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Predictability and temporal variation of tidal stream power

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Summary: This abstract uses numerical models of several candidate sites around Great Britain to consider the predictability and temporal variations in tidal stream power.

Introduction

One of the key advantages given for tidal power is that it is predictable. This is true in principle but can be difficult to predict in practice. Set against this, a key disadvantage of tidal power is that it is intermittent. This paper uses examples to highlight the problems with predictability and intermittency of tidal power.

Methods

The results presented in this paper are mainly derived from a number of numerical models of several candidate sites for tidal stream energy extraction around Great Britain. These are models of the Pentland Firth [1], Portland Bill and the tidal race to the south of the Isle of Wight [2]. The models use the discontinuous Galerkin version of ADCIRC to solve the shallow water equations. The presence of tidal turbines is simulated using actuator disc theory to represent the thrust from the turbines and to differentiate between the power available for generation, from the power extracted from the flow.

Results — Predictability

The most straightforward way to predict tidal power at some point in the future is to model the physics of the tidal flow. Accurate and robust modelling remains difficult without tidal turbines and almost impossible when tidal turbines are present. Developing these models is vital to the future of the industry, but they will always be computationally expensive and we will need to use computationally inexpensive methods to extrapolate to arbitrary times in past or future. The standard approach taken to do this is harmonic analysis. This technique works well for predicting water levels, and slow tidal currents, but is well known to produce poor results in fast tidal races.

As an example of the inaccuracy of harmonic analysis, we have investigated the numerical model of tidal hydrodynamics used in [1]. A location was selected in the Inner Sound (Pentland Firth), which is one of the first areas where a large array of tidal turbines is planned. A point at 58.6624N 3.1244E was analysed. Harmonic analysis was carried out on this timeseries using the industry standard T_Tide software, using all available tidal constituents. Fig. 1 shows the power (kinetic flux) predicted directly by the numerical model, and the kinetic flux predicted by harmonic analysis of the model data. There is clearly a substantial mis-match, with the harmonic analysis failing to pick up many of the oscillations in the data.

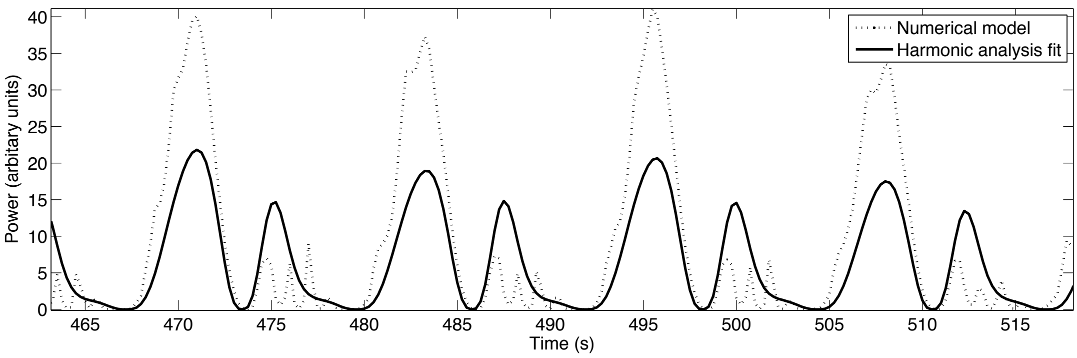

Fig. 1. Comparison of kinetic flux predicted from numerical model of Inner Sound with kinetic flux predicted by harmonic analysis of the model

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Results — Temporal variation

It is useful to consider a variety of timescales, ranging from daily variations, to variations in power output over many years, when analysing the temporal variations in tidal power output [3].

First consider the variation in power over a day. No power can be generated at slack water or when the flow is below the cut-in speed of the turbine. The amount of daily variation is strongly dependent on the cut-in speed and power capping strategy used by the turbines. At a national scale, the phase difference between spatially distant sites will help to smooth out the variations in power and, in principle, the timing of power production could even be varied at large sites [4].

The next longest important time scale is the spring/neap tidal cycle. When analysing this scale it is useful to consider the average power produced over a single M_2 tidal cycle and to consider the ratio of the power produced at a neap cycle with that on a spring cycle [5]. This ratio varies significantly between different sites. The ratio between power at neaps to power at springs for the Pentland Firth is around 1:8 to 1:10, whereas this drops to 1:4 for Portland Bill and 1:6 for the Isle of Wight tidal race. Again, these figures are dependent on the power capping strategy adopted. Unlike the daily variation the spring/neap cycle is in phase all over the world, and hence there will be a significant variation in the total output of tidal power plants over a period of a fortnight.

It is also important to consider the variation in power output over a timescale of years [6]. The dominant physics that leads to a change in the power availability at this scale is the variation in "nodal factor" — the correction to the amplitude of the M_2 tide to account for variation in the plane of the Moon's orbit relative to the equator. This varies over a period of 18.6 years. This leads to a small but significant variation in the power a tidal stream farm can be expected to produce from year to year. For the Pentland Firth the model predicts the variation shown in Fig. 2 for two different turbine configurations.

References:

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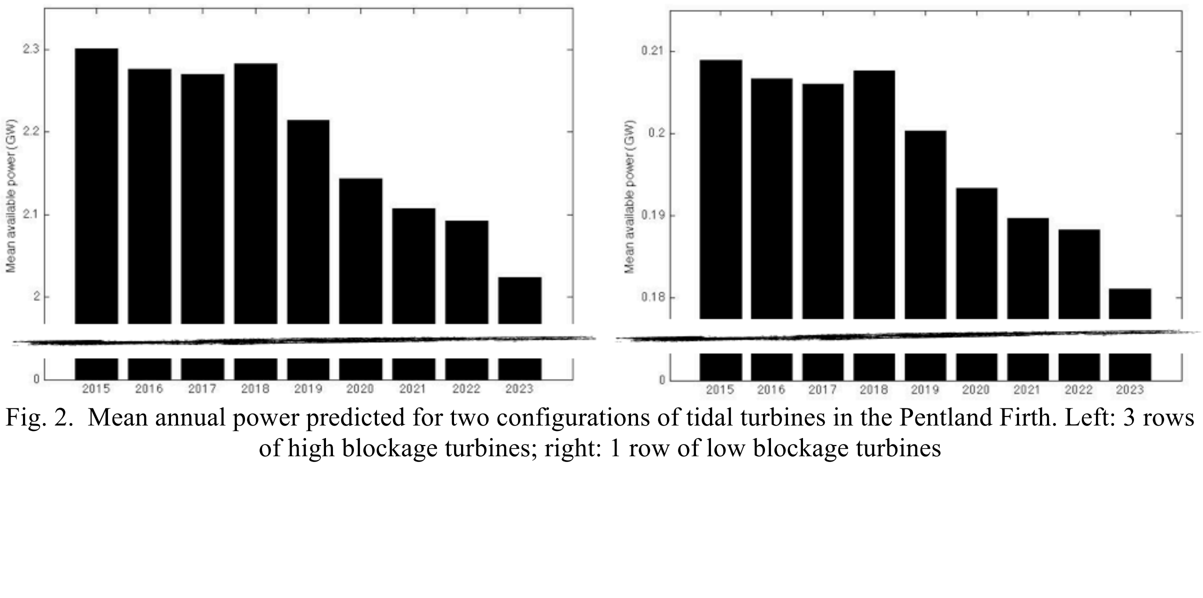

Fig. 2. Mean annual power predicted for two configurations of tidal turbines in the Pentland Firth. Left: 3 rows of high blockage turbines; right: 1 row of low blockage turbines