University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

MICHAEL SHIVES

MSc (University of Victoria, 2012)
BSc (Carleton University, 2008)

"Numerical Models for Tidal Turbine Farms"

Department of Mechanical Engineering

Monday, June 5, 2017
2:15 P.M.
David Turpin Building
Room A144

Supervisory Committee:
Dr. Curran Crawford, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Ned Djilali, Department of Mechanical Engineering, UVic (Member)
Dr. Richard Karsten, Department of Mathematics, Acadia Univeristy (Outside Member)

External Examiner:
Dr. Alberto Aliseda, Department of Mechanical Engineering, University of Washington

Chair of Oral Examination:
Dr. Terry Prowse, Department of Geography, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Anthropogenic climate change is approaching predicted tipping points and there is an urgent need to de-carbonize energy systems on a global scale. Generation technologies that do not emit greenhouse gas need to be rapidly deployed, and energy grids need to be updated to accommodate an intermittent fluctuating supply. Rapidly advancing battery technology, cost reduction of solar and wind power and other emerging generation technologies are making the needed changes technically and economically feasible.

Extracting energy from fast-owing tidal currents using turbines akin to those used in wind farms, offers a reliable and predictable source of GHG free energy. The tidal power industry has established the technical feasibility of tidal turbines, and is presently up-scaling deployments from single isolated units to large tidal farms containing many turbines. However there remains significant economic uncertainty in financing such projects, partially due to uncertainty in predicting the long-term energy yield. Since energy yield is used in calculating the project revenue, it is of critical importance.

Predicting yield for a prospective farm has not received sufficient attention in the tidal power literature. This task has been the primary motivation for this thesis work, which focuses on establishing and validating simulation-based procedures to predict flows through large tidal farms with many turbines, including the back effects of the turbines. This is a challenging problem because large tidal farms may alter tidal flows on large scales, and the slow-moving wake downstream of each rotor influences the inflow to other rotors, influencing their performance and loading. Additionally, tidal ow variation on diurnal and monthly timescales requires long-duration analysis to obtain meaningful statistics that can be used for forecasting.

This thesis presents a hybrid simulation method that uses 2D coastal ow simulations to predict tidal flows over long durations, including the influence of turbines, combined with higher-resolution 3D simulations to predict how wakes and local bathymetry influence the power of each turbine in a tidal farm. The two simulation types are coupled using a method of bins to reduce the computational cost within reasonable limits. The method can be used to compute detailed 3D ow fields, power and loading on each turbine in the farm, energy yield and the impact of the farm on tidal amplitude and phase. The method is demonstrated to be computationally tractable with modest high-performance computing resources and therefore are of immediate value for informing turbine placement, comparing turbine farm-layout cases and forecasting yield, and may be implemented in future automated layout optimization algorithms.