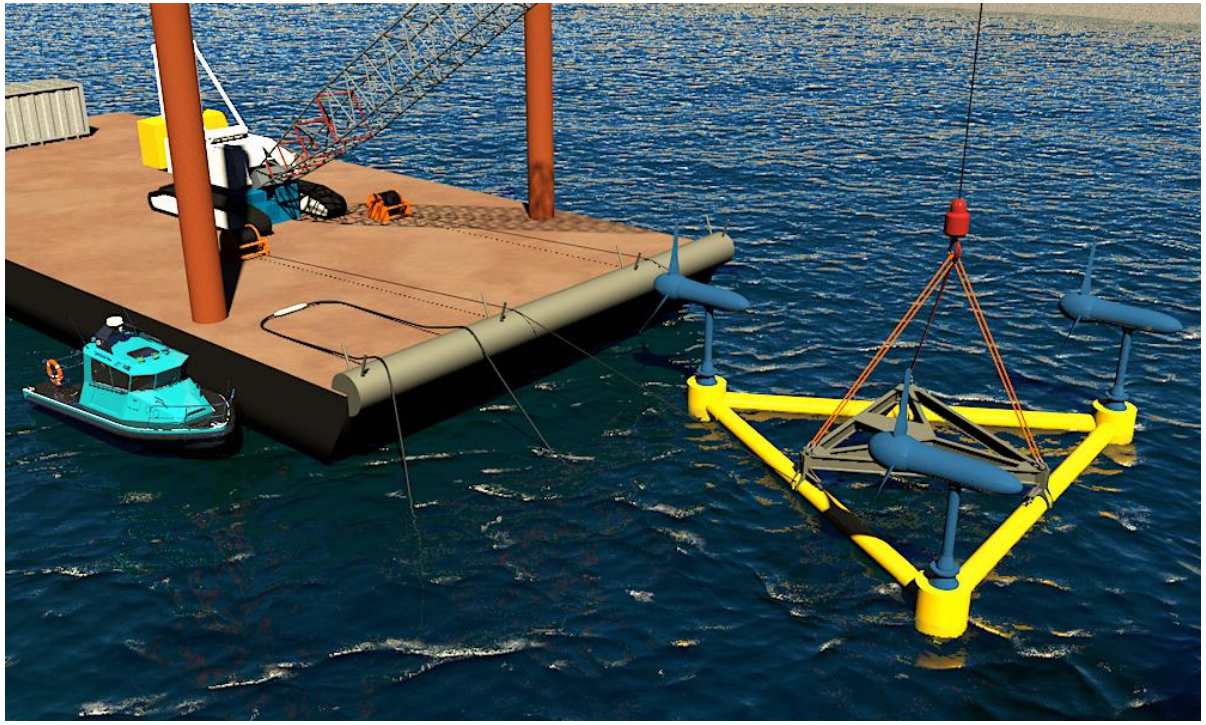
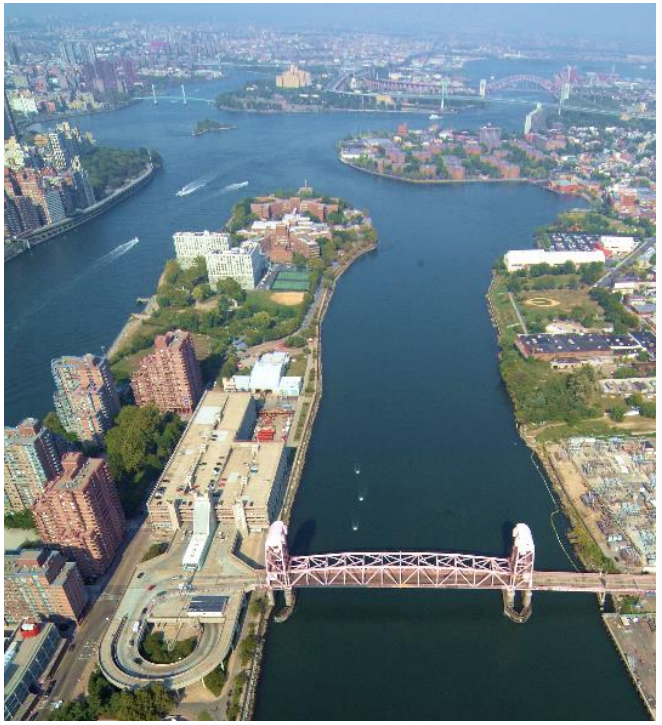




Integrated Development and Comprehensive IO&M Testing at RITE of a KHPS TriFrame Mount

Dean Corren
Verdant Power Inc.
dcorren@verdantpower.com 802.238.2432
February 2017

Project Overview

Integrated Development and Comprehensive IO&M Testing at RITE of a KHPS TriFrame Mount

Challenge: Reduce marine and hydrokinetics (MHK) Cost of Energy

- Installation, operations, and maintenance (IO&M) cost reduction
- Scale-up

Approach: Integrated TriFrame and IO&M Process Design

- Optimize capital expenditures (CAPEX) and operating expenditures (OPEX)
- Reduce time and cost for on-water work IO&M
  - Installation and retrieval and replacement (R&R) Cycle
- Meet structural performance requirements
- Regulatory and environmental requirements
- Advance TF design from Technology Readiness Level (TRL) 3 to TRL 8
- U.S. MHK technology at FERC-permitted site: Roosevelt Island Tidal Energy (RITE) Project

Partners: Ramboll, Mojo Maritime, Kleinschmidt, Manufacturing Resources Inc. (MRI)

Program Strategic Priorities

Technology Maturity

- Test and demonstrate prototypes
- **Develop cost effective approaches for installation, grid integration, operations and maintenance**
- Conduct R&D for innovative MHK systems and 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 hybrid 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

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

Target: Device mount and IO&M process that significantly lowers MHK project LCOE

- 5m TF Baseline: $20.00/kWh
- 5m TF (TRL 8 projection): $5.50/kWh
- First commercial arrays: $0.80-$1.50/kWh (UK)
- DOE 2030 target: < $0.35/kWh

Key Metrics: (for the 5m scale project):

- CAPEX (Install): $939K reduce to $360K
- OPEX (R&R): $445K reduce to $230K
- Annual Energy Production (3T): 146 MWh/y increase to 248 MWh/y
- Availability: 55% baseline increase to 88-93%

Industry Impact:

Demonstrate a widely applicable, scalable mount and IO&M process that allows advancement to competitive LCOE for MHK projects

Project Strategic Alignment

Market Development

- **Support project demonstrations to reduce risk and build investor confidence**
- Assess and communicate potential MHK market opportunities, including off-grid and [illegible]electric
- **Inform incentives and policy measures**
- **Develop, maintain and communicate our national strategy**
- **Support development of standards**
- Expand [illegible] technical and research community

Target: MHK pilot projects lead to utility-scale arrays at increasingly competitive LCOE, allowing for investor support and market expansion

Key Metrics (for the 5m scale project):

- MHK pilot and initial array projects not cost competitive for utility market
- 2016 incentive rates:
  - $0.65–$3.00/kWh (CA/UK)
  - $0.22/kWh (Maine)

Industry Impact:

- Design and operating experience leads to performance standards
- Demonstration of the scalable commercial mount at U.S. site leads to export market for US MHK goods and services
- Planning for resilient infrastructure in United States

Technical Approach

Technical Approach

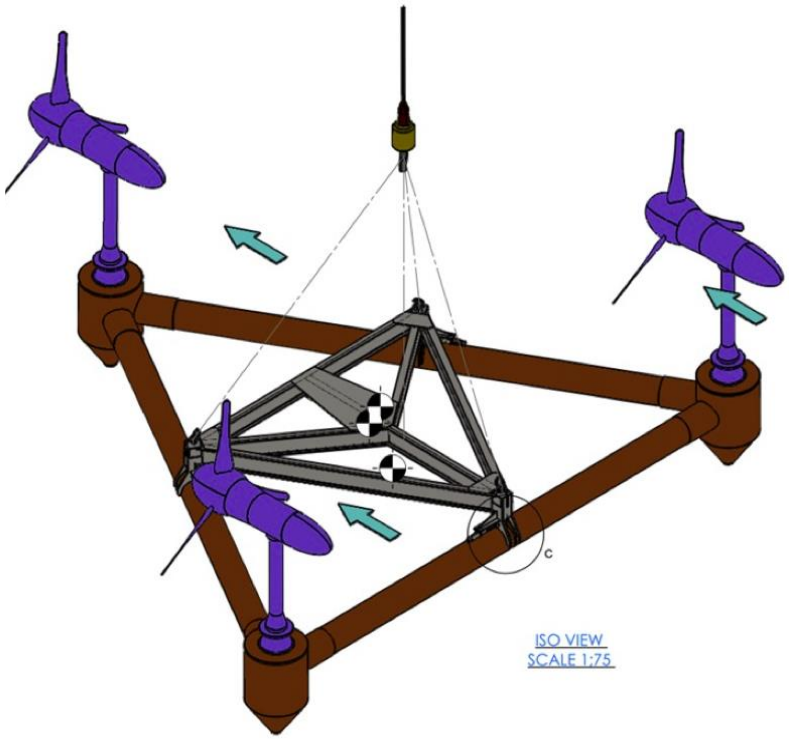
- Integrated design with iterative input from design, analysis, fabrication, and marine contractors to maximize cost-effectiveness
- Incorporate scalability for open water applications

Key Issues and Significance

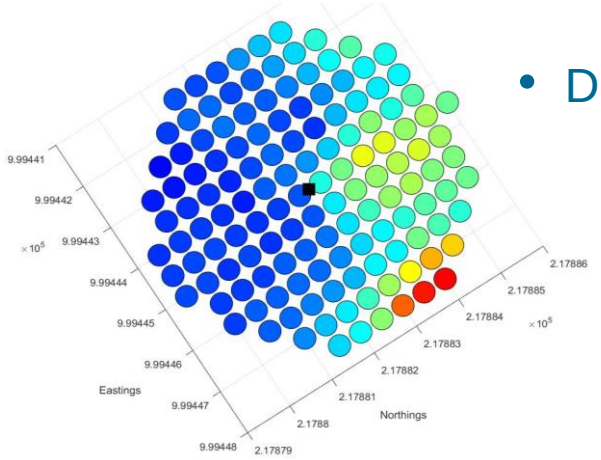
- Mount performance: Structural, position, orientation, level, stability
- Cost-effective installation and R&R cycle for LCOE reduction

Unique Aspects of Approach

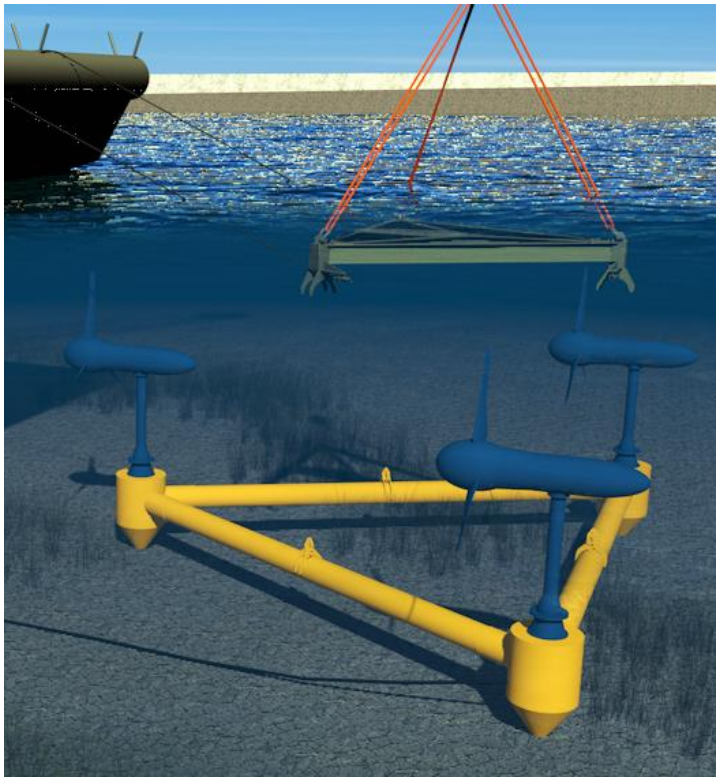
- Precise Positioning: TriFrame Positioning System (TFPS)
- Launch and Recovery System (LARS)
- Long-term monitoring



Unique Aspects of the Verdant Approach



- Design: Precise Positioning
  - High-resolution bathymetry
  - Positioning analysis
  - TF pre-leveling



- Operations (utilizing Mermaid®):
  - Installation: Precise Positioning
    - TFPS
    - Position = Orientation, level
  - O&M: R&R Cycle
    - LARS
- Performance Verification and Documentation
  - TF long-term monitoring
  - Loads, strains, accelerations, vibration

Key 2016 Technical Accomplishments

- TriFrame design specification delivered as project milestone 1 (August)
- Project baseline metrics delivered (as in slide #4) (August)
- Initial TriFrame and LARS designs drafted (September)
- Project risk reviews conducted with NREL (June & September)
- Preliminary consultations held with project marine contractor and fabricator (October)
- Initial Deployment and Operations Plan delivered as project milestone 2 (November)

Target

Once completed (with Budget Period [BP] 2and 3 approval), this project will be a significant and visible demonstration of the MHK industry maturing:

- *focused on complete systems, commercial projects, competitive LCOEs, and standards*
- *providing detailed operational data to the MHK database, and encourage investor support for building domestic and export markets for U.S. MHK goods and services.*

Project Plan & Schedule

- Contracted Project Initiation Date: May 6, 2016
- Contracted Budget Period-1 Completion Date: July 5, 2017
- No schedule slippage to date; MS deliveries on time
- Project Down-Select and Go/No-Go: Projected March 2017
- Planned BP2 and 3 Activities:
  - BP2: TF System Finalization and Fabrication
  - BP3: TF System Deploy, Install, Test, R&R at RITE
- Anticipated Project Completion: December 2018

Project Budget

Budget History (BP-1)					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$0	$0	$0	$0	$175.131k	$45.573k

- Project is on schedule and within budget
- 44% / $220.704k of BP1 budget has been expended as of Sept 2016
- Matching funding (BP1) is provided by Verdant Power and Ramboll

Full Project Budget

BP-1 (Current)		BP-2*		BP-3*		Totals	
DOE	Cost-Share	DOE	Cost-Share	DOE	Cost-Share	**DOE**	**Cost-Share**
$398.218k	$100.123k	$1,872k	$1,875k	$1,875k	$1,878k	**$4,146k**	**$3,854k**

*- Pending Down-Select and Go/No-Go at BP-1 Completion

Partners, Subcontractors, and Collaborators

- Ramboll: TF Design
- Mojo Maritime: TF IO&M Expertise
- Kleinschmidt Associates: Regulatory
- Kens/KT Marine: Marine Contractors
- Cornell University, MRI, New York State Energy Research and Development Authority, ConEd (BPs 2&3)

Communications and Technology Transfer

- 2016 International Marine Renewable Energy Conference (IMREC) and Marine Energy Technology Symposium (April 2016)
- Anticipate submission of TF Project paper for 2017 IMREC conference
- Publicly available final project report
- Project data uploaded to the MHK-Data Repository

Next Steps and Future Research

FY17 / Current Research

- Complete BP1 preliminary TF and LARS designs, Deployment Plan, Risk Register, through Down-Select
- *BP2, if approved:*
  - Complete final design of TF, LARS, instrumentation and balance of system
  - Complete IO&M process design and Mermaid implementation
  - Procurement, fabrication, risk and cost management
- *Anticipated FY18 (BP3, if approved):*
  - Deployment, installation, in-water testing, R&R cycle, data collection, and final reporting

Proposed Future Research

- TF scale-up for 10m diameter turbines
- Simultaneous turbine and BOS scale-up
- Resource assessment of U.S. 10m+ sites
- Support for International Electrotechnical Commission standards development and implementation