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ReDAPT - MC6 & 7 – Turbine Deployments and Achievements in Operation

Jon Rhymes – Engineering Director

Overview – 1MW DeepGenIV Concept

Turbine

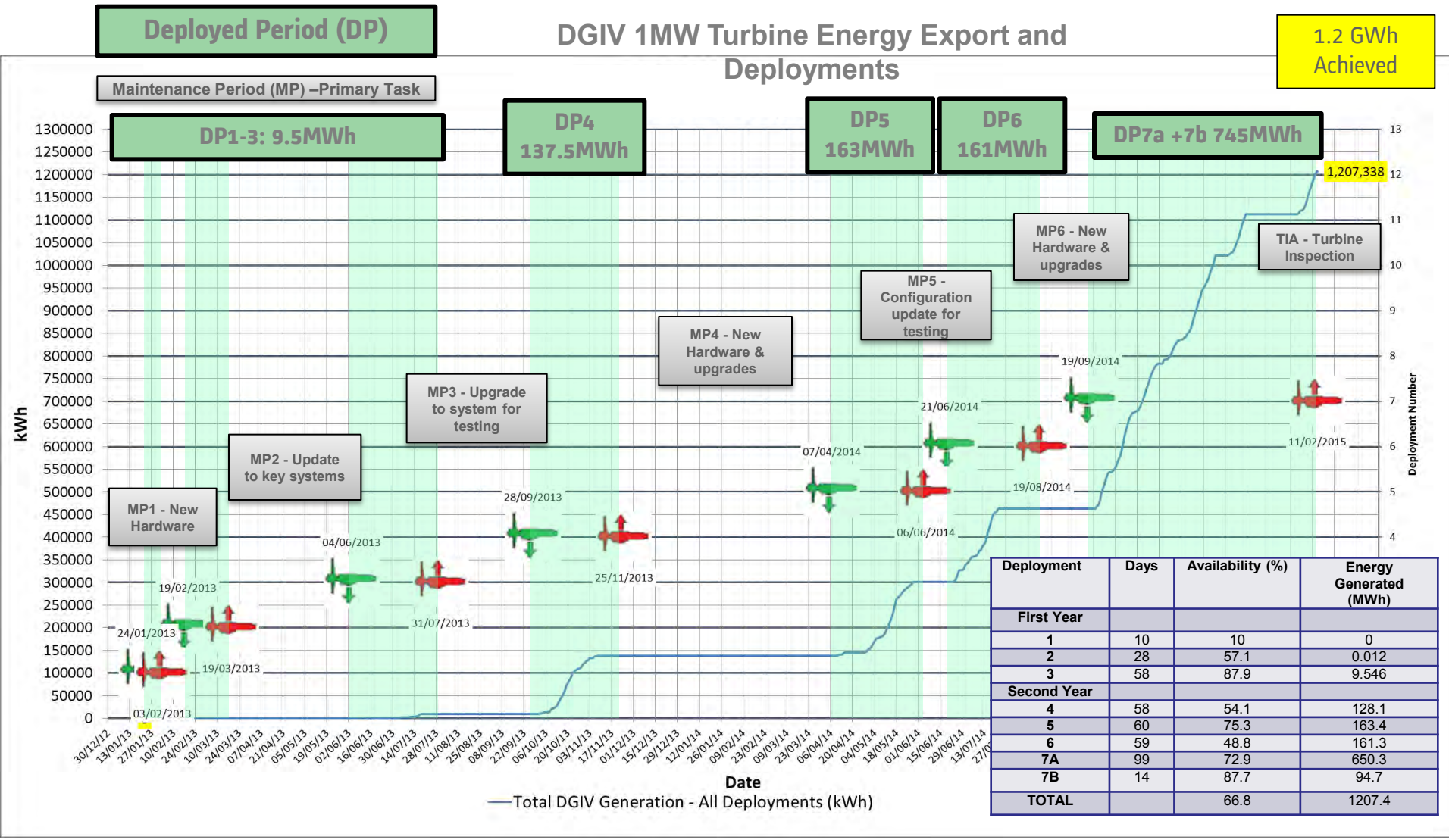
- Buoyant nacelle
- Deployed using a low cost vessel
- Deployed without requiring divers
- Variable pitch blades to control rotor speed, loads, and power
- 3 Position Clamp
  - Detachable from tripod for easy maintenance
  - Ability to yaw to any heading
- Provides grid compliant power at the end of the cable
- Maximum rated power achieved at 2.7m/s flow speed.

Foundation (Previously used by DGIII)

- Lightweight structure
- Installed using Dynamically Positioned (DP) vessels
- Attached to the seabed using piles
- Able to accept different sized turbines

ReDAPT

Turbine Generation Overview



Deployment	Days	Availability (%)	Energy Generated (MWh)
First Year			
1	10	10	0
2	28	57.1	0.012
3	58	87.9	9.546
Second Year			
4	58	54.1	128.1
5	60	75.3	163.4
6	59	48.8	161.3
7A	99	72.9	650.3
7B	14	87.7	94.7
TOTAL		66.8	1207.4

Deployment 7A: 19/09/2014 – 27/12/2014

Deployment Information	
Duration	99 days
Generating Hours	1262 hours
Energy Generated	650.3MWh
Availability	72.9%
Number of Tests Conducted	13

Key Testing

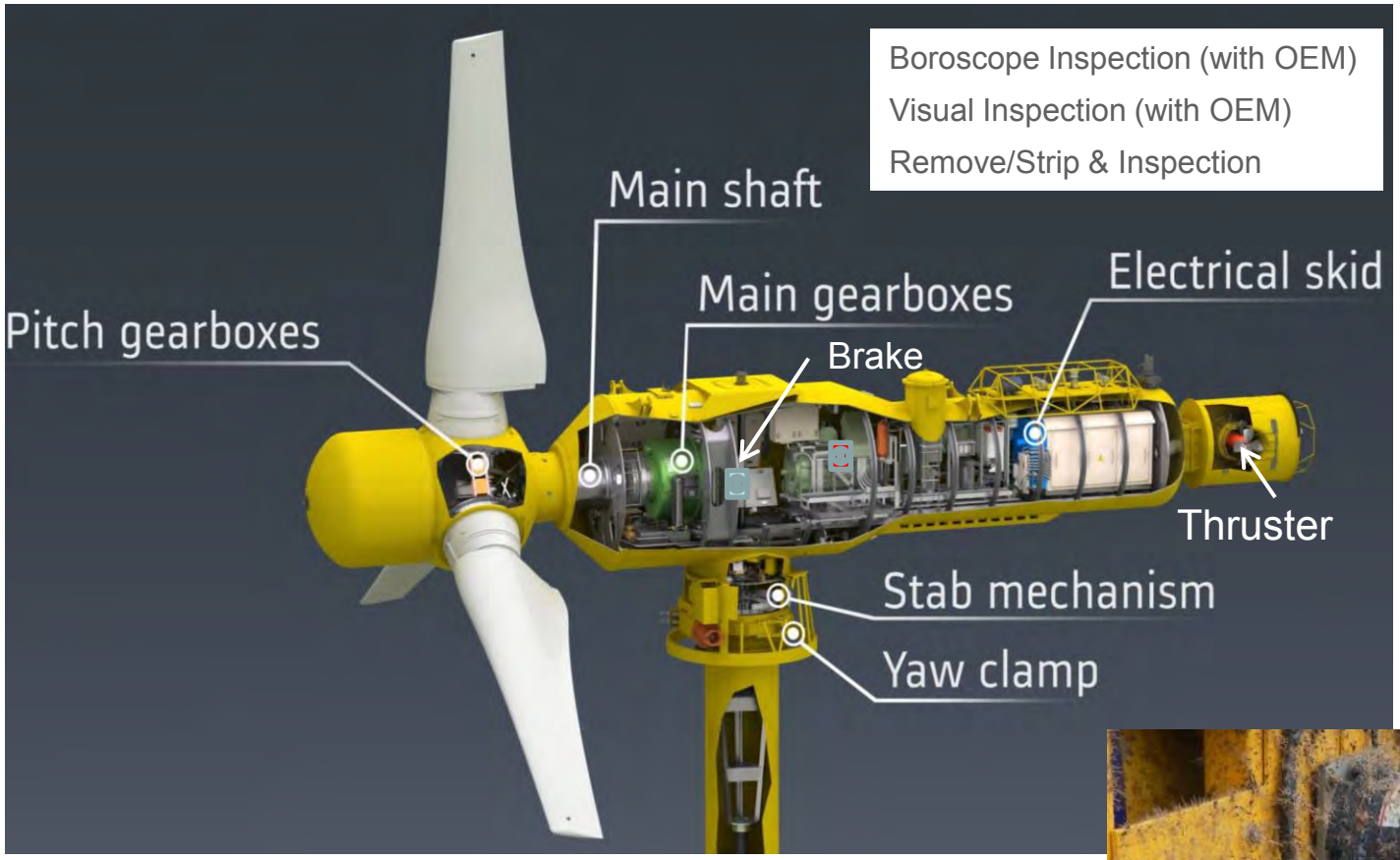
- Controller optimisation and Rotor testing to establish optimal performance
- Full IEC standard power curve
- Completion of all ReDAPT flow data gathering
- Noise survey –characterising acoustic signature of turbine

Marine Operations

- Contingency re-energisation operation:

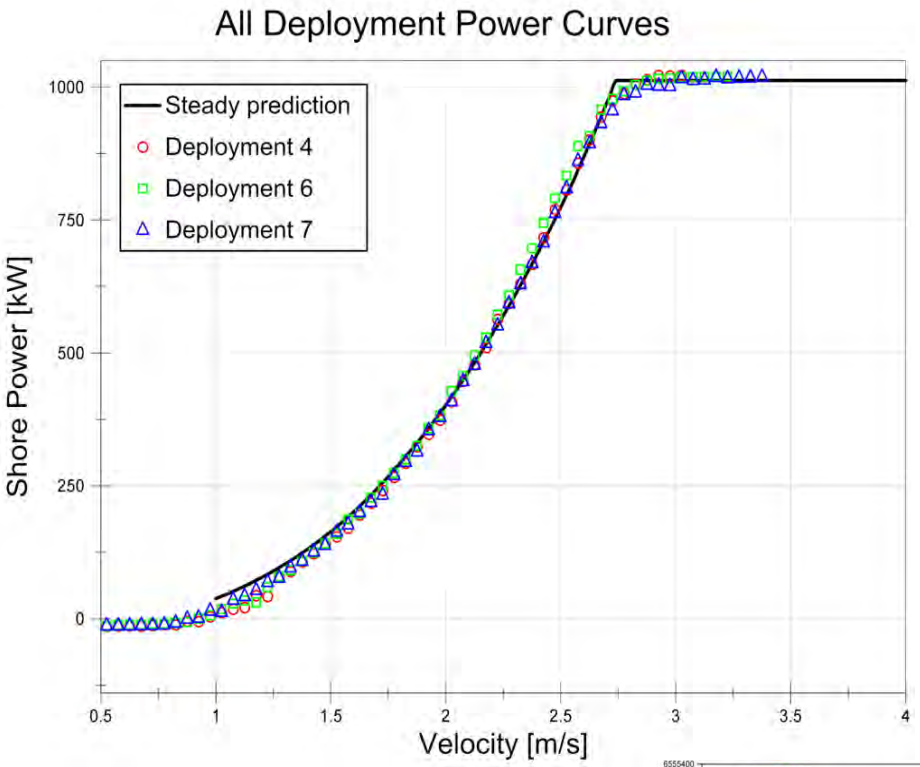
Following the communications loss the turbine could not be re-energised without the risk of damage to the frequency converter – vessel connection required to set the turbine up in a safe state for re-energisation.

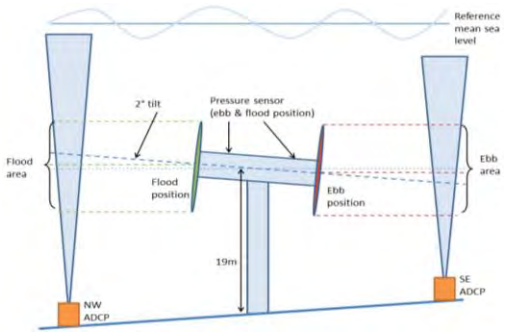
Turbine Strip – focus areas

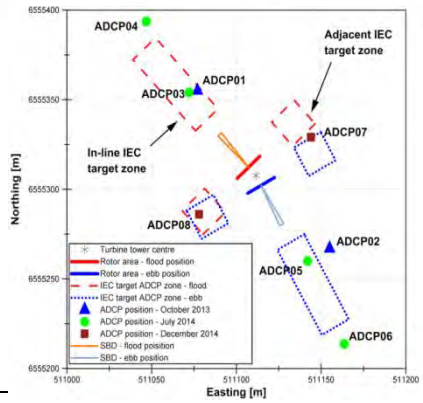


- The inspections resulted in no major unexpected findings, however some Biofouling was seen.
- Investigations yielded many valuable lessons learnt to carry forward to future turbine designs.

Turbine Performance







Overview

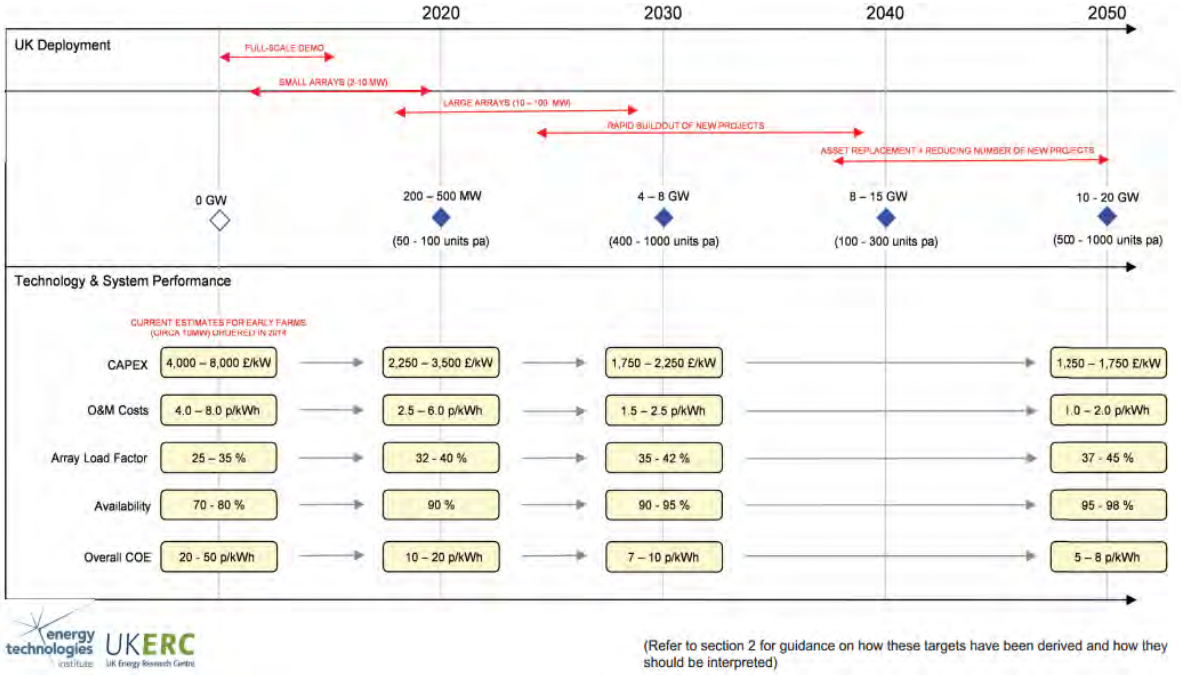
- Power curves measured and reported following methodology in IEC/TS 62600-200 during deployments 4, 6 and 7.
- ADCP position / orientation changed to investigate sensitivity to produced results.
- Full-deployment power curves (average of Flood and Ebb) shown in figure.

Lessons Learned

- Difficult to meet IEC/TS 62600-200 acceptance criteria. Specific TRN advised to measure power curve.
- Power curve impacted by other performance testing. Keep tests separate.
- Reference height of ADCP and turbine needs to be well understand to reduce uncertainties.
- ADCP siting and orientation is key to ensure accuracy of heading
- Care needs to be taken in the time synchronisation of the discrete datasets for analysis.

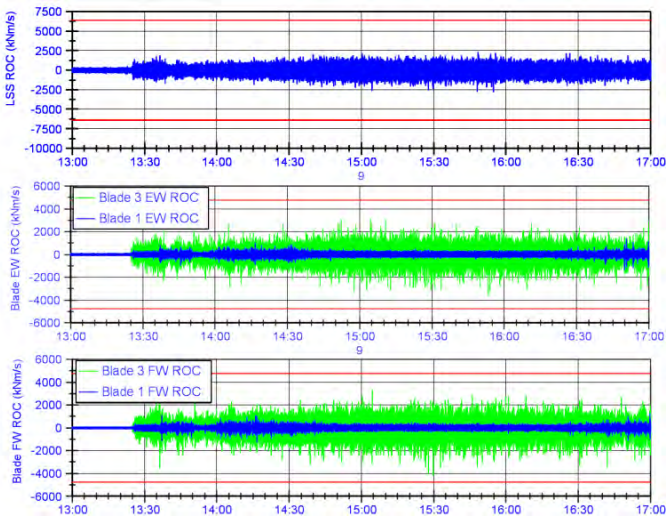
Cost of Electricity Modelling

- The measured performance of the DEEP-Gen IV turbine is in line with the predictions, adding confidence to the fact that given the site conditions yield for a single turbine (or even a small array) can be determined.



- Availability of DEEP-Gen IV is in line with ETI roadmap in latter deployments. Alstom are confident that the ETI roadmap target of 90% availability for first large arrays will be achievable.
- Challenges in terms of maintenance turn-around still remain.
- Studies agree that early small arrays still require significant capital support and/or risk mitigation support mechanisms. Once the sector has delivered several small arrays, the level of capital support can be reduced.

Environmental Interaction



Deck Plate Mounted Camera

- Very little success has been had with a deck plate mounted camera due to camera complexity and cable failure
- Further to this all cameras suffered with visibility in the turbid flow field

Acoustic Survey

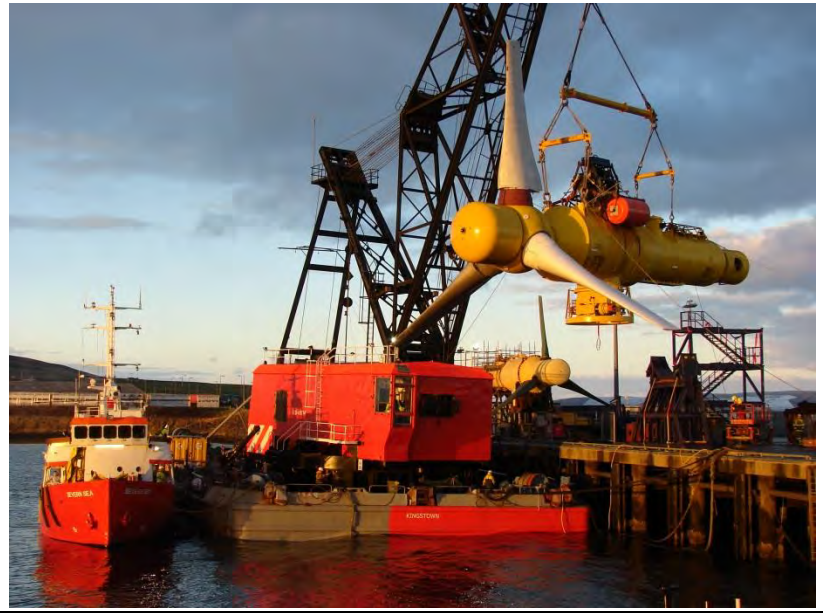
- Acoustic surveys began to characterise the noise associated with a tidal site and that associated with the turbine.
- The noise levels of the turbine were characterised at an appreciably low level when generating, idling and yawing.
- The frequency of the noise produced by the turbine was predominantly lower frequency noise <500Hz and there was little noise associated with high frequencies.
- It was also noted that the noise of the tidal flow passing through the site was quite significant.

Strain Gauge Monitoring

- In order to highlight potential marine life interactions the strain gauge data from the blades was analysed
- Thresholds were established and signals monitored that could be used to characterise an interaction
- Initial studies helped to identify brake events, shutdowns and signal losses, such that these could be quickly interpreted.
- No events representing a potential mammal interaction were observed.

ReDAPT Key Outcomes

- Product Design
  - Good validation of design process models including methods to interpret environmental data and predict loads
  - Tidal Bladed validation with site data and strain gauge measurements
- Design Verification and Rotational Testing
  - Importance of sub-system and software design/technology proving by rig test
- Deployment and Retrieval
  - Minimise the number of ROV operations and umbilical's in the water
  - Validation of deployment method, battery power margins and contingencies
  - Free ascent optimised
- Performance and Yield
  - Power curve and yield as expected
  - Grid compliant power quality
- Turbine Control
  - Importance of sub-system and software validation
  - Pitch control optimised
  - Power, Torque, Speed control Validation
  - Yaw and clamp performance optimised
  - Safety system and contingencies



Further Information on ReDAPT

- ETI Website contains links to the Public Domain Reports

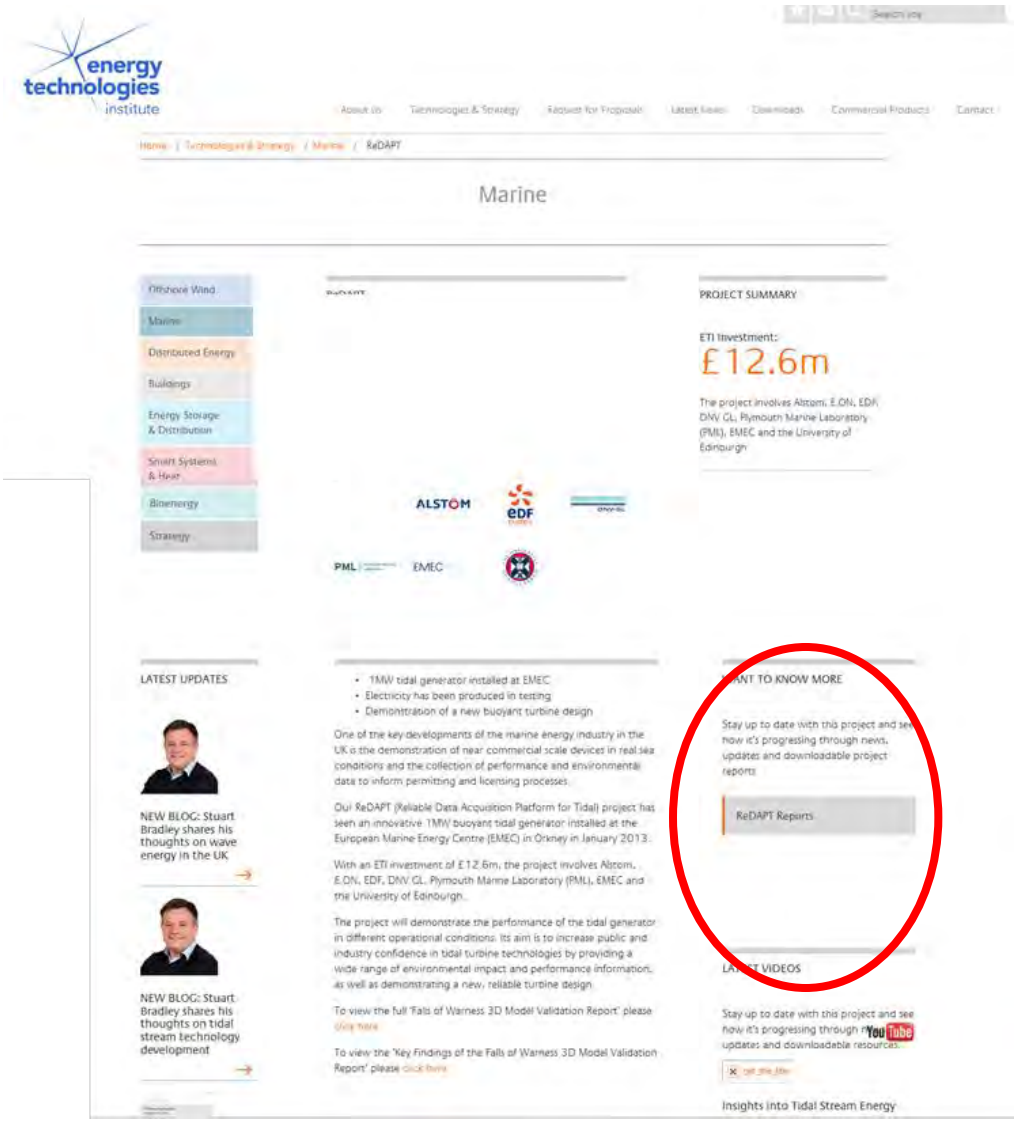
http://www.eti.co.uk/project/redapt/

- UKERC – Energy Data Centre (EDC) database for ADCP measured flow data

http://data.ukedc.rl.ac.uk/browse/edc/renewables/marine

- Alstom – Paul Chesman – ReDAPT Programme Manager

Paul.chesman@alstom.com



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