

Open-Source Tidal Energy Converter (OSTEC) Test Bed – Enabling In-Water R&D for Current Energy Conversion

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The Open-Source Tidal Energy Converter (OSTEC) is an instrumented reference turbine designed to serve as a test bed for foundational R&D and data generation in real open-water tidal flow conditions. It was funded by the U.S. Department of Energy to advance our understanding and to identify knowledge gaps in the techno-economic performance of tidal energy converters (TEC) [1]. This marine turbine test bed also enables testing, demonstration, and improvement of recommended best practices in international standards, including the IEC's technical specifications on marine energy converters (TC 114) [2].

A 3-bladed axial-flow turbine was selected as it is the most common marine turbine archetype. The OSTEC diameter is 2.5 m, which is sufficiently large scale to enable Reynolds number independence and to allow upscaling of material and component, load response and stress-strain behavior, and fluid-structure-interactions [1,3]. The DOE marine hydrokinetic family 1 (MHKF1) advanced reference blade geometry was selected as the initial blade configuration since its design is well-documented and its power performance was demonstrated in scale model testing [4, 5]. The OSTEC test bed is extensively instrumented for measurements of tidal energy resource, power performance, environmental monitoring, loads, including mooring, overall thrust and blade loads (embedded optical strain gages, accelerometers, strain rosettes for blade root bending moments), operating parameters, and many other measurements [6].

The OSTEC test bed will be deployed from a 15 m x 6 m Turbine Deployment Platform (TDP) at the UNH-AMEC Tidal Energy Test Site at Memorial Bridge in Portsmouth, NH, an easily accessible, cost-effective open-water test site. Turbines up to diameters of approximately 3 m can be deployed from the TDP through a moon pool via a turbine pitching mechanism. Tidal currents up to 2.8 m/s (2-minute average) were measured at the site with an ADCP during spring ebb tides [7,8,9]. The TDP survived tropical storms and Nor'easter storm surges. A tidal turbine has been successfully deployed at the site since 2018.

This contribution to UMERC+METS 2024 will give an overview of the OSTEC and then focus on the research and development enabled by this test bed.

The OSTEC capabilities were compared to the DOE Water Power Technology Office's Multi-Year Program Plan (MYPP) for marine energy, and numerous opportunities exist in all four MYPP focus areas: Foundational R&D, Technology-Specific Design & Validation, Reducing Barriers to Testing, and Data Access and Analytics. Studies enabled by the OSTEC test bed include: Blade R&D (geometries, materials, coatings, sensors), blade failure modes (pitch misalignment, damaged blades, missing blade, etc.) and health monitoring, numerical model Verification and validation (V&V –TurbSim, OpenFAST, CFD & FSI, etc.), digital twinning of CECs, advanced controls research utilizing rotor speed or torque regulation, debris detection and mitigation using acoustic imaging and turbine control, concurrent environmental

studies, turbine wake studies, gearbox lubricant research, blade/component coatings for corrosion protection or biofouling mitigation, process monitoring using dedicated sensors (e.g., accelerometers) or generator output analysis, novel power electronics development, IO&M process studies, CapEx, OpEx, LCOE benchmarking studies. The OSTEC test bed was designed with modularity in mind, within reason. Some parts of the OSTEC can readily be exchanged, e.g., blades, while other sections or assemblies can be adapted if needed. There are significant opportunities for research on and documentation of Operation and Maintenance costs, examples of what worked well and what didn't, and lessons learned.

A digital twin of the OSTEC, a high-fidelity fluid-structure-interaction (FSI) model supports planning of field measurement campaigns, mechanical load analysis on blades and downstream components, and design modifications for testing different blade materials or components, e.g., different blade-attachment subassemblies.

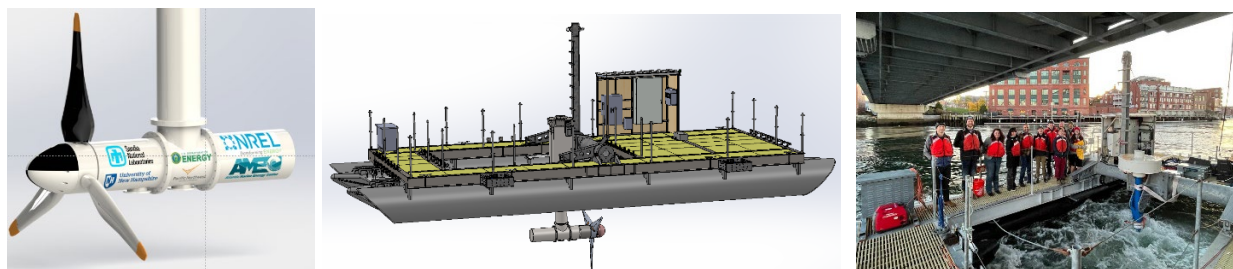


Figure 1. Left: Instrumented marine turbine system – OSTEC, 2.5m diameter. Middle: OSTEC in the “deployed” position on the 15m x 6m UNH-AMEC Turbine Deployment Platform (TDP). Right: UNH, National Lab and DOE WPTO staff on TDP at Tidal Energy Test Site during blade strain testing on a cross-flow turbine in October 2022.

USDOE OSTEC Testbed Studies (MYPP Mapping)

<https://www.energy.gov/sites/default/files/2022-03/wpto-mypp-marine-energy-overview.pdf>

Foundational R&D	Tech-Specific Design & Validation	Reduced Barriers to Testing	Data Access & Analytics
<ul style="list-style-type: none"> ✓ R&D on components, controls, manufacturing, and materials. ✓ Component, e.g., blade, performance & failure mode testing ✓ Blade attachment assembly testing • Pitch assembly & bearing testing ✓ Materials & coating testing ✓ Advanced controls testing ✓ Develop & validate numerical models & methods for fluid-structure interactions (FSI). ✓ Model V&V dataset for low-fidelity BEM-FEA and high-fidelity CFD-FEA FSI models (e.g., OpenFAST-BeamDyn, ANSYS CFD-FEA) ✓ Develop & apply quantitative metrics for techno-economic performance ✓ Calculate metrics, e.g., $C_p@BOP$, LCOE ✓ Study methods for LCOE & proxies CapEx, e.g., mass ✓ Study proxies for IO&M costs, e.g., U_{max}, U_{50}. ✓ Study new metrics, e.g., relative-risk-ratio, U_{max}/U_{mean} 	<ul style="list-style-type: none"> ✓ Validate performance and reliability of systems by in-water testing ✓ Power & economic performance assessed ✓ Reliability of full-system & subsystems assessed ✓ Improve cost effective methods of IO&M ✓ Full assessment of IO&M for turbine deployment from surface platform ✓ Full assessment of IO&M to establish baseline and identify cost-savings ✓ Support development of international standards ✓ Assessment of IEC standards for resource characterization, power performance, mechanical and design loads, acoustics, mooring design, etc. ✓ Evaluate existing and potential future needs for IO&M infrastructure (e.g., vessels, port facilities, etc). ✓ Full assessment of IO&M infrastructure supporting turbine testbed 	<ul style="list-style-type: none"> ✓ Enable access to world class testing facilities to accelerate technology development. ✓ Work with agencies and other groups to ensure that existing data is well-utilized and identify potential improvements to regulatory processes and requirements. ✓ Support additional scientific research on mitigating environmental risks and reducing costs and complexity of environmental monitoring ✓ Testing eco-friendly lubricants – ORNL ✓ Testing of environmental monitoring sensors ✓ Debris monitoring system testing – PNNL ✓ Inflow and wake flow recovery studies - Sandia ✓ Establish template, protocols and best practices for test planning 	<ul style="list-style-type: none"> ✓ Aggregate and analyze data on marine energy performance ✓ Extensive public dataset ✓ Power Performance ✓ Mechanical & design load cases ✓ Mechanical loads on blades, rotor, PTO (gearbox, motor-generator) ✓ Health-monitoring data ✓ Leverage expertise, technology, data methods, and lessons from the international marine energy community ✓ State-of-art methods for data processing & analysis ✓ ADP & ADV data on turbulent inflows and wake recovery ✓ Power performance assessment using different methods ✓ Mechanical load processing & analysis ✓ Uncertainty quantification & propagation

Figure 2. Comparing and mapping of OSTEC test bed capabilities to the DOE WPTO Multi-Year Program Plan (MYPP).

References

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