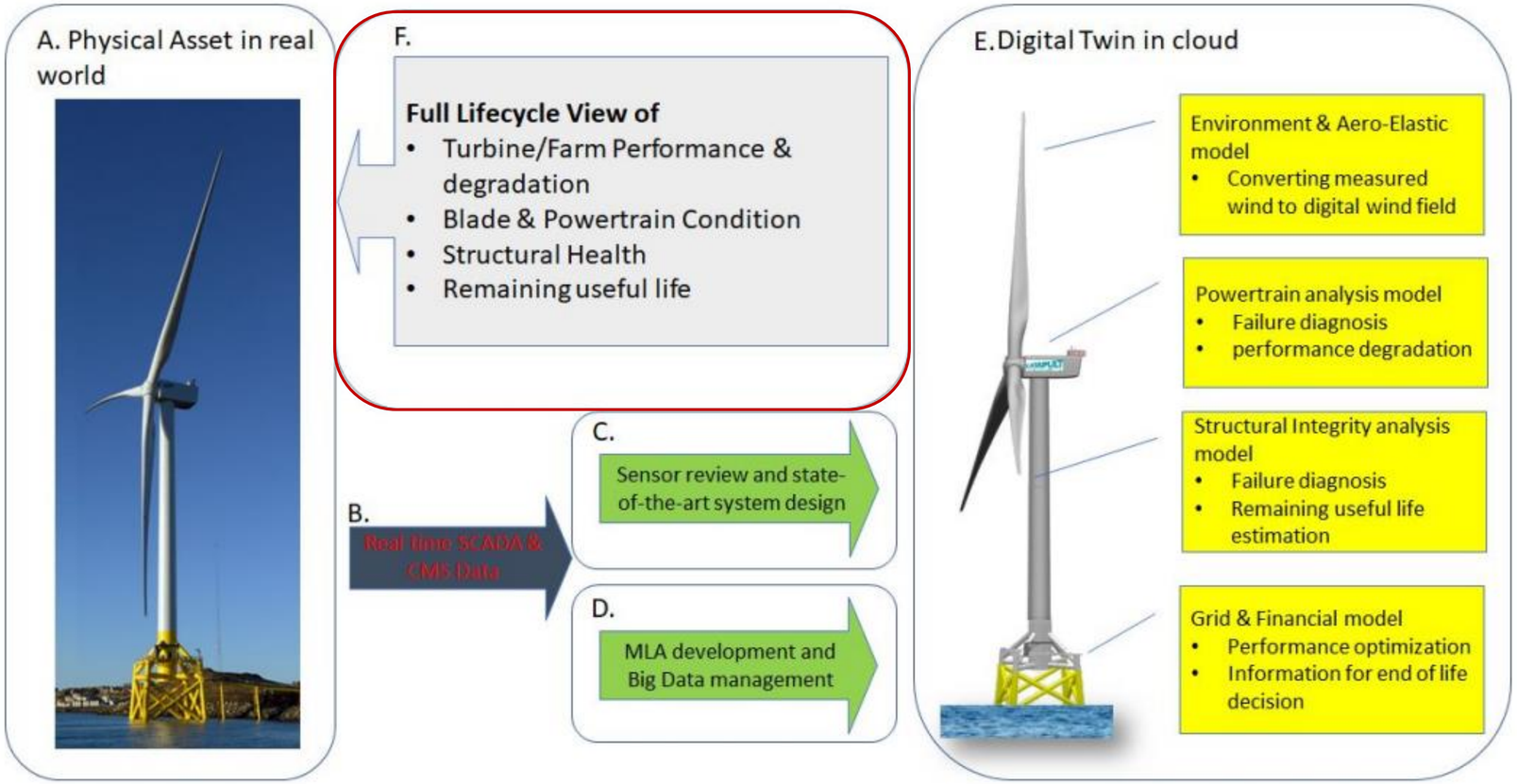
- Design specifications
- Production information
- Operational record

Modelling

- Computational/analytical models
- Engineering simulations
- Sensor fusion
- Digital objects/individual digital twins

Linking

- Connecting digital objects in a chain, e.g., condition monitoring with test (advanced testing), condition monitoring with maintenance (smart O&M) etc.
- Enabling digitalisation with extended chain and wider industry to find new products, new processes and new businesses



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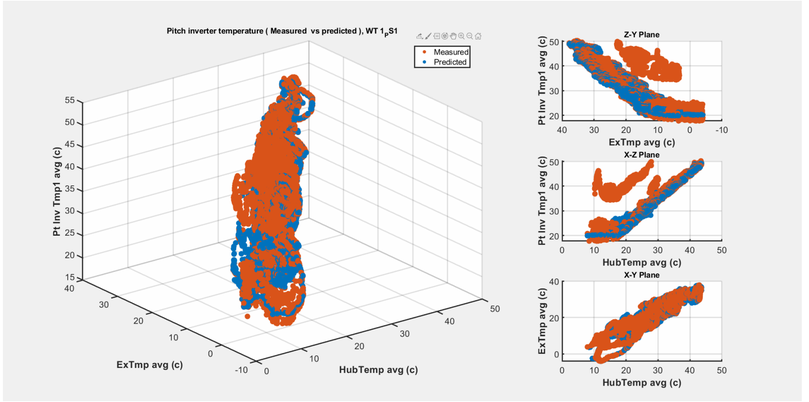
Intelligent Condition Monitoring

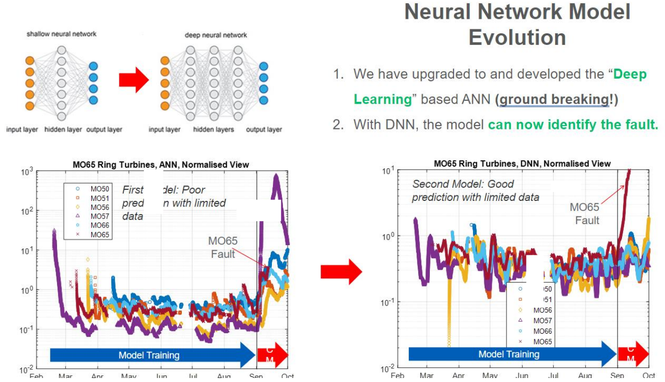
- **Combine specialist engineering knowledge and data science expertise with first-hand industry SCADA data**
- **Apply Artificial Intelligence (AI) to monitor critical components in offshore wind turbines**
- **Use Machine Learning (ML) to create novel analytics where No effective detection method for SCADA data exists**

- ❑ Pitch control system
- ❑ Pitch bearing
- ❑ Converter health monitoring
- ❑ Generator health monitoring
- ❑ Cable monitoring
- ❑ …

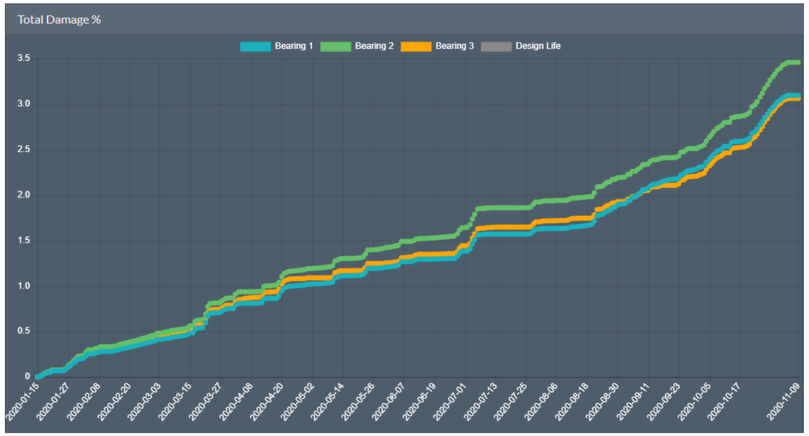
Pitch control system monitoring



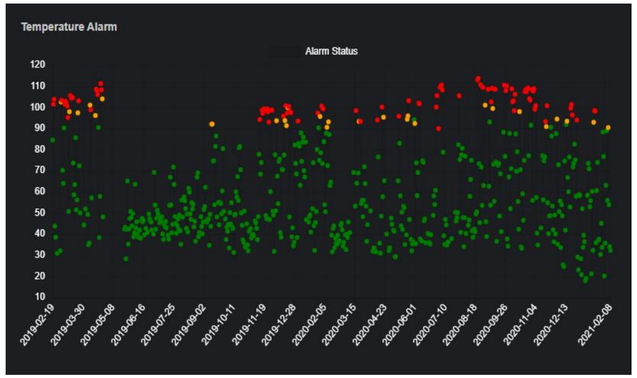
Converter condition monitoring



Pitch bearing monitoring



Cable monitoring



Generator structure monitoring (SHM)

Color map with % outbound fraction (0°, outbound (m+2S))

Turbine	wtg	alarm	historical	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Apr 2021
		On HOLD	ALARM	0	6	19	7	18	0
		On HOLD	NORMAL	0	0	0	0	0	14

Color map with % outbound fraction (45°, outbound (m+2S))

Turbine	wtg	alarm	historical	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Apr 2021
		On HOLD	ALARM	10	23	0	4	27	11
		On HOLD	NORMAL	10	10	0	15	6	3

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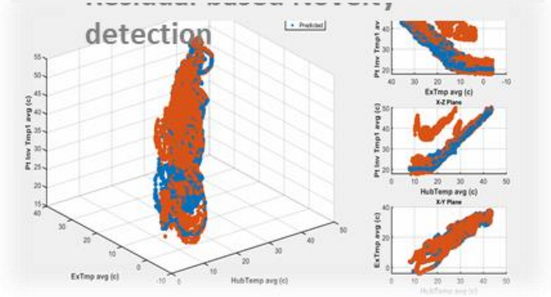
Digital Twin Functions – Our Offers

Residual based novelty detection



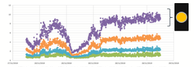
Blade Health Status

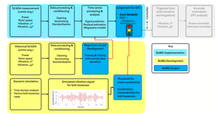
Wake Effect Optimizer

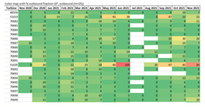
Pitch System DT Module

GE StayAshore – P8 Bolt Monitoring with Generator Stator Vibration (BoMG)

- This project developed a tool to monitor the vibration of the generator stator plates
- Utilised a MLP neural network to predict vibrations and model the residuals as a damage characteristic parameter (DCP)
- DCP was monitored over time
  - Producing alarms or warnings based on 12 week trend analysis
- Validated on the entire GE fleet (as of 2022)



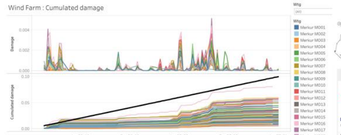


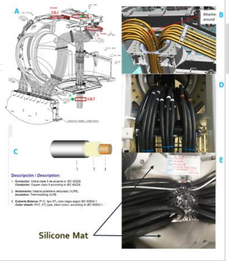


Bolt Status Module

GE StayAshore - P9 Nacelle Power Cable Ageing Monitoring (NPCAM)

NPCAM tool can estimate the lifetime consumption of the nacelle power cables based on operational SCADA data through advance machine learning algorithm.



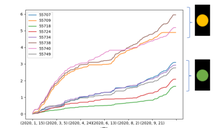


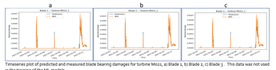
Cable Aging Monitoring

Pitch Bearing Wear Module

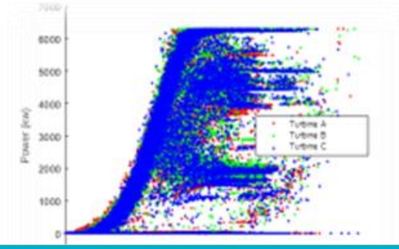
GE StayAshore – P7 Pitch Raceway Usage Monitoring (PRUM)

- The PRUM tool was developed to estimate bearing damage
- Applied ML using high resolution and SCADA Data
- Validated using SCADA data from 6 Haliade 150 turbines
- The algorithm can effectively estimate raceway damage to within an average 5% error per year.
- The tool can also raise warnings and alarms on a per day and accumulated tally.





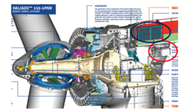
Main Bearing Fatigue Module

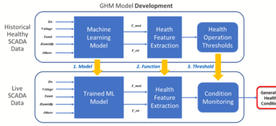


Generator Health Module

GE StayAshore – P18 Generator Health Monitoring (GHM)

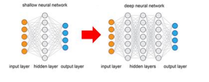
- Winding temperature model for Haliade 150 generators
- Generator thermal performance can be traced and monitored online, which could enable condition-based generator maintenance
- Traffic light system for generator operation intervention, avoiding no-condition tracing failures





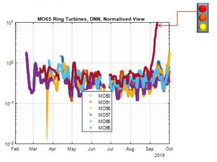
Converter Health Module

GE StayAshore - P1 Converter Condition Monitoring (CCM)



Deep Artificial Neural Network (DNN) has been deployed

1. CCM tool has been successfully validated using the SCADA data from 14 operational turbines from Merkur Wind farm.
2. The tool can effectively differentiate "healthy" and "unhealthy/faulty" converter.



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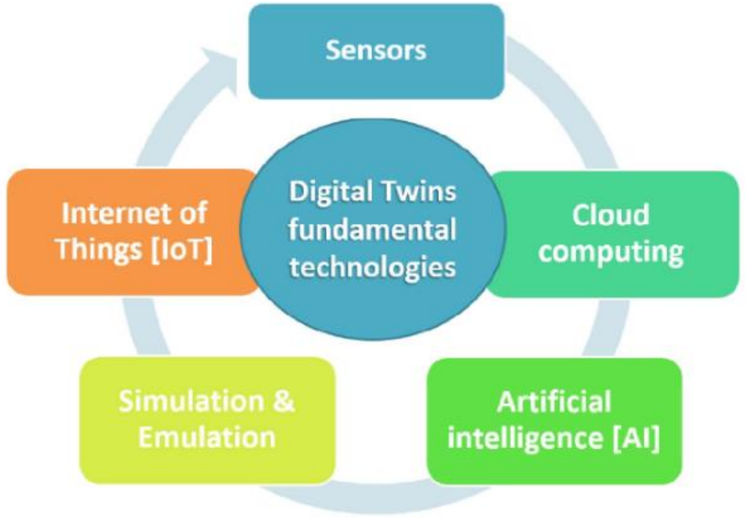
Digital Twinning Activities

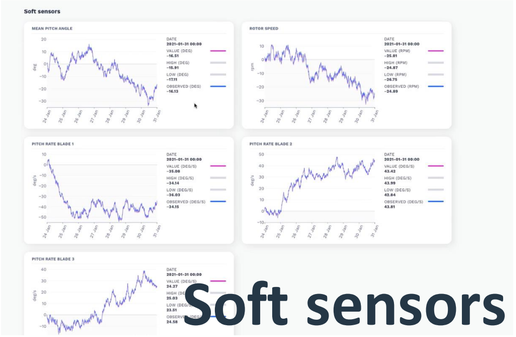


WindScope

Ada Mode

Linking

Modelling



Optimum Sensor Placement (OSP)

UNASYS

Linking

Transmission Dynamics

Data

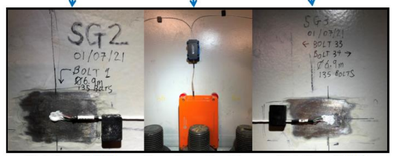


Figure 18. SmartBug position 3 (SN: 206043)

Figure 19. SmartBug position 4 (SN: 206044)

International collaboration & academic partnership

Tufts University

University of Nevada, Reno

University of Strathclyde Glasgow

- Data analytics remain the critical tool to inform turbine O&M and drive down cost
- We develop and embed our analytic tools on digital twin platforms

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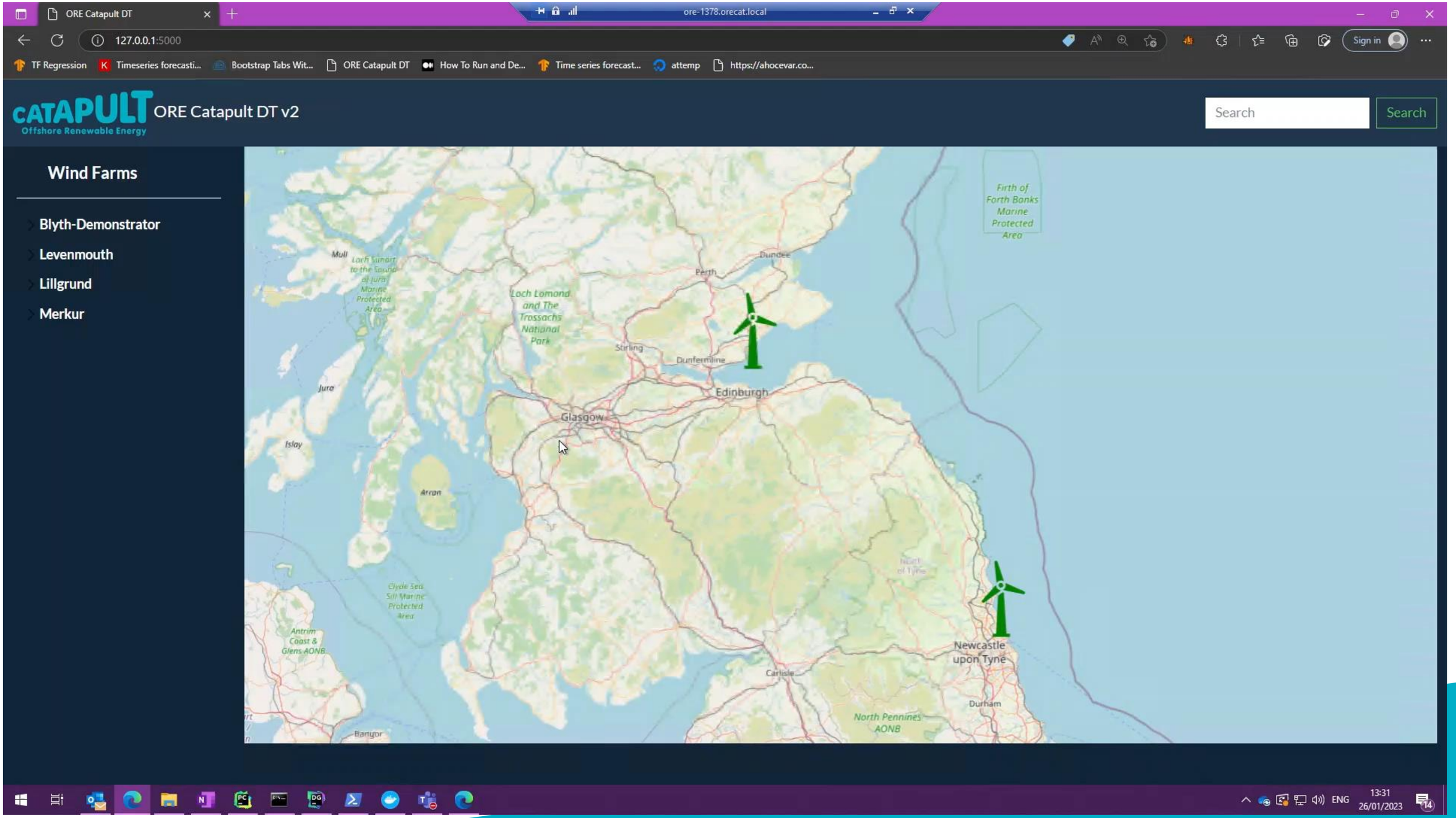
Digital Twin Cloud Platform



UNASYS

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Technical Challenges

Data

- Lack of data sharing
- Large amount of operational data with little useful information
- Ideal measurement not available in time or space

Modelling

- Multi-time-scale, multi-physics systems
- Large uncertainty in modelling, e.g., farm-level airflow, floating wind etc.
- Digital objects subject to validation

Linking

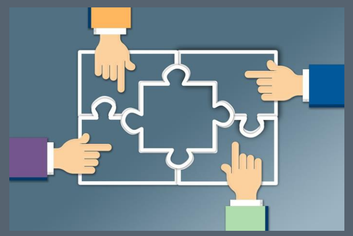
- Limited number of connected digital objects
- No strong business case
- Public funding

Guideline and Recommendation

Creating **FAIR** data frameworks

Connecting people and data to foster **innovation**

Collaboration & **competition** between organisations



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