GRAND RENEWABLE ENERGY 2014 Abstracts
27 July - 1 August, 2014
Tokyo Big Sight, Tokyo Japan

sr043H00390pdf

INFLUENCE OF SITE BATHYMETRY ON TIDAL RESOURCE ASSESSMENT

Alberto Perez-Ortiz[1], Alistair Borthwick[2], John Pescatore[2], Helen Smith[3], Paul Vigars[4], Qing Xiao[5]
[1]Industrial Doctoral Centre for Offshore Renewable Energy
[2]The University of Edinburgh
[3]University of Exeter
[4]Alstom Ocean Energy
[5]The University of Strathclyde,

SUMMARY: Tidal resource assessment requires parameter studies involving many variables including, but not limited to, the layout of tidal devices within the tidal stream, amplitude, frequencies and phases of tidal constituents, coastal geometry and hydraulic resistance characteristics of sea bed and shelf. The local bathymetry, which may be very complicated and include islands and headlands, has a direct effect on the distribution and value of the tidal power resource. This paper will examine the effect of different channel layouts on tidal flows, with a view towards a better understanding of the effect of the site bathymetry on tidal resource assessment, the optimal location of the tidal array and its technical specifications.

Keywords: tidal energy, resource assessment, site selection, bathymetry

INTRODUCTION

Tidal power assessment is undergoing rapid advances, as the marine renewable energy industry approaches the commercial stage. In the U.K., certain tidal sites have been identified for consenting and development. In order to optimize the layout of tidal arrays, it is necessary to utilize accurate tidal models that properly include the interaction between devices and the ambient flows.

Preliminary tidal energy characterization can be carried out using analytical models based on the driving tidal amplitude, frequency, and phase, and the coastal geometry and seabed friction [1] [2]. More complex resource assessment techniques are required to characterize velocity profiles at the site during spring and neap tides. At present, most approaches at basin-scale involve the numerical solution of the shallow water equations (SWE), which can capture the effects caused by site geometry and seabed features [3] on sea surface elevations and average stream-wise and transverse velocities. Turbine effects on the flow can be modelled in SWE codes either as an equivalent friction term, or a momentum sink [4], or using an electrical analogy [5].

There remains considerable uncertainty regarding the values ascribed to the parameters that influence tidal power resource assessment. The present paper will focus on the sensitivity of tidal models to the resolution of the bathymetry. Proper data pre-processing including bathymetry smoothing can serve to avoid numerical instabilities at open boundaries, but at the cost of missing some seabed features. In addition, the bed friction parameter is of particular concern in that it can have a kind of dual role in a numerical model: (1) it represents the effect of the bed conditions on the boundary layer, and the resulting resistance effect on the flow; (2) it is a tunable parameter that can be used to calibrate, and later validate the model against observed data on tidal amplitudes and velocities. Site geometry and bathymetry have a profound effect on the local tidal flow hydrodynamics, and the interaction with the turbines needs to be accounted for in the process of design and optimization of the tidal array.

Although previous resource assessment studies of coastal areas have addressed the effect of detailed local bathymetry at specific sites [6], there remains plenty of scope for improved understanding of the coupled effects of local bathymetry and mesh resolution on resource assessment.

Effects of channel bathymetry on velocities

Table 1 presents two cases that will be considered of tidal flow through a 10 km long strait connecting two large semi-circular bays each of radius 30 km. The entrances to the strait have rounded corners and the bays have active open boundaries to mitigate spurious accelerations (Figure 1). In each case, a constant head drop of 0.5 m is imposed from west-to-east over the strait.

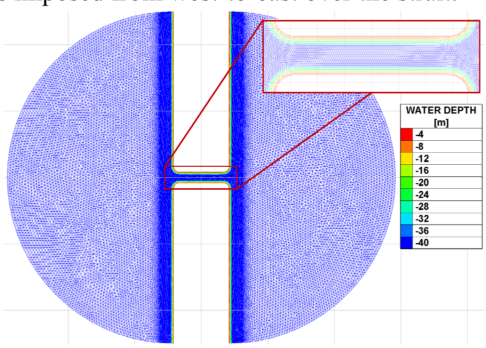

Figure 1.Geometry, bathymetry and mesh of a channel with semi-circular boundaries at west and east ends of the model.

Table 1. Geometric description of the two straits analyzed.

	Width (km)	Section (m^2)	Depth (m)	Side slope (horizontal: vertical)
Case 1	1.5	60,000	40	0.0:0.0
Case 2	1.0 top 2.0 bottom	60,000	40 max.	12.5:1.0

A Manning coefficient of 0.035 s/m$^{1/3}$ was used to represent the frictional resistance of the seabed and lateral walls. The dynamic eddy viscosity coefficient is set constant at 10^{-4} N·s/m^2.

Figure 2 and Figure 3 visualise the magnitudes of the preliminary flow velocity fields for both cases for unidirectional flow at steady state, computed using the SWE code Telemac-2D [7]. Clearly, despite having the same cross-sectional flow area, the two cases produce decidedly different velocity profiles, with locally higher speeds in the centre of the strait induced in Case 2.

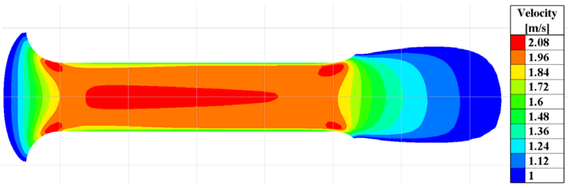

Figure 2. Computed velocities in rectangular section strait with horizontal bottom, Case 1.

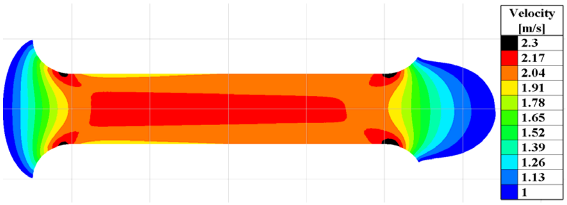

Figure 3. Computed velocities in trapezoidal section strait with no slope in the stream-wise direction, Case 2.

ANTICIPATED RESULTS

This paper aims to assess the impact of bathymetry on the extractable energy resource, and optimal location of tidal farms. Moreover, the technical specifications of hydrokinetic devices themselves are partly dependent on the local bathymetry because manufacturers have developed turbines to operate most efficiently within specified depth ranges.

In the first part, the paper will present the methodology employed to carry out the analysis. This section will include verification of the SWE code against results from a one-dimensional analytical model of tidal flow in the absence of turbines [2]. Analyses of grid convergence and boundary proximity effects on computed sea surface and velocities will be conducted. Energy extraction by tidal arrays will then be computed by means of a momentum sink, following Plew and Stevens [8]. Tests used to verify the energy extraction methodology will be described in the paper. Technical characterization of tidal turbines will be implemented using data available from literature.

In the second part, the paper will analyze the sensitivity of tidal models to bathymetry resolution with a set of configurations which emulate real site conditions that will include seabed features such as small and high water depth gradients, islands and headlands. Eddy viscosity and its effects on the solution will be taken into account using a turbulence model available in the SWE code, i.e. the Smagorinsky model. For each bathymetric configuration, an analysis of tidal array location and technical characteristics will be carried out to optimize energy yield.

References

[1] C. Garrett and P. Cummins, "The power potential of tidal currents in channels," *Proc. R. Soc. A Math. Phys. Eng. Sci.*, **461**(2060): 2563–2572, 2005.

[2] I. G. Bryden and S. J. Couch, "ME1—marine energy extraction: tidal resource analysis," *Renew. Energy*, **31**(2): 133–139, 2006.

[3] A. Pérez-Ortiz, J. Pescatore, and I. Bryden, "A Systematic Approach to Undertake Tidal Energy Resource Assessment with Telemac-2D," in *European Wave and Tidal Energy Conference*, 2013.

[4] S. Draper, G. T. Houlsby, M. L. G. Oldfield, and A. G. L. Borthwick, "Modelling tidal energy extraction in a depth-averaged coastal domain," *IET Renew. Power Gener.*, **4**(6): 545–554, 2010.

[5] S. Draper, T. A. A. Adcock, A. G. L. Borthwick, and G. T. Houlsby, "An electrical analogy for the Pentland Firth tidal stream power resource," *Proc. R. Soc. A Math. Phys. Eng. Sci.*, **470**, 2014.

[6] V. Ramos and G. Iglesias, "Performance assessment of Tidal Stream Turbines: A parametric approach," *Energy Convers. Manag.*, **69**:49–57, 2013.

[7] J.-M. Hervouet, *Hydrodynamics of Free Surface FLows. Modelling with the Finite Element Method.* Wiltshire, United Kingdom: John Wiley & Sons, Ltd, 2007, p. 341.

[8] D. R. Plew and C. L. Stevens, "Numerical modelling of the effect of turbines on currents in a tidal channel – Tory Channel, New Zealand," *Renew. Energy*, **57**: 269–282, 2013.

ACKNOWLEDGMENTS

The authors would like to thank Alstom Ocean Energy for their support. The Industrial Doctoral Centre for Offshore Renewable Energy is funded by the Energy Technologies Institute and the RCUK Energy Programme, grant number (EP/J500847/1).