Control of an Open-Source Tidal Energy Converter (OSTEC) Testbed

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Keywords: #Tidal turbine controls # Power take-off # Component efficiency #Simulation #Simulink

Tidal energy converters (TEC), e.g., marine hydrokinetic turbines, harness the kinetic energy of tidal currents to generate clean renewable power. The Open-Source Tidal Energy Converter (OSTEC) project's purpose is to design, build, and deploy an instrumented marine turbine system in a real tidal environment and will serve as a testbed for research and development. With its 2.5 m rotor diameter and 26 kW rated power, this axial flow tidal turbine will generate open-source datasets on power performance, mechanical and design loads, and tidal inflow conditions at meaningful Reynolds number scales.

Marine hydrokinetic energy conversion devices exhibit significant variability in design and performance. As these systems progress toward commercialization, developing control strategies becomes crucial for optimizing efficiency. A common approach for controlling marine current turbines is Maximum Power Point Tracking (MPPT)—a control scheme designed to maximize energy extraction. MPPT operates by identifying and maintaining an optimal operating point based on the device's characteristic performance curve, using real-time measurements of rotational speed, power output, and inflow velocity.

Two distinct control strategies are planned for the operation of the OSTEC turbine: speed control and torque control. A simulation code has been developed in Simulink to evaluate these strategies, allowing for the modeling of various control schemes based on measured inflow conditions and turbine performance curves. The initial simulation framework includes only the load and generator; however, future iterations will integrate additional turbine models to enhance simulation fidelity by representing other drivetrain components. Most of these drivetrain elements can be modeled using a spring-mass system, effectively capturing the dynamic behavior of the tidal turbine.

A constant gain control model is implemented by determining an appropriate gain value from a single characteristic MPPT corresponding to the inflow velocity. During dry testing in the lab, the OSTEC turbine operation provides an opportunity to initially compare turbine performance with simulation results for speed control. However, torque control requires the application of load to the turbine, necessitating deployment in a real tidal flow environment or on a dynamometer to obtain meaningful results. To mitigate the risk of damaging the generator, the implementation of torque control is postponed until the pre-deployment water check and calibration procedure, where load will be applied to the rotor under controlled conditions.

The power performance of the OSTEC turbine, deployed in a real tidal environment, will be assessed and compared with simulation results. This comparison will validate the turbine's response time to turbulence timescales and provide critical insights into optimizing control strategies. By selecting the most effective control scheme, the overall efficiency and power output can be maximized.

In summary, to optimize efficiency, two control strategies—speed control and torque control—will be evaluated using a Simulink-based simulation framework. While speed control can be tested simply in lab conditions, torque control requires real-world deployment or dynamometry for accurate assessment. The turbine's power performance in a tidal environment will be compared with simulation results to validate its response to turbulence timescales and refine control strategies for maximizing efficiency and power output.

Acknowledgements:

This work is supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) through the Waterpower Technologies Office (WPTO). This work was authored in part by the Pacific Northwest National Laboratory, operated by Battelle Memorial Institute for the U.S. Department of Energy (DOE) under Contract No. DE-AC05-76RL01830, and in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. This abstract describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.