FSFOUND: ‘Float & Submerge’ Gravity Base Foundations

EDF ENERGY R&D UK Centre

Overview

1. EDF R&D UK Centre Renewables Team
2. EDF Group Offshore Wind Portfolio
3. FSFOUND Project Summary
4. Gravity Base Foundations – Construction & Installation
5. Gravity Base Foundations – Condition monitoring

R&D UK Centre Renewables Team

12 **Team members**

Multiple skills

- Wind measurements and uncertainties
- Cost modelling
- Data management
- Blade expertise
- Inspection techniques
- Asset management
- Operations & Maintenance
- Maritime constr. & and operations

Our partners

CATAPULT Offshore Renewable Energy

EPSRC Engineering and Physical Sciences Research Council

SAMS

Idcore

University of Strathclyde Glasgow

energy technologies institute

Why?

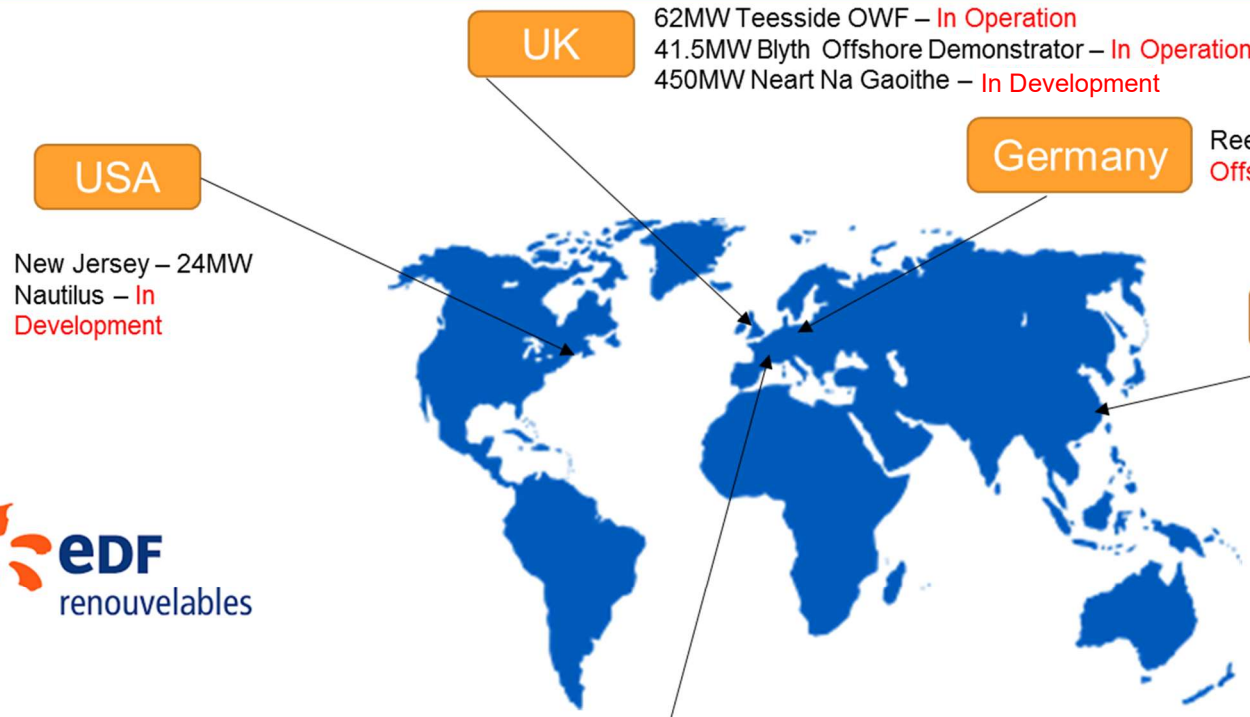
Decrease the cost of renewables for the different Companies within EDF Group

How?

Identify Innovations and evaluate them to help EDF be more competitive
Anticipate future challenges in a rapidly evolving environment
Leveraging UK capabilities for the Group's benefits

50	Activities in 2018 through conventions or contracts with EDF Group and EDF Energy	6	EU and UK collaborative projects	16%	Public funding

EDF Group: Global Offshore Portfolio & Services



UK

62MW Teesside OWF – In Operation
41.5MW Blyth Offshore Demonstrator – In Operation
450MW Neart Na Gaoithe – In Development

Germany

Reetec & Offshore Wind Solutions
Offshore Wind O&M Services

USA

New Jersey – 24MW
Nautilus – In Development

China

JV with UPC Asia Wind Management
250MW Dongtai IV – In Development
250MW Dongtai V – Development to start in 2019

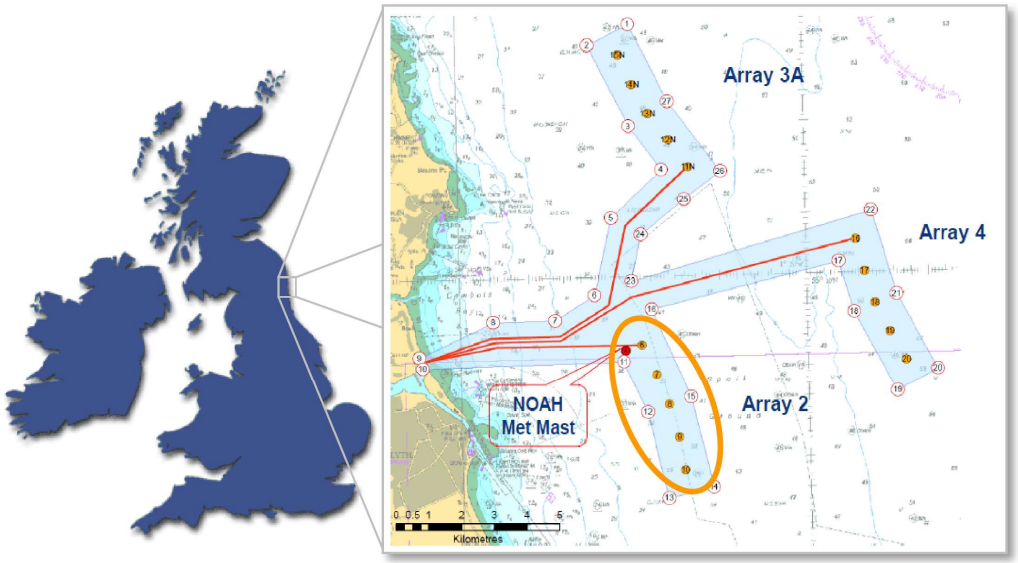
EDF renouvelables

EDF renewables

France

500MW Courselle OWF – In Development
500MW St Nazaire – In Development
500MW Fecamp – In Development
24MW PGL (Floating) - In Development
~600MW Dunkirk – In Development

FSFOUND: Blyth Offshore Demonstrator - Site Description



Blyth Offshore Demonstrator Ltd – Array 2			
Capacity	41.5 MW	**Water Depth**	~38m
Turbine	5 x MHI Vestas V164-8.3MW	**Soil Conditions**	Sand, silt and clay
BoP	5 x Gravity Base Foundations 66kV electrical system Onshore substation	**Cable Route**	~11km offshore (array and export) 1.5km onshore
Location	~5.6km off the coast of Blyth	**Commercial Operations**	October 2017

FSFOUND: Introduction and Summary

Title

Development and demonstration of float-and-submerged gravity base foundations (GBF) for offshore wind turbines: FSFOUND

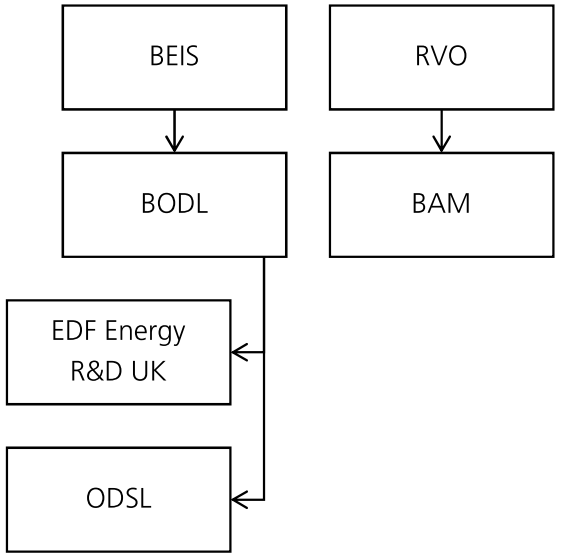
Project context

To demonstrate the feasibility of the float-and-submerged gravity base foundation solution at all critical stages: design, manufacture and quayside construction, preparation and loadout, seabed preparation, towing, installation, commissioning and operations.

DemoWind
Delivering cost reduction in offshore wind

Department for Business, Energy & Industrial Strategy

Rijksdienst voor Ondernemend Nederland



Project Value:
£3,636,607

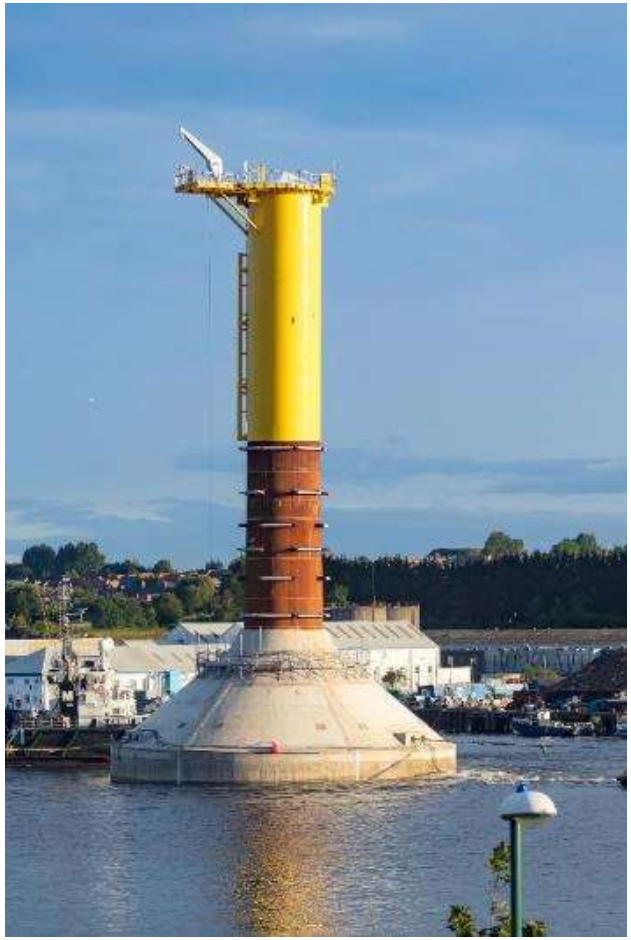
BEIS Contribution:
£604,957

Start Date:
20/10/2016

Scheduled Completion Date:
01/02/2019

In collaboration with:
Blyth Offshore Demonstrator Ltd & EDF Energy Renewables
EDF Energy R&D UK Centre
ORE Catapult Development Services Ltd.
BAM Wind Energy JV

FSFOUND: Objectives & Benefits



Specific project objectives

- To move the FS GBF solution **from TRL 6 to TRL 7**, thereby verifying the RDI initiative.
- To verify the manufacturing and installation methodology and benefit from the lessons learnt in order to **optimise plans for the future** transnational exploitation of GBFs;
- To **minimise potential delays** and cost overruns through the development of multiple installation scenarios against a meteorological model.
- To **design and install a condition monitoring system** on two GBFs to monitor their behaviour.
- To assess the **structural response to extreme and fatigue loads** on the GBF and compare theoretical loads with real ones

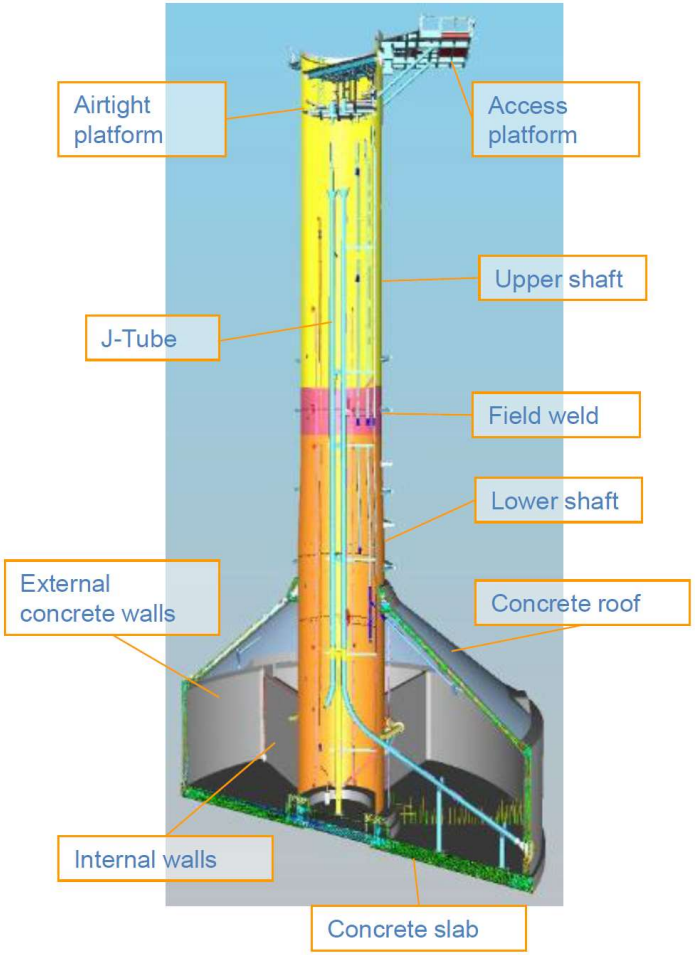
Benefits

- **Lower installation costs** by employing standard tugs and self-buoyancy rather than specialised vessels.
- **Lower costs during the operational phase** as a result of reduced inspection and maintenance.
- Fabrication and deploy the GBF in **physical proximity** to the offshore site
- **Increased deployment** of WTGs in sites where piling is not technically feasible

Gravity Base Foundation Description

Key Facts

- 26 year design life
- Constructed in a dry-dock at Tyneside
- > 1,800 m3 of concrete per foundation
- > 500 tonnes of steel re-bar per foundation
- > 600 tonnes of steel for each steel shaft per foundation




Neptune Energy Park
EN AVANT 20
DORDRECHT
EN AVANT 1
DORDRECHT

FSFOUND: Construction & Installation - Conclusions

Realisation of Project Objectives

- Project has demonstrated the progression of GBFs from TRL level 6 to 7
- Verification of the manufacturing methodology in a localised proximity
- Installation removed dependency on HLVs – reducing costs

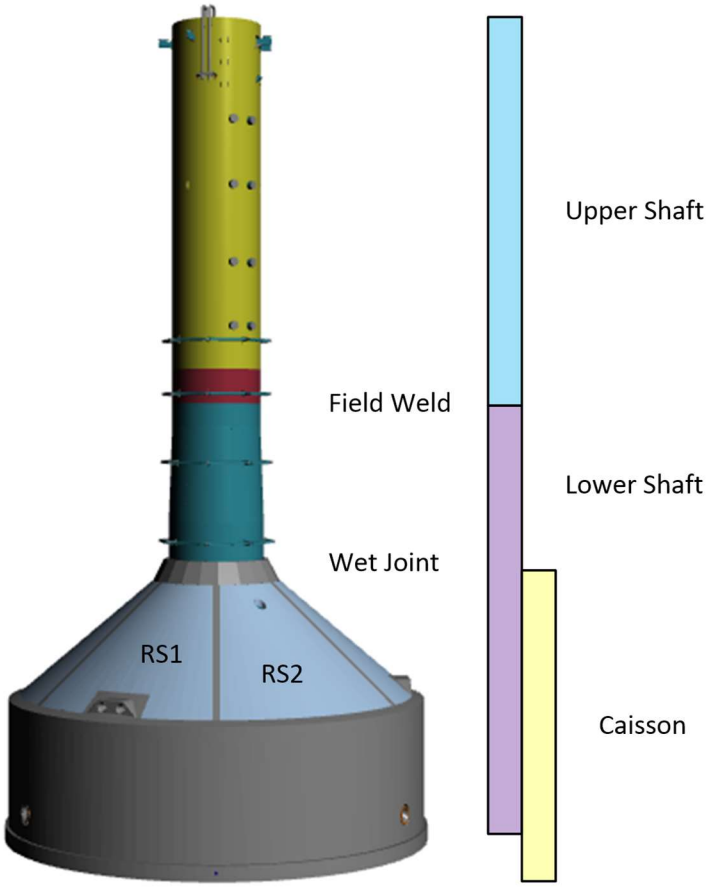
Lessons Learnt

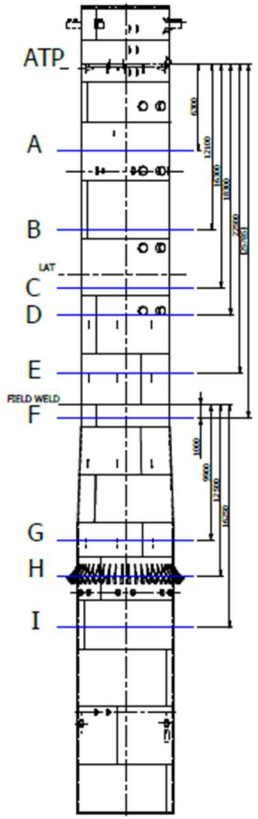
- Close planning and monitoring negated programme slippage
- BIM for construction limited clashes/pinch points during construction
- Dry dock limitations – Access, lack of space, gate functionality
- Factory style manufacturing without dry dock constraints proposed by BAM
- Streamlining of overall installation methodology envisaged - secondary ballast

FSFOUND: Condition Monitoring System (CMS)

1. Validation of the design, including input to verifying simulation models
2. Providing feedback to the design limits of the structure, such that an updated life expectancy can be calculated (if required)
3. Understanding the interaction between: GBF and Seabed (e.g. settlement) GBF and WTG (e.g. modal interaction, load transfer) GBF/WTG combination and the Environment (e.g. wind/wave misalignment loads) Effect of internal divisions on the displacement of the caisson outer walls
4. Provide inputs to the design of a Structural Health Monitoring system for GBF system
5. Provide a platform for the development of a prognostic methodology for NDT of GBFs

FSFOUND: CMS - Sensor Locations





A – “Air Space” Inclinometer

B – “Secondary Steel” Inclinometer

C – Pressure sensor (internal tide height reference)

D – “Upper Shaft” Inclinometer, Upper Dissolved Oxygen sensor

E – “Above Field Weld” Strain gauges (Bending, Compression, Torsion)

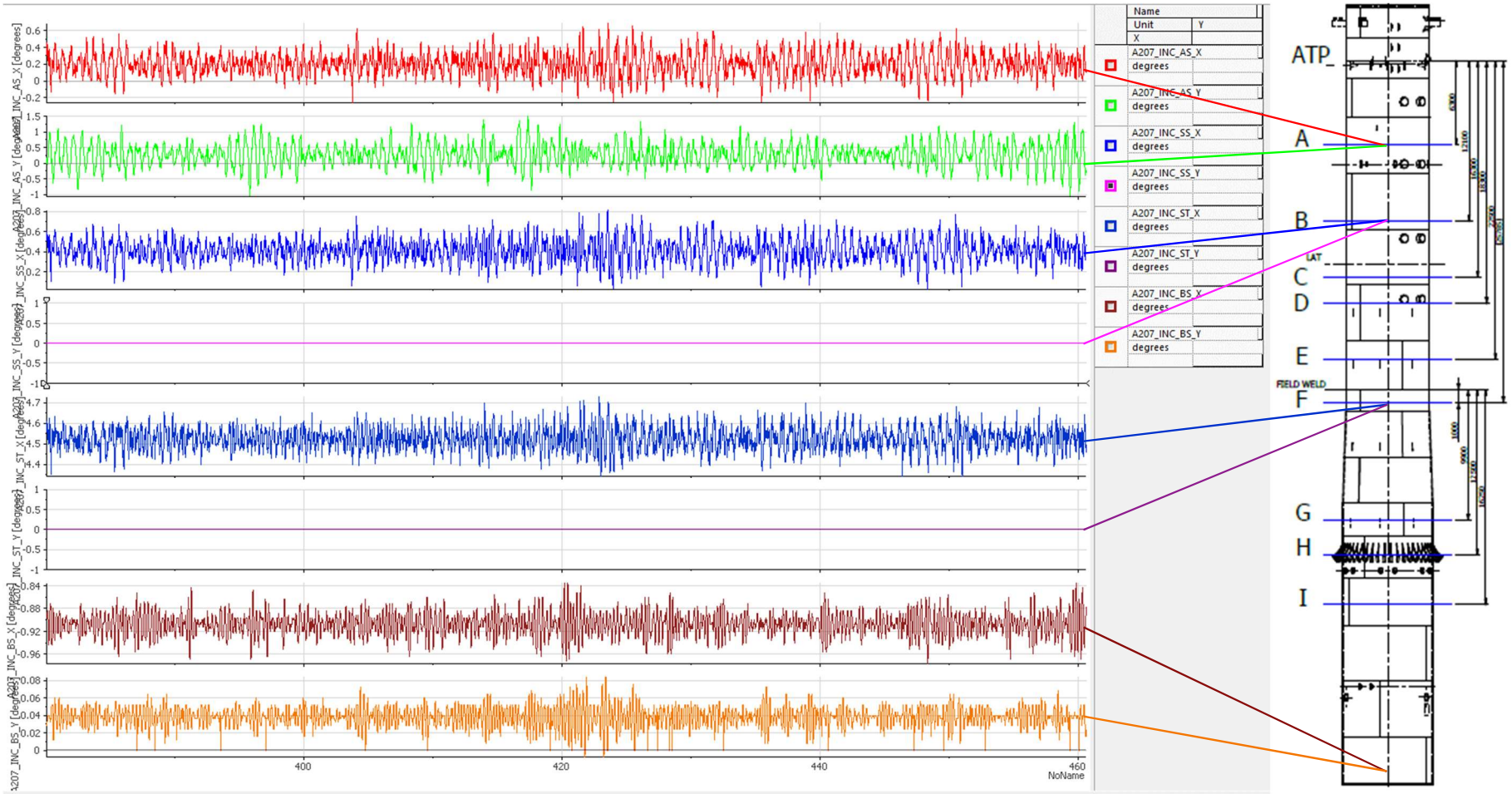
F – “Shaft Transition” Inclinometer

G – “Above Wet Joint” Strain gauges (Bending, Compression, Torsion)

H – “Wet Joint” Inclinometer, Lower Dissolved Oxygen sensor

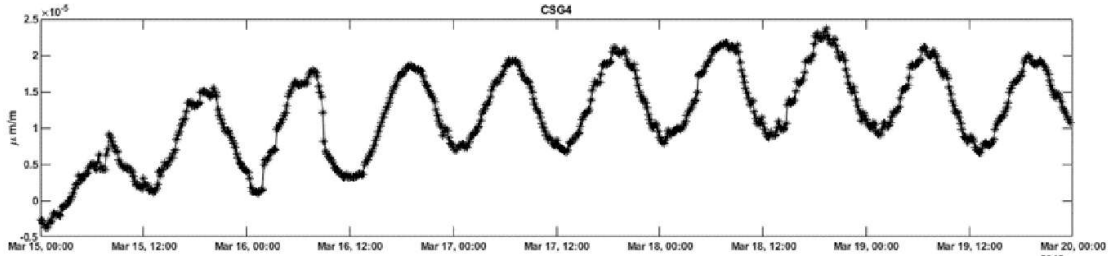
I – “Below Wet Joint” Strain gauges (Bending, Compression)

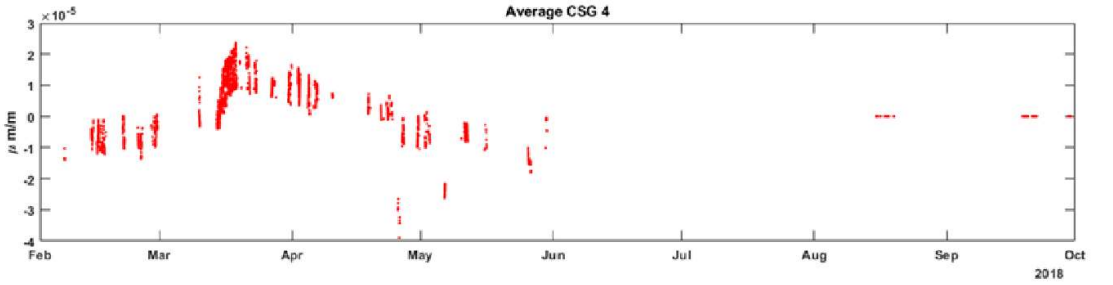
FSFOUND: CMS - Inclinometer Profiles

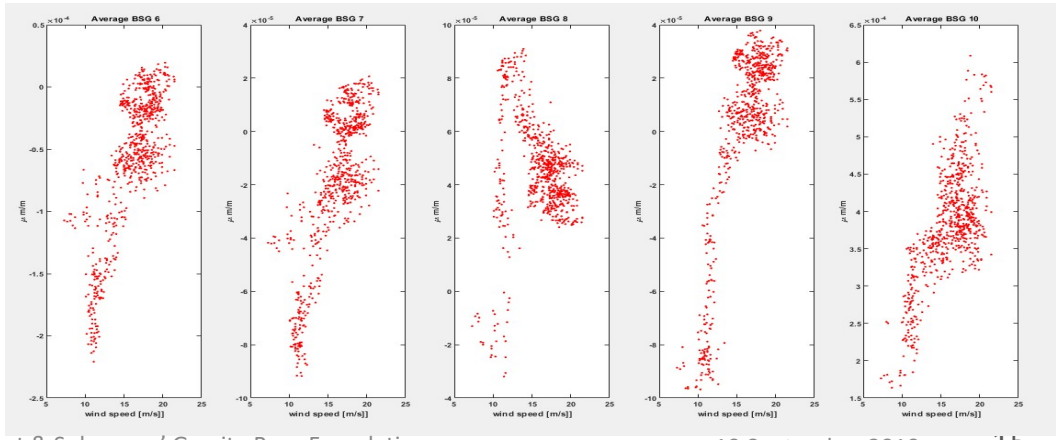


FSFOUND: CMS - Strain Gauges

- Compressive Strain Gauges show signs of tidal influence
- Torsional Gauges: Peak loads of around 25-50% of Design ULS, and 70% of Design FLS
- Bending Gauges: Correlation to power generation and wind direction







FSFOUND: Condition Monitoring System – Conclusions

Realisation of Project Objectives

- Successful instrumentation of two GBFs
- Approximately two years of useful NDT data acquired
- Significant ULS and FLS design margins seem to exist, even during an extreme winter event (Beast from the East)
- No apparent differential settlement in both GBFs

Lessons Learnt

- Vertical installation of sensors requires significant additional time and risk management
- Hundreds of metres of cables vs. thousands of tonnes of sand ballast
- Protection, reliability and longevity of the CMS system – large drop off after two years
- Wind Farms and Energy Companies have very secure networks – Make sure IT are involved from inception!

Thank you

Dr. Jack Paterson
Research Engineer
EDF Energy R&D UK Centre
Renewables
jack.paterson@edfenergy.com