Tidal Current Energy: Development of a Device Performance Protocol

Scott J. Couch, Henry F. Jeffrey & Ian G. Bryden

Institute for Energy Systems, University of Edinburgh, EH9 3JL (Scotland)

***Abstract* – Development of devices for the exploitation of tidal current energy is reaching the pre-commercialisation phase. In order to equitably test device performance, a standardised procedure for testing is desirable. To meet the remit of the UK government funded Marine Renewable Deployment Fund demonstration scheme, a performance testing protocol was required. This paper discusses the development of, and summarises the requirements of the protocol developed to meet this requirement.**

***Index Terms* – Marine technology, Performance testing, Technology assessment, Tides.**

I. INTRODUCTION

There can be little doubt that tidal currents represent a substantial untapped European energy resource. In the UK alone, recent resource assessments based on developing technology at the prototype testing stage have quantified the 'technically extractable' tidal current resource as 18 TW.hr/year [1]. The typical 'historic' approach to harvesting of tidal energy is through exploiting extreme tidal ranges using barrages to trap and then release high waters through appropriate turbines in a manner similar to exploitation of hydro power [2] (e.g. La Rance, France [3]). In the current climate, the potential environmental impact and vast capital investment required to develop tidal barrage systems has limited development of this approach in Europe. Over the last ten years, interest in exploitation of tidal currents as opposed to tidal range has gathered pace. Various concepts have been proposed, and a number have reached the pre-commercialisation full-scale prototype testing phase (e.g. figure 1). These devices are designed to harness the energy in extreme tidal currents when operational below the surface. Strong parallels can be drawn between the early years of the wind energy industry and the emerging tidal current energy industry when considering resource characteristics, technologies proposed, harvesting strategies and industry development.

II. BACKGROUND

On 2nd August 2004 the United Kingdom Secretary of State for Trade and Industry announced a new 'Marine Renewables Deployment Fund' (MRDF) worth £50 million. At the core of this program is a 'Wave and Tidal Stream Energy Demonstration Scheme' taking up to £42 million of the total fund. The MRDF supports the development of full-scale, grid-connected, multi-device wave and tidal-current energy demonstration facilities. As an emerging technology, no defined regulatory framework exists for testing, monitoring or certification of tidal current energy devices. Consequently, an important objective of the demonstration scheme is the production of transparent, unambiguous, consistent and meaningful assessments of the performance of tidal devices and arrays of tidal devices. This will enable the performance of devices to be effectively validated and, enable government, industry and the finance/investment community to form soundly based judgements of the commercial prospects of the technologies being demonstrated. To ensure that the performance of different devices is assessed on a consistent basis, the need for an explicit protocol was identified. The intention of the protocol would be to set out in detail how performance assessment should be conducted. As a recognised authority in the field of marine renewables, the University of Edinburgh (UoE) was commissioned by the UK Department of Trade and Industry (DTI) with the production of a 'Tidal Current Energy Device Performance Assessment Protocol' (the Protocol) to meet these requirements. This paper discusses the methodology and outcomes developed and utilised during the production of this Protocol. A similar parallel program to produce a wave energy protocol has also been conducted by colleagues at UoE.

Figure 1: Prototype testing of tidal current energy devices: (i) OpenHydro Group Ltd., (ii) MCT's Seaflow, (iii) RGU's SeaSnail

III. METHODOLOGY

Before embarking on a program of work it is necessary to understand the parameter space under consideration and the over-arching objectives. The UoE team therefore had to distil the requirements of the client into a definable problem. The identified objective of the work is to produce a Protocol that is fit-for-purpose within the limitations of current understanding, and therefore ready for immediate application within the confines of the MRDF Scheme. Fit-for-purpose in this context is defined as obtaining an effective balance between quality and quantity of data collection, processing and delivery and operational achievability without being overly burdensome on the Scheme participants. The approach taken in developing the Protocol and underlying methodology involved five main stages in order to meet these objectives. The first stage was to examine approaches adopted in more mature industries where the technology employed and operating conditions could be considered to be analogous to the tidal current energy case. Consideration was then required whether or not the differences between the systems and underlying physics invalidated the transferability of the methodology for the targeted application. From this platform, and tapping into the accumulated knowledge in this field held at UoE, the second stage involved the production of a draft version of the Protocol, obtaining input from key stakeholders where deemed appropriate. Stage three involved hosting a workshop with, and inviting written response from, identified key stakeholders to discuss the draft Protocol. Stage four involved analysis of the feedback provided from the consultation in stage three, adoption, refinement or rejection of the responses and proposals received and alteration of the relevant aspects of the Protocol impacted on. Stage five produced the key project deliverables, the preliminary Protocol and accompanying documentation identifying key knowledge gaps that impact on the performance testing of tidal current energy devices.

As an emerging technology, the companies developing devices to exploit tidal current energy are obviously very concerned about commercial confidentiality regarding how their individual devices operate. The intent of the government funded MRDF Scheme is to provide assistance to fund early stage pre-commercialisation demonstration projects to facilitate bridging the funding gap between emerging technology development, and commercialisation of a saleable product, with the intention of encouraging the development of a sustainable marine renewables industry in the UK [4]. The development of the Protocol had to take account of these concerns in order not to compromise the intended Scheme participants. Therefore, an important early decision made in consultation with the client was that the intent of the device performance Protocol within the Scheme was to demonstrate how much usable electricity was or would be produced from a given energetic resource. This was not therefore an attempt to produce an all-encompassing standard. How the technology interacts with the energy resource and converts that energy into usable electricity for delivery to the grid is therefore considered as a ‘black-box’ operation by the Protocol. What illustrates that the technology is ready for market is demonstration of reliability and performance for a given investment. The data to inform this is considered the key output of the Scheme, and guides the provisions of the Protocol.

IV. PROTOCOL SUMMARY

The delivered preliminary Protocol document stipulates two separate procedures. Both procedures specify a field based measurement program, data analysis methodology and standardised reporting format, which are summarised as follows [5]:

- The first procedure specifies a methodology for characterising the resource available at the intended location of the test site.
- The second procedure specifies a methodology for characterising the device performance envelope. Device performance is characterised using a measured power curve, measured annual energy production and a continuous record of operational status.

The procedure to characterise the local resource is conducted prior to site development in order to quantify the undisturbed resource. A survey of the site in accordance with the requirements of IHO “Order 1” standard as prescribed by the 4th edition of the IHO Standards for Hyrdrographic Surveys [6] is required. Scheme participants are exempted from identified clauses within the IHO standard which are not relevant for this particular application. The tidal current resource is monitored for a minimum continuous period of 30 days using acoustic Doppler techniques. The measurement record is then to be analysed using harmonic analysis techniques which enable both characterization of the velocity and energy resource at the site and prediction of both variables into the future.

The performance envelope of an individual Tidal Energy Converter (TEC) device is characterised using a power curve in a manner similar to that adopted by the wind industry. The power curve relates the variation of electrical power produced by a particular TEC device to the variation in the magnitude of the incident resource (characterised as the current velocity). The power curve is generated by collecting simultaneous measurements of current velocity and power output of an individual device for a 15-day period during device operation. This ensures that a fully representative range of tidal current velocities and associated power outputs is captured. In order to fully assess TEC device operation and performance, data relating to net annual electrical power production and operational status are also required to be gathered across the duration of the supported project.

V. KNOWLEDGE GAPS (IMPACTING ON PROTOCOL METHODOLOGY AND SPECIFICATION)

Significant 'grey' areas of fundamental understanding currently restrict building upon the existing Protocol towards producing a procedure for performance testing of TEC devices at the level of a national or international Standard. These knowledge gaps also influenced the scope and direction of the existing Protocol methodology. Identification of these knowledge gaps provides pointers for future research that will need to be addressed if the exploitation of tidal current energy is to develop into a mature industry [7]. A sample of the knowledge gaps identified is listed below:

- Understanding of the larger scale impact on the underlying tidal resource of TEC operation at industrial scales requires further development. The EPSRC funded SUPERGEN Marine program has begun to address this issue and has made significant progress using analysis from first-principles, numerical, and physical modelling. However a definitive all-encompassing answer to this research question has yet to be produced. Further work is therefore required; in particular data from the field to corroborate the existing research findings and then enable the existing work to be taken forward.
- The impact of wave-current interaction on TEC device performance is a potentially significant knowledge gap which has as yet received very limited consideration and therefore is not well understood. In large part, this is because understanding of wave-current interaction itself is a developing area of oceanographic science. Therefore the underlying science is not fully formed or ready to be applied to the emerging field of tidal current energy.
- It remains unclear whether small scale turbulence, larger scale turbulent motions or cohesive eddies at the scale of the TEC device will have any significant impact on device performance or even survivability, although there is obvious potential that it could become a major issue. In order to address potential concerns, particularly with regards to small scale turbulence, appropriate data has to be gathered. How best to gather this data is also a research question in itself.

VI. CONCLUSIONS

The methodology adopted and outcomes achieved during the development of a device performance protocol for testing of emerging Tidal Current Energy technology has been summarised. Marrying underlying scientific understanding with valuable input from the key stakeholders experiences have underpinned this work. Additionally, the facilitation of this knowledge transfer exercise has been achieved in an efficient and effective manner using the methodology outlined. This has enabled the production of a Protocol document which has been arrived at by iterating scientific and research knowledge towards a consensus viewpoint of the best approach to addressing the performance assessment requirements of the tidal current energy industry.

ACKNOWLEDGEMENT

Appreciation is extended to the DTI and Future Energy Solutions who have worked closely on this project alongside the University of Edinburgh. Further appreciation is extended to the workshop participants and stakeholders consulted, all of whom played a key role in development of the Protocol.

REFERENCES

1. Carbon Trust (2006). "Future Marine Energy. Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy". http://www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=CTC601 [cited 26/02/07].
2. Bryden, I.G. (2002). "Tidal Power Systems". *Encyclopaedia of Physical Science and Technology, third edition, Volume 16*, pp. 751-761.
3. Frau, J.P. (1993). "Tidal Energy: Promising Projects. La Rance, a successful industrial-scale experiment, *IEEE Transactions on Energy Conversion*, **8(3)**, pp.552-558. http://ieeexplore.ieee.org/iel3/60/6508/00257073.pdf?arnumber=257073 [cited 26/02/07].
4. Department of Trade and Industry (2005). "Wave and Tidal-stream Energy Demonstration Scheme". http://www.dti.gov.uk/files/file23963.pdf [cited 26/02/07].
5. The University of Edinburgh (2006) "*Preliminary* Tidal Current Energy: Device Performance Protocol, version 1.2". Report submitted to the UK Department of Trade and Industry, 22 September 2006.
6. International Hydrographic Organization (1998). "IHO Standards for Hydrographic Surveys, 4th edition", available from http://www.iho.shom.fr/. [cited 26/02/07].
7. The University of Edinburgh (2006) "Tidal Current Energy: Device Performance Protocol – Response to feedback from 19th July workshop and consultation". Report submitted to the UK Department of Trade and Industry, 22 September 2006.