Tidal resource characterization at a strait between an island and a semi-infinite landmass

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Summary: Many sites where tidal energy may be exploited can be modelled as a strait between an island and a semi-infinite landmass. The presence of the island constrains the flow and induces a local acceleration in the current that yields high energy densities in the strait. This presentation will describe a preliminary study that is on-going into the influence of the strait and island geometry and the seabed friction on tidal power extraction from the strait. The length of the strait, width of the island, and seabed drag are anticipated to have a positive correlation with the ratio of maximum dissipated power to the undisturbed kinetic energy flux in the strait.

Introduction

As the tidal energy industry progresses towards the construction of the first commercial arrays, increasingly accurate understanding of the available tidal resource is needed. There are currently two main approaches to tidal resource assessment. The first uses a combination of theoretical and numerical models to assess energy extraction in idealised coastal geometries [1]. The second applies numerical models to simulate tidal currents and the consequent hydrodynamic effects from energy extraction at real coastal sites [2]. Furthermore, the findings from the first approach are useful for verification of models under development using the second approach.

Coastal geometries such as the channel between two infinite basins have been analysed extensively for tidal energy exploitation. The extractable resource from a channel has been characterized using one-dimensional analytical models [3] and for more complex two-dimensional models by the numerical solution of the shallow water equations [4]. In addition, other coastal geometries of interest to tidal energy such as oscillating bays and headlands have also been investigated [5]. An important number of tidal energy projects may be developed in coastal sites defined by a strait between an island and a semi-infinite landmass. The present work aims to increase the understanding of this coastal geometry and identify the key parameters driving the energy resource available at the strait.

Computational method

This study will be carried out solving the non-conservative form of the shallow water equations (SWE) using the finite element numerical code Fluidity-ICOM [6].

Fig. 1 presents the proposed model set-up and outlines the geometry parameters considered for the analysis. An island in the vicinity of a semi-infinite landmass is located at the south part of the domain. The semi-infinite landmass, island and northern boundary are defined using slip conditions. Open conditions are applied at the east and west boundaries of the model. The geometry of the model is defined by a characteristic domain length L, domain width B and mean water depth h. For each island and tidal farm setup, an analysis of the model length is carried out to investigate the sensitivity of the open boundaries to wake effects or long wave reflections from the internal flow obstacle(s). Likewise, the selected model width ensures that a free-stream current velocity u_{fs} is relatively undisturbed to the north of the island. The geometry of the island is elliptical, and it is defined by its length L_i and width B_i. The distance between island and landmass define the width of the strait s, where u_o refers to the current velocity at the strait.

A quasi-steady analysis is undertaken with constant water head drop ($h_w - h_e$) set from west to east of the domain. The head drop is established to yield a desired current velocity in the strait in the absence of power extraction by turbines. Seabed energy dissipation is parameterised using a dimensionless friction coefficient C_f. A range of C_f is considered that agrees with published numerical models of real coastal sites [7].

Energy extraction is implemented in the model through the addition of a turbine stress term in the momentum equations based on the turbine thrust and structural drag smeared across a grid element [8]. The turbine stress term that accounts for the tidal farm is modelled following the methodology described by Plew and Stevens [9], whereby the turbine stress term is evaluated for N turbine, with each turbine is defined by its rotor swept area

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(A_T), support structure area (A_S), and thrust and drag curves. This permits different types of turbine arrangements within the farm, noting the restriction that the momentum effect of turbines is assumed uniform across each mesh element. Mesh refinement could help reduce this drawback. The tidal farm has a width B_f equal to the width of the strait and it is located at the centre of the strait (Fig. 1). The length of the farm L_f is based on the chosen mesh edge length at the strait and typical downstream length scale of a staggered two row tidal array.

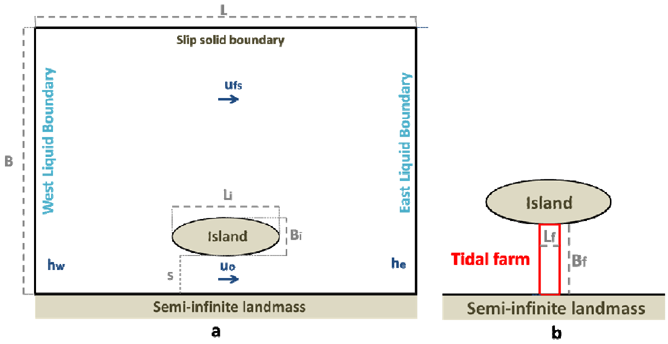

Fig. 1. Strait between an island and a semi-infinite landmass, a) model geometry and tidal parameters; and b) geometry of the tidal farm

Anticipated Results

The ratio of maximum dissipated power to the undisturbed kinetic flux at the strait is analysed for a set of different geometrical parameters and seabed friction coefficients. Although no conclusive results are yet available, a positive correlation between this ratio and length and seabed friction of the strait is expected. Increases in the length of the island and/or seabed friction imply larger impedance to flow in the strait and so the contribution from tidal farm to the total impedance of the strait is lower in relative terms. An increase in the width of the island means higher impedance for the flow bypassing the island, and thus should correlate favourably with the ratio of maximum dissipated power to the undisturbed kinetic flux at the strait.

Conclusions

This study analyses the ratio of maximum dissipated power to the undisturbed kinetic flux at the strait between an island and a semi-infinite landmass for a set of geometry parameters. The ratio is expected to correlate positively with the length of the strait, width of the island and seabed drag.

Acknowledgements:

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