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Performance and loadings of tidal turbines deployed in arrays using LES-ALM

P. Ouro*[1], L. Ramirez[2], M. Harrold[3], T. Stoesser[4]

[1] School of Engineering, Cardiff University, United Kingdom, ourobarbap@cardiff.ac.uk
[2] University of A Coruña, Spain, luis.ramirez@udc.es
[3] College of Engineering, University of Exeter, United Kingdom, harroldm@exeter.ac.uk
[4] School of Engineering, Cardiff University, United Kingdom, stoesser@cardiff.ac.uk

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Despite tidal energy is one of the fastest growing renewable energy resources, the number of tidal projects in which turbines have been deployed on-site is scarce. Most of these projects adopting tidal turbines as energy harnessing devices use horizontal axis tidal turbines which are meant to be deployed in groups or arrays. Tidal turbines farms need to be arranged in such a way that turbines are not too close in order to avoid turbulence-induced effects that can challenge the lifespan of turbines located in the wake of other turbines. On the other hand, the turbines should be too far between them so the power to be extracted from the tidal site is maximised. The study of tidal turbine arrays by means of experimental work is very difficult and expensive as requires large amounts of equipment and facilities. Thus, computational methods are a promising alternative that can provide accurate results that permit to understand how to arrange multiple turbines improving the interplay between the devices.

Computational Fluid Dynamic (CFD) models need to resolve the most relevant spatial and temporal turbulence scales in the turbulent wake generated downstream tidal turbines [1]. Large-Eddy Simulation (LES) arises as an ideal turbulence closure capable of resolving the flow scales larger than the grid size whilst modelling the smallest scales. However, performing LES of moving bodies with body-fitted meshes becomes computationally unaffordable demanding thousands of CPUs. An alternative is the Actuator Line Methods (ALM) that represents the turbine blades as a set of finite points that coincide with the gravity centre of the sections they are divided into. The combination of ALM with adequate LES solvers, e.g. adopting Cartesian meshes and fast Poisson equation solvers, would allow to study different turbines arrangements at a relatively moderate computation expense.

Here, several turbine arrays are simulated using a novel ALM implemented in the LES solver Hydro3D. First, the computed flow field is validated with experiments performed by Stallard et al. [2] achieving a great match for both streamwise velocity and turbulence intensity at different stages in the wake. Results from the ALM-LES also show that those turbines working in the wake generated by upstream turbines have lower performance and larger loading fluctuations triggering fatigue loading. These outcomes provide enough evidences that LES-ALM is a promising tool towards optimising the layout of tidal turbines arrays.

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