



Oceanenergy - OE Buoy TRL 6



Resolute Marine - SurgeWEC TRL6



Wave Carpet – TRL4



Controls Optimization of Three Different WEC Devices

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February 2017

Scope:

- Offline controls optimization of three devices
- Wave tank validation of controls
- In-ocean validation of wave prediction accuracy
- Full-Scale Demonstration on one wave energy converter (WEC) device

The Challenge:

- Attaining significant performance improvements using advanced controls (feed-forward and feed-back)
- Maturing controls frameworks to be robust and real-time capable
- Attaining good-enough wave prediction accuracy at sea

Partners:

- Resolute Marine Energy (RME)—Device Developer
- Ocean Energy USA—Device Developer
- CalWave—Device Developer
- Dresser Rand—Air-Turbine Supplier
- University of Michigan—Feedback Controls law development
- Integral Consulting—Waveprediction field-campaign in Santa Cruz

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

Technology Maturity

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The Impact

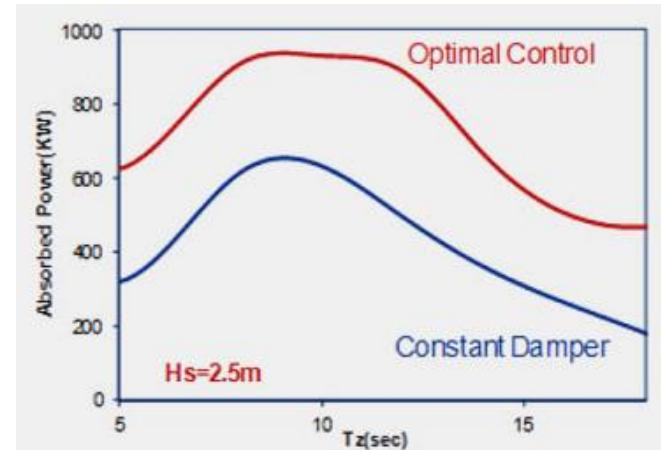
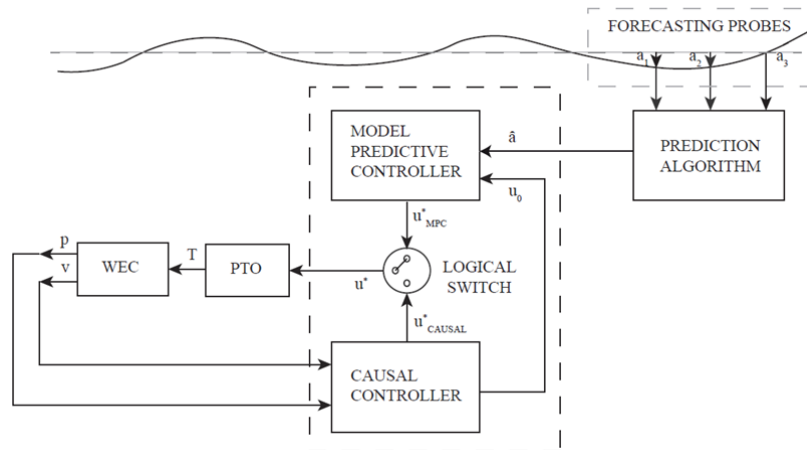
- Target Metric: System Performance Advancement II (SPAII) Target Metric—Improve power output by > 50%, resulting in a reduced levelized cost of energy (LCOE)
- Optimal Control on three WEC devices leveraging robust linear and non-linear controls methods
- Retire technical risks on optimal controls framework from Technology Readiness Level 3 (TRL3) to TRL6
- Test and validate wave prediction framework at sea
- Integrated demonstration of wave-prediction and controls at sea
- Final Product: Optimal Controller for three 3 different WEC devices
- Proven controls building blocks that can be applied to other devices
- Reduce cost to implement optimal controls by an order of magnitude.

Devices being optimized:

- RME Surge WEC (Resolute Marine Energy)
- CalWave WaveCarpet (CalWave)
- OE Buoy (Ocean Energy USA)

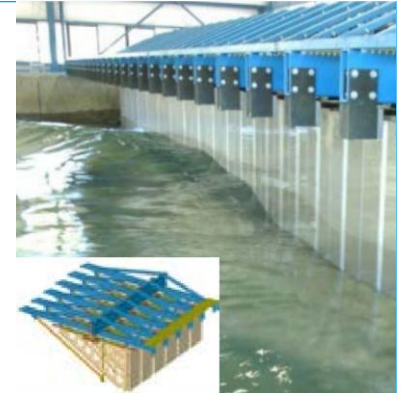
Offline Controls Optimization of three WECs

- Optimal controls using causal and non-causal control
- Investigation of different power-takeoff (PTO) options
- Separation of plant model and controls model in computational domain



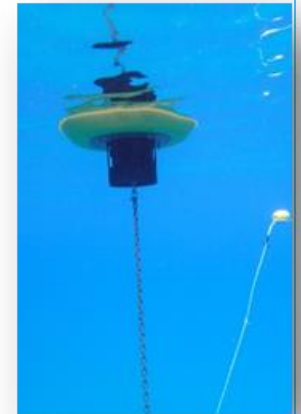
Wave Tank Validation of Control Strategies

- Focus on retiring fluid/structure interaction risks
- Fully controlled PTO to allow for different controls mode implementations



Validation of Wave Prediction Accuracy at Sea

- Campaign in Santa Cruz to deploy measurement buoys
- Five campaigns to incrementally retire technical risks while improving wave-prediction codes



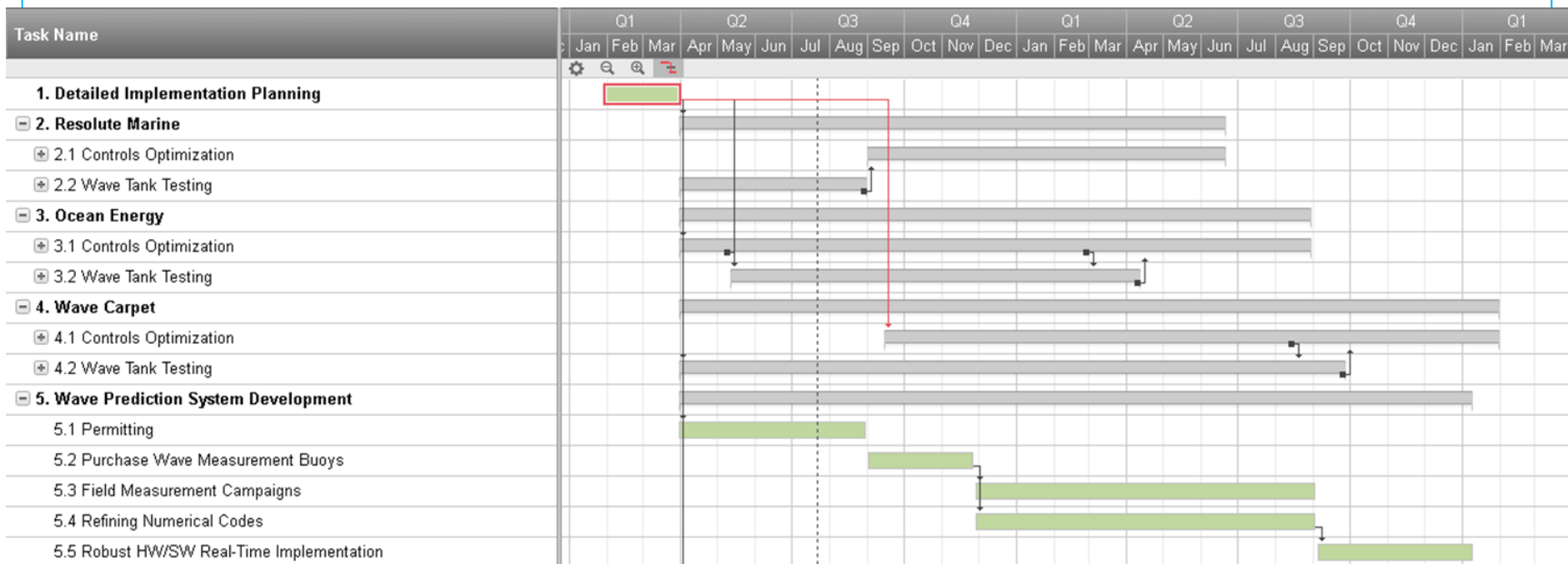
Fully Integrated Demonstration

- Down-select to full-scale device at Go/No-Go
- Systems integration with PTO
- Deployment of wave-prediction systems and controls on in-ocean demonstration

- Detailed Implementation Plan
- Wave prediction field campaign started on 11-21-16
- Offline controls development effort well advanced on OE Buoy and RME Surge WEC device
- Model-build for RME device (1:10 scale) complete

Project Plan & Schedule

- Original contract period: 2-1-16 through 2-1-18
- Phase I delays due to:
 - Delayed contract execution (1 month)
 - National Environmental Policy Act permitting taking longer than expected (3-month delay)
- Go/No-Go decision point in summer 2017
- All sub-tasks on schedule to complete by Go/No-Go point



Budget History

| FY2014 | | FY2015 | | FY2016 | |
|--------|------------|--------|------------|--------|------------|
| DOE | Cost-share | DOE | Cost-share | DOE | Cost-share |
| NA | NA | NA | NA | \$325k | \$81k |

- No variances from original budget
- Total DoE commitment is \$2.5M
- Expended about 10% of total budget as of FY16

Partners, Subcontractors, and Collaborators:

- Resolute Marine Energy—Device Developer
- Ocean Energy USA—Device Developer
- CalWave—Device Developer
- Dresser Rand—Air-Turbine Supplier
- University of Michigan—Feedback Controls law development
- Integral Consulting—Waveprediction field-campaign in Santa Cruz

Communications and Technology Transfer:

- Results will be presented at upcoming conferences
- Several journal papers under development

FY17/Current research:

- Offline Controls Optimization of three different WECs
- Wave Tank Testing/Validation
- In-Ocean Wave Prediction Accuracy Demonstration

Proposed future research:

- Phase II focus on fully integrated at-sea demonstration