SIMPLIFIED CFD MODELLING OF TIDAL TURBINES FOR EXPLORING ARRAYS OF DEVICES

Submitted by

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature:

ABSTRACT

The status of marine current tidal energy technology is currently in the research and development phase, with a few deployments and tests of prototypes under-way in some countries. There is a huge pressure for tidal farms to be of Gigawatt scale in order to have a real, economically viable impact on renewable energy utilization targets outlined for 2020. A route to achieving this is the large scale energy farm philosophy, similar to wind farms, based on very large numbers of unit current tidal stream devices. However, this emerging technology development raises different research questions which lead to further problems in the practical implementation of tidal stream devices. Thus, the aim of this study was: (i) to develop a new, computationally cheap computational fluid dynamics (CFD) based model of the Momentum-Reversal-Lift (MRL) tidal turbine, and (ii) to perform a detailed calculations of the flow field of single and multiple turbines using the developed model to investigate the flow features such as, downstream wake structures, dynamics of the free surface, wake recovery, and the influence of wake interactions on the performance of individual devices.

A new CFD based *Immersed Body Force* (IBF) model has been developed to represent the MRL turbine. The IBF model was developed based on the concept of actuator disc methodology by incorporating additional geometric features that induce energy absorption from the flow which also lead to a downstream wake structure intended to reflect more closely those of the real turbines than simple momentum sink zone models. This turbine model was thoroughly used to investigate the performance of the MRL turbine and the associated flow characteristics and proved its capability in analysing several issues relating to this design of tidal turbines.

Several calculations have been carried out and a full range of operating points of the MRL turbine was formulated. A maximum power coefficient of, $C_p = 0.665$, was obtained with a blockage ratio of, $B = 0.016$. However, the performance of the turbine was improved at a higher blockage ratio both in a single and tidal stream farm investigations. The power coefficient of a single turbine was improved by about 3$\%$ when simulated with a blockage ratio of, $B = 0.029$, and even a higher value was obtained in a tidal stream farm containing three turbines configured in the spanwise direction which reached up to, $C_P = 0.761$, with a global blockage ratio of, $B = 0.027$. These power coefficients are higher than the Lanchester-Betz limit of $C_P = 0.593$ obtained at $B = 0$, which is mainly due to the tidal turbine operating in a constrained environment, high blockage ratio, that increases the thrust force on the device. The power coefficient of the IBF model showed consistently higher values compared to experiments and a detailed CFD model results. This indicates that the power coefficient calculated using the IBF model includes some other losses within the turbine region, such as losses due to viscous, shear etc.

Investigations on the influence of closely packed clusters of turbines in a tidal stream farm showed that a laterally close configuration of turbines improved the performance of individual turbines due to the blockage effect, which is created by the array of turbines in the span-wise direction. In contrast, a small longitudinal spacing between turbines inflicted a massive energy shadowing that affects the performance of downstream turbines. However, a tidal stream farm with a staggered turbine layout can reduce the longitudinal spacing by about 50% with a minimum of 6D lateral spacing compared with a regular turbine layout due to the advantage of using an accelerated bypass flows.

Keywords: MRL, IBF model, Wake interaction, Power extraction, LES

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