Design and Testing of an Open-source Tidal Energy Converter to Advance IEC Marine Energy Standards

M.C. Bichanich1, M. Wosnik1, V.S. Neary2, K. Wakefield2, D. Kim2, R. Cavagnaro3, A. Bharath4, D. Forbush5, B. Gunawan2, S.E. Harris2

1Atlantic Marine Energy Center (AMEC), University of New Hampshire (UNH), 2Sandia National Laboratories (SNL), 3Pacific Northwest National Laboratory (PNNL), 4National Renewable Energy Laboratory (NREL)

Motivation and Strategy

- Tidal energy is a predictable renewable energy resource around the world that remains largely underutilized due to harsh conditions and high hydrodynamic loads associated with the marine environment.
- Publicly available data on flow-structure interactions of relevant-scale marine hydrokinetic turbines (MHKTs) deployed in energetic tidal flows is limited.
- The project team consisting of SNL, UNH, NREL, and PNNL, is tasked with the design, fabrication, deployment, testing of a 2.5-m fully instrumented reference model MHKT to collect, analyze and archive a complete load and performance characterization dataset.
- Data regarding the structural health, tidal resource, and performance of the turbine will be collected and published in the open-source Portal and Repository for Information on Marine Renewable Energy (PRIMRE).
- The data collected will help to inform the International Electrotechnical Commission’s (IEC) standards for marine energy (TC 114).

UNH-AMEC Tidal Energy Test Site / Energy Resource

- The Memorial Bridge is located between Portsmouth, New Hampshire and Kittery, Maine.
- Memorial Bridge crosses the lower Piscataqua River in the Great Bay Estuary (GBE) system, one of the most energetic tidally driven flows on the East Coast of the USA.
- Instantaneous currents can exceed 3 m/s during spring ebb tides at site (Acoustic Doppler Velocimeter), with 2-minute mean current speeds up to 2.8 m/s (Acoustic Doppler Current Profiler).
- Nominal depth at site ~18 m maximum tidal range ~4m.

Turbine Deployment Platform

- The UNH Center for Ocean Renewable Energy utilized USDOE funding for ocean renewable energy infrastructure to build a 15 m x 6 m floating Turbine Deployment Platform (TDP).
- HDPE pontoons provide buoyancy, and a galvanized steel frame provides structural strength.
- The TDP is moored to a bridge pier via custom pile guides and 6.7 m tall vertical guide-posts.
- Turbines are deployed through a moon pool (3.3 m x 5.7 m) via a turbine pitching mechanism.

IEC Marine Energy Standards

- IEC 62600-2: Design requirements for marine energy systems
  - The performance of the MHKT under various loading conditions and failure modes will be tested.
  - IEC 62600-200: Power Performance Assessment of Electricity Producing Tidal Energy Converters
  - Metrics such as the power coefficient, capacity factor, and total power will be measured on this grid-connected MHKT.
  - IEC 62600-201: Tidal energy resource assessment and characterization
  - Key environmental factors such as the flow speed, salinity, and temperature will be measured.
  - IEC 62600-202: Early-stage development of tidal energy converters
  - The MHKT will fall under Stage 3, field-scale testing with a Technology Readiness Level of 5-6.

Instrumented Rotor Design, Blade Test Bed

- The MHKT blades adopt Sandia’s family of hydrofoil profiles designed for optimal performance in marine environment.
- Each blade is outfitted with 3 fiber optic strain gauges on both sides and 4 gauges on the blade root, an accelerometer, and a temperature sensor.
- The rotor of the turbine is attached to main driveshaft via a custom, multi-axis load cell.
- The blade-to-hub attachment is designed to be modular, blades can be swapped out for experiments with other blades, materials, tips, etc.

Data Acquisition

- In partnership with NREL, UNH developed a Mobile Data Acquisition System (UNH MODAQ, right).
- A separate DAQ system in the nose cone of the turbine records the blade strain.
- Temporally synchronized data from turbine and environmental sensors — important for load and power characterization.

Modular Nacelle Design

- The modularity of the nacelle allows for replacement/testing of specific components.
- The nacelle is made of off-the-shelf steel pipe sections with welded flanges on the interior and exterior for simplicity and modularity.

Data Dissemination

- The data from all experiments and testing of various IEC measurement and load cases will be available through the open-source PRIMRE.
- This will be one of the first data sets of this kind to exist fully in the public domain.
- This data will inform MHKT design and reduce time and cost for turbine developers.
- The project will use current versions of the IEC marine energy standards and will inform future revisions.

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