SAND2019-12029PE

Advanced WEC Dynamics and Controls

2.1.2.701

Marine and Hydrokinetics Program

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Sandia National Labs

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Project Overview

Project Summary

- Wide body of research has shown **massive potential for control to improve WEC performance** (more power, reduced loads, & **fundamentally transform the WEC design problem**)
- Project focus is **realizing those benefits for WEC developers** by creating a tractable engineering workflow

Project Objective & Impact

The goal of this project has been to deliver actionable methods for WEC developers to apply in order to improve the performance of their devices via control. This goal has been achieved and extended upon as our research has led us to better understand the need to incorporate the knowledge available from WEC control design into the large WEC design process.

Project Information

Project Principal Investigator(s)

Ryan Coe & Giorgio Bacelli
Sandia National Labs

WPTO Lead

Bill McShane

Project Partners/Subs

US Navy
Michigan Tech.
Oregon State University

Project Duration

- Oct. 2016
- Sept. 2019

Alignment with the Program

Marine and Hydrokinetics (MHK) Program Strategic Approaches

Data Sharing and Analysis

Foundational and Crosscutting R&D

Technology-Specific Design and Validation

Reducing Barriers to Testing

Alignment with the MHK Program

Foundational and Crosscutting R&D

- Drive innovation in components, controls, manufacturing, materials and systems with early-stage R&D specific to MHK applications
- Develop, improve, and validate numerical and experimental tools and methodologies needed to improve understanding of important fluid-structure interactions
- Improve MHK resource assessments and characterizations needed to optimize devices and arrays, and understand extreme conditions
- Collaboratively develop and apply quantitative metrics to identify and advance technologies with high ultimate techno-economic potential for their market applications

- Sandia leverages expertise from aerospace, defense, and robotics control to deliver methodologies for WEC device and control design capable of delivering dramatic improvements in performance and economic viability.
- To deliver a robust framework for WEC device and control testing and design, Sandia has developed and validated numerous methodologies and experimental techniques. The methods provide WEC developers with a tractable path for WEC and control design. Experimental methods have increased the effectiveness of wave tank testing, enabling WEC developers to accomplish more in less tank time.

Alignment with the MHK Program

Technology-Specific Design and Validation

- Validate performance and reliability of systems by conducting in-water tests of industry-designed prototypes at multiple relevant scales
- Improve methods for safe and cost efficient installation, grid integration, operations, monitoring, maintenance, and decommissioning of MHK technologies
- Support the development and adoption of international standards for device performance and insurance certification
- Evaluate current and potential future needs for MHK-specific IO&M infrastructure (vessels, port facilities, etc.) and possible approaches to bridge gaps

- Sandia's Advanced WEC Dynamics and Controls project has produced the most popular dataset on MHK-DR.
- Sandia's improved testing methods are being used heavily for the update of IEC Technical Specification 62600-103 ("*Best practices and recommended procedures for the testing of pre-prototype scale devices*").

Project Budget

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget (FY17–FY19 Q1 & Q2)	
Costed	Costed	Costed	Total Costed	Total Authorized
$1,381K	$1,132K	$470K	$2,983K	$3,528K

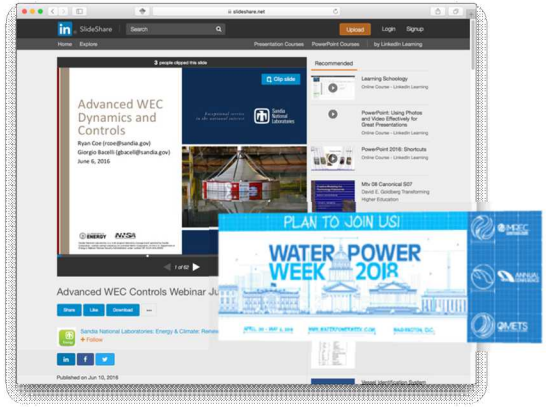
- *Leverage synergies/funding from*
  - *MARINET2*
  - *Sandia internal funding (SWEPT Lab)*

Management and Technical Approach

- **Problem:** Clear potential for improvements based on WEC control since 1970s, but limited real-world benefits
- **Goal:** Holistic approach to realize these gains *and provide a basis for co-design*
- **Strategy:** Leverage methods and *tools proven successful in other applications* to provide a *tractable work flow for WEC control design*

End-User Engagement and Dissemination Strategy

Annual workshop & 4 webinars



Most popular public dataset on MHK-DR

MHK

Marine and Hydrokinetic Data Repository

U.S. DEPARTMENT OF ENERGY

Broad ranging research collaborations

AALBORG UNIVERSITY DENMARK
UNIVERSIDADE DE VIGO
Oregon State University
Maynooth
Michigan Technological University
1885
JOHNS HOPKINS UNIVERSITY
MaRINET2

4 patent applications (2 granted)

UNITED STATES PATENT AND TRADEMARK OFFICE
DEPARTMENT OF COMMERCE

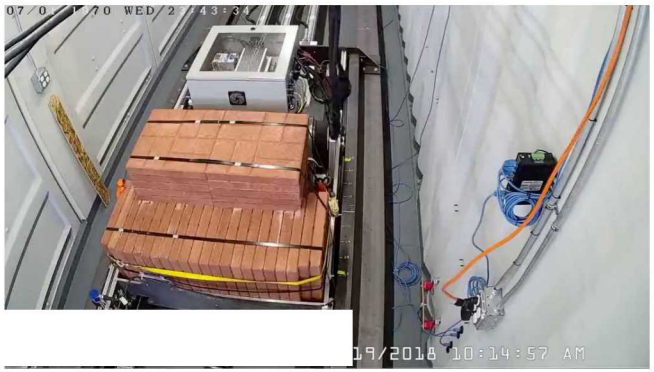
Private developer collaborations

AQUA HARMONICS
CalWave Power Technologies
COLUMBIA POWER TECHNOLOGIES
power from the next wave

40+ project publications

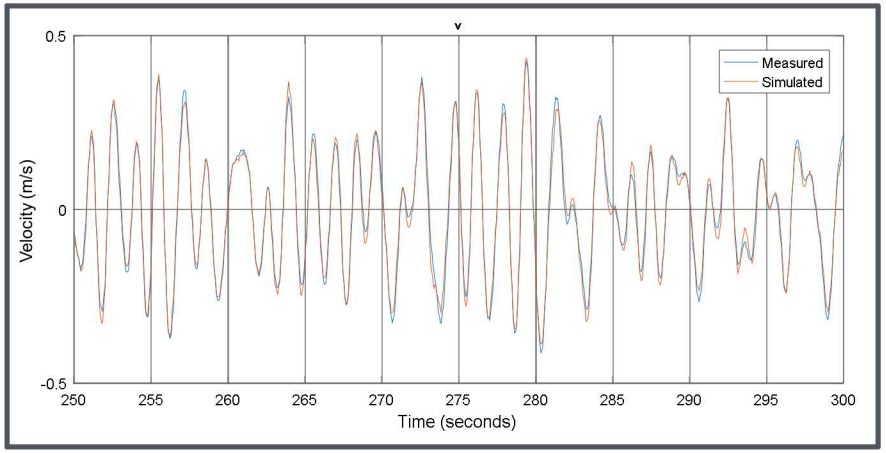
Technical Accomplishments

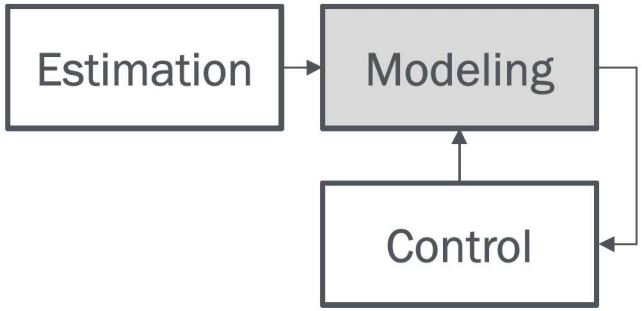

Wave tank test at Navy facility in MD



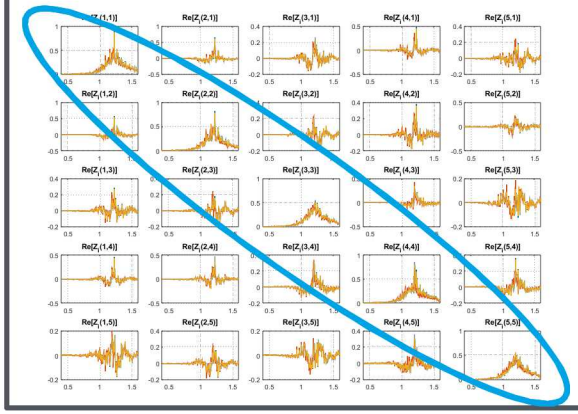
Testing practices deliver better results in less time

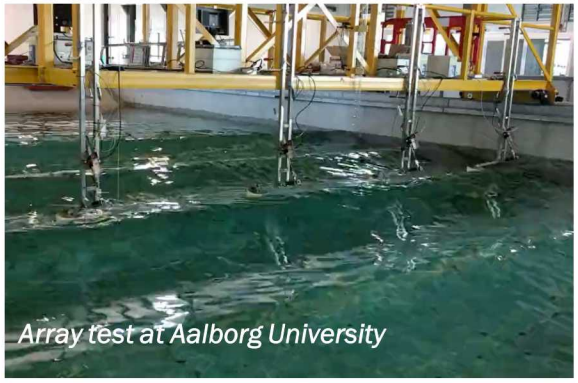
Models better than 90% accurate





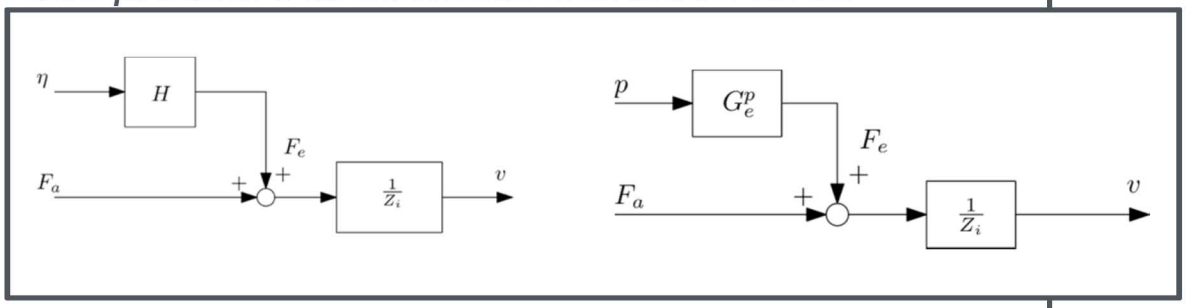
Works just as well on multi-device & multi-DOF systems

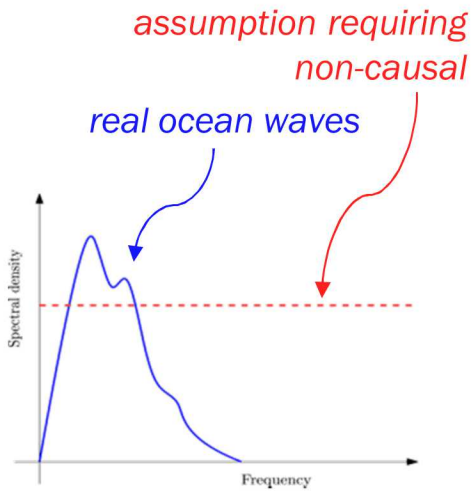


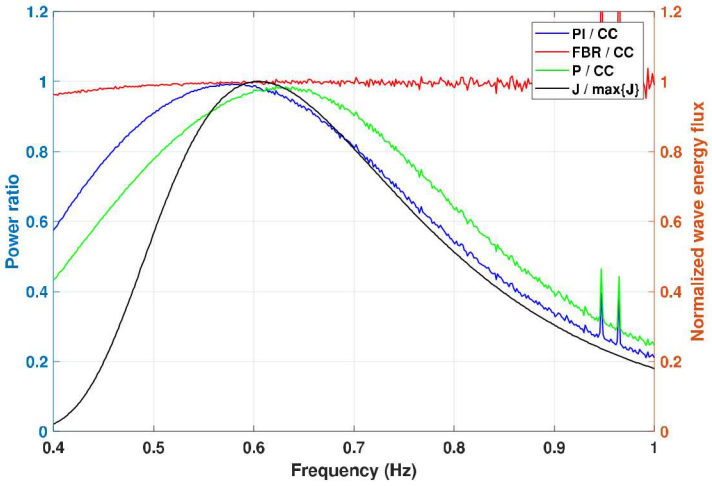

Array test at Aalborg University

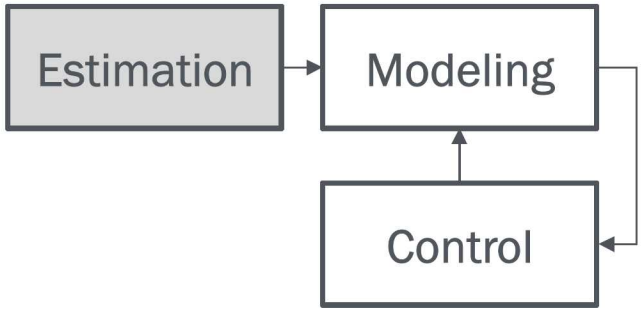
Technical Accomplishments (Cont.)

Use pressure to estimate excitation force





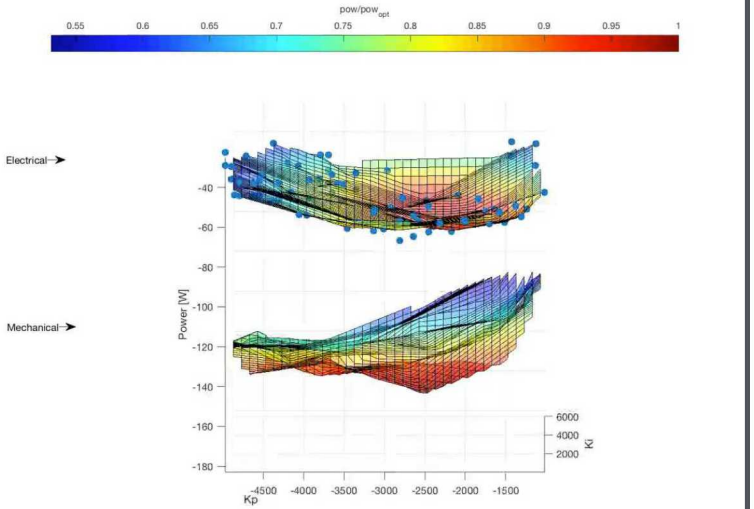




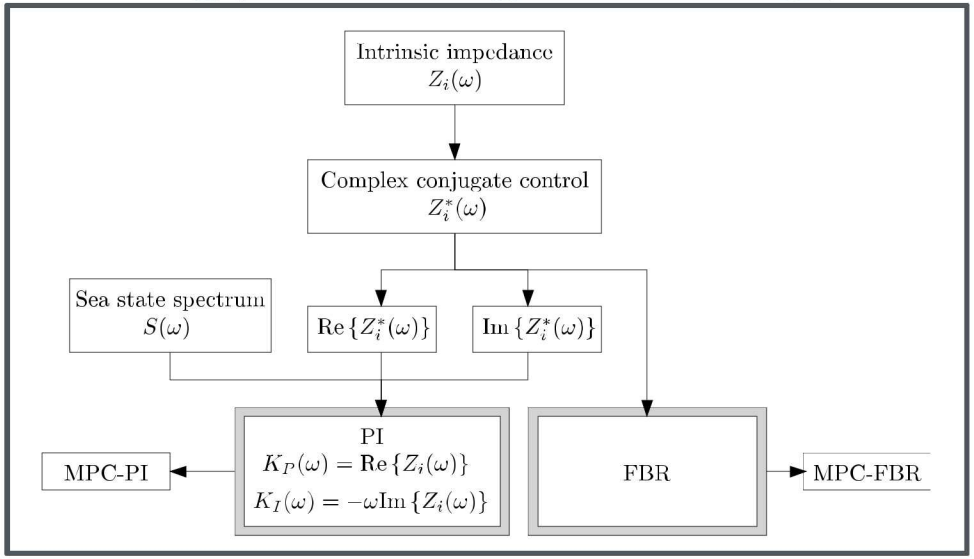
Engineering approach shows that in real waves, need for prediction greatly reduced

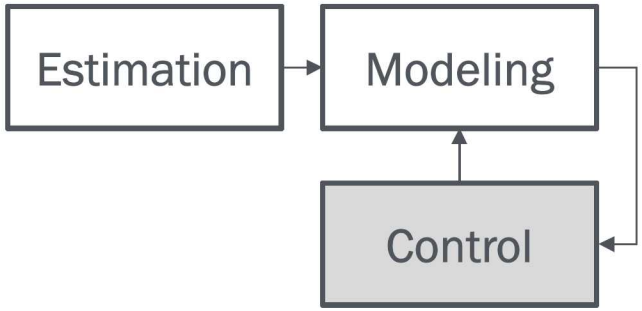
Technical Accomplishments (Cont.)

Control design focused on LCOE

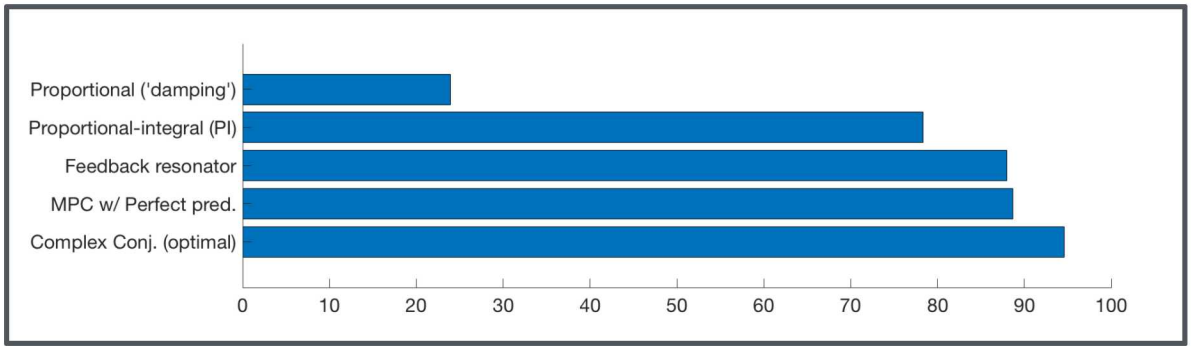


Feedback approach based on impedance matching, provides insight for co-design

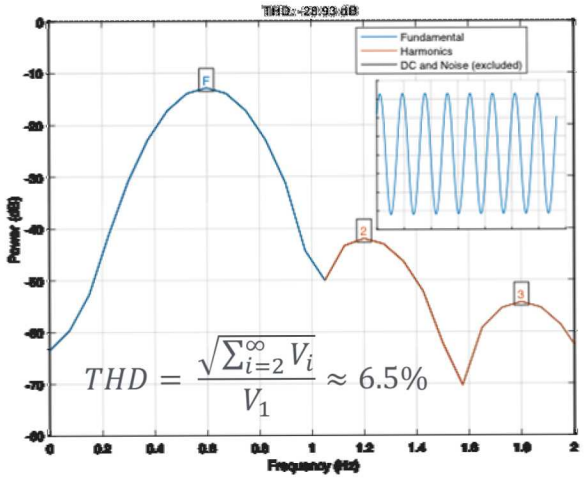




Nearly optimal performance without prediction

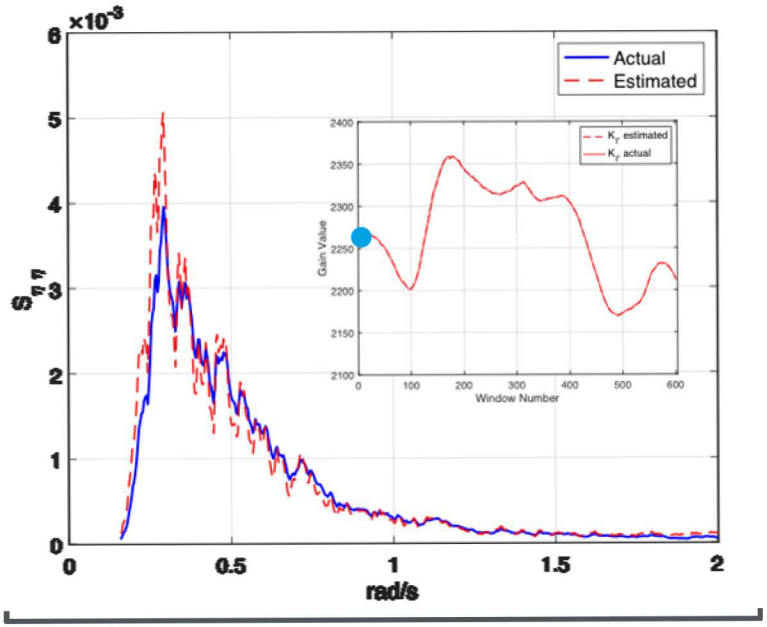


Progress Since Project Summary Submittal



Just how nonlinear are WEC hydrodynamics?

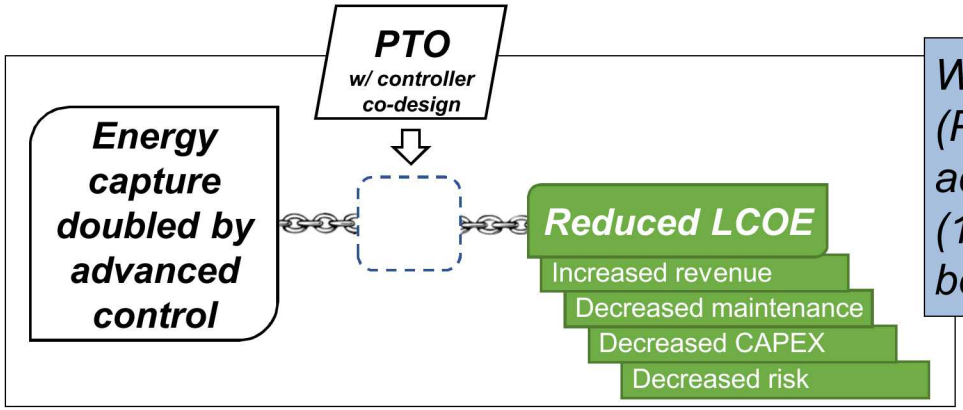
Self-tunin controller fc changing weathe



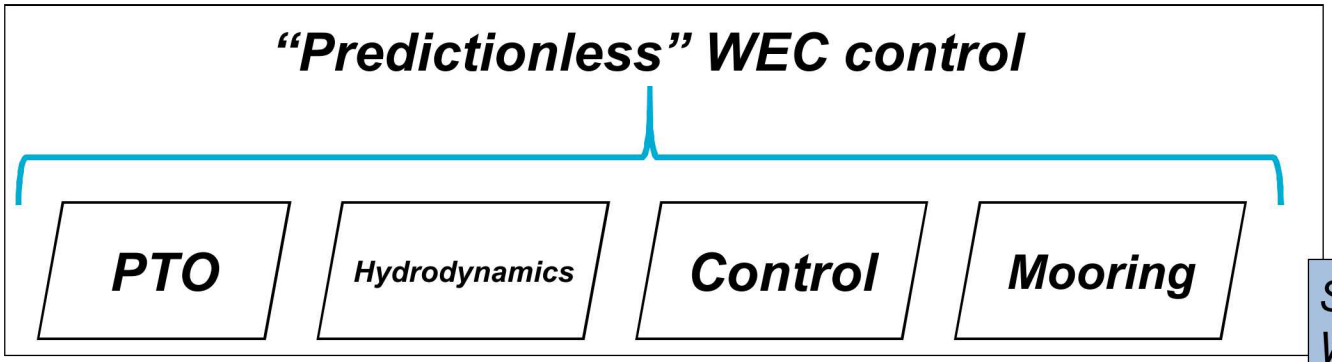
Are these methods really device-agnostic?

Future Work

- **Problem:** WEC PTO design is *linchpin* enabling efficiency gains and load reduction from advanced controls to be realized in terms of LCOE (*absorbed* power -> *generated* power)
- **Goal:** Develop method for ***co-design*** of WEC PTO and control systems utilizing predictionless control to deliver 100% power increase in full-scale WEC



Without better power take-off (PTO) systems, the benefits of advanced control (100%+ more power) cannot be realized in terms of LCOE



Sandia's "predictionless" WEC control enables synchronous co-design