Water Power Technologies Office (WPTO)
Marine and Hydrokinetic

Controls Technology Overview
Tuesday February 14th, 2017
Controls Session Overview

Controls Technology Overview:

- Studies have shown that advanced control can provide significant increases (on the order of 200-300%) in Wave Energy Capture (WEC) energy absorption.
- Controls strategies and technologies are being leveraged from other industries (e.g. aerospace, defense) that can maximize ocean energy capture over a range of ocean conditions.
- We have more wave controls projects than current / tidal projects (the controls value proposition is greater for WECs)

The Challenge: The kinetics of the oceans are complex, random, and harsh. An Marine Hydrokinetic (MHK) device that can’t be tuned to real-time or near real-time ocean conditions will seldom extract the maximum amount of energy available. A clever design or control strategy, extracting the maximum amount of energy over a wide band of ocean conditions, is essential for increasing energy capture and reducing Leveled Cost of Energy (LCOE).
2014 Peer review and response: In 2014, DOE controls research was just beginning.
• More industry projects should be initiated and that National Laboratory projects should engage with industry to maximize industry benefit.
• Leverage Controls from other sectors (Defense, Aerospace, etc.)

The WPTO listened. Please let us know if we have taken Controls projects in the most beneficial direction.
• Six industry projects and two National Laboratory projects have been undertaken.
• National Laboratories have engaged directly with industry to refine research efforts through webinars as well as planning an upcoming controls workshop during the IMREC METS conference in May.
  – Ensure Lab products are relevant
  – Ensure Lab products are disseminated
• Controls research and testing has leveraged defense and aerospace successes.
### Technology Maturity
- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for innovative MHK systems & 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
- 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
- Develop 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
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

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**Five Industry lead and two Lab lead projects**

**One Industry lead project**
Figure is not comprehensive of all program funded activities.
Cost reduction opportunities:
- Averaged across wave and tidal:
  - Wave: 63¢ per kWh
  - Tidal: 33¢ per kWh

Installed Capital Cost:
- Advanced Materials, innovative manufacturing, array layout, design for resource class, efficient installation and permitting

Operations & Maintenance (O&M):
- Prognostic maintenance, design for service/survivability, advanced coatings

Annual Energy Production:
- Energy Capture/Conversion Efficiency, Resource Characterization, Advanced Controls, Optimized Structures
MHK Controls Opportunity: Responding to the Real-Time Environment

**Device Position and Motion – 6 DoF**

- **Primary Structure**
  - Loads
  - Vibration
  - Wave Pressure
  - Force
  - Biofouling Effects

- **Surface Metocean Measurements**
  - Wave time histories
  - Directional wave spectra
  - Vessel traffic
  - Ambient noise

- **Sub-surface Metocean Measurements**
  - Water Properties
  - Current velocities and direction
  - Turbulence statistics
  - Noise

- **Meteorology**
  - Wind speed and direction
  - Air temperature
  - Relative humidity
  - Barometric pressure

- **Environmental**
  - Device / marine organism interaction
  - Device / fluid interaction
  - Electromagnetic Field (EMF)

- **Power Quality / System Health**
  - Device Voltage, Current
  - BOP Power
  - Consumption
  - Temp, Humidity, Seals
  - Internal sound

**Control system**
Opportunity:
Controls Can Be Used to Maximize Tidal /Current Energy Capture
specific wave energy technologies:
three Industry projects

potentially supporting multiple wave device archetypes:
one Industry and two Lab projects

Key:
Green: Wave technologies
Blue: Current technologies
Gray: not briefed in this session

specific current energy technologies:
one Industry project

specific current energy technologies:
one Industry project (see task 5 in ALFA)
Rapid Innovation

- 92 teams registered in competition to double energy capture from waves
- **Five-fold improvement** from winning team; four of nine finalists exceeded DOE’s goal
- **Technology advancements** are helping to accelerate the pace of commercialization

- Winner **implement a fast tuning control system** in the tank test
- Sandia’s Advanced Controls project **provides a public test data and analysis** provides a ‘roadmap to controls’

Controls technologies are essential for the MHK Industry to thrive