Assessing the Hydro-Environmental Impacts of Tidal Turbines

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Summary: *Tidal stream turbines have the ability to supply a sizeable proportion of the world's energy demands. The hydro-environmental impacts associated with tidal turbine deployment can include both near field effects in the waters immediately adjacent to the turbines and far field effects such as alteration to the estuary-wide tidal regime. These effects are, as yet, still relatively unknown although numerical models have been used to show that they can be significant. This research aims to develop a methodology that can be used to determine the maximum energy that can be extracted from a tidal water body without significant adverse environmental impacts.*

Introduction

Tidal current turbines have the potential to provide a considerable proportion of global energy requirements. At present the commercial viability of marine current devices is being tested using single devices; however investigation into large-scale tidal turbine arrays has yet to be significantly explored. The feasibility of such technology will depend on the expected power output, as well as the consequential hydro-environmental impacts.

This research aims to determine a methodology to quantify and assess the significance of these impacts. A resulting significant impact factor will be developed that reflects the fraction of kinetic energy that can be extracted using tidal turbine devices without significant environmental effects. A second long term goal will be to develop an approach using flushing to identify the array layout that would achieve maximum energy output whilst minimising adverse environmental impacts.

Methods

The methodology will primarily involve numerical modelling. The model system is a two-dimensional finite difference model. The source code of the model will be assessed and modified to include a flushing analysis capability.

Basic statistical and data analysis techniques, such as regression analysis, will be used to analyse model output so that the hydrodynamic and environmental impacts may be quantified and relationships between impacts and power extraction can be formulated.

Physical modelling techniques will be used to construct scale models in a tidal basin and perform measurements and observations of current speeds, water levels and solute transport. These measured data will be used to validate the numerical model.

The developed model will be applied to idealised cases to assess the impacts due to various turbine array layouts. The model will also be applied to a case study site, namely, The Shannon Estuary.

Additionally a detailed review of relevant literature and research to date will be carried out. The focus will be on reviewing and comparing both experimental tests and numerical modelling studies into assessing the associated impacts of tidal turbines.

Results

Recent research has identified the main hydrodynamic impacts associated with tidal turbine deployment as changes to water surface elevations and current velocities. Studies show that impacts on the tidal range will be minimal, however changes to current velocities have the potential to be significant.

Whilst the extent of these influences will be site specific, in general it has been found that tidal stream energy extraction will result in a velocity deficit immediately upstream and downstream of the turbines as well as inside an array. The velocity deficit exists up to a considerable distance downstream of a turbine, but will gradually recover, returning to free stream velocity as flow moves further away from the device. This is illustrated in the velocity deficit profiles presented in Figures 1 and 2 below.

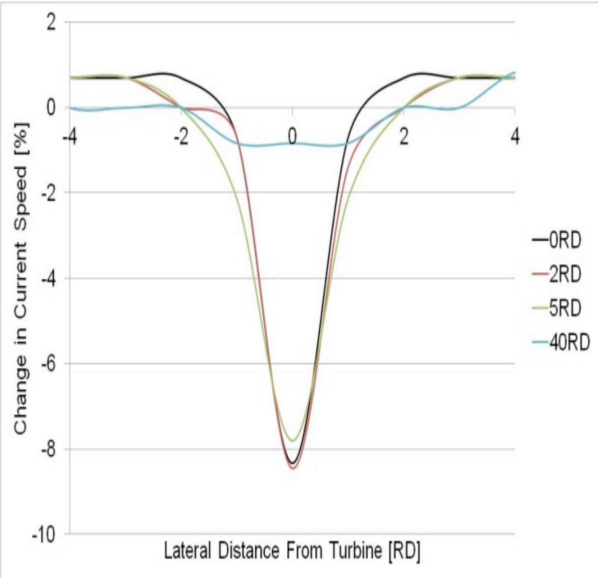

Figure 1:Velocity deficits along lateral transects at various distances downstream of a turbine [1]

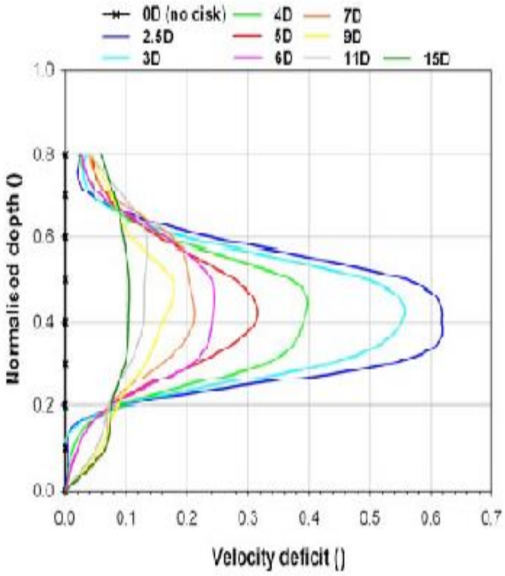

Figure 2:Vertical velocity deficit profiles downstream of a porous disc [2]

These alterations to the tidal regime will have associated environmental impacts, such as changes to sedimentation rates and other costal processes including bacterial and pollutant concentrations in the water column, and may also have negative implications for marine life.

If commercial tidal turbine deployment is to be achieved the significance of these impacts will have to be constrained to a point at which adverse environmental effects do not occur. Published studies have established initial guidelines for a significant impact factor, which is defined as the percentage of the total kinetic energy resource at a site that could be extracted without significant economic or environmental effects [3]. Based on this it is proposed to develop an impact index, using flushing time as the environmental indicator, which would indicate the significance of hydro-environmental impacts for different turbine arrays. Such a tool would be of enormous benefit in the planning and siting of tidal turbine arrays.

Conclusions

Research to date has demonstrated that the hydro-environmental impacts associated with tidal turbine deployment may be substantial and adverse, having the potential to change the underlying hydraulic characteristics of tidal environments.

If large-scale turbine deployment is to be deemed environmentally viable the tidal kinetic energy extracted at a site will have to be limited, at present this constraint is estimated to be 20% [4].

Tidal stream turbine technology is still in its infancy and further research into this area is required. The proposed numerical modelling will enable a more detailed assessment into quantifying the significance of the associated impacts of tidal turbine deployment, allowing accuracy of the significant impact factor to be increased. Once this is achieved a design for an optimum array layout with maximum energy extraction and minimal adverse hydro-environmental impacts can be determined.

References:

[1] Nash, S, et al. (2013). *Investigating the Optimal Layout of a Tidal Turbine Array using Numerical Modelling*.

[2] Bahaj, A.S, et al. (2007). *Characterising the Wake of Horizontal Marine Current Turbines.*

[3-4] Black and Veatch (2005) *Phase 2, UK Tidal Stream Energy Resource Assessment.*