DE-EE0008098-Open Water Testing of a Scaled Next Generation Point Absorber Wave Energy Device with Phase Control

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Project Overview

Project Summary

This project will prove that materials and components selected to build a 1:7 scale prototype of the AquaHarmonics (AH) device are appropriate for the environmental conditions and mechanical stresses at WETS, and the ability demonstrate IO&M and test overall performance.

Intended Outcomes

This project will prove that materials and components selected to build a 1:7 scale prototype of the AquaHarmonics (AH) device are appropriate for the environmental conditions and mechanical stresses demanded by device operation as well as meeting cost requirements and demonstrate ability to economically perform deployment, mooring, maintenance, and decommissioning activities in a real-world open ocean conditions.
Project will provide performance map showing device operation across a range of wave heights and periods. This data can be used to generate expected power generation characteristics at various potential deployment sites.

Project Information

Principal Investigator(s)

- Alex Hagmüller

Project Partners/Subs

- SNL- controls, HIL testing
- Glosten Naval Architects-ULS/IEC analysis
- OSU-tank testing
- ,HNMREC- 30m WETS partner,
- PEV- Permitting
- , Sea Engineering,-deployment/recovery
- Saddle Point Machine-machined parts
- ,Williwaw Engineering-electrical consulting
- Blitz R&D- Structural analysis
- Loupe-industrial automation

Project Status: Ongoing

Project Duration

- September 2017 - September 2024

Total Costed (FY19–FY21)

$2,733,743.89

Project Objectives: Relevance

Relevance to Program Goals:

- System Design and Validation activity area focuses on

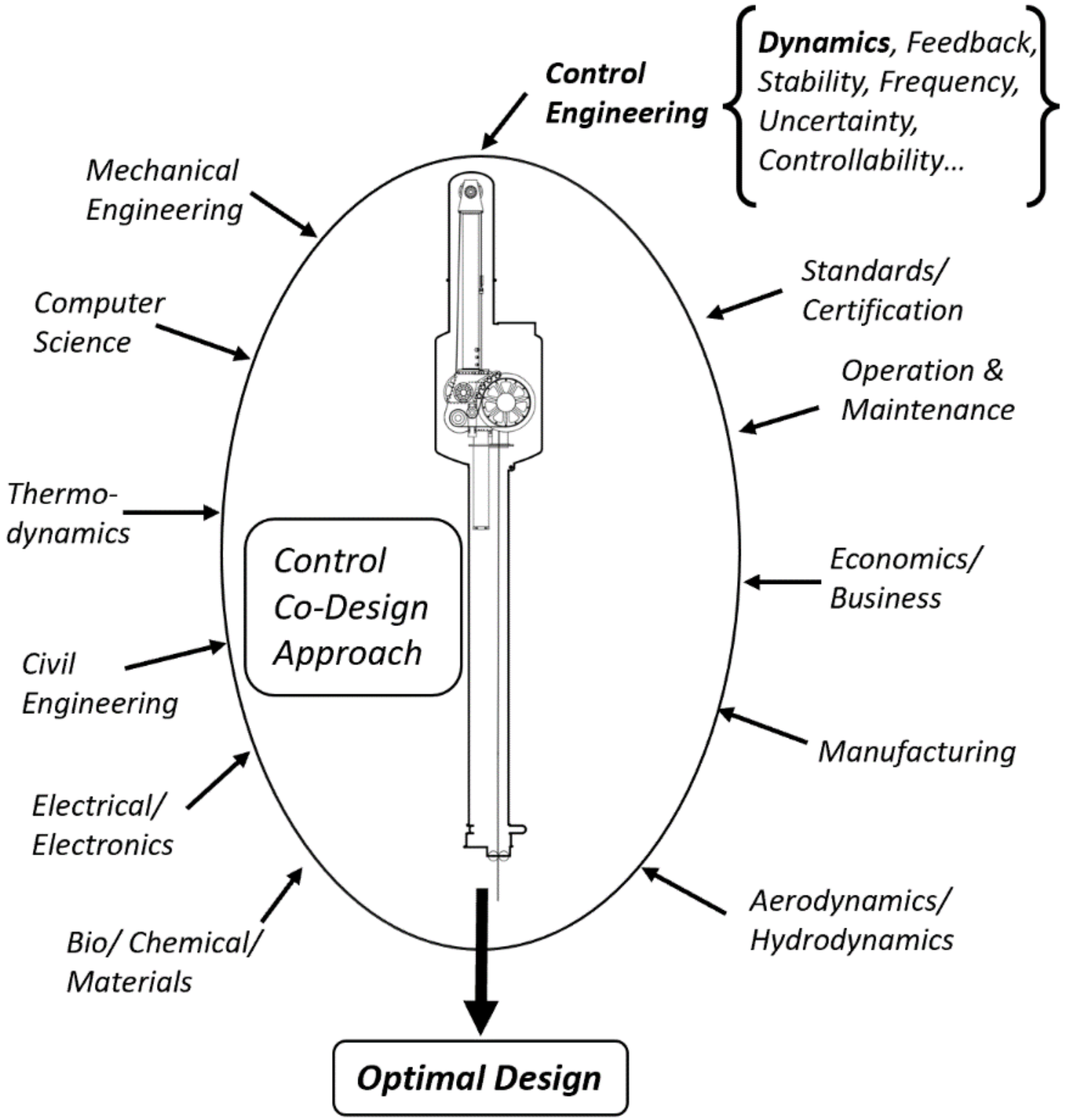
(1) supporting the design, manufacture and validation industry-designed prototypes at multiple relevant scales; Furthering the development and continuing the momentum that AquaHarmonics Inc. achieved through the US DOE Wave Energy Prize

- (2) improving methods for safe and cost-efficient installation, grid integration, operations, monitoring, maintenance, and decommissioning; -development of evolved human machine interface, integrated real-time system, dark-start capabilities, grid export power controls, simplified single-point mooring system, yaw stabilization
- (3) supporting the development and adoption of international standards for device performance and insurance certification; - Started with DNVGL specification, and have moved to IEC specification for design and validation. Use of ORCAFlex, CFD, WEC-Sim and scaled tank testing to develop power and structural design criteria
- (4) supporting the early incorporation of manufacturing considerations into device design processes; use of hydroforming for complex hull parts and analysis of large machined parts as castings for mass manufacturing. Scalability of power electronics and HMI
- (5) leveraging expertise, technology, data, methods, and lessons from the international marine energy community and other offshore scientific and industrial sectors. – Leveraging expertise from SPACEX, aerospace casting, design for manufacturing and lean manufacturing, multi-part and sub-assembly symmetries, common tooling, simplified datums and assembly methods for quick one-person assembly of PTO.

Project Objectives: Approach

Approach:

- Through controls co-design, scaling laws and system identification method from 1:20th scale tank testing are used to develop a parametric-power-take-off and energy storage system model to develop a 1:7th scale device PTO, ESS, hull, mooring and grid interface for deployment in the open ocean.



Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- The project's expected outputs include:
  - grid-tied1:7 scale wave energy conversion system at WETS
  - A revised wave-to-wire numerical model allowing for further concept optimization
  - First developer test at the Sandia Wave Energy Power Take Off (SWEPT) facility allowing for significant de-risking
  - Up-and-Down scalable software and controls hardware

Outcomes:

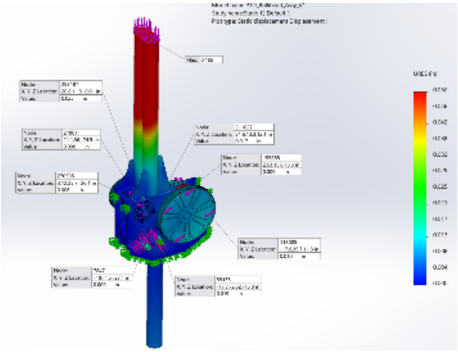
- Ocean deployable WEC system for blue-economy markets, villages, and ocean observing instrumentation requirements, de-sal, UUV re-charging
- WEC concept refinement and LCOE reduction
- Improved understanding of WEC design and analysis process through controls-co-design

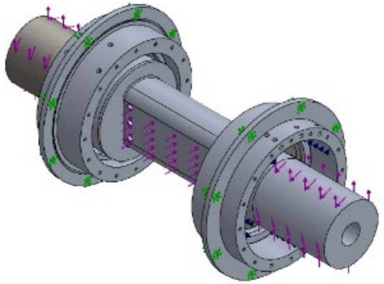
Project Timeline

FY 2017-2019

BP1

Fabrication and testing of PTO; Prepare for SWEPT testing at SNL.





FY 2020-2021

Proceed through Go/No Go

FY 2022-2024

Fabrication of 1:7th scale; Ship to WETS; Demonstrate IO&M and power performance

Figure 3: Testing the AH PTO at Sandia's SWEPT lab. Left: AH PTO. Right: SNL HIL Actuator.

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$4,000,005.00	$ 1,127,500.00	$ 5,127,505.00

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$1,307,458.70	$882,352.50	$543,932.69	$ 2,733,743.89

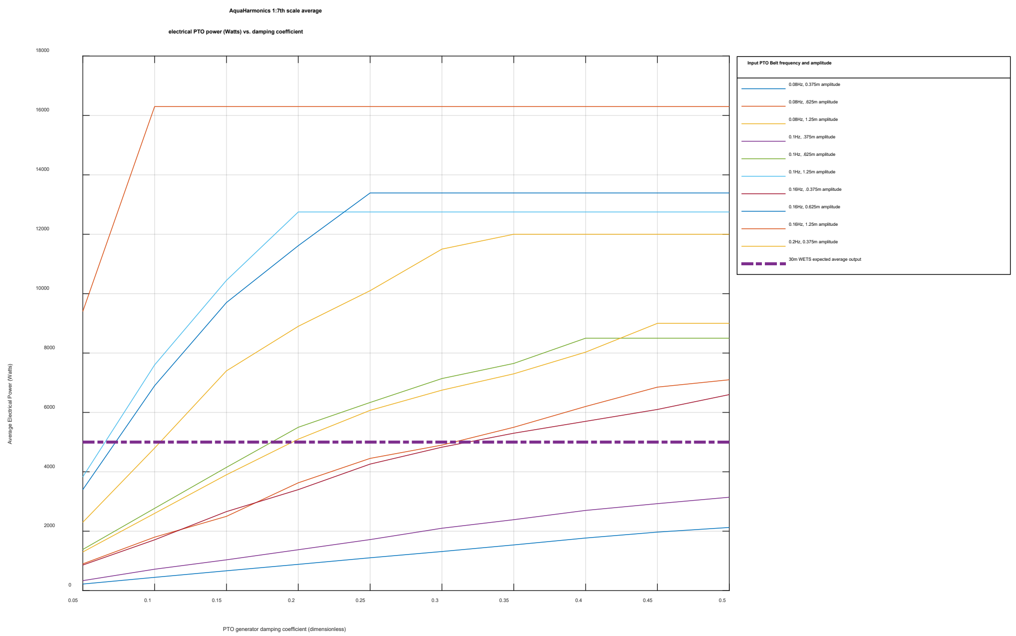
- Vendor Contract Issues on original hull design; changed from composite to aluminum.
- Custom designed motor/generator and motor drive all had to be re-designed due to mis-leading motor drive specification
- Custom designed motor/generator magnet cost (neodymium) due to trade war
- Delays in testing at the SWEPT lab by over a year due to COVID-19
- Custom designed motor/generator appears to have been destroyed in a lightning storm in ABQ, NM during SWEPT lab testing. New hardware developed in its place
- Selected active front end would be difficult for HECO to approve for grid-connection. Solar grid-tie inverter was reverse engineered and made as the grid interface instead,

End-User Engagement and Dissemination

- End-User engagement strategy
  - The success of the project will meet the needs of the blue economy
  - Specific end-users were engaged at the beginning of the project, and needs were assessed in terms of power and deployment environments
  - Periodic updates to the progress of the project have been communicated
  - Looking at early market adopters in the blue economy, eg, UUV recharging, Ocean Observing, remote village power, disaster relief.
    - These end users have needs in the power range of the WEC in this project
    - The end user environments fit the design environments of the WEC
- Project results and information have been uploaded to MHK-DR, and will be also uploaded to TETHYS.

Performance: Accomplishments and Progress

- The most important technical accomplishments achieved over the life of the project include:
  - Development of a high-performance real-time system, controls, and human machine interface
  - Power generation at input frequencies and amplitudes for representative sea-states was tested at the SWEPT lab. PTO can generate average power outputs 324 % greater than estimated deployment average power output, with conservative torque limits set on PTO (more to be had!)
  - ACE metric from WEP was 7.6 m/$M. New ACE metric in this project is 11.64 m/$M, a 53% improvement.
  - BP 1 was successfully completed and Go/NO-GO was completed.
  - Currently in BP2, Phase 1 SWEPT testing completed and Phase 2 to be completed in July 2022
  - Many technical barriers were overcome, including but not limited to
    - Development of a custom PTO belt
    - Development of a custom motor/generator
    - Development of a real-time system, controls, power electronics and grid interface
    - Development of an efficient high-force, large stroke pneumatic tensioner



Preliminary results from sinusoidal force input during SWEPT lab testing. PTO generator thermal and torque limits were set conservatively. Plateaus in the data show where torque saturation of the motor occurred.

Wave #	Test #	Tp (s)	Hs (m)	P (kW)	Adjusted Weighting Each Climate Alaska	Washington	Northern Oregon	Oregon	Northern California	Southern California	Hawaii
IWS 1	23	1.63	0.117	41.6	24.3%	13.7%	15.5%	17.5%	20.7%	15.2%	32.8%
IWS 2	24	2.20	0.132	173.0	33.2%	27.7%	30.7%	26.8%	23.0%	27.0%	24.5%
IWS 3	20	2.58	0.268	590.3	7.5%	4.1%	5.6%	5.8%	1.2%	1.4%	0.1%
IWS 4	19	2.84	0.103	101.0	20.0%	33.8%	34.4%	29.5%	46.6%	39.1%	13.3%
IWS 5	17	3.41	0.292	983.2	2.4%	2.2%	3.7%	3.4%	1.6%	1.0%	0.0%
IWS 6	14	3.69	0.163	342.0	1.2%	4.5%	4.2%	5.4%	6.4%	9.5%	1.3%
avg				371.8	88.6%	86.0%	94.1%	88.4%	99.5%	93.2%	72.0%
	<CP> (kW/m) =				35.5	32.7	39.3	37.9	31.5	31.2	16.8
	AACW(j) (m) =				4.4991	4.5560	4.5318	4.4742	4.4499	4.5869	4.4346
		ACCW (m) =									
		ACCW (m) =		4.50							
		Total CCE ($)		$	387,000						
		ACE (m/$M)		11.64	Threshold met						

Performance: Accomplishments and Progress (cont.)

- Granted patent No US 10,941,748 B2 Mar. 9th, 2021 “Sea Wave Energy Converter Capable of Resonant Operation”
- Development of ability to commission device wirelessly via an iPad
- Technical papers and journal articles

- [1] Saeidtehrani, Saghy & Lomonaco, Pedro & Hagmüller, Alex & Levites-Ginsburg, Max (2017), “Application of a simulation model for a heave type wave energy converter”
- [2] Bacelli, G. & Ginbsurg M., Hagmüller A., Gunawan B. (2019), “Characterizing the dynamic behavior and performance of a scaled prototype point absorber wave energy converter in a large wave flume”
- [3] W. W. Weaver et al., (2019), "WEC Array Networked Microgrid Control Design and Energy Storage System Requirements," OCEANS 2019 MTS/IEEE SEATTLE, Seattle, WA, USA, 2019, pp. 1-6.

Future Work

- Plans and timeline for future work and project scope
  - Final SWEPT testing, hull manufacturing, WEC System assembly, open water deployment, testing and recovery, project reporting
  - $ 1,164,212.94 remaining in total project funds.
  - Testing at WETS 30m berth planned for June 2023.
- Additional provisional and full patents have been applied to
- New IP developed through SWEPT testing/performance validation including hardware and software

Q&A