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Advanced Energy Harvesting Control Schemes for Marine Renewable Energy Devices

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Project Overview

Advanced Energy Harvesting Control Schemes for Marine Renewable Energy Devices

- Turbulent flows are typical of marine and hydrokinetic (MHK) sites
- This project investigated, analyzed, modeled, and tested advanced controls to increase energy from hydrokinetic turbines in turbulent flow
- Testing was performed in flumes and in the field
- Test data confirmed that advanced controls will increase energy production from a cross-flow turbine

Project Overview

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The Challenge:

- Limited turbulence data sets were available for MHK sites (tidal or river)
- These data had not been integrated into a systems model of an MHK device to evaluate performance of control schemes
- Unexplained control limits were observed in prior ORPC test work, which limited power outputs

Project Overview

Partners:

- University of Washington (Northwest National Marine Renewable Energy Center and Applied Physics Laboratory)
  - Brian Polagye, Control testing and integration
  - Brian Fabien, Control system theory
  - Jim Thomson, Turbulence characterization
- AeroCraft
  - Computational fluid dynamics of cross-flow turbines in shallow water environment
- Nortek, Inc.
  - Instrumentation supply

Program Strategic Priorities

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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
- 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

- Achieved 25.5% increase in annual energy production (AEP) and power-to-weight ratio (PWR), targeted 10%
- Achieved 20.3% reduction in levelized cost of energy (LCOE), target was 20%
- Benefits to industry included advances in environmental monitoring and turbulence studies:
  - Hundreds of hours of video of fish interactions, de-risking ORPC's power system
  - Full video data-set provided to PNNL to develop automated tools to reduce cost and effort
  - Advanced turbulence and wake studies, performed and published by UW

Technical Approach

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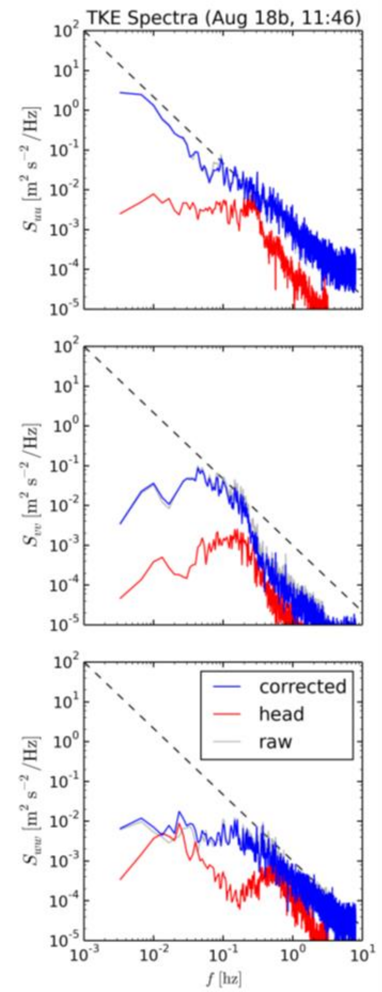
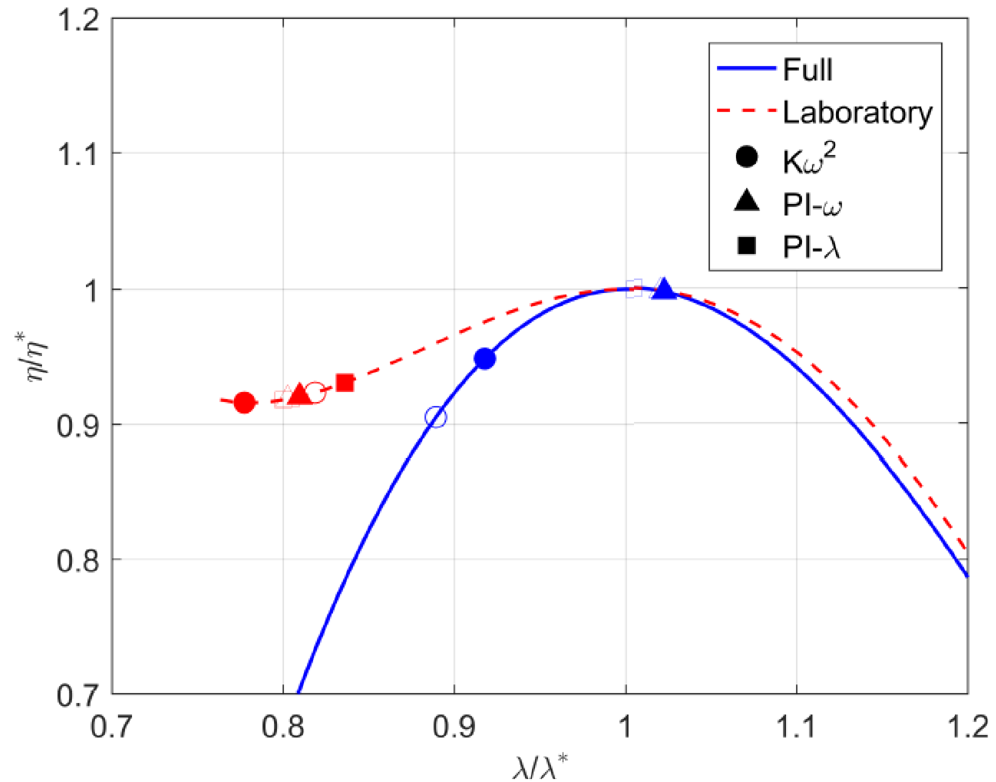
- Models of various control schemes were developed in Matlab Simulink and tested during laboratory experiments.
- Turbulence and flow characteristics were measured at Igiugig, AK, in the summer of 2014.
- Turbulence is uncorrelated between upstream and downstream measurements.
- The turbulent kinetic energy spectra and generator power spectra measured in Igiugig, AK, shows that turbine power is affected only “engulfing gusts.”



Technical Approach

- Laboratory and field (full-scale) testing of control schemes was conducted and compared to simulation
- In general, good agreement between methods



Open markers denote stability limits predicted by simulation as compared to laboratory and field (full-scale) experiments. Performance curves normalized around optimal operating point.

Accomplishments and Progress

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Technical Achievements

- Proved viability of $K\omega^2$ control for micro-grid connections
- Operated stably over large range of tip speed ratios
- Operated stably at maximum power point in turbulent flows

Benchmarks

- Increased AEP and PWR by 25.5%, exceeding 10% goal
- Reductions of 20.3% in LCOE were achieved (20% goal)

Awards

- National Hydropower Association, Outstanding Stewards of America's Waters Award for Operational Excellence, 2016

Project Plan & Schedule

- Project original initiation date: 01/01/2014
- Project planned completion date: 12/31/2015
- No slips in schedules until Q7
  - Q7 deliverables (Data Analysis and System Integration Plan delayed until Q8)
  - Unrealistic to have completed Data Analysis in same quarter as Data Collection (Q7)
- Go/No-Go decision point February 9, 2015

Project Budget

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Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$30.0K	$165.6K	$1,092.7K	$240.0K	$604.9K	$75.7K

- No variances from planned budget
- All portions of the project budget were expended

Research Integration & Collaboration

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Partners, Subcontractors, and Collaborators:

- University of Washington: Brian Polagye, Brian Fabien, Jim Thomson
- AeroCraft, Hal Youngren
- Nortek, Michael Mathewson

Communications and Technology Transfer:

- Eight peer reviewed papers published
- Three Ph.D. students trained
- Two engineering interns employed on project

Next Steps and Future Research

FY17/Current research: Ongoing research on control schemes is being conducted by ORPC in conjunction with a university and a U.S. national laboratory.

Proposed future research: The developed control schemes will be implemented on future ORPC deployments.