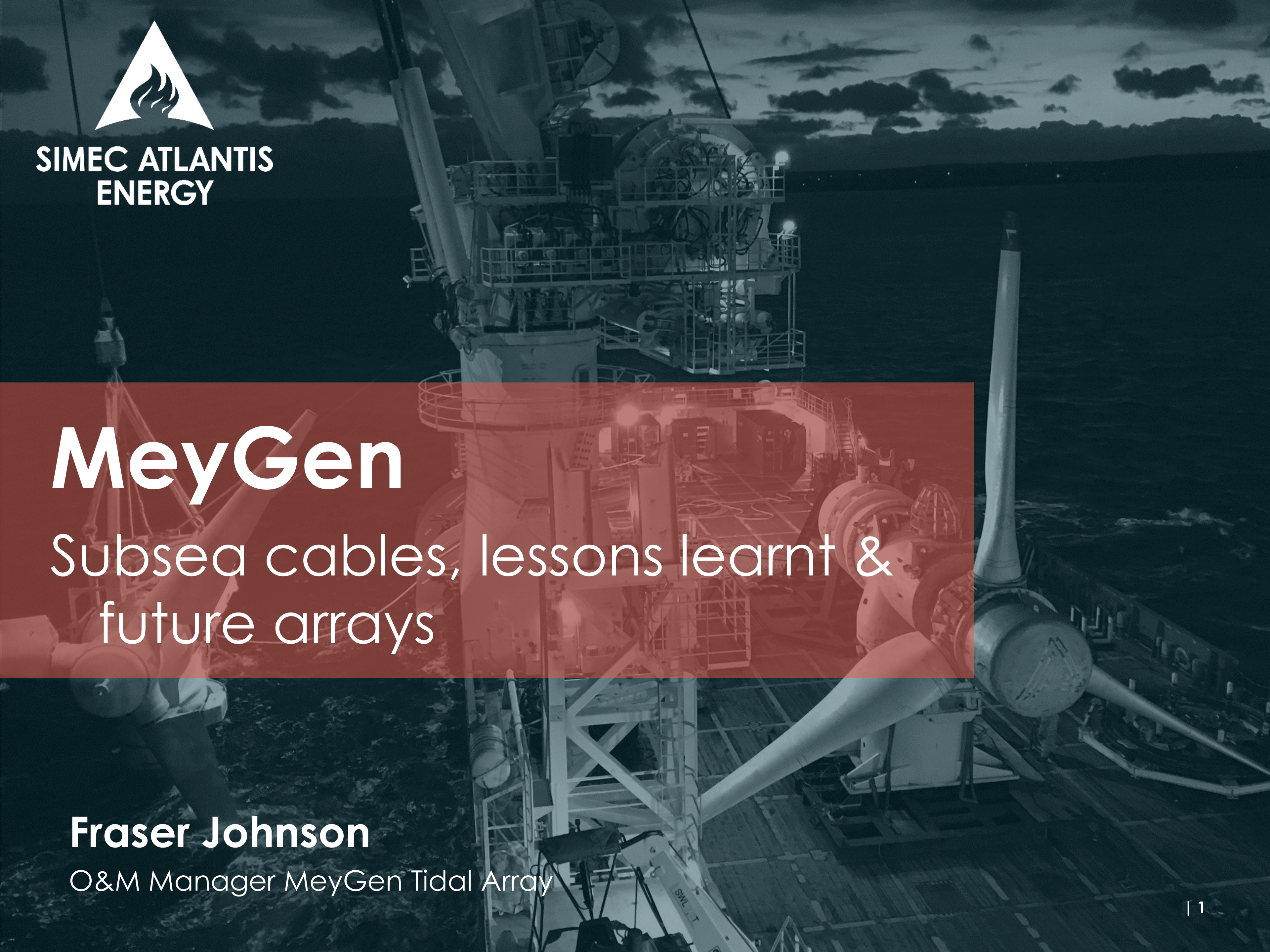

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MeyGen

Subsea cables, lessons learnt & future arrays

Fraser Johnson

O&M Manager MeyGen Tidal Array

£51M PROJECT FINANCING OF THE FIRST PHASE OF THE WORLD'S LARGEST TIDAL POWER PROJECT, MEYGEN

ATLANTIS RESOURCES

MEYGEN PHASE 1A CLOSED

WHAT AN INCREDIBLE ACHIEVEMENT!

WE WOULD LIKE TO THANK ALL OF OUR PARTNERS,
WITHOUT YOU, THIS WOULD NOT HAVE BEEN POSSIBLE

We're bringing the world tidal power energy today,
follow our journey at atlantisresourcesltd.com.

MEYGEN
THE TIDE OF CHANGE IN CAITHNESS

Inner Sound of the Pentland Firth

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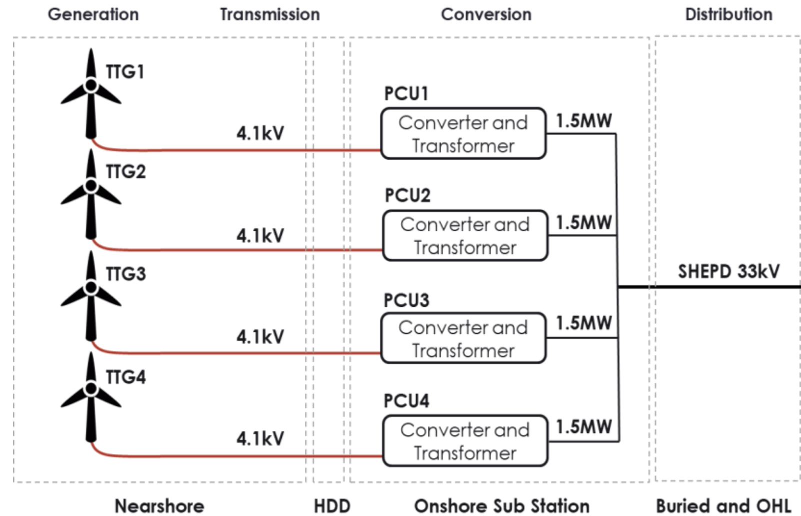

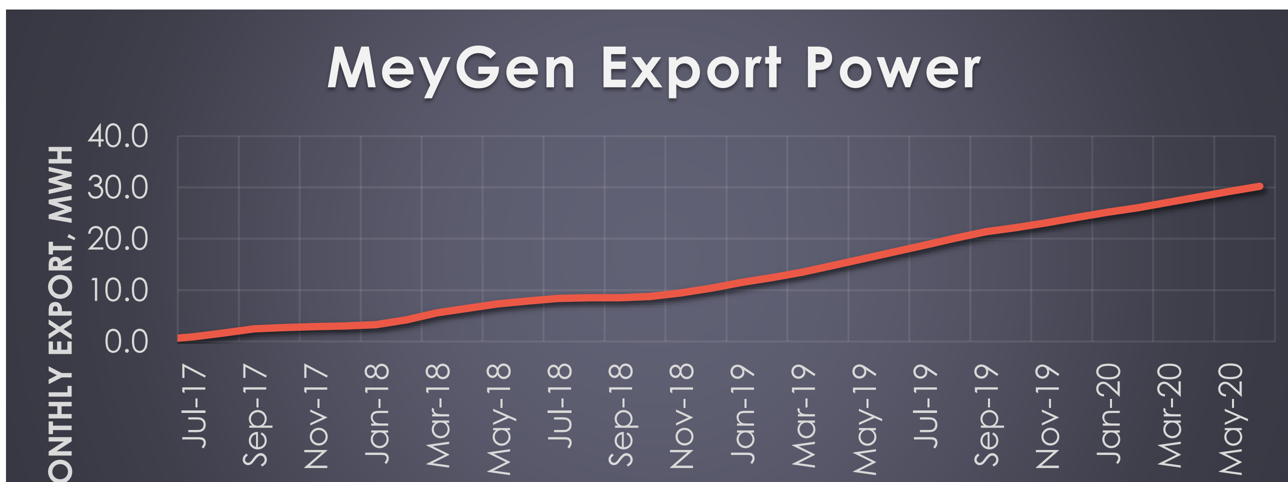

Project Milestones

----- **Licences and Consent** ----- **Finance & contracts** ------------ **Construction** ------------ **O&M** ---

October 2010
Crown Estate Agreement Lease

July 2012
Section 36 Consent and Marine Licence applications

September 2013
Section 36 consent granted

January 2014
Marine Licence granted by Marine Scotland

July 2014
Generator's Licence issued by Ofgem

August 2014
Funding conditions satisfied

September 2014
Construction contracts concluded

January 2015
Onshore construction commenced

July 2015
4 x HDD bore complete

October 2015
Export cables installed

May 2016
AR1500 FAT on Nautilus test bed at OREC

June 2016
SHEPD energise 14.8km 33kV grid connection

October 2016
Turbine support structures installed

November 2016
Turbine offshore installation works begin

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

MEYGEN
THE TIDE OF CHANGE IN CAITHNESS

1st of Class and beyond

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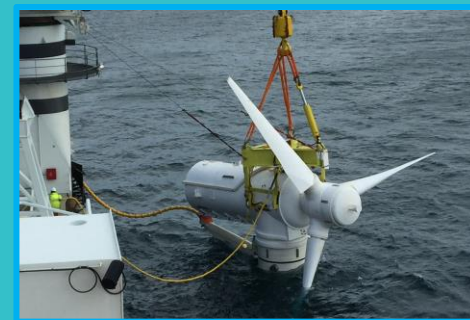
MeyGen turbines

ANDRITZ Hydro Hammerfest

HS300

HS1000

MK1 – 1.5MW



MK2 – #MW

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A400

AR1000

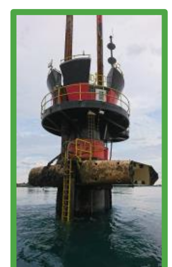
AR1500 / AR1700

AR2000 - AR3500

Marine Current Turbines

SeaFlow 300

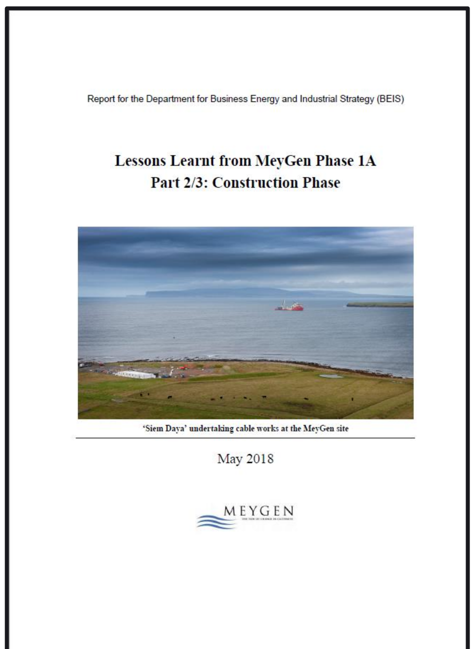
SeaGen 1.2MW

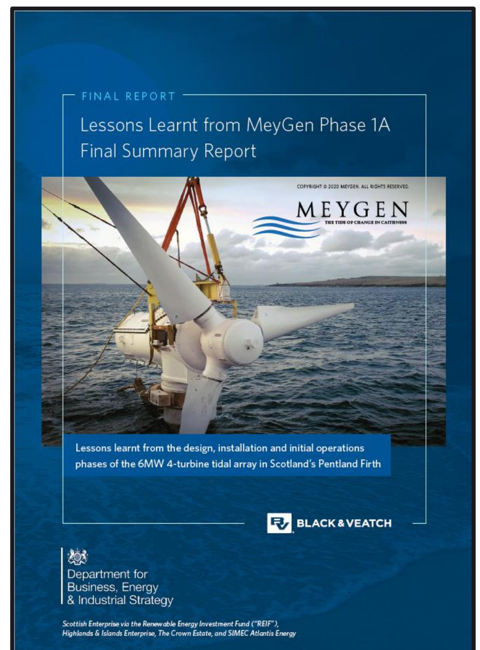


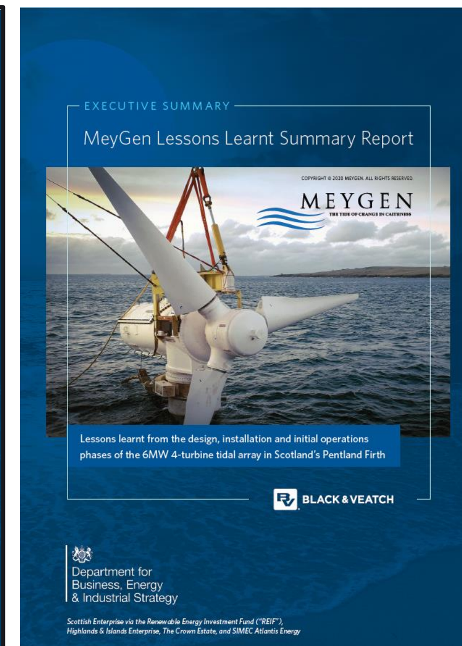
Lessons Learnt by the worlds 1st tidal array

- Knowledge sharing is a key aspect of DECC's funding into MeyGen Phase 1A
- Provide an overview of technical lessons learned on the MeyGen project
- Assist the whole industry be more successful in project development:
  - Improve understanding of and thereby reduce technical challenges/risks
  - Improve financial viability
- Inform future technology innovation needs

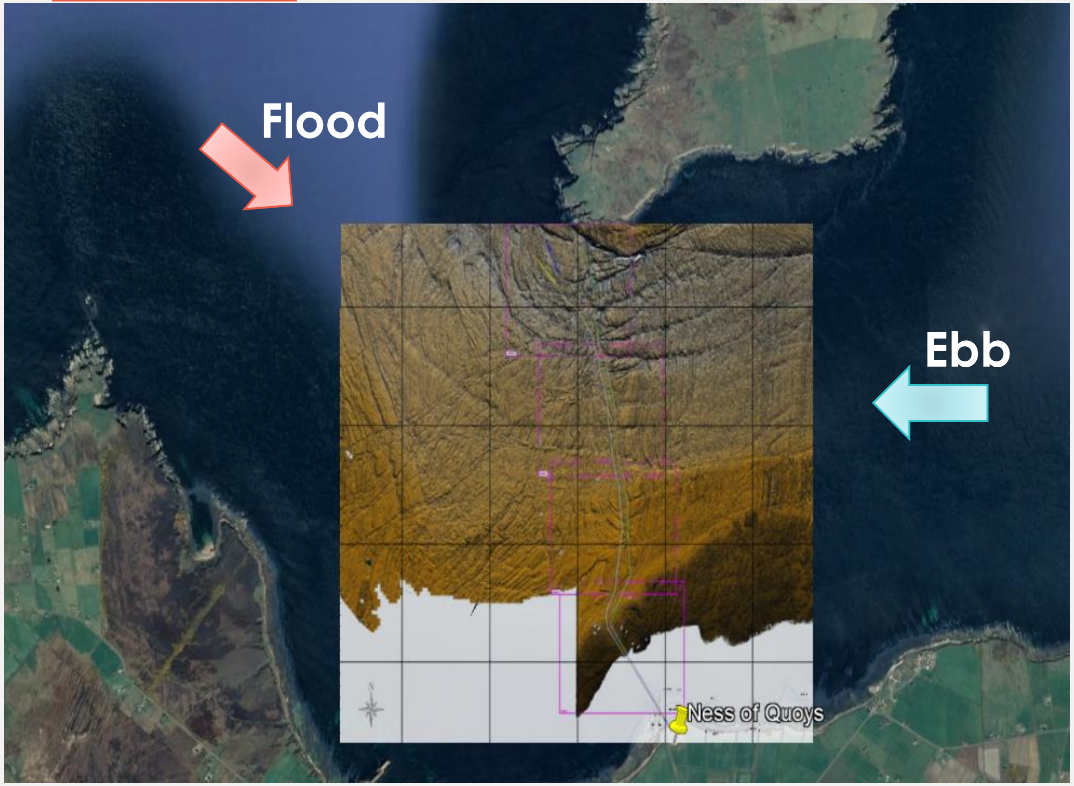
Documents can be downloaded using the links embedded in the images below.





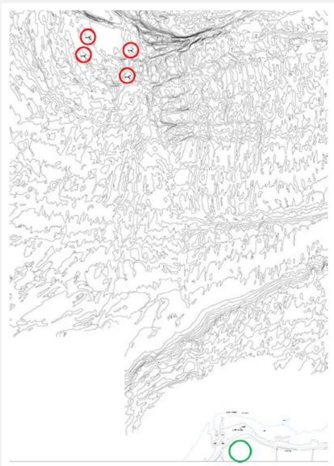


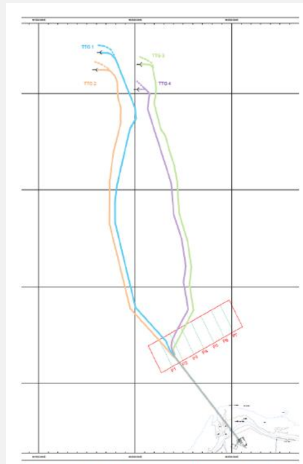
Cable installation

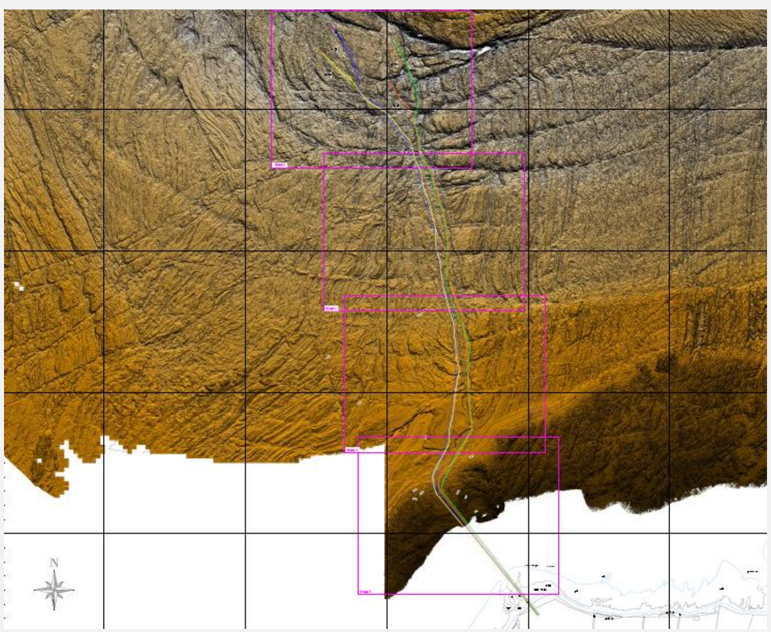


- Cable route selection
- Cable stability:
  - **Displacement**
  - **Local sway**
- Cable installation
- Cable design

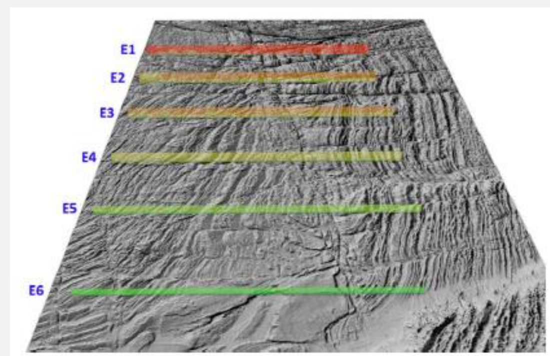
Cable route selection & stability

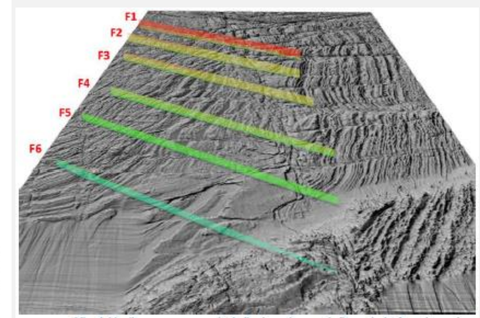


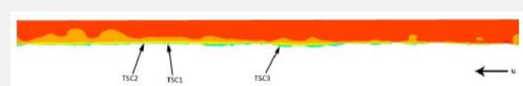


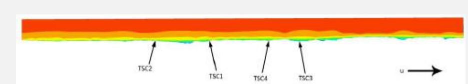


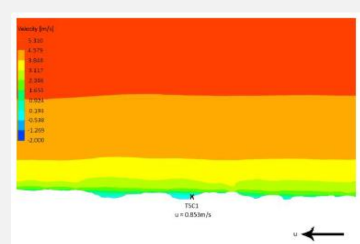
- CFD analysis to estimate lift and drag coefficients using site bathymetry and flow data
- Provided detailed assessment, but of a limited number of locations
- Unable to take account of seabed features that have been shown to provide cable stability

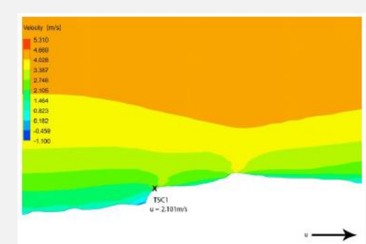








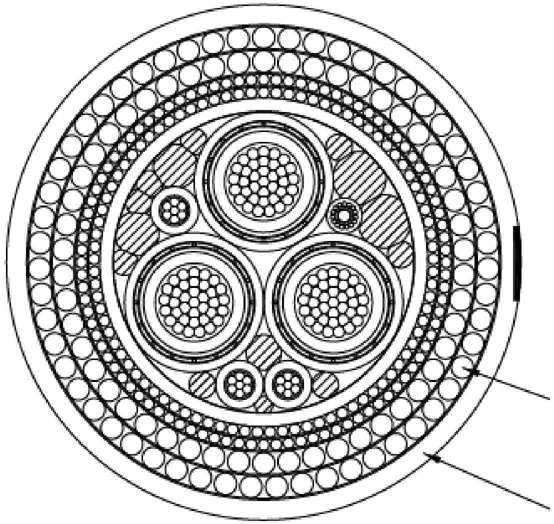




Cable stability measures

Method	Suitability	Comments
Rock dumping	No	Transported by current & waves
Concrete mattresses	No	Transported by current & waves
Chain or cable laid in parallel	No	Additional cost, vessel mob and
Continuous rock bags	No	Substantial material & handling costs
Hydrodynamic features	No	Does assist but additional measures necessary
Fastening to seabed	No	Diver/ROV use limited to near shore
"crowbar" roll prevention	No	Technical risk therefore development work required
Attachments such as 'uraduct'	Yes	possibly for some regions, testing cost
Periodic rock bags / weight	Yes	possibly for some regions
Clamshells/articulated pipe	Yes	Near shore region, post lay due to limited install speed
Cable bundling	Yes	Increases weight
Hairy Cable	Yes	Reduces likelihood VIV inception
Armouring	Yes	Increased armouring increases TSC mass

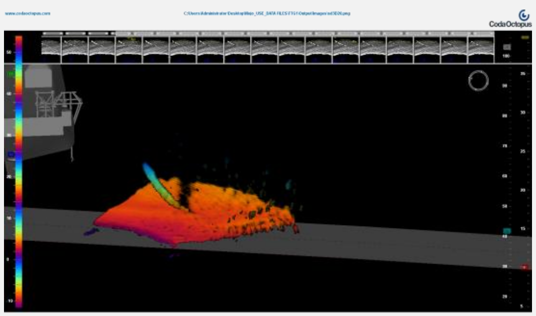
- Make it heavy, high mass / meter
  - 116mm diameter
  - Quad armour
  - 25kg/m



- Handling becomes difficult with cable protection required to prevent exceeding MBR under own weight

MEYGEN
THE TIDE OF CHANGE IN CAITHNESS

Cable installation



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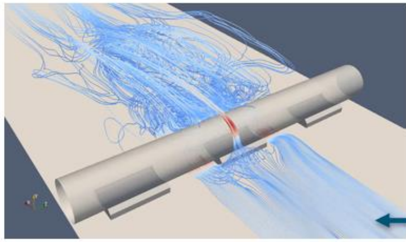
- Accurate placement of cables to maximise protection afforded by natural features
- An attempt was made to use CodaOctopus to monitor cable touchdown.
- The system worked flawlessly under extremely hard conditions, but it is not suitable for use on rocky seabed.
- Better route planning, turning bollards and gates using rock bags / USBL targets
- Real time touchdown monitoring - CableFish

UWA cable stability research



UWA's research fills the knowledge gaps in cable behavior on rocky seabeds

Account for nearbed flow | Seabed features affect flow around cable.

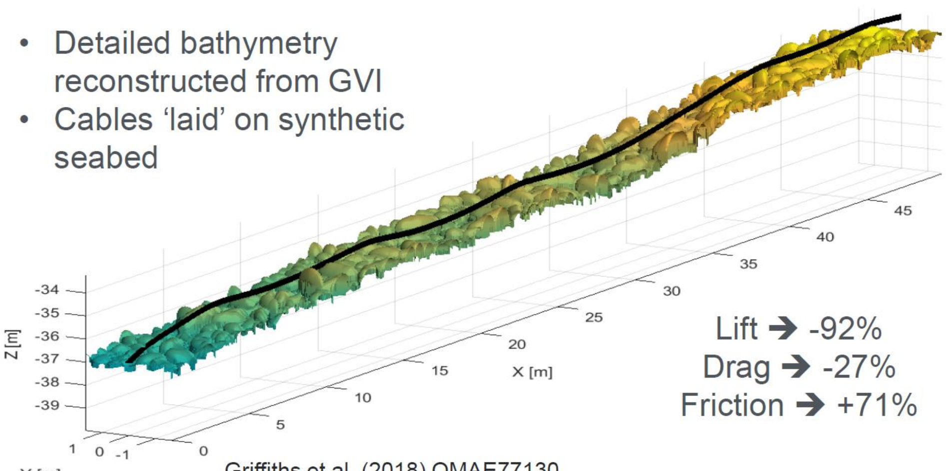
Account for gappiness | Hydrodynamic force reduction due to gap flow.

Account for lateral resistance | Rotation of hydrodynamic forces and mechanical interlocking increase lateral resistance to movement.

Can be applied within EXISTING clauses of DNV-RP-F109.

Evidence 3: Field corroboration: Meygen

- Detailed bathymetry reconstructed from GVI
- Cables 'laid' on synthetic seabed



Lift ➔ -92%
Drag ➔ -27%
Friction ➔ +71%

Griffiths et al. (2018) OMAE77130

Proceedings of the 38th International Conference on Ocean, Offshore & Arctic Engineering
OMAE2019
June 9-14, 2019, Glasgow, Scotland

OMAE2019-95557

HYDRODYNAMIC FORCES ON NEAR-BED SMALL DIAMETER CABLES AND PIPELINES IN CURRENTS, WAVES AND COMBINED FLOW

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Crawley, WA, Australia

ABSTRACT

The on-bottom stability design of subsea pipelines and cables is important to ensure safety and reliability but can be challenging to achieve, particularly for renewable energy projects which are preferentially located in high energy metocean environments. Often these conditions lead to the seabed being stripped of all loose sediment, leaving the cables to rest on exposed bedrock where roughness features can be similar in size to the cables. As offshore renewable energy projects progress from concept demonstration to commercial-scale developments, new approaches are needed to capture the relevant physics for small diameter cables on rocky seabeds to reduce the costs and risks of export power transmission and increase operational reliability. These same considerations also apply to the cables and small diameter pipes – such as umbilicals – required by oil and gas projects located on rocky seabeds.

Recent experimental testing using the University of Western Australia's unique Large O-tube has enabled the experimental measurement of hydrodynamic forces on small diameter cables and pipes in proximity to smooth and rough beds. The tested conditions extend well beyond the existing published parameter range including much higher KC conditions together with seabed roughness which is comparable in size to the diameter. The results provide design data of great relevance to the ongoing development of marine renewable and conventional oil and gas projects, especially on rocky seabeds. This paper presents a summary of the existing knowledge on the subject as a preface to preliminary test results and gives tentative conclusions on the likely outcomes from this work.

BACKGROUND

On-bottom stability of pipelines and cables

In this work, the term 'pipe' is henceforth used to refer to all kinds of subsea pipelines, cables and umbilicals unless specifically stated otherwise.

The state of the art in pipe on-bottom stability design has been comprehensively described by Zeitoun et al. (2008) [1], with an updated summary of the research contributions made over the last decade in this field provided recently by Griffiths et al. (2018) [2]. These capstone papers point to a broad body of expertise and industry understanding gained from the use of existing recommended practices in design, such as the commonly-used DNVGL-RP-F109 [3].

For hard or rocky seabeds, recent studies have investigated the tripartite interaction between fluid flow, geotechnical pipe-seabed interaction and pipe structural response. These interactions occur at temporal and length-scales that inhibit segregation of geotechnical, hydrodynamic and structural response aspects. For example, where a pipe spans over rocky outcrops, there are correlations between the along-pipe variation in lift and drag – which depends on whether the pipe is in span or touching down – and the locations of support and seabed resistance – which relies on contact with the seabed.

A recent contribution has been the evaluation of the increased lateral resistance due to the seabed ruggedness by Griffiths et al. (2018a) [4]. This effect enabled accurate back-analysis of field-observations which confirmed the stability of the Phase 1a cables installed by MeyGen for their tidal stream energy project in the Pentland Firth (Griffiths et al, 2018b) [5].

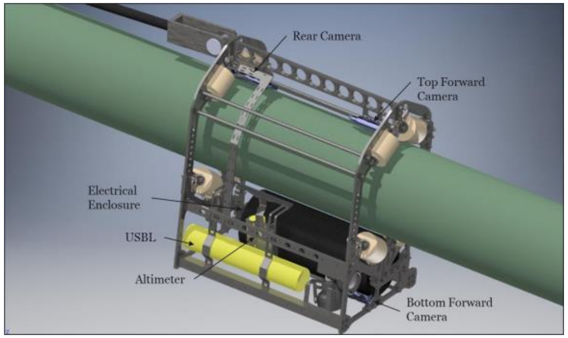
1

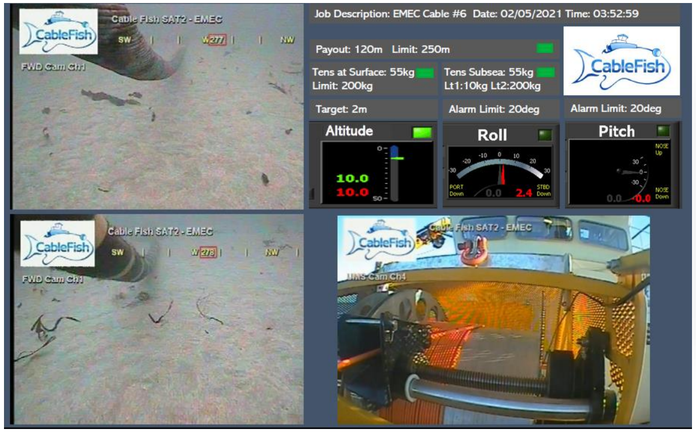
Supply chain opportunity

- A cable route that utilises the seabed bathymetry to hide the cable in the seabed
- An industry standard and assessment method that is representational of the installation environment
- A marine contractor who can install cables in a high tidal flow to 0.5m accuracy
- A means of monitoring the cable touchdown position
- Cable installation software that can be provided an external flow data, possibly from another vessel to aid route planning during the installation

The more we can do to protect the cable at installation using the natural features:

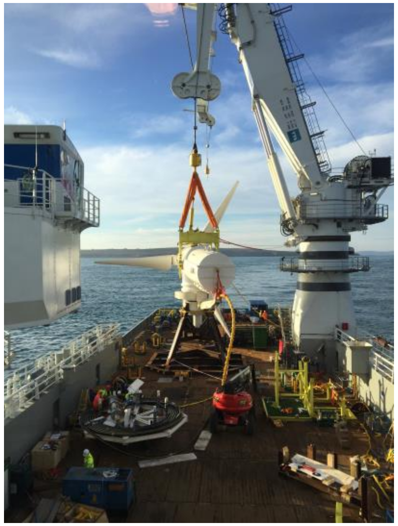
- ➢ the lower like hood of needing to install additional stability measures,
- ➢ a lower requirement to conduct annual inspections of the cables
- ➢ the potential of a lower premium for asset and business interruption insurance





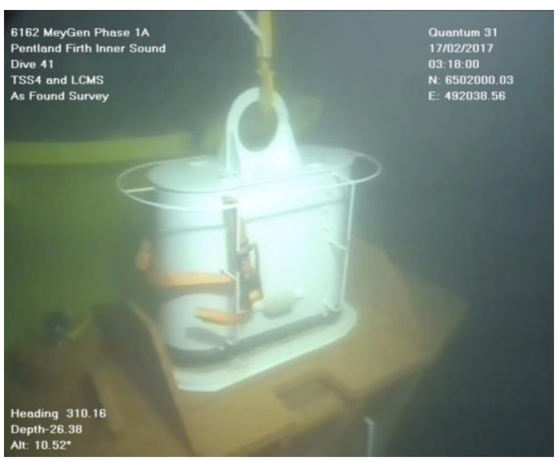
Cable connectors – Dry-mate

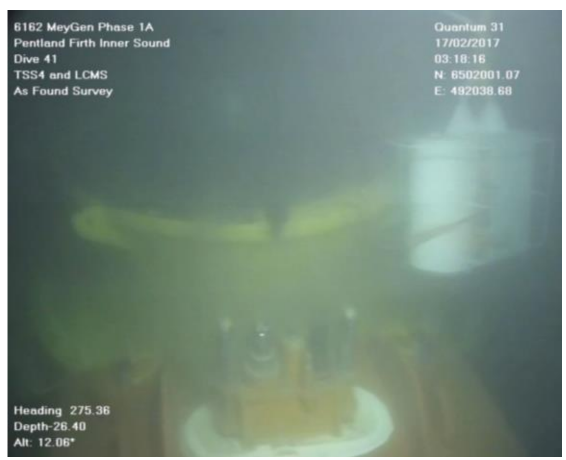
- Dry-mate connector seen as a cheaper option to wet-mates
- CAPEX may be seen to be cheaper, but the cost of the marine works is estimated to be >£3.5m more than that for a wet-mate connection system over a 25 year life of a turbine.
- Limits marine works to neap tides, ~80 days per annum
- Restricts operators ability to play the vessel spot market
- Requires cable handling which is a risk to assets and marine crew

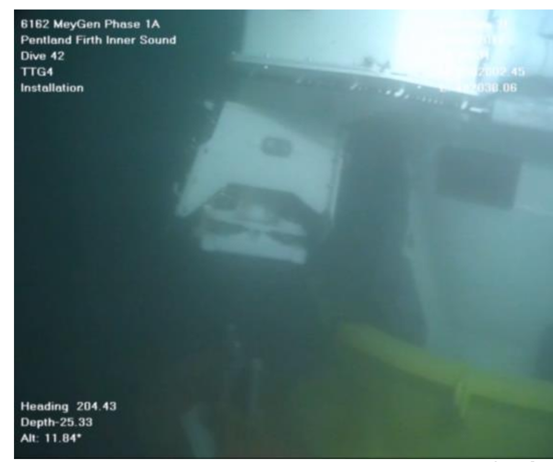


Cable connectors - Wet-mate

- Fit and Forget, cable laid to the seabed and left in place for the life of the project.
- Use of off the shelf wet-mates from Gisma, Siemen and Seacon
- An industry common connector is not required, what we need is a MK2 design:
  - A connector rated at 500 mattings not 100
  - A better understanding of the system failures due to speed of connection
  - A plug with an automatic cover to prevent the ingress of dirt while not connected
  - A unit for 50m not 3000m
  - A connection system that can be repaired in 12 hours in a container workshop not have to be returned to the factory taking 6 to 10 weeks

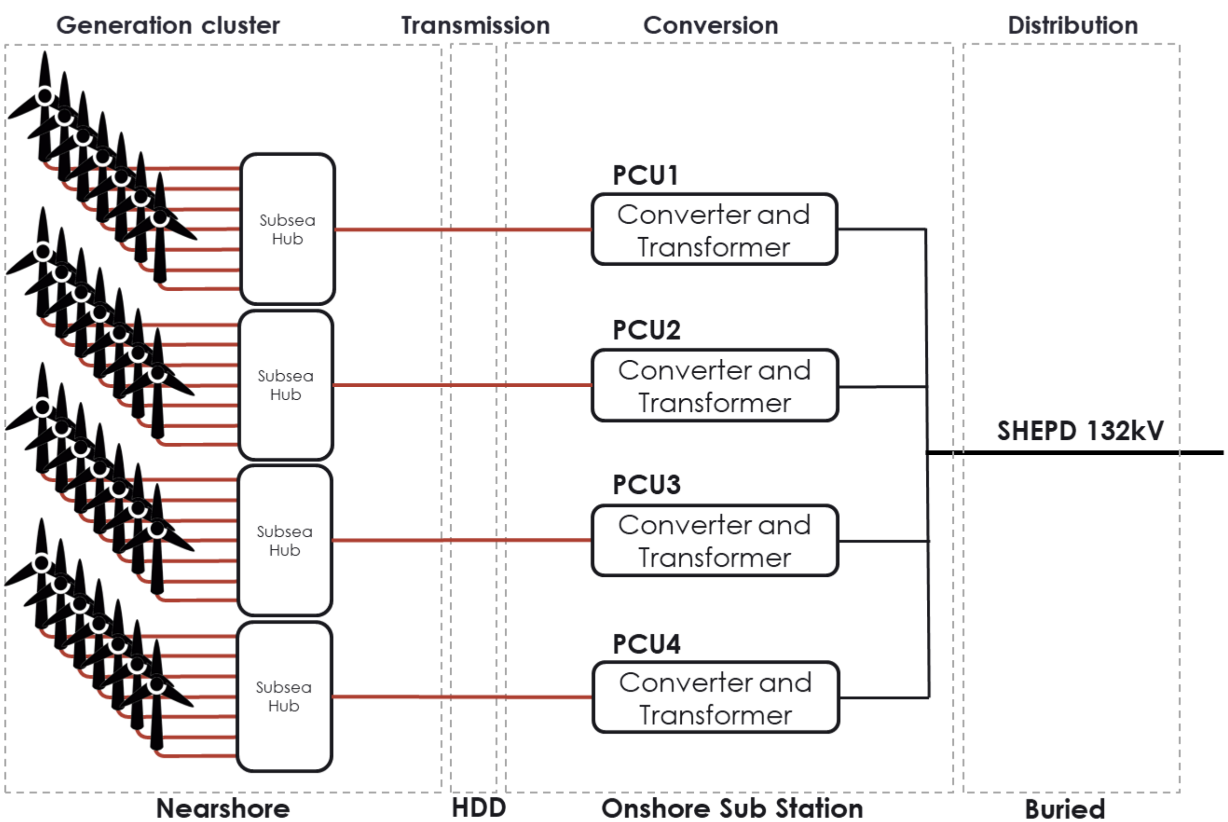






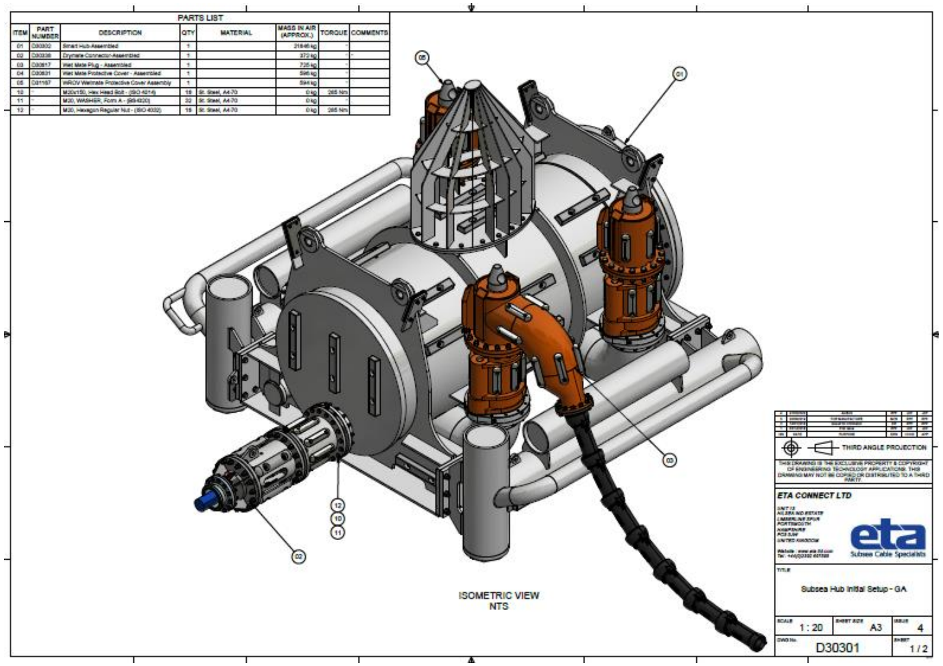
Beyond Phase 1A

- Larger diameter rotors to increase the swept area and extract more energy ~26m
- Larger installed capacity ~3.5MW
- Reduce the number of systems
- Active turbine control systems to manage rotor speed at higher flows and in larger waves. Maximise yield while preventing overspeed and managing fatigue life



Subsea hub connecting multiple turbines

- Modular design:
  - Switch gear
  - Transformer
  - Dry-mate connection to export cable
  - Wet-mate connection to turbines
  - Bespoke intervention tool to install and remove wet-mate connectors
- Demonstration unit to be installed at MeyGen Q3 2020.



Global market potential

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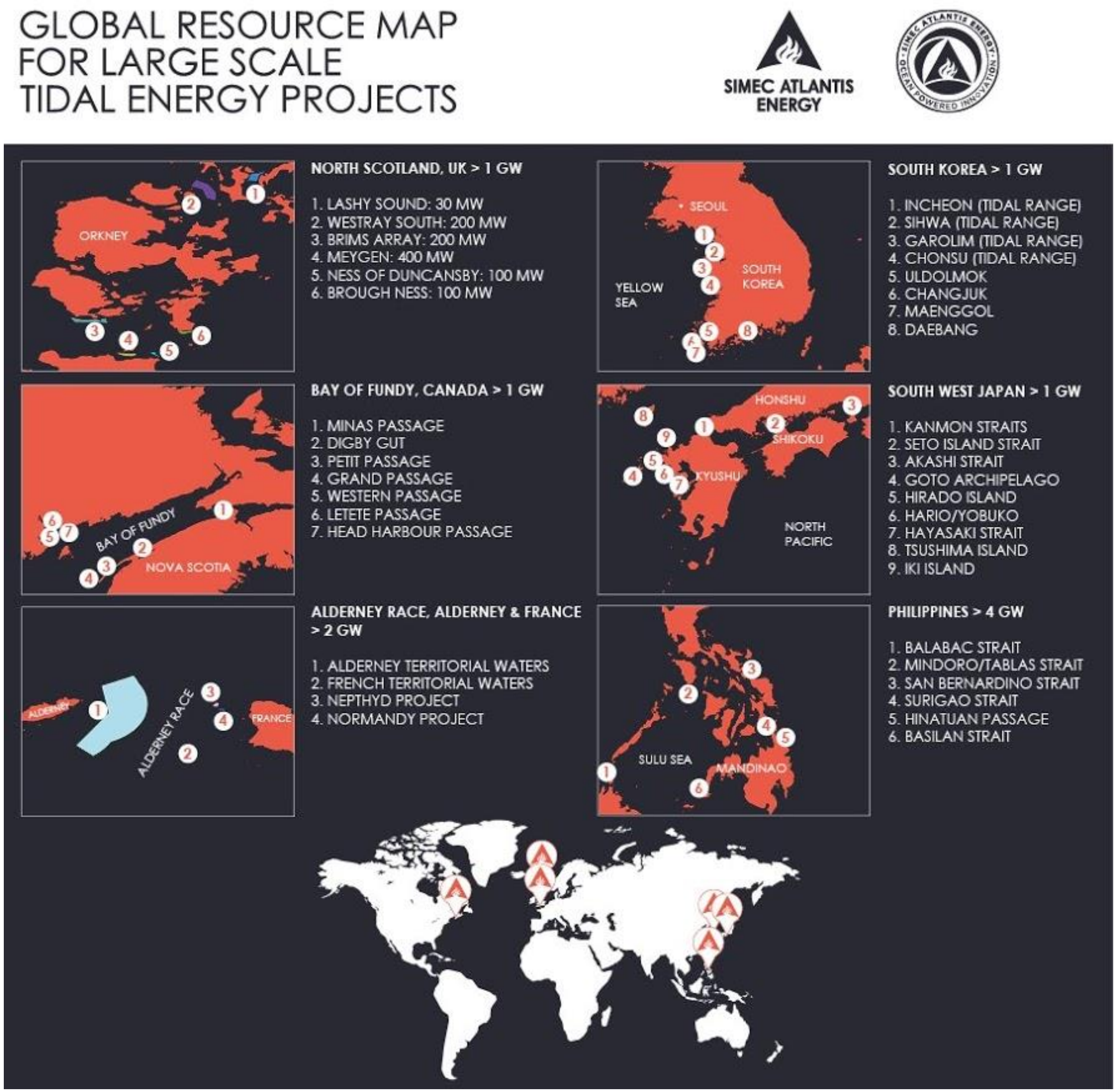
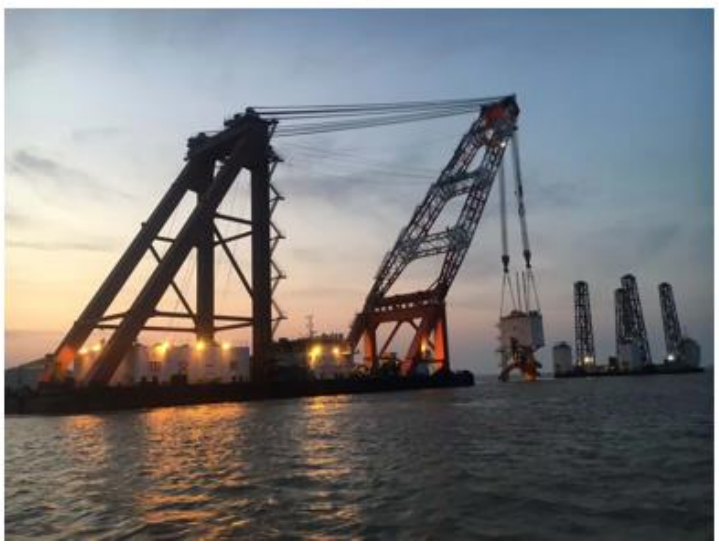


SAE – Past and current suppler activities

Wuhan China, April 2020

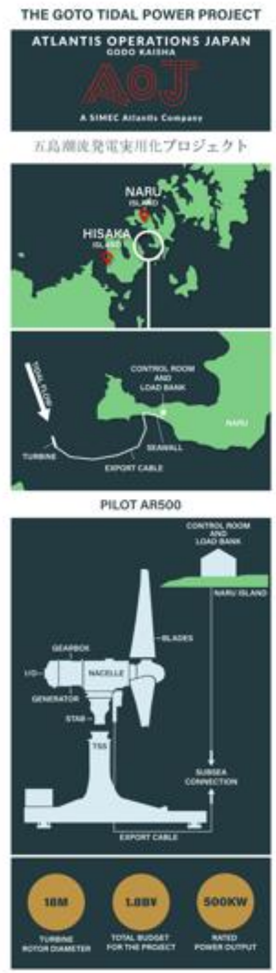
SG500kW
Installed 2020

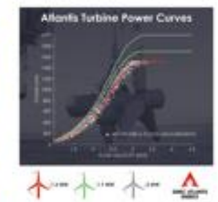
SF300kW
Installed - 2003

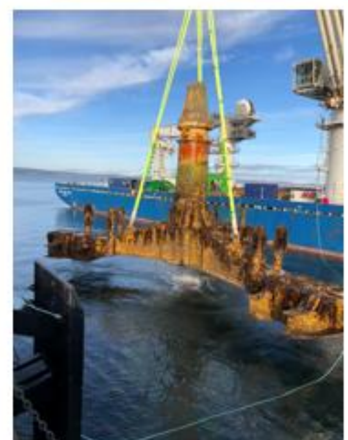


Goto Japan, Q4 2020

500kW demonstrator







https://simecatlantis.com/2020/04/27/overcoming-the-pandemic-to-build-a-mammoth-turbine-in-wuhan/

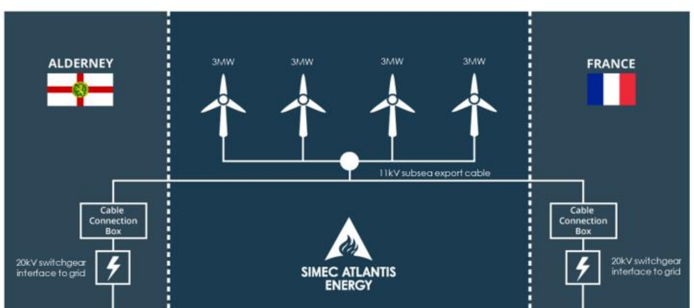
Normandy Hydroliennes - Raz Blanchard

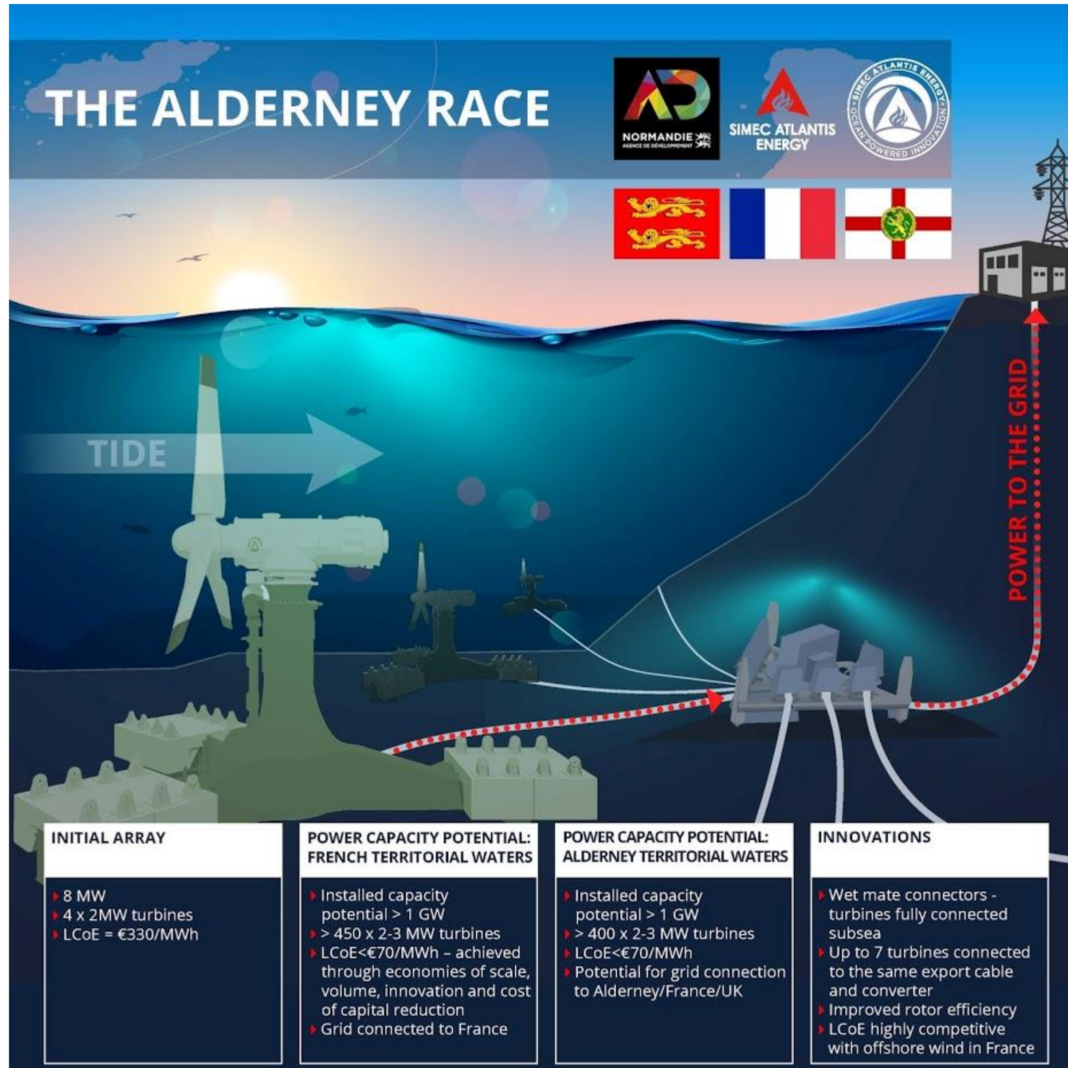
NORMANDIE HYDROLIENNES

- Tidal demonstration project
  - 12MW capacity, at grid connection point
  - 4 x 3MW turbines
  - Monopile foundation
  - 4 collector cables, 1 subsea hub and export cable
  - 7km subsea cable

Project programme

- 2020 - 22 Project design and consent
- 2022 / 23 Financial close
- 2024/ 25 Project construction





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