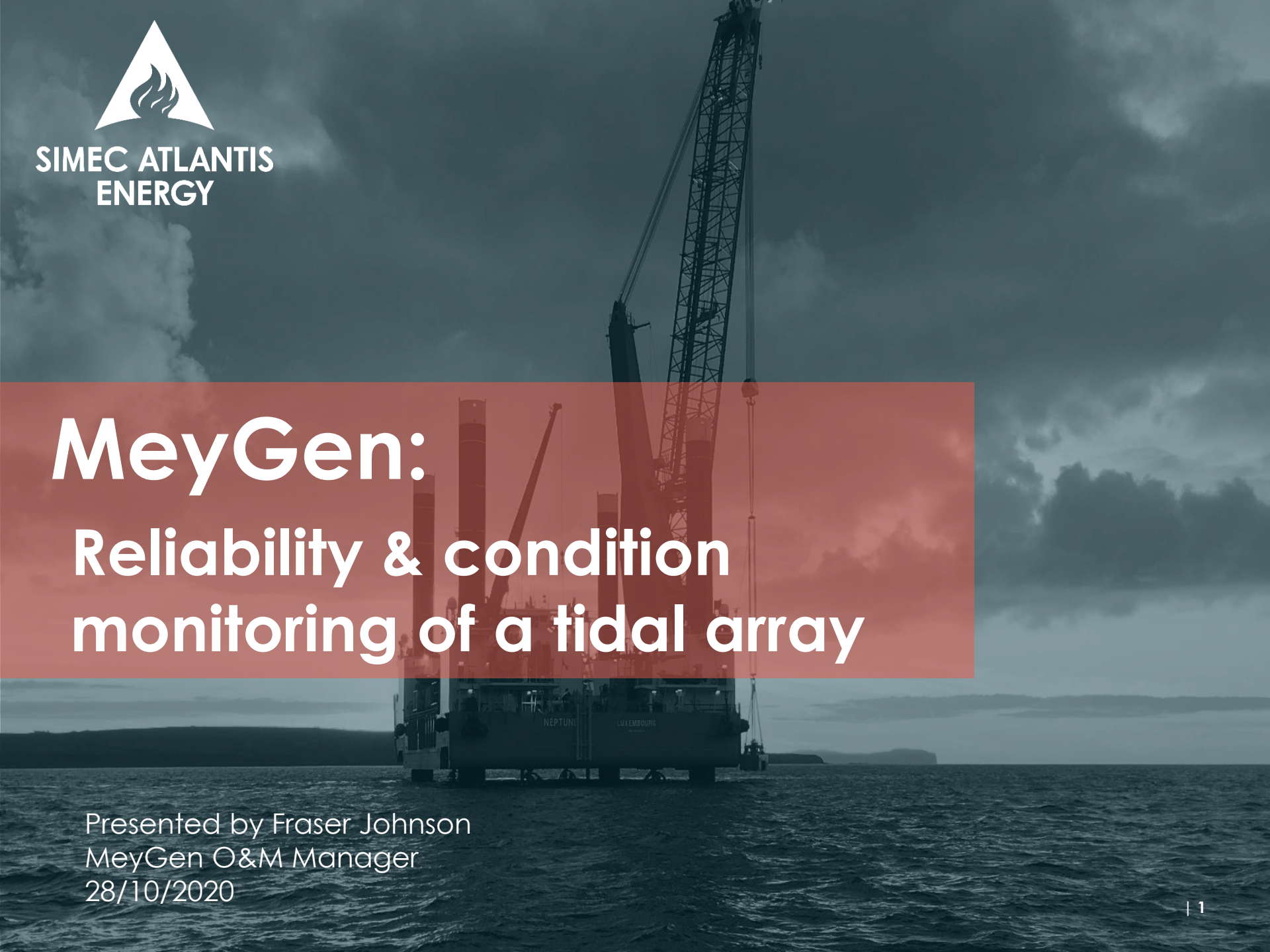


SIMEC ATLANTIS ENERGY

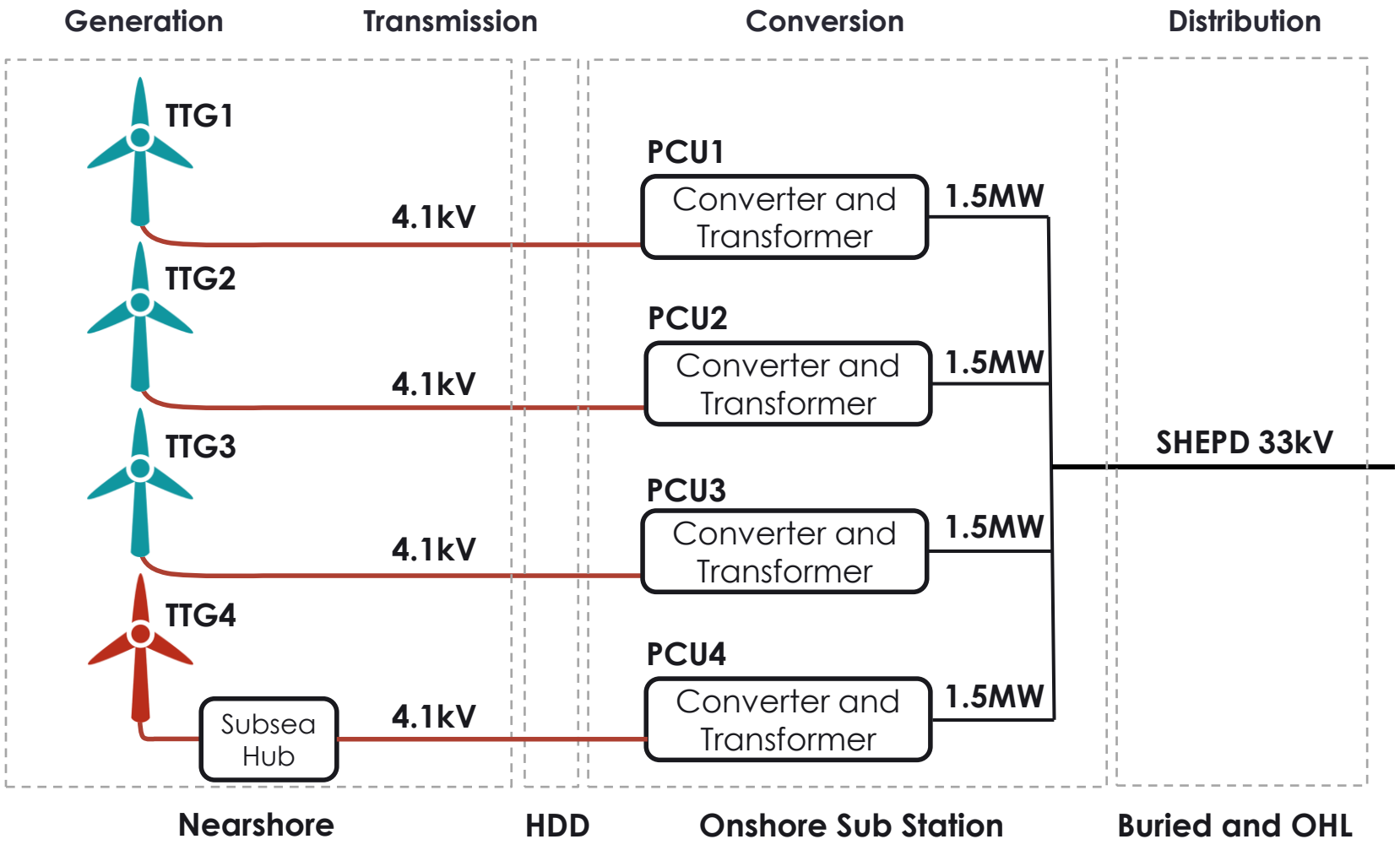
MeyGen:

Reliability & condition monitoring of a tidal array

Presented by Fraser Johnson
MeyGen O&M Manager
28/10/2020

4 x 1.5MW tidal turbines

SIMEC ATLANTIS ENERGY



MeyGen location

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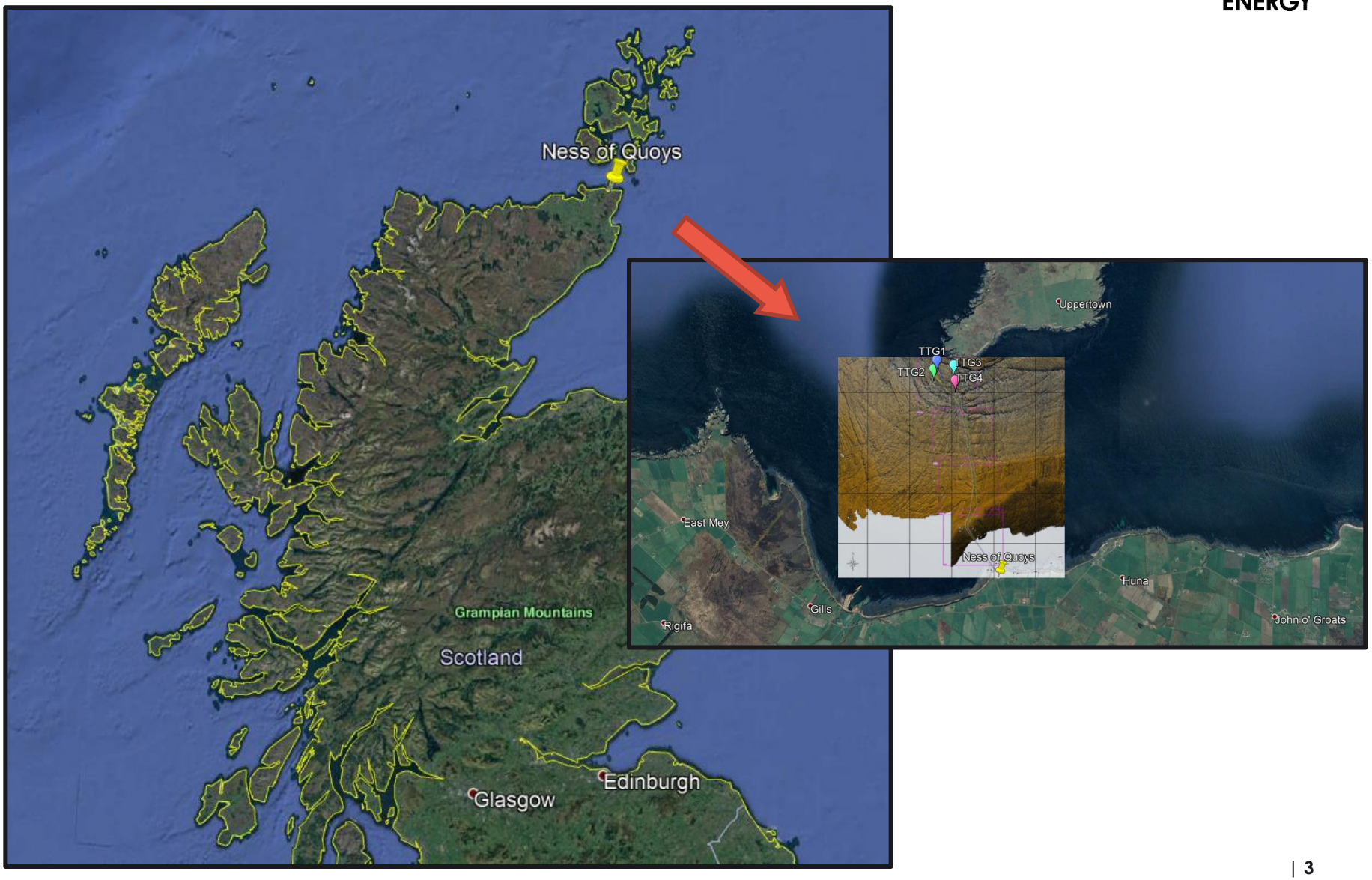


MeyGen Project Construction Dates

SIMEC ATLANTIS ENERGY

Licences and Consent — Finance & contracts — Construction — O&M

October 2010
Crown Estate Agreement Lease

September 2013
Section 36 consent granted

July 2014
Generator's Licence issued by Ofgem

September 2014
Construction contracts concluded

July 2015
4 x HDD bore complete

May 2016
AR1500 FAT on Nautilus test bed at OREC

October 2016
Turbine support structures installed

April 2018
MeyGen Phase 1A 'officially' enters into operation

July 2012
Section 36 Consent and Marine Licence applications

January 2014
Marine Licence granted by Marine Scotland

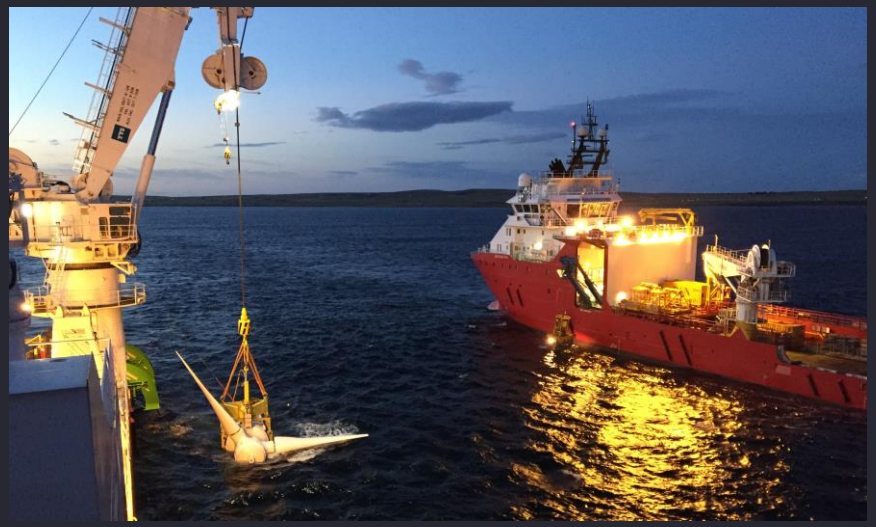
August 2014
Funding conditions satisfied

January 2015
Onshore construction commenced

October 2015
Export cables installed

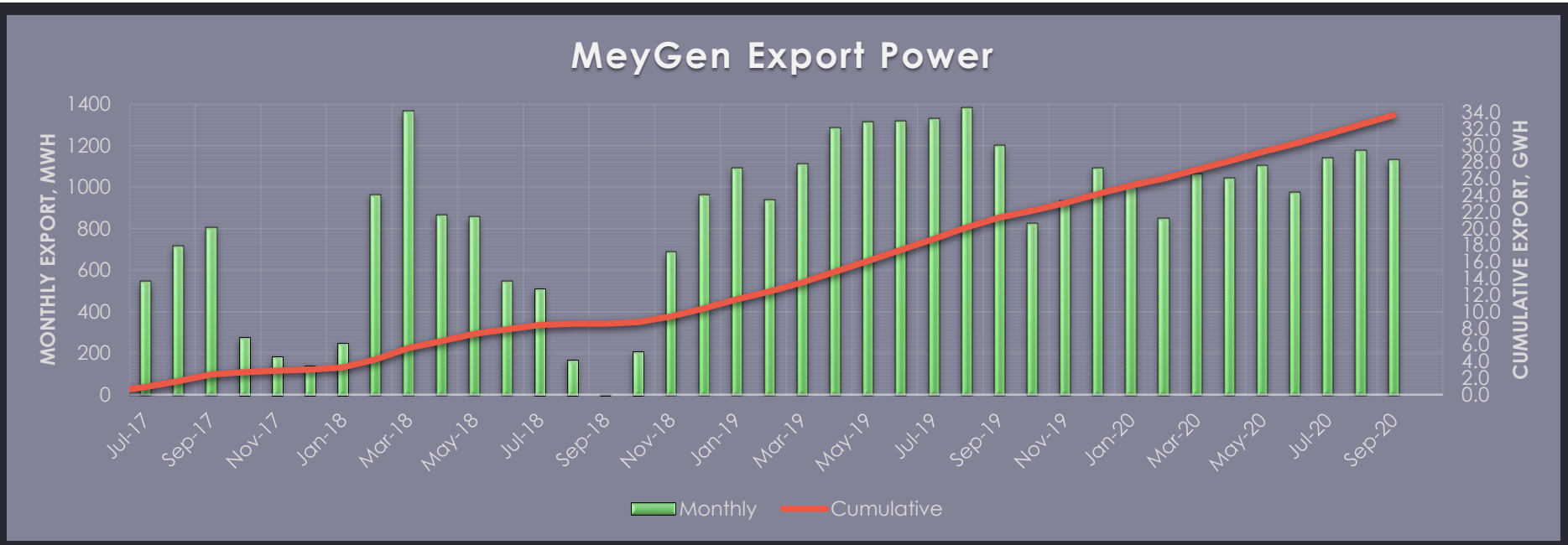
June 2016
SHEPD energise 14.8km 33kV grid connection

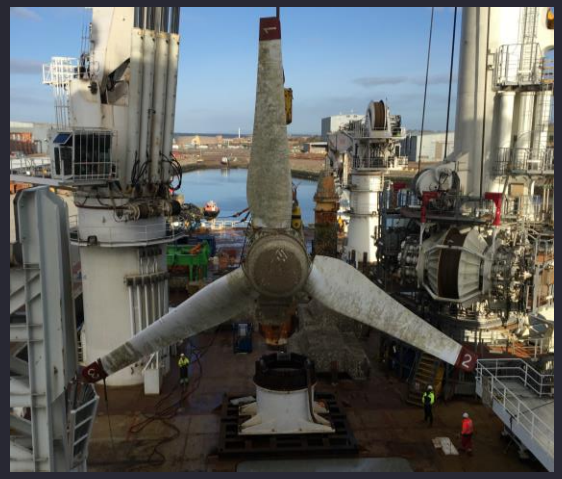
November 2016
Turbine offshore installation works begin



MeyGen Array Generation

SIMEC ATLANTIS ENERGY





Array Operating Data

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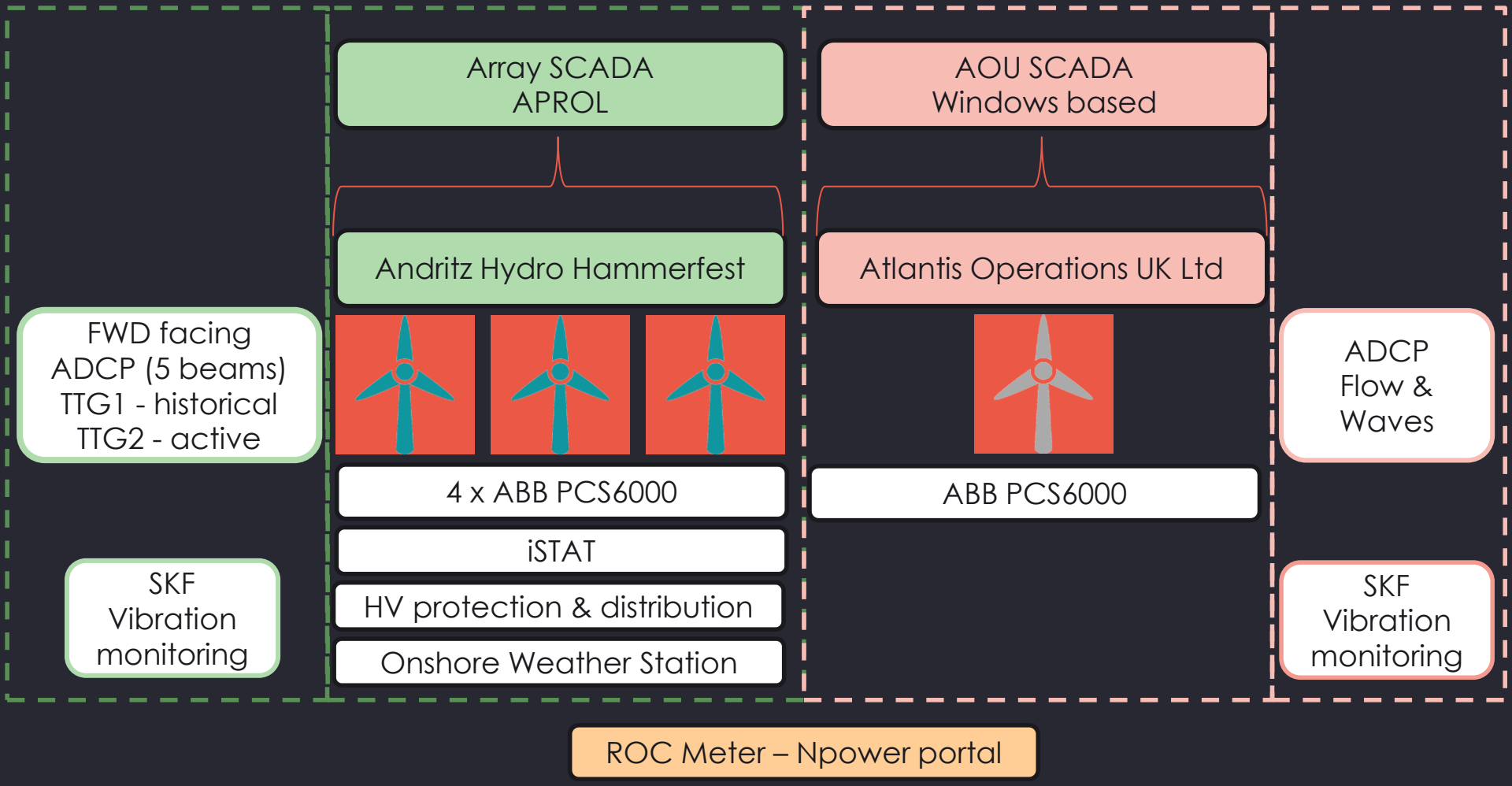
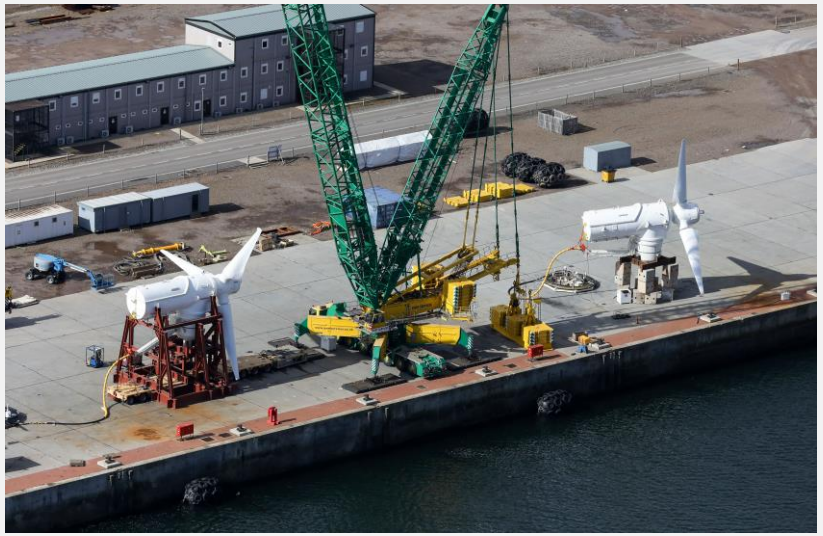


Array monitoring – What do we monitor and why?

SIMEC ATLANTIS ENERGY

- Revenue generation, MWh:
  - Against forecast
    - % Availability (time weighted)
    - Average monthly capacity factor
      - Modelled flow data
      - Measured power curve
- Maintenance:
  - Planned preventative maintenance:
    - Set by suppler based on # of cycles be they mechanical and thermal
  - Unplanned reactive maintenance:
    - In operation failure
- Asset Integrity& Risk management:
  - Foundations
  - subsea cables
  - Onshore buildings



Phases of Condition monitoring

SIMEC ATLANTIS ENERGY

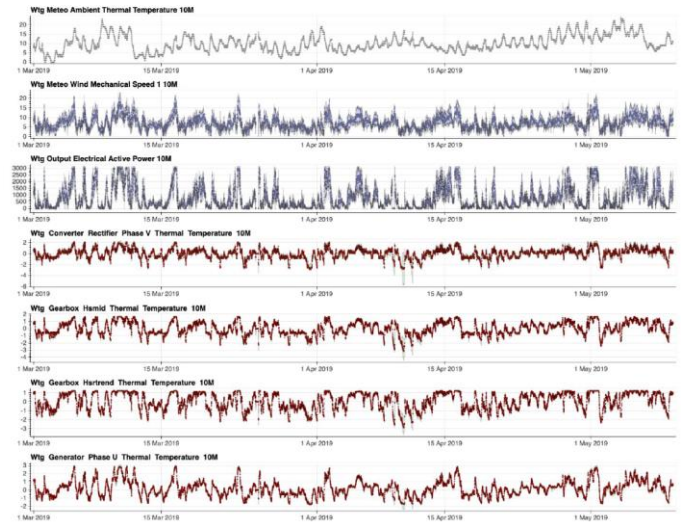
NORMALITY MODELLING
Holistic modelling of the entire system as single process, establishing a data-based digital twin.

PREDICTIVE MAINTENANCE
Model component behaviour at fleet scale to calculate what turbine health should be, will be and where faults are developing.

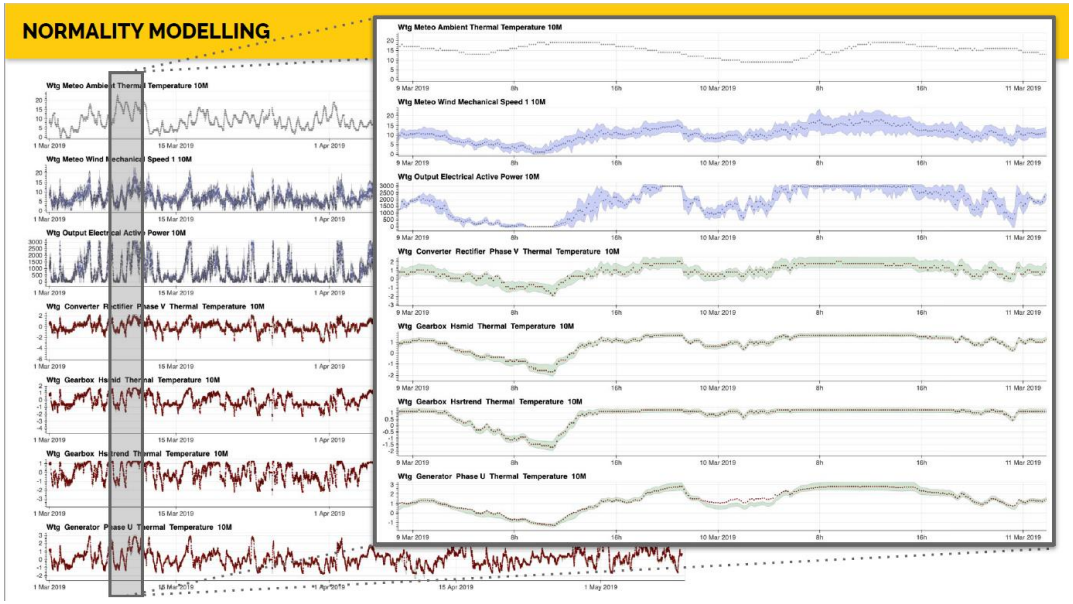
PREDICTIVE OPTIMISATION
Model production at fleet scale and calculate what actual production should be, will be and where fleet is underperforming.

- Generate a digital finger print of each turbine system based on a number of pre-defined rules, such as:
  - Thermal variations change between increasing and de-creasing flow.
  - Assessment of vibrations are more aligned to automotive characteristics than wind turbines due to the rapid rate of rise and fall that can be experienced.
  - Pitch speeds and the range of motion is heavily linked to turbulence, by they site inherent or waves.

NORMALITY MODELLING



NORMALITY MODELLING

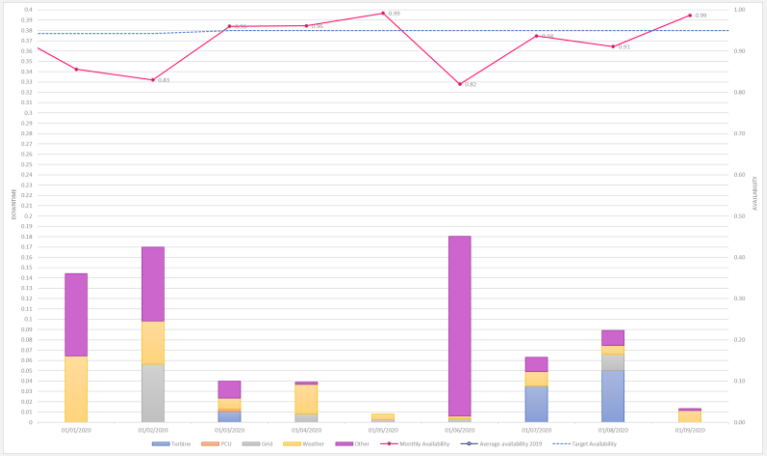


Courtesy of Jungle.ai

Unpicking variations in performance

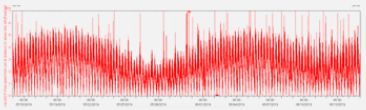
SIMEC ATLANTIS ENERGY

- Variations in spring and neap tides affects the monthly capacity factors
- Time based availability can be affected by down time conducted during slack tide then no generation is possible.

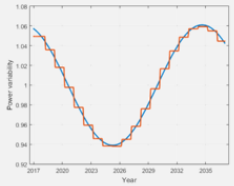


- Energy yield forecast and capacity factors estimated by applying the calibrated flow, corrected for lunar cycle, to the specific power curves:

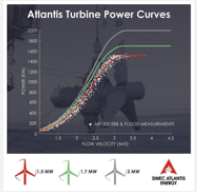
Calibrated flow



Lunar cycle



Power curves



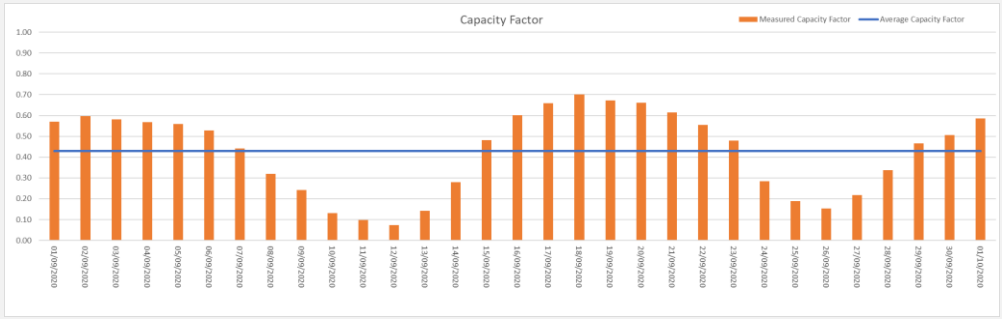
- The equation for capacity factor (CF) is:

$$CF = \frac{E}{E_{rated}}$$

Where E=Energy yield of the turbine
E_{rated} =Energy yield of the turbine if operating at maximum power continuously

NOTE 1: Energy yield forecast and capacity factor estimate assumes 100% availability and no system losses. These are added later in the financial model directly

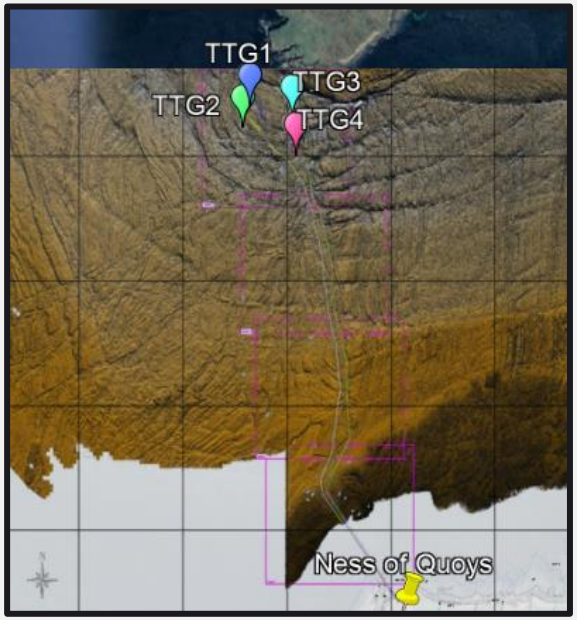
NOTE 2: When calculating capacity factor, a whole month of data should be used so that there is an even spread of spring and neap tides, otherwise the capacity factor estimate will be biased towards a high or low flow period

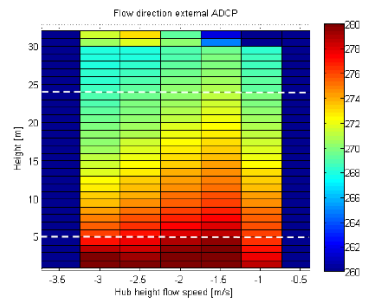


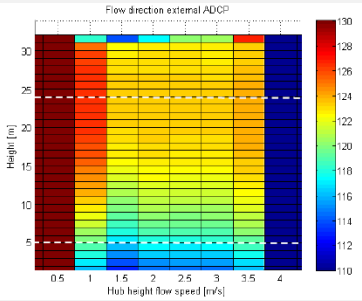
Variations in flow

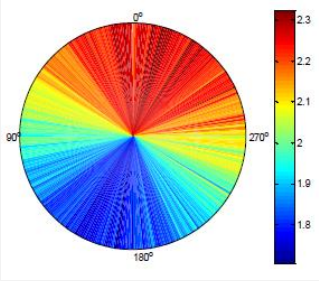
SIMEC ATLANTIS ENERGY

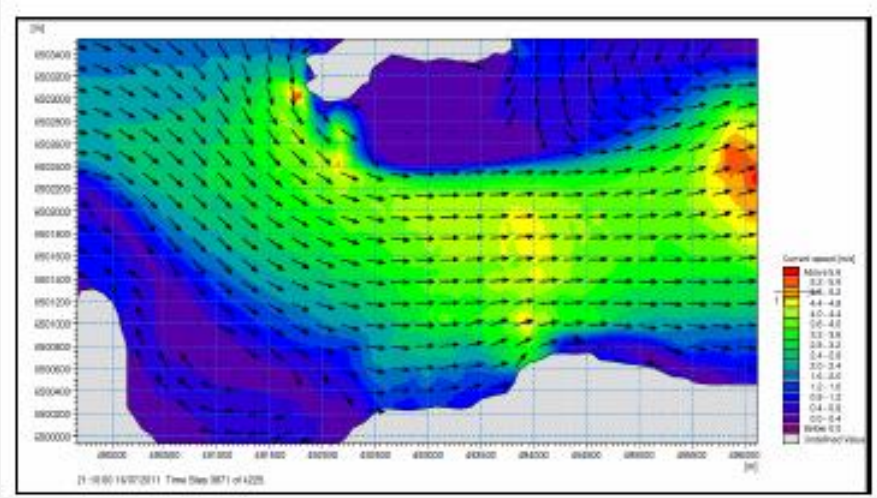
- Flow across the MeyGen site can vary:
  - Between Flood and Ebb
  - Exhibits vertical twist
  - As the flow develops, the flow direction across the rotor changes
  - With the maximum flow being offset to a zero azimuth

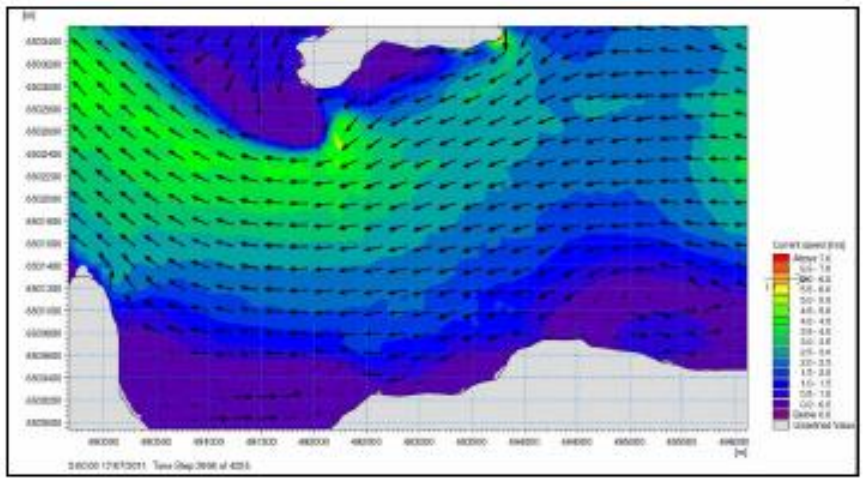










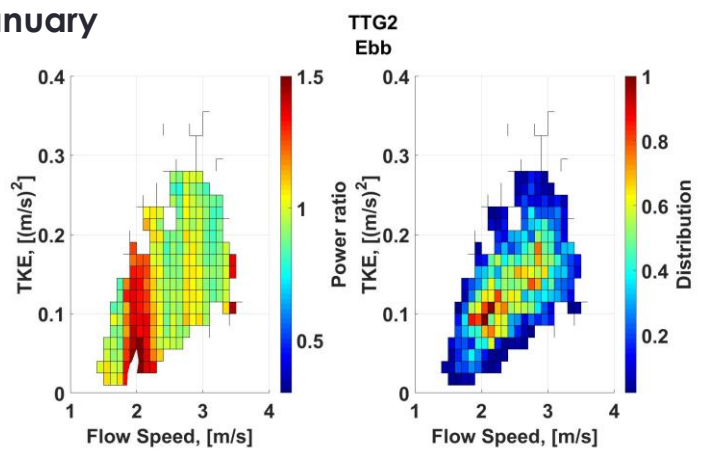


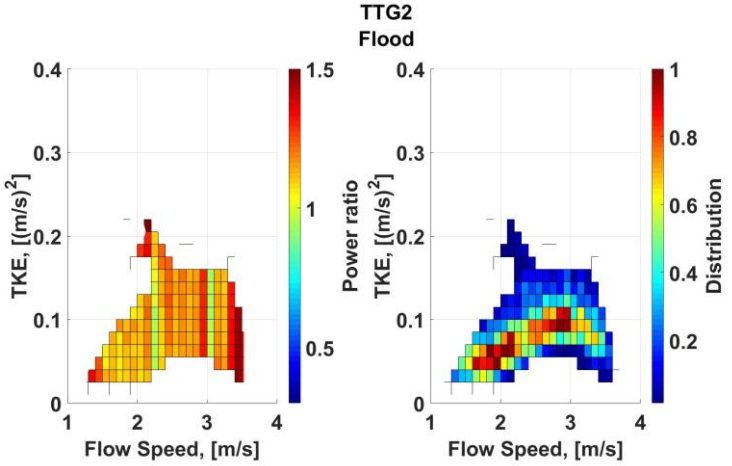
Variations of performance due to turbulence

SIMEC ATLANTIS ENERGY

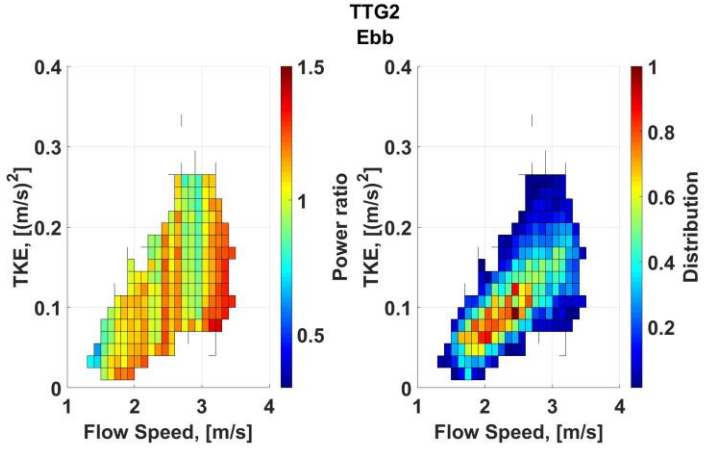
Fluctuations in Capacity factor due to turbulence can be in the order of 5%

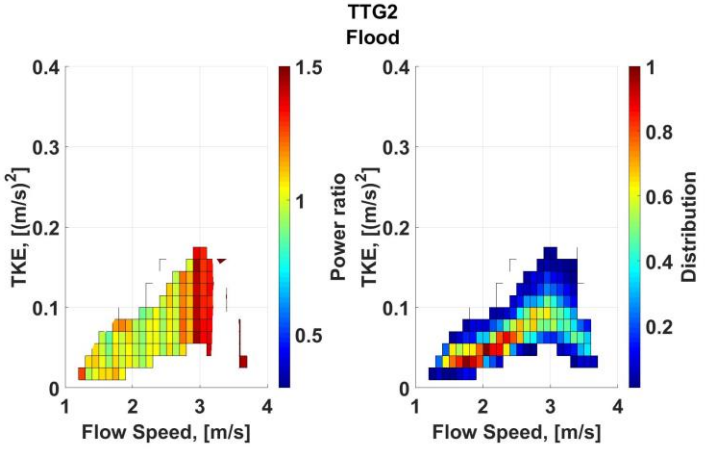
January





June

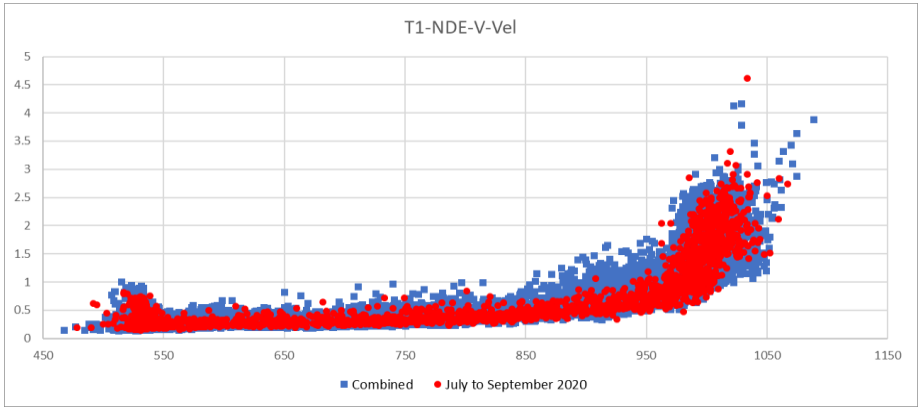


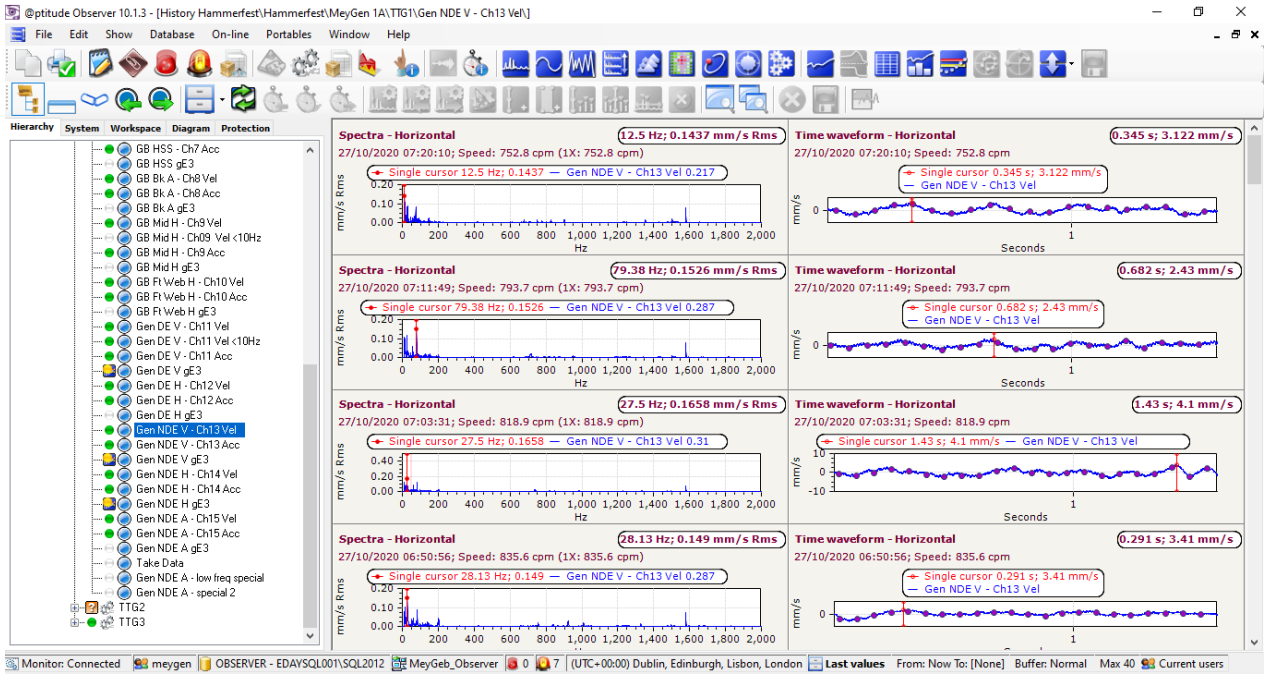


Vibration monitoring

SIMEC ATLANTIS ENERGY

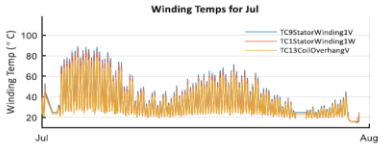
- Use of standard limits for wind turbines not whole appropriate due to variations in RPM:
  - 50% increase in rated RPM in <2 seconds
- Database of actual operating data required to propose system relevant High and High High values

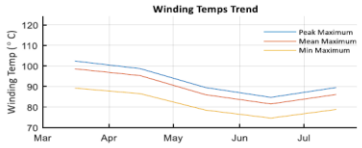


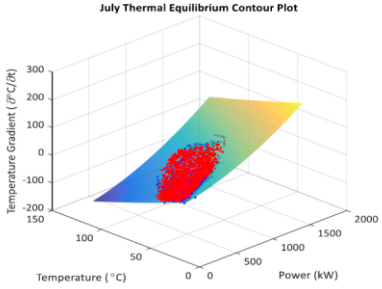


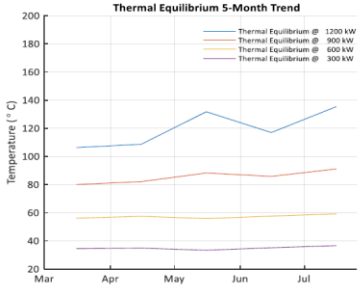
Moving towards predictive maintenance

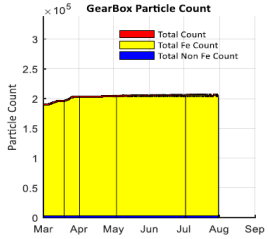
SIMEC ATLANTIS ENERGY

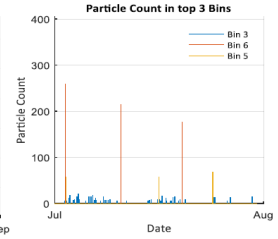


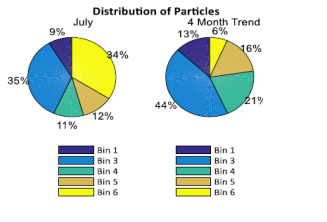


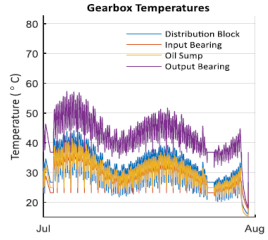


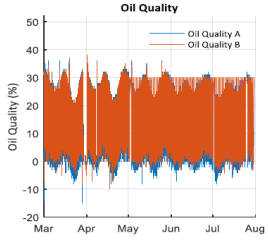


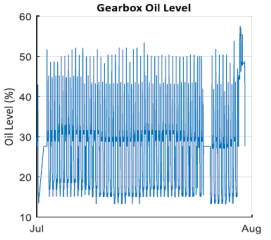


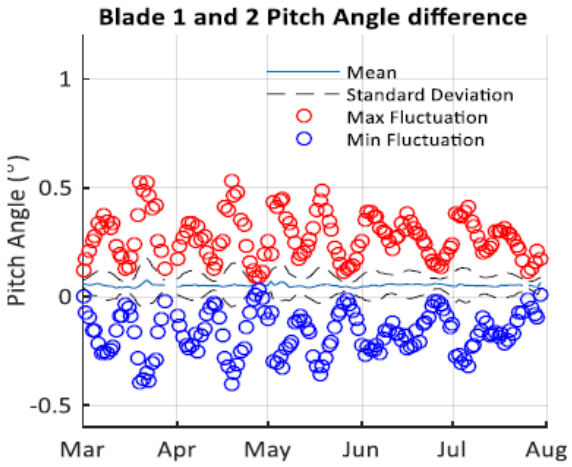


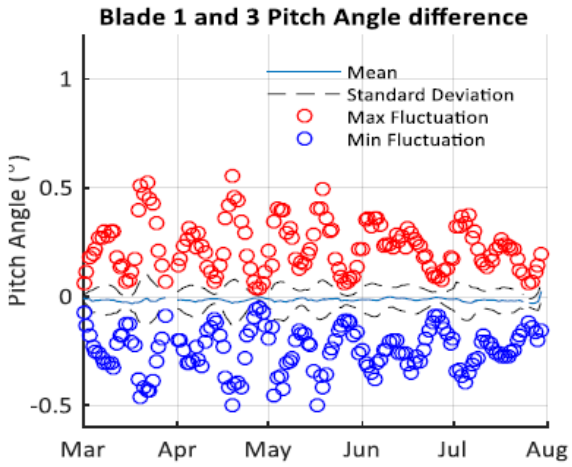


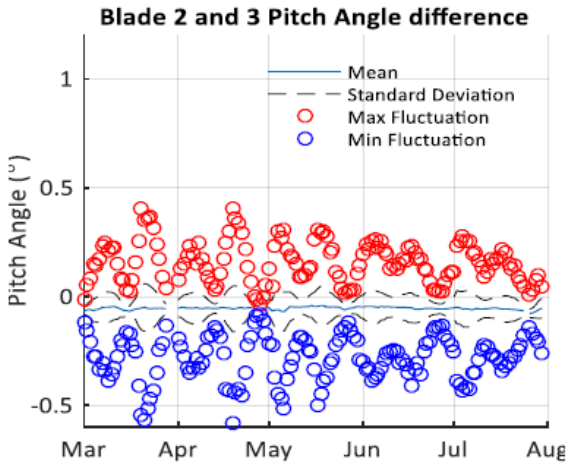










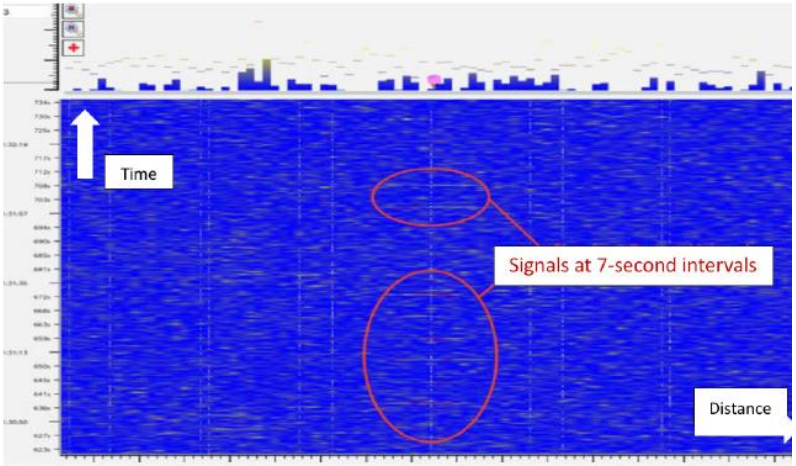


Asset integrity - Cables

SIMEC ATLANTIS ENERGY

- Seen as high risk by insurance underwriters
- Cables laid on exposed rocky seabed
- Considerable spanning
- Limited options for secondary protection, 4Te rock bags being the only current option
- Annual surveys and localised protection installed to prevent sliding
- Difficult to protect against spanning

- Actively looking to install a permanent DAS system to listen to a cable and report on movement, with aspirations to also report on cable strain



Faint signals identified in the DAS sound-field generated by 3kV flashover tests at 7-second intervals.

Courtesy of FOTECH

Asset integrity – turbines and foundations

SIMEC ATLANTIS ENERGY

- Annual visual surveys of the turbine support structures and turbines
  - Debris
  - Fouling
  - Cathodic protection
  - Entanglement

Current and future activities

SIMEC ATLANTIS ENERGY

- Continuing annual visual surveys and working to reach a position where cable risk can be self insured.
- Collecting operating data from the generating system (turbine to Grid) to develop a true foundation for robust asset management of a tidal array.
- Developing a better understanding of the tidal flow, turbulence across the site month on month, year on year.
- Conclude our work to normalise the turbine data and be informed by the 1st maintenance cycle in 2023.

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