11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

TIDAL TURBINE MODELLING WITH OPENFOAM – TOWARDS A TIDAL ARRAY

Gavin R Tabor[1], Matthew Berry[2], Mulualem Gebreslassie[2] and Michael Belmont[2]

[1] CEMPS, University of Exeter, North Park Road, Exeter. email:g.r.tabor@ex.ac.uk
[2] CEMPS, University of Exeter.

Key words: *Computational Fluid Dynamics, Turbine Modelling, Tidal Array Modelling*

A combination of concerns about climate change, fossil fuel depletion and energy supply issues are driving a significant interest in techniques for renewable energy generation. One potential energy source which could make a significant contribution to UK energy supply is tidal energy; the UK possesses around half the European Tidal Stream resource[1] and the 10 most promising UK sites alone could contribute 10% of UK electricity supply[2]. However tidal marine energy generation is still an immature technology which requires significant technological development. The development of different turbine technologies is one aspect of this; the marine environment is a very different environment from that for wind turbines, and the established HAWT design which represents the industry standard in that area is not necessarily the best for tidal energy generation. In addition, whilst 'bigger is better' for wind turbines, various factors place a limit on the overall size of an individual turbine unit for tidal generation (possibly around 500 kW), and so any realistic tidal energy generation installation is likely to consist of numerous (hundreds) of smaller turbines operating as an array or farm.

At the University of Exeter we have been involved in a substantial research project to investigate the modelling of tidal farm arrays, concentrating on arrays of a novel design of turbine known as a Momentum Reversal Lift (MRL) turbine. A significant portion of this work involves CFD simulation, ranging from detailed simulation of individual turbines through to simulation of 30-element arrays to match experimental data being generated at the All Waters tank in Edinburgh. This CFD has been carried out using OpenFOAM, due to its capabilities, cost and adaptability. Specifically, we report on the following aspects of the project :

- Detailed blade simulations for individual turbines. The MRL turbine exhibits a complex motion, with individual blades rotating about their long axes on an armature which itself rotates about a parallel axis at twice the speed. Modelling this has involved a complex simulation using nested sliding meshes, implemented as an extension to the existing mesh motion capacity of OpenFOAM, together with low-Re RANS simulations to resolve vortex shedding processes on the blades.

- Although accurate, the nested sliding mesh simulations are seriously costly, and to extend the simulations to multiple turbines (and 3d) an alternative, cheaper methodology had to be found. We present a novel methodology, referred to as *Immersed Body Force* (IBF) [3][4], as an extension of the standard actuator disk model for wind turbines; this represents the effect of the blades in terms of body forces embedded into the domain, including a vortex ring to encourage the development of vortex structure in the downstream wake. This has been implemented into OpenFOAM; testing and comparison with the sliding mesh results and experiment indicate that it reproduces the power uptake and wake structure well, for various design variants and including free surface effects through the Volume of Fluid methodology.

- Given this much faster IBF methodology we have been able to calculate results for multiple turbines, including arrays of 3, 7, and 15 interacting turbines. This has allowed us to explore the behaviour of small arrays of turbines, working towards 30 element arrays to be tested against experimental results.

- The project also looks at methodologies for automated optimisation, for which OpenFOAM and our IBF methodology are being used to create surrogate models of various complexities. We present preliminary results for this work using various approaches to the problem of determining the cost function for the farm.

REFERENCES

[1] "Tidal stream energy resource and technology summary report". Report prepared for the Carbon Trust by Black and Veatch

[2] House of Commons Select Committee on Science and Technology. "Wave and Tidal Energy - 7th report 2000/01" (hc291), (2001)

[3] "Numerical simulation of a new type of cross flow tidal turbine using OpenFOAM – Part I: Calibration of energy extraction". M.G.Gebreslassie, G.R. Tabor and M.R.Belmont. Renewable Energy 50 pp. 994 – 1004 (2013)

[4] "Numerical simulation of a new type of cross flow tidal turbine using OpenFOAM – Part II: Investigation of turbine-to-turbine interaction". M.G.Gebreslassie, G.R. Tabor and M.R.Belmont. Renewable Energy 50 pp. 1005 – 1013 (2013)