Conference Paper, Published Version

Nash, Stephen; Fallon, David; O'Brien, Noreen; Hartnett, Michael

The Application of a High Resolution Nested Hydrodynamic Model to Quantification of Power Output from Tidal Turbine Arrays

Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/109701

Vorgeschlagene Zitierweise/Suggested citation:
Nash, Stephen; Fallon, David; O'Brien, Noreen; Hartnett, Michael (2012): The Application of a High Resolution Nested Hydrodynamic Model to Quantification of Power Output from Tidal Turbine Arrays. In: Hagen, S.; Chopra, M.; Madani, K.; Medeiros, S.; Wang, D. (Hg.): ICHE 2012. Proceedings of the 10th International Conference on Hydroscience & Engineering, November 4-8, 2012, Orlando, USA.

THE APPLICATION OF A HIGH RESOLUTION NESTED HYDRODYNAMIC MODEL TO QUANTIFICATION OF POWER OUTPUT FROM TIDAL TURBINE ARRAYS

Stephen Nash[1], David Fallon[2], Noreen O'Brien[3], and Michael Hartnett[4]

Tidal current turbines have the potential to provide a sizable proportion of global energy requirements. Installations to date have only been single devices for test purposes but any commercial application will undoubtedly involve multiple devices deployed in arrays, analogous to wind (turbine) farms. The commercial viability of such large-scale deployments will depend on the expected energy yield, or power output; the accurate prediction of power output from tidal turbine arrays is therefore extremely important. The present research involves the application of a high resolution nested hydrodynamic model to quantify power output from tidal turbine arrays.

The power, P, available for extraction by tidal turbines is the kinetic power of the moving tides and may be calculated using:

$$P = \frac{1}{2}\rho A V^3 \tag{1}$$

where ρ is water density, A is the swept area of the turbine and V is the undisturbed tidal current velocity. Due to physical constraints and inefficiencies in the energy conversion process, the actual power extracted by a turbine is less than the available power and may be expressed as:

$$P = \frac{1}{2}\rho C_P A {V_R}^3 \tag{2}$$

where C_P is the power coefficient which can range from 0.35-0.5 (Myers and Bahaj, 2006) and V_R is the current velocity at the turbine rotor. V_R is a function of both the undisturbed velocity of the tidal current prior to it passing through the turbine (the upstream velocity) and the reduced velocity of the tidal current after it has passed through the turbine (the downstream velocity). Determination of the upstream and downstream velocities is therefore critical in any approach to power quantification.

The estimation of power output from a single turbine deployment is relatively straightforward once the required variables in eq. 2 are known. However, the estimation of power output from a multiple device array is complicated by the hydrodynamic interaction between turbines within the array. The hydrodynamic effects of tidal turbines include flow deceleration resulting from energy extraction by the turbine and drag losses around the structure as well as flow acceleration resulting from blockage effects. While these effects may be relatively insignificant for a single device they can be quite significant for a large number of turbines deployed together in an array. The upstream and downstream current velocities, and by extension the rotor velocity, manifest at a turbine could therefore be quite different if the turbine is deployed

---

[1] Lecturer, Discipline of Civil Engineering, College of Engineering & Informatics, National University of Ireland, Galway, Ireland (stephen.nash@nuigalway.ie)

[2] PhD Student, Discipline of Civil Engineering, College of Engineering & Informatics, National University of Ireland, Galway, Ireland (david.fallon@nuigalway.ie)

[3] PhD Student, Discipline of Civil Engineering, College of Engineering & Informatics, National University of Ireland, Galway, Ireland (n.obrien1@nuigalway.ie)

[4] Senior Lecturer, Discipline of Civil Engineering, College of Engineering & Informatics, National University of Ireland, Galway, Ireland (michael.hartnett@nuigalway.ie)

within an array as opposed to singularly. While significant research has been conducted in the use of numerical models for turbine power prediction, the power output figures are often inaccurate and over-predicted due to omission, or only rough estimation, of the hydrodynamic interactions between turbines.

In the present research a nested model developed by the Authors is used to model a tidal turbine array at the resolution of the individual turbines (see Fig 1). The governing equations of the two-dimensional, depth-averaged model were modified to incorporate energy extraction and drag terms for horizontal-axis tidal turbines. Based on actuator disc theory, energy extraction was incorporated by considering the act of extraction as a retarding force which is evenly distributed across the turbine swept area. The model simulates both the hydrodynamic effects of individual turbines and the interactions between neighbouring turbines in an array. The model is applied to an idealised rectangular channel and to the Shannon Estuary on the west coast of Ireland, an area identified as a potential site for tidal turbines. In both cases the model is used to quantify the power output from an idealised tidal turbine array. It is shown that the hydrodynamic interaction between turbines can significantly affect the power output of individual devices, and thus the total yield from an array. It is also shown that careful placement of turbines can optimise the power yield from an array.

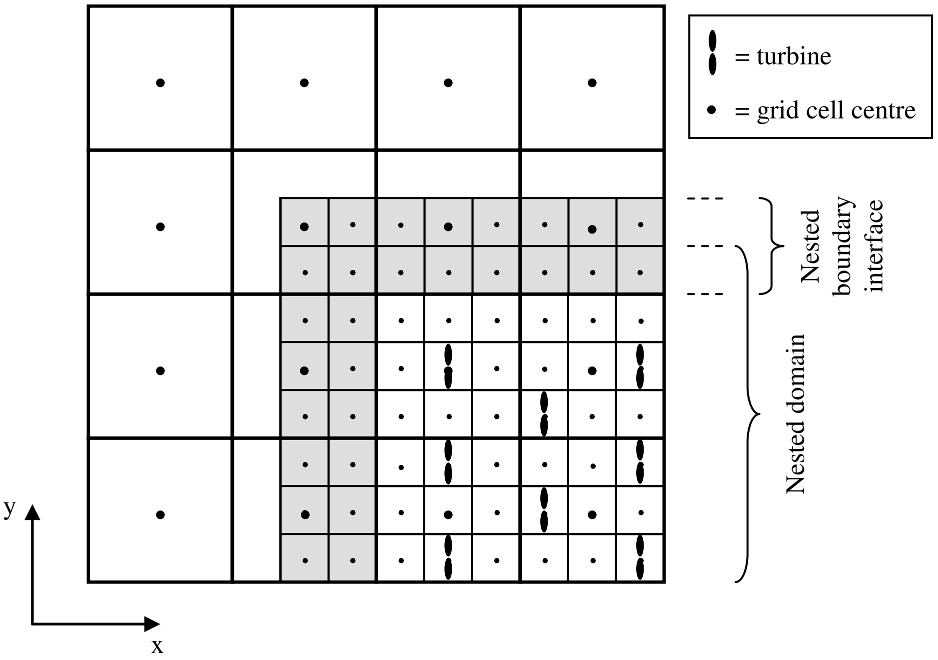

Figure 1 Grid configuration for a 3:1 nesting ratio showing the CG boundary interface (shaded).

REFERENCES

Myers, L.E. and Bahaj, A.S. (2006) “Power output performance characteristics of a horizontal axis marine current turbine,” Renewable Energy, Vol. 31, pp. 197–208.