Tidal Energy Converter System Demonstrator

demonstrating that tidal energy can be cost competitive with offshore wind and other low-carbon energy technologies

by Andrew Baldock & Daniel Matson

Many competing tidal energy technologies exist. Great Britain, and its principal islands, has a coastline of about 19,491 miles. Numerous studies have demonstrated that the country has a globally significant tidal energy potential. Harnessing this natural resource and making it cost effective, and therefore attractive to investors, is the challenge. The Energy Technologies Institute commissioned and funded the Tidal Energy Converter System Demonstrator project to establish the pathway to an *'optimised low cost architecture'* which will deliver long-term commercial viability, i.e. that the generation of tidal energy can be cost competitive with offshore wind and other low-carbon energy technologies.

An example of a full-scale horizontal axis tidal turbine prototype - Courtesy of Atlantis Resources Corporation

Background

The aim of the Energy Technologies Institute (ETI) commissioned and funded Tidal Energy Converter System Demonstrator, commonly known as the Tidal Energy Converter (TEC) project, is to establish the route to a long-term commercially viable cost of energy from tidal current technologies. The project is specifically focussed on array scale deployment. Cost of energy is a measure of the average cost over the lifetime of the plant of generating a unit of electricity.

The TEC project is one of a suite of projects in the ETI Marine Energy Programme (MEP). Overall, the programme aims to help engender the investor confidence necessary to accelerate the UK's use of marine energy technology. It is intended to achieve this by addressing key technology and commercial challenges through a combination of resource and design tool developments and technology demonstrators.

Collectively these projects, together with the ETI's work alongside government and academia, is helping to support the acceleration of the industry to enable marine to be an active part of a future energy mix.

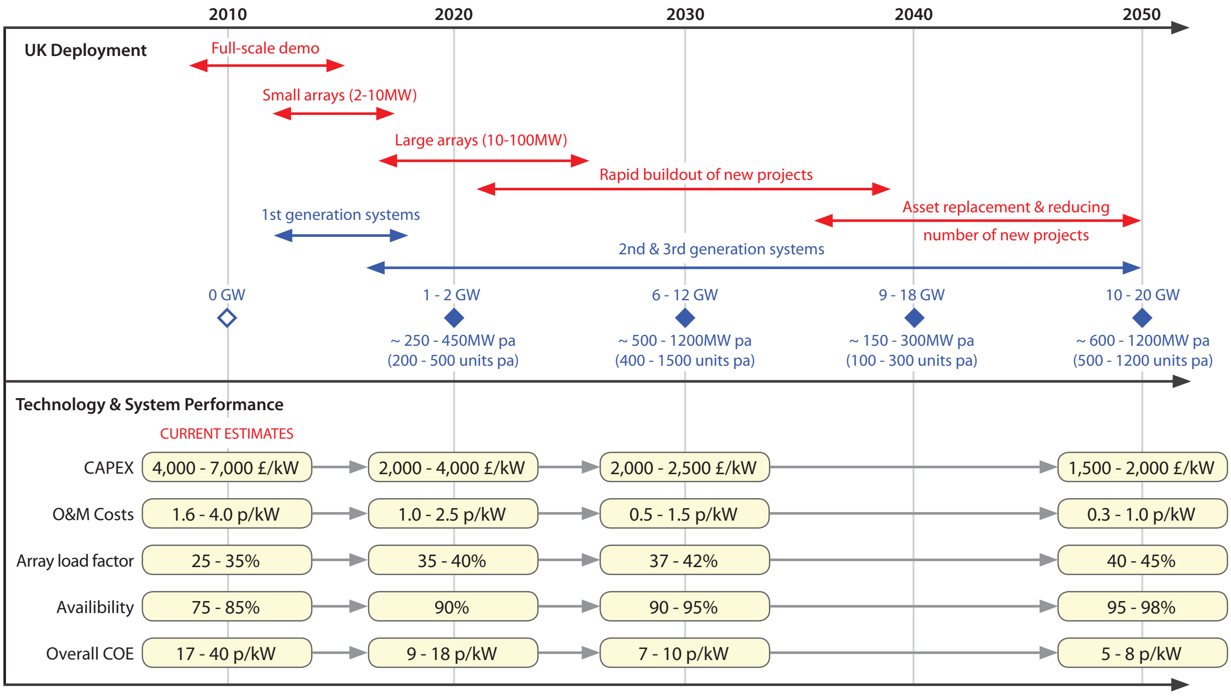
In summary, the MEP aims to accelerate the development and deployment of commercially viable marine energy technologies that will:

- Make a material contribution to the future UK energy system.
- Deliver significant greenhouse gas emissions reductions in the UK.
- Contribute to long-term energy security in the UK.

Collaboration

The TEC project is a collaboration between three partners. Atlantis Resources Corporation is the lead contractor, Black & Veatch is acting as project manager and is providing technical expertise, primarily on the support structure and foundation aspects, and Lockheed Martin is acting as the system integrator and is also providing technical expertise, primarily on electrical and mechanical aspects.

The partners have achieved a significant milestone in the journey towards the MEP's goals with the completion of TEC's Phase 1a. Phase 1b, which will produce the system outline design, is due to be completed in October 2013.



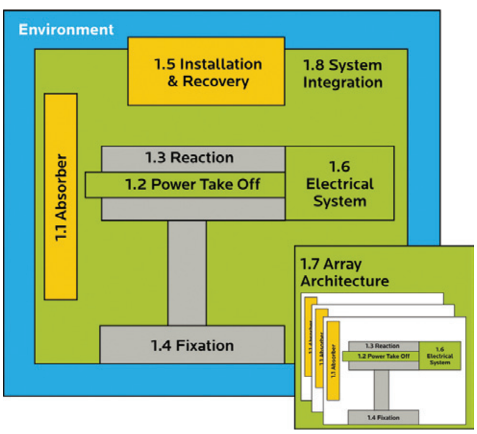
The ETI & UK Energy Research Centre Marine Energy Technology Roadmap - Courtesy of ETI)

Current technologies

There are many competing tidal energy converter prototypes. One step along TEC's pathway to demonstrating a cost of energy for array-scale tidal current technologies was to arrive at a 'preferred architecture' for 2020 via a very comprehensive analysis of existing technologies and system approaches. This, broadly, was Phase 1a's aim.

The analysis covered all of the principal components of the systems and subsystems required for array scale deployment:

- ***Hydrodynamic absorber***: Conversion of hydrodynamic forces in the tidal current into rotational mechanical energy in the turbine blades.
- ***Power take-off system***: Conversion of the rotational mechanical energy from the hydrodynamic absorber into electricity.
- ***Electrical conditioning system***: Conditioning the generated electricity to make it fully compatible with, and therefore transferable onto, the grid.
- ***Reaction system***: Physical structure holding the turbine in place and reacting all the forces to the seabed.
- ***Fixation system***: Method of fixing the reaction system to the seabed.
- ***Array design***: Laying out turbines in an array and electrically connecting a number of turbine outputs to shore.



Systems block diagram of the Atlantis team's 'Baseline Architecture' against which to compare all other technologies and innovations Courtesy of Atlantis Resources Corporation

Phase 1a analysis

Key to the Phase 1a analysis was to adopt a systems and whole life cost approach rather than focus on one part of the system in isolation. This approach sets TEC apart from most other studies, which tend to start from one turbine 'invention' and then create the rest of the system around this invention. The TEC analysis looked at the full range of different horizontal axis turbine designs, different supporting structures, and all known methods for fixing equipment to the seabed.

Incorporating lifecycle and operational factors was also a central tenet of the Phase 1a analysis. For example, the installation and recovery of the turbine, for initial deployment and for future maintenance purposes was considered at length, and optimised across all related aspects for a large-scale array.

Assessing array performance, as opposed to that of individual tidal energy converters, was a very important element of TEC. Understanding this area is central to moving from demonstration to commercial scale systems. Commercial operators need technologies which function effectively at large array scales.

Turbine Array Performance (TAP) model

At the heart of the analysis was Lockheed Martin's TAP model, a proprietary techno-economic model designed to optimise the configuration of tidal energy arrays. All of the participating developers' systems were subject to detailed scrutiny using the model. For calibration, the TAP takes empirical input data from Atlantis' turbine operation at the European Marine Energy Centre in the Orkney Islands and at the National Renewable Energy Centre in Blyth, to establish a base case for comparison. Turbine configurations were tested for a variety of turbine blade lengths, water depths, wave loadings and tidal flows; and for each set of possible component configurations.

Cost reduction potential

TEC Phase 1a led to the overall conclusion that there was no golden technology bullet but a gold mine of cost reduction potential. The project found that rather than a single innovation or component, it was a combination of cost-effective innovations, optimised on a system-wide basis, which delivers the best life cycle cost of energy. The preferred architecture was found to be optimal in 95% of the UK's identified tidal sites. This important conclusion was derived by the strategy of taking into account the lowest lifecycle cost of energy for a large volume deployment, anywhere in UK waters; rather than focusing on developing a single component or subsystem for a specific prototype or site and then undertaking significant scaling work to develop a mass volume solution.

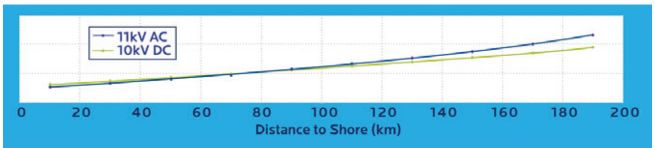
Considerations

With some aspects of the project, received wisdom was validated while other concepts were challenged. It was found that, despite escalating power train costs in the nacelle, cost of energy for a 30m blade is less than for smaller blades. This holds true up to 30-35m diameter. It was found that preserving the hydrodynamic profile, as close to the hub as possible, is a priority. During the blade's design life this has a significant effect on cost of energy.

Naval architects are designing vessels optimised for the tidal environment, which has a particularly high velocity and is challenging for conventional offshore construction vessels. The analysis suggested that vessels optimised for tidal array deployments can help reduce costs of all subsea operations by as much as 50%. This includes installation, operation and maintenance, drilling and piling. Using optimised vessels increases availability by more than 20% for installation and operation and maintenance interventions.

There has been ongoing investigation in the offshore renewable industry as to whether electricity should be brought back to the mainland via AC or DC transmission lines. The project found that DC lines become economic for distances to shore above 70-80km, which is consistent with other studies associated with, for example, offshore wind farms.

Below this threshold, reliability and cost challenges made AC favourable. Above this threshold, the greater efficiency of DC power transmission outweighs these benefits. Most of the tidal industry would benefit from AC transmission since most sites are within 70km of the shore.



Courtesy of Atlantis Resources Corporation

This conclusion was drawn from a wider investigation considering whether related infrastructure was best established on or offshore, below or above sea and internal or external to the turbine, leading to the design of an optimal arrangement for a large-scale array.

Conclusion/current status

In its Marine Energy Roadmap, published in conjunction with the UK Energy Research Centre in 2010, the ETI recognised a critical objective for the marine industry is to achieve a cost of energy, for large-scale projects of c. 200MW scale, to be within the 9-18p/kWh range from 2020.

This was seen as the level at which marine energy could successfully compete with other forms of generation for investment, and demonstrate an ability to reduce costs beyond 2020. The preferred architecture identified by TEC Phase 1a has achieved that target.

Phase 1b of the project is currently creating an outline design of the optimal system based upon the preferred architecture. Pending approval by ETI, Phase 2 will build a demonstrator based upon the design.

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