



Florida Atlantic University-Southeast National Marine Renewable Energy Center

Cooperative Research and Development Final Report

CRADA Number: CRD-10-377

NREL Technical Contact: Walter Musial

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5000-72681
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NOTICE

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Cooperative Research and Development Final Report

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the final CRADA report, including a list of subject inventions, to be forwarded to the DOE Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Florida Atlantic University-Southeast National Marine Renewable Energy Center

CRADA Number: CRD-10-377

CRADA Title: Florida Atlantic University (FAU) - Ocean Current Energy Conversion Device Testing and Modeling

Joint Work Statement Funding Table showing DOE commitment:

| Estimated Costs | NREL Shared Resources a/k/a Government In-Kind |
|------------------------|---|
| Year 1 | \$285,000.00 |
| TOTALS | \$285,000.00 |

Abstract of CRADA Work:

Florida Atlantic University's Southeast National Marine Renewable Energy Center (SNMREC) and the National Renewable Energy Laboratory's National Wind Technology Center (NWTC) will collaborate to advance research and development (R&D) of marine and hydrokinetic (MHK) renewable energy technology, specifically renewable energy captured from oceanic currents such as the Florida Current.

SNMREC is endeavoring to establish infrastructure and capabilities that will form the base of a marine energy technology testing center focused on energy production from open-ocean currents and ocean thermal resources. As part of this effort, SNMREC is also aiming to create technology development tools and an experimental hydrokinetic device to operate in the Florida Current. NWTC has experience in developing testing infrastructure and modeling tools. SNMREC has expertise in ocean engineering and operations, a large inventory of ocean instrumentation, and ready access to the ocean. NWTC and SNMREC will therefore work together on numerical modeling, technology design review and testing, the development of standardized MHK instrumentation, field testing, establishing testing protocols, and moving the SNMREC testing capability through A2LA accreditation.

Summary of Research Results:

Task 1 – Modeling

NREL developed computer based aero-rotor design and analysis codes, HARP_Opt (https://nwtc.nrel.gov/HARP_Opt) and TurbSim (<https://nwtc.nrel.gov/TurbSim>), to model hydro-rotors. Harp_Opt utilizes a multiple-objective genetic algorithm and blade-element momentum (BEM) theory flow model to design horizontal-axis wind and hydrokinetic turbine rotors. TurbSim is a stochastic inflow turbulence code that is designed to provide a numerical simulation of a full-field flow that contains coherent turbulence structures and is used as input into rotor design codes. NWTc provided SNMREC with technical support in the use its HARP_Opt and TurbSim by:

1. providing literature and an overview of the theory behind the HARP_Opt and TurbSim programs
2. assisting in the setup, use and understanding of the output of the HARP_Opt and TurbSim software packages.

Task 2 – Turbine and Rotor Blade Design

Due to delays in turbine system development and deployment, NREL and SNMREC did not collaborate on this task with SNMREC.

Task 3 – Development of Instrumentation and Data Acquisition System

NREL developed and publicly released the Modular Ocean Instrumentation System which can be configured to achieve specific test objectives for a given marine energy device deployment. SNMREC researchers were provided access to these designs.

(<https://www.energy.gov/sites/prod/files/2017/03/f34/modular-ocean-instrumentation-system.pdf>)

NREL and SNMREC researchers collaborated on the conceptual design of marine energy specific prognostic health monitoring systems, leveraging NREL's experience with wind turbine systems. The SNMREC/NREL team applied for funding opportunities to pursue the systems design and implementation but funding has not been received to date. NREL and SNMREC researchers also collaborated on several proposals to validate different turbine blade designs but funding has not yet been obtained.

Task 4 – Inflow Characterization of the Florida Current

Engineering design of MHK systems requires a thorough understanding of the mean and turbulent inflow conditions that are likely to be encountered. SNMREC is developing a testing range offshore of Southeast Florida in the Florida Current. Characterizing the coherent turbulent structures in the Straits of Florida at the proposed site would be useful for rotor blade design, as well as for providing NWTc with data sets to enhance the TurbSim code.

NREL collaborated with FAU in efforts to characterize the mean-flow and turbulence in the Florida Current. NREL held periodic calls with FAU to inform data collection efforts, performed

preliminary turbulence analysis of ADCP data, and determined that the resolution of the obtained data was not sufficient to quantify the turbulence at scales that were relevant to ocean current turbines. NREL assisted FAU with performing motion correction of IMU-equipped ADV data, and provided feedback on a master's thesis on that topic. NREL supported FAU in the use of TurbSim to generate time-series of turbulence inflow for input to device design tools to utilize once additional data is collected.

Task 5 – Testing Protocols

NREL leveraged decades of experience and knowledge of renewable energy (e.g. wind energy) technology research and development to provide feedback and guidance to SENMREC in the establishment of the wave energy test center.

NREL leveraged experience with establishing and operating the National Wind Technology Center to provide SENMREC with:

- Wave Energy Test Protocols and an example Generic Wave Energy Test Plan
- Information on NWTC operations, agreements, environmental health and safety considerations, costs and cost recovery
- Guidance on establishing and maintaining testing accreditation
- Examples of NREL documents for: Risk evaluation, Job Hazard Analysis, testing agreements, General Safe Operating Procedures.

Subject Inventions Listing:

None

Report Date:

26 September 2018

ROI #:

None

Responsible Technical Contact at Alliance/NREL:

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DOE Program Office:

Office of Energy Efficiency and Renewable Energy (EERE), Wind and Water Technologies Office

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