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Build and Test of a Novel, Commercial-Scale Wave Energy Direct-Drive Rotary Power Take-off under Realistic Open-Ocean Conditions

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The Challenge: Design, build, and test a novel power take-off (PTO) that can reliably and cost effectively produce grid-compliant power from a low-speed and dynamically variable energy resource.

Partners:

- Ershigs
- National Renewable Energy Lab (NREL)
- Siemens
- SpenTech
- Greenberry
- Katon
- Northern Power Systems

Program Strategic Priorities

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Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- **Conduct R&D for innovative MHK components**
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- Support research focused on retiring or mitigating environmental risks and reducing costs
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- Exchange of data information and expertise

Drive innovation in MHK-specific applications

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Targeted Improvements		
PWR	**Availability**	**LCOE**
55%	10%	-28%

Project Impact:

- Delivers Technology Readiness Level 6
- Advances technical performance of StingRAY wave energy converter (WEC)
- Validates wave-energy-specific electro-mechanical power take-off
- Validates novel air-gap control system for wave- and, potentially, wind-market
- Delivers stakeholder confidence, risk reduction and supply chain required in support of WEC open-water demonstration

Technical Approach

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- Design, manufacture, assembly and validation of a first-in-kind PTO using experienced, highly-qualified suppliers
- Land-based test of large-scale PTO prior to WEC open ocean deployment
  - Safe, lower-risk, methodical approach
  - Modular design allows over-the-road transportation
  - Safely expose the PTO to controllable forces
  - Time- and cost-efficient exposure to wide range of operating conditions
  - Tests significant portion of supervisory control and data acquisition (SCADA) hardware and software, and PTO controls
  - Tests electric plant and small-scale energy-storage system

Technical Approach

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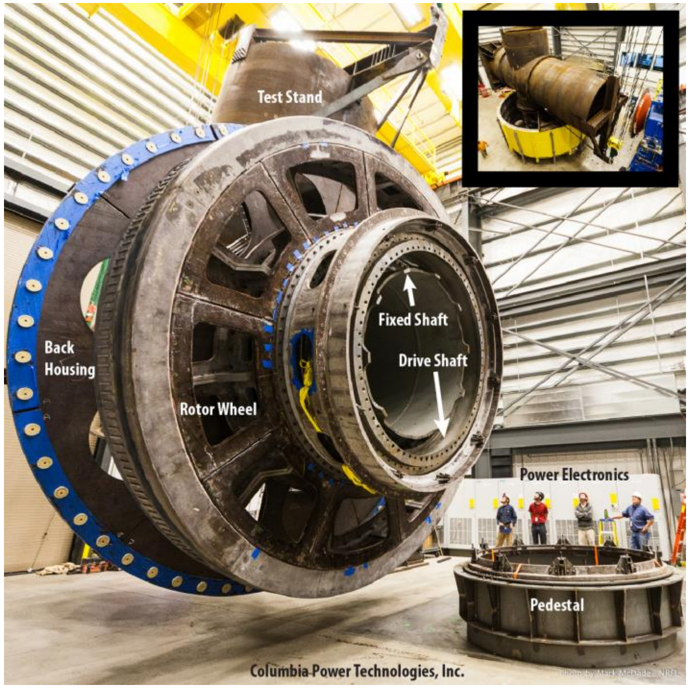
- 12-stage test plan
  - Stages 1–5: assembly, inspection, verification and set-up procedures for characterization of major sub-components
  - Stages 6–12: test various aspects of the generator—using IEEE and IEC test recommendations for continuous and cyclic modes of operation—and address any contingency testing

- Current Issues
  - High learning rate due to pioneering use of wind energy test facility for wave energy system
  - Impact on team due to remote test location
  - Seal manufacturing failure
  - Ensuring all pre-test procedures and requirements are completed



Accomplishments and Progress

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- First-in-kind utility-scale direct-drive WEC PTO
  - Organizational and test planning and final PTO design completed
  - Equipment manufactured, pre-assembled remotely, disassembled and shipped to the National Wind. Technology Center (NWTC)
  - Testing initiated
- Impact on Wave Energy Test Site.(WETS) deployment
  - Improved core competencies and confidence
  - Supply chain advancement
- Identification of areas for design and process improvement
- Metric Improvements recorded at BP1 Go/No-Go

Metric Improvements					
PWR		**Availability**		**LCOE**	
Targeted	**Actual**	**Targeted**	**Actual**	**Targeted**	**Actual**
55%	60%	10%	11%	-28%	-31%

Project Plan & Schedule

- Period of Performance: 12/1/13 – 6/30/17
- Major Schedule Impacts
  - Pre-assembly of modular rotor wheel components
  - Test Stand
    - Shift from FRP to steel
    - Significant delay and increased design and material cost
    - Proof Testing
- BP2 Go/No-Go passed in 1Q16

Project Budget

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Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,085K	$271K	$909K	$1,341K	$98K	$2,022K

- Mod 05 Budget $5,023K
- Expected final budget ≈$6,250K
  - Test stand cost increases
    - Substitution of steel for fiberglass
    - Logistics, proof-testing and integration with generator
  - Pre-assembly cost increases
  - Remote assembly difficulties
  - Increased time for test center integration
- 90% of expected budget expended to date
- Oregon Wave Energy Trust – $100K

Research Integration & Collaboration

Partners, Subcontractors, and Collaborators:

Ershigs, Inc. – Generator and Test Stand Structural Design

NREL – NWTC Test Facility and Support

Siemens – Generator Active Materials and Power Electronics Supplier

Northern Power Systems – Generator Mechanical Design

Greenberry – Test Stand Supplier

Katon – Bearings Supplier

SpenTech – Drive Shaft, Fixed Shaft, and Drivetrain Flanges Supplier

Communications and Technology Transfer:

- 2016 IEEE PES General Meeting – July 2016
- CPower-NREL Open House at NWTC – November 2016

Next Steps and Future Research

FY17/Current research:

- Completion of Test Plan
- Decommissioning and Shipping
- Design Report
- System Performance Advancement and Integration Report
- Final Report

Proposed future research:

- Next generation air-gap control system
  - Improved installation and maintenance capabilities
  - Smaller air-gap
  - Reduced weight and cost
  - Application in alternative markets