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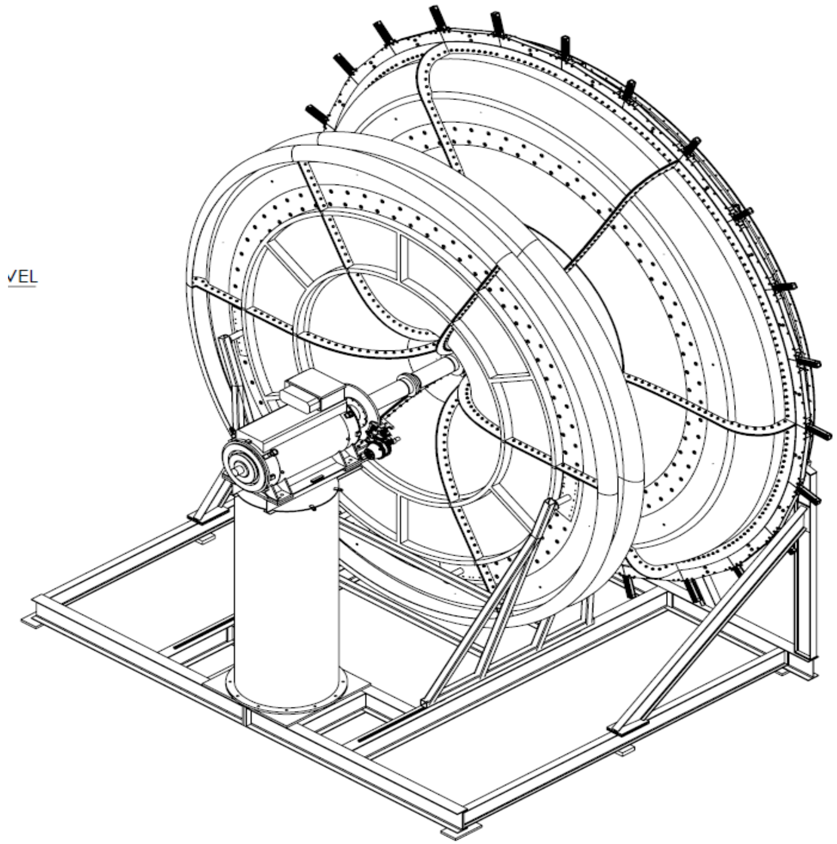

HydroAir Power Take Off System

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HydroAir Power Take Off System

- Design, construction and grid-connected testing of a large-scale 500kW HydroAir turbine power-take-off (PTO)
- Turbine mounted to an Oscillating Water Column (OWC) on the Ocean Energy buoy

The Challenge

- Higher power-to-weight datio (PWR) with design optimization
- Increasing maintenance intervals and minimizing overhaul periods
- Reduction in operating expenditures (OPEX)

Partners

- Dresser-Rand, A Siemens Business
- Ocean Energy Limited (OEL USA)

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

Project Strategic Alignment

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The Impact

- Build and test a large-scale 0.5-MW PTO device at Wave Energy Test Site (WETS), Hawaii
- First grid-connected, full-scale WEC system that will be tested with six months open-sea operation at WETS
- Commercially viable and reliable product deployment in the ocean with reliable design and low OPEX
- End product of this project will be an advanced OWC-compatible air turbine that can be used as a ‘building-block’ in a variety of Wave Energy devices
- Research and development and new product development resulted in use of glass-fiber and carbon-fiber materials for key components
- PTO-related metrics have been communicated to the DOE

Project Strategic Alignment

Market Development

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- First grid-connected, full-scale WEC system that will be tested with six months open-sea operation at WETS
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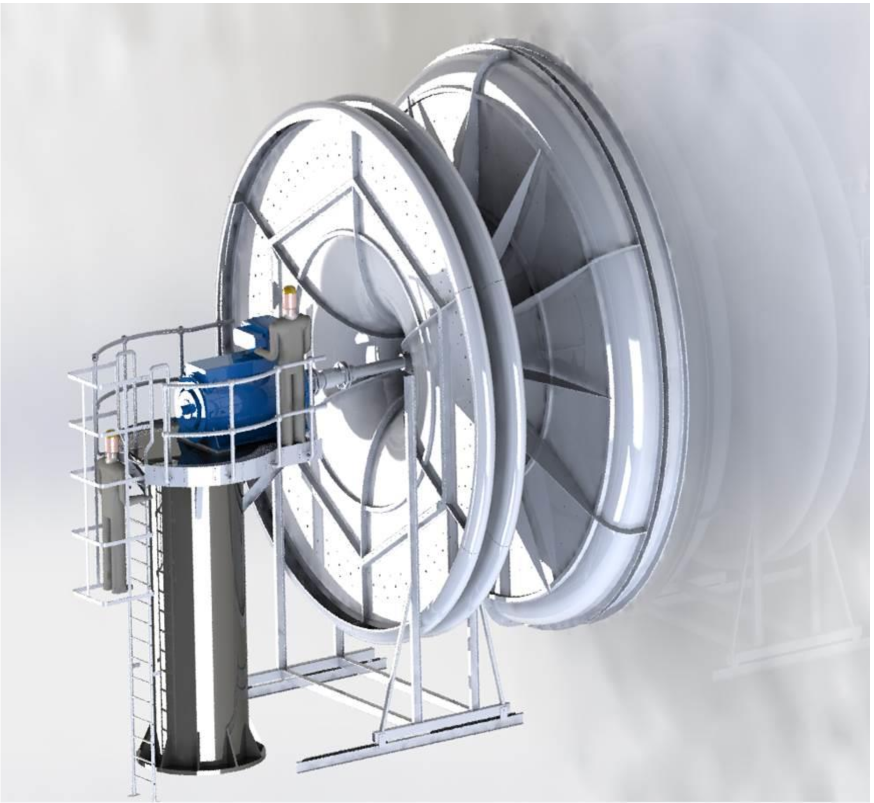
- End-product of this project will be an advanced OWC-compatible air turbine that can be used as a ‘building-block’ in any OWC design

Reliable and Optimal Design

1. HydroAir turbine represents a paradigm shift in air-turbine technology:
2. High efficiency over a broad range of operations — variable nature of ocean waves
3. Inherent design simplicity with minimal moving components – resulting in high reliability and availability
4. Compared to conventional impulse turbine, average power output can be increased by a factor of two (2) using the HydroAir turbine, because of its broad-banded efficiency characteristics.



HydroAir Turbine Assembly

Improved Efficiency

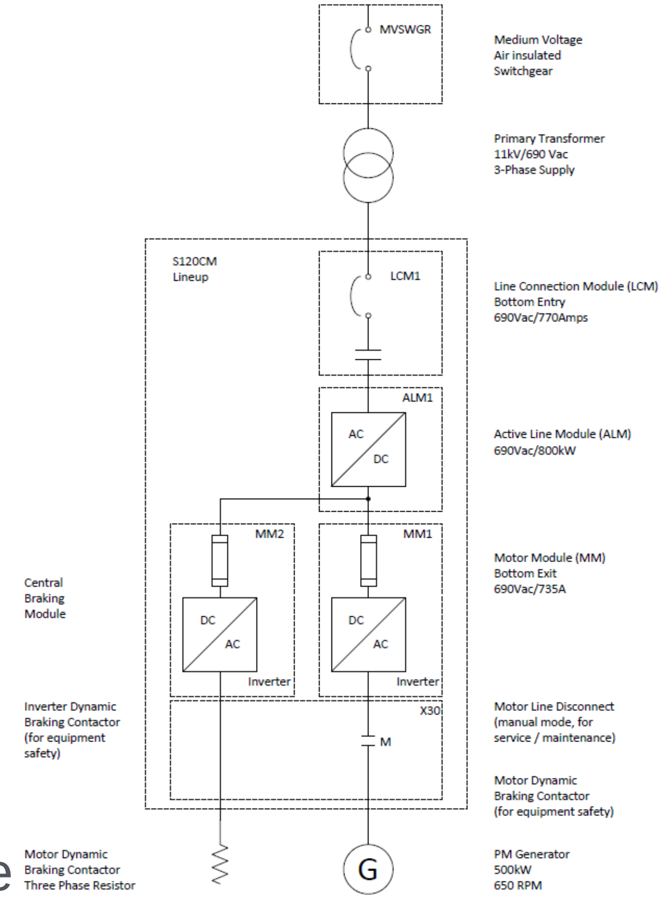
- The rotor blades, guide vanes, and ducts are designed to increase the efficiency
- Reduces the pneumatic losses and thereby increases overall efficiency

Improved Reliability and Survivability

- Having only one moving element, the rotor, increases the reliability of the turbine
- Having the shut-off-valve increases the survivability

Power-take-off Algorithm

- Power received at generator is matched to damping characteristic of the HydroAir turbine
- Enables power production at varying rotor speeds



Electrical Power system

Accomplishments and Progress

	FY2014	FY2015	FY2016
Quarter One		Requests for Quotation for Major Buyouts (MBOs) processed	Manufacturing drawings uploaded to MHK DR
Quarter Two		Failure modes and effects analysis (FMEA) document with HydroAir turbine design-related risks and mitigation completed	Purchase Orders for turbine components placed
Quarter Three		Overall PTO design review completed. Computational fluid dynamics analysis validating turbine efficiency delivered	Electrical components delivered to Dresser-Rand assembling facility
Quarter Four	Conceptual Turbine design completed. Rated operating parameters finalized.	Purchase Orders for MBO placed	PTO integration with OE buoy OWC system on-going

Project Plan & Schedule

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Project duration

- Initiation date: October 2014
- Planned completion date: December 2017

Challenges

- Integration of the turbine with OWC chamber resulted in modified support structure for turbine

Go/No-Go decision points for FY15

- Design review of the Power-take-off system including the turbine assembly, aerodynamic performance and electrical package
- Test procedure for commissioning the PTO
- FMEA to identify risks and propose mitigation strategies

Project Budget

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	Budget History					
	FY2014		FY2015		FY2016	
	DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
Initial	$ 501 K	$ 164 K	$ 1,707 K	$ 560 K	$ 292 K	$ 96 K
Revised	$ 84 K	$ 21 K	$ 721 K	$ 243 K	$1,538 K	$ 909 K

- Project underspent by $500K (DOE $316K / Cost-share $184K through FY2016 as compared to revised budget authorized by mod issued 06May16).
  - Down-selected WETS as HydroAir PTO test site. Deployment dependent on completion of Ocean Energy (OE) WEC Device (EE6924)
  - Timing for completion of design effort longer than originally planned
  - No cost extension granted; however, total cost-share increased by $450K to align with OE deployment
- 80.0% of the program budget has been expended

Research Integration & Collaboration

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Partners, Subcontractors, and Collaborators:

Dresser-Rand, Siemens Government Technologies (Project Lead)

Siemens Industry, Inc.

Ocean Energy Limited

WETS, Hawaii

Paxford Composites

Composite Consulting Group

Communications and Technology Transfer

- Technology transfer from the UK to the United States
- HydroAir turbine assembly documents uploaded to MHK-Data Repository
- To date, 15 documents have been uploaded to MHK-Data Repository

Next Steps and Future Research

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FY17/Current research

- Finalizing system integration between HydroAir PTO and OE buoy
- Testing and commissioning the PTO
- Open sea testing at WETS for one year

Proposed future research

- Increase availability by introducing state-of-the-art grid-valve to regulate air flow through turbine duct
- Testing of a 1-MW PTO to reach Technology Readiness Level 8
- Commissioning and testing in energetic sea states to reach commercialization level