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Modelling a Tidal Turbine in Unsteady Flow

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ABSTRACT

A brief review of the literature is provided on the characteristics of marine currents and the approaches used for simulating tidal turbines. The feasibility of using CFD models to simulate time-dependent turbulent flow around a tidal turbine is then explored. Two different approaches for specifying the structure of the turbulent inflow conditions in CFD models are compared: the von Kármán spectral approach and the Synthetic Eddy Method (SEM) of Jarrin *et al*. (2006). The former model is commonly employed in the wind industry and is coded into Garrad Hassan's *Tidal Bladed* and NREL's *TurbSim*. Different approaches are also tested for decomposing the turbulence at the inlet into resolved and modelled components. The results from these tests indicate that the turbulence produced using the SEM inlet conditions is slightly less susceptible to decay with downstream distance than the von Kármán approach provided that the modelled turbulent kinetic energy accounts for only a small fraction of the total turbulence energy.

Simulations of the unsteady flow around a tidal turbine, represented here as a simple porous disc, provide some insight into the effect of large-scale flow oscillations on the wake of the turbine. The wake structures obtained from unsteady CFD simulations are compared to those obtained using a steady approach. The results indicate that the presence of large coherent turbulent structures in the incident flow field produces a shorter wake than predicted by steady flow simulations.

This work represents the first stage in the development of a unified model which will couple meta-scale simulations of flow in an estuary or complete channel to detailed small-scale simulations of the flow around tidal turbine devices.

KEY WORDS: Tidal Stream Energy; Tidal Turbine; Turbulence; CFD; Unsteady Flow.

INTRODUCTION

The motivation for studying the wake of horizontal axis tidal stream turbines is to understand how device proximity influences both net power output from devices in an array and individual device loading. Over the last decade interest in tidal stream devices has grown rapidly. Major reviews of the resource characteristics and the devices presently in development have been produced by the Energy Policy Research Institute (EPRI 2005, 2006), BC Hydro (2002) and the Carbon Trust (2005, 2006). Much of the resource appraisal work has been aimed at evaluating the environmental impact of extracting energy from natural tidal streams. Studies by Garrett & Cummins (2005) and Bryden & Couch (2006) show that the amount of energy that can be extracted without significantly altering the flow through a channel is dependent on the site bathymetry but that energy extraction of up to 20% of the kinetic energy of the free stream could be achieved at many sites. These environmental indicators and preliminary estimates of device performance indicate that up to 16.5TWh/yr (a mean output of 1.6GW) of electricity could be generated from sites in UK waters.

A wide range of tidal stream devices are presently in development. Although the design details vary between developers, most obviously in terms of the support mechanism and generator used, these can broadly be classified into three groups: vertical axis turbines and both open- and ducted-horizontal axis turbines. At the present time all three types of device are undergoing offshore testing (the ducted devices of Lunar Energy and OpenHydro at EMEC, the vertical axis devices Kobold in Italy and WPI in Norway amongst others) but perhaps the closest to commercial deployment are open-bladed horizontal axis turbines: Marine Current Turbines deployed in the Bristol Channel in 2000 (Seagen) and Strangford Lough, Ireland in 2007 (Seaflow), Verdant Power in New York and Hammerfest Stromm in Norway (see Table 1).

Despite the progress made in device design and development, the nature of the high velocity marine flows at the planned deployment sites is still poorly understood. Tidal energy devices are subjected to loading by tidal current, surface waves and turbulent structures within the flow. Whilst the mean flow velocities are reasonably well understood, our understanding of the influence of combined wave and tidal loads and the long-term effects of turbulent loads is lacking.