Performance and near-wake characteristics of a vertical-axis hydrokinetic turbine under a turbulent inflow and free-surface

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ABSTRACT

In this work we investigate the performance and near-wake characteristics of a full-scale vertical-axis tidal turbine under a uniform inflow and turbulent inflow. The governing equations are the incompressible Navier-Stokes equations expressed within an arbitrary Lagrangian-Eulerian (ALE) framework. The finite-element based variational multiscale (VMS) formulation, augmented with a weakly imposed Dirichlet boundary condition at no-slip surfaces, is used. A turbulent inflow is prescribed using a synthetic turbulence generation (STG) method referred to as Smirnov's random flow generation and the near-wake characteristics are studied using a multi-domain method. While the performance of the turbine slightly reduced under a turbulent inflow compared to a uniform inflow, there was a negligible difference in its performance between the two turbulent inflow conditions. A turbulent inflow also resulted in large fluctuations of the instantaneous power coefficient which has important implications for the fatigue life of certain components. Lastly, the wake recovery was notably improved under a turbulent inflow suggesting that a shorter streamwise inter-device spacing may be acceptable in highly turbulent tidal sites.

We also studied the effect of a free surface on the performance and flow field of a vertical-axis tidal turbine with different blade-strut configurations. The level set equation is introduced to model the free surface. Two different blade-strut configurations were considered: quarter-struts and tip-struts with a rounded junction. For each blade-strut configuration, a deep immersion depth of h = 0.8D and shallow immersion depth of h = 0.1D was considered, where h is the distance between the blade-tips and free surface, and D is the rotor diameter. There was a negligible effect of the free surface on turbine performance and the flow field during deep immersion. Moreover, the tip-struts configuration was 15% more efficient than the quarter-struts configuration under deep immersion. Under shallow immersion, the performance of both blade-strut configurations reduced although the performance of the tip-struts configuration was affected less. Moreover, the free-surface deformation and near-wake characteristics were notably affected due to interactions between the turbine wake and free surface.

REFERENCES

[1] A. Bayram, M. Dhalwala, P. Oshkai, A. Korobenko, "Numerical simulations of a vertical-axis hydrokinetic turbine with different blade-strut configurations under free-surface effects", *Engineering with Computers,* (2022), *available online:* https://doi.org/10.1007/s00366-022-01758-8

[2] M. Dhalwala, A. Bayram, P. Oshkai, A. Korobenko, "Performance and near-wake analysis of a vertical-axis hydrokinetic turbine under a turbulent inflow", *Ocean Engineering,* Vol. 257, 111703, (2022), *available online:* https://doi.org/10.1016/j.oceaneng.2022.111703