DEHLSEN ASSOCIATES, LLC

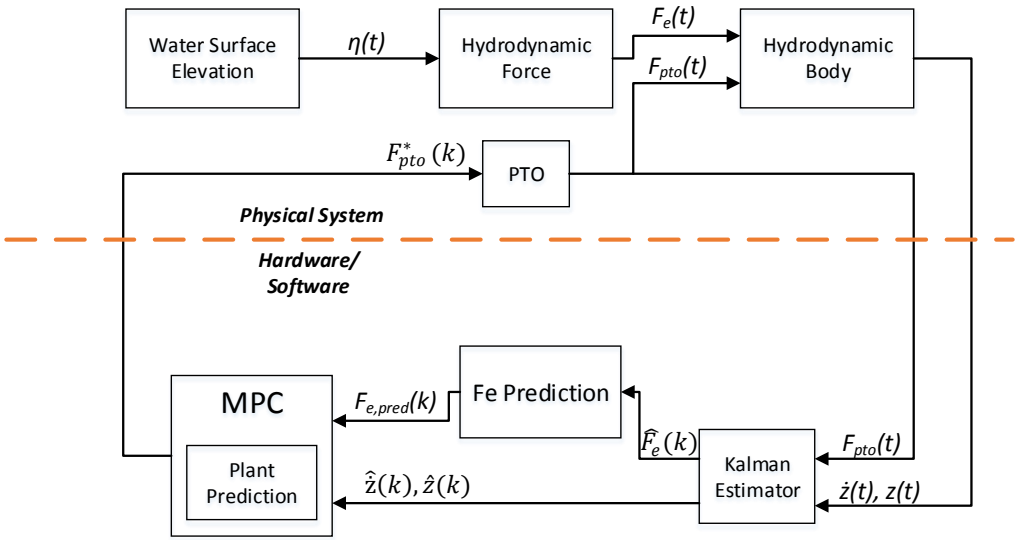

Diagram of controller resulting from this work

Advanced Controls for the Multi-pod Centipod WEC device

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Project Overview

Advanced Controls for the Multi-pod Centipod WEC device

Dehlsen Associates, LLC proposed to develop innovative advanced control algorithms to optimize power production and dynamic loads for the multi-pod Centipod wave energy converter (WEC).

The Challenge: Use model predictive control (MPC) to develop an advanced control system, maximizing power extraction on the Centipod WEC that could run in real time and be applied to various power-take-off (PTO) topologies.

Project Overview

Partners:

DNV GL – Numerical modelling

Oregon State University & Helios - Controls development

National Renewable Energy Laboratory and (NREL) and Sandia National Laboratories - Extreme events guidance

Program Strategic Priorities

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

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

The Impact

- **WEC closer to economic viability:** Implementation of MPC can provide up to 50% levelized cost of energy (LCOE) reduction compared to a simple fixed damping control method
- **WEC performance enhanced:** MPC showed a 160% increase in annual energy production (AEP) in this project
- **MPC shown to be practically implementable:** Controller was capable of running in real time on a simulated 435Mhz processor

Technical Approach

The approach for this project will follow the process below:

1) Establish a numerical model in DNV GL's WaveDyn software
2) Characterize baseline performance of WEC
3) Build reduced order model of WEC in Matlab to aid in controller development
4) Verify reduced order model against WaveDyn

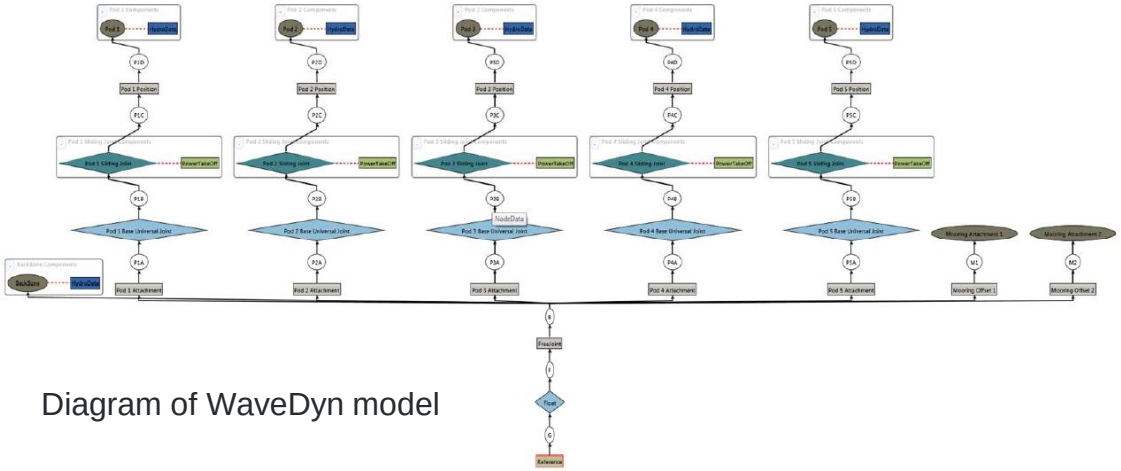

Diagram of WaveDyn model

Technical Approach

5) Develop MPC controller in Matlab
6) Create DLL of controller and couple with WEC model in WaveDyn
7) Calculate performance of WEC with MPC
8) Verify feasibly of real-time implementation

Accomplishments and Progress

- Project completed
- Exceeded all performance metrics proposed
- Proved the potential of the MPC controller
- Showed a 160% improvement in AEP with MPC
- Demonstrated MPC could run in real time

Project Plan & Schedule

- Project began in December 2013
- Project ended in October 2015
- Project completed on schedule

Project Budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$190K	$48K	$310K	$77K		

- No variance from original budget
- Project complete
- $625k total project budget (DOE and cost-share)

Research Integration & Collaboration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors, and Collaborators:

Oregon State University
Helios Engineering
DNV GL
National Renewable Energy Laboratory
Sandia National Laboratories

Communications and Technology Transfer:

- Publications Include:
  - *M. Starrett, R. So, T. K. A. Brekken and A. McCall, "Increasing power capture from multibody wave energy conversion systems using model predictive control," 2015 IEEE Conference on Technologies for Sustainability (SusTech), Ogden, UT, 2015, pp. 20-26.Development of a state space model for wave energy conversion systems*
  - *M. Starrett, R. So, T. K. A. Brekken and A. McCall, "Development of a state space model for wave energy conversion systems," 2015 IEEE Power & Energy Society General Meeting, Denver, CO, 2015, pp. 1-5.*
- Public report currently available on Marine and Hydrokinetic Data Repository

Next Steps and Future Research

FY17/Current research:

- Project complete
- Implementing controller on full-scale PTO hardware in a laboratory environment in 2017 through separate project
- Testing will further validate results

Proposed future research:

Next steps (outside of project scope) are being undertaken to test controller with PTO hardware