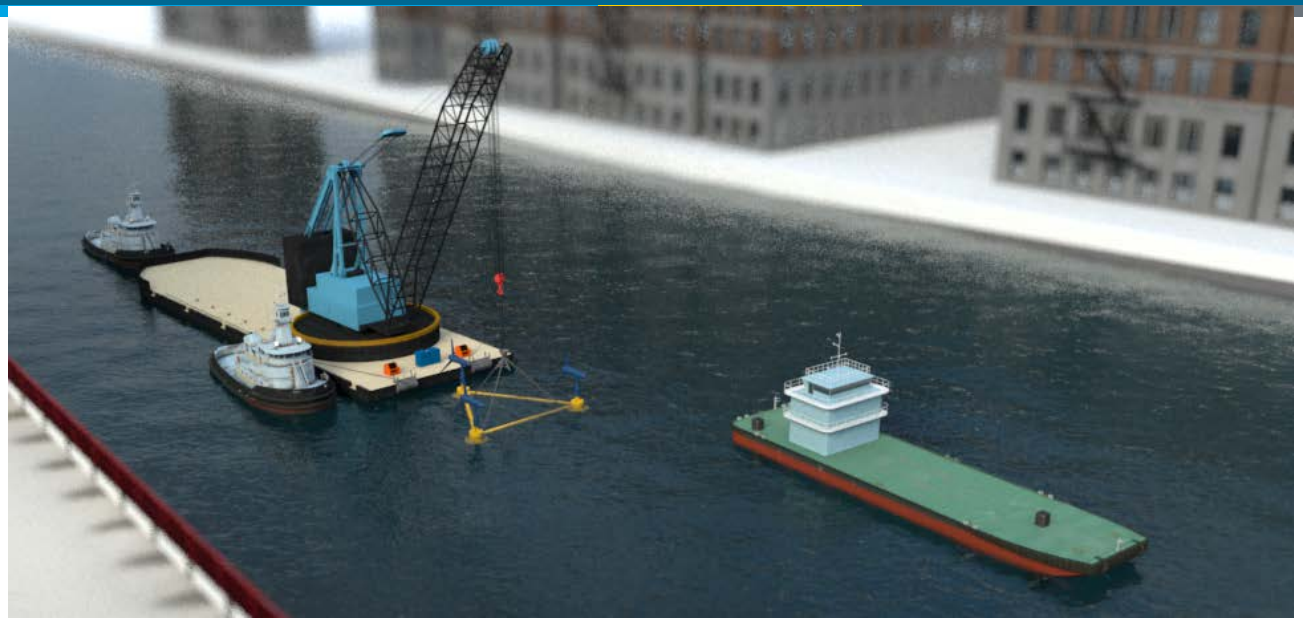


Kinetic Hydropower System (KHPS) TriFrame Mount Integrated Development and I,O&M Testing at RITE

DE-EE0007349

Marine and Hydrokinetics Program

October 10, 2019

Dean Corren

Verdant Power, Inc.

Project Overview

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

Project Summary

Develop, build, operate, and maintain a TriFrame™ (TF) mount with three Verdant Gen5d KHPS axial-flow turbines. Deploy at Verdant's FERC-licensed (P-12611) RITE Project in NYC. Goals include advancing the TF from TRL 3 to 8 and optimizing for both CAPEX and OPEX. **Metrics include time and cost of on-water I,O&M operations,** meeting all requirements, and providing for **scale-up**. Key is the **Integrated Design Process (IDP),** closely and iteratively linking mechanical design with operational procedures to reduce CAPEX, OPEX, and LCOE.

Project Objective & Impact

Advance commercial MHK by reducing LCOE with a mount design that simultaneously targets CAPEX and on-water operations OPEX. The project employs an Integrated Design Process (IDP), closely linking mechanical design with operational procedures in order to reduce the combined contributions of CAPEX and OPEX to LCOE. The IDP is iterated, steered by a detailed risk analyses. Goals include: advance the TF TRL from 3 to 8, provide for scale-up to at least 10m diameter turbines, and determining metrics of the time and cost of the installation and maintenance cycle on-water operations. TF structural performance data correlated with resource and turbine data will provide valuable information to the industry, and for model validation.

Project Information

Project Principal Investigator(s)

Dean Corren, CTO, Verdant Power, Inc.

WPTO Lead

Steve DeWitt, Technology Manager

Project Partners/Subs

Partners/ subs: Ramboll, James Fisher Marine Service. Major vendors: Ken's Marine, Donjon Marine, K-T Marine, Durabond

Project Duration

5/6/16 to 12/31/20

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

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

This project:

- Employs a risk-managed integrated design approach to develop a mounting system that is cost-effective in both CAPEX and OPEX, including I,O&M operations
- Measures the performance of a novel mounting and installation system for MHK turbines at the representative 5m diameter scale
- Measures the costs of I,O&M operations, and is helping establish land-based and on-water asset needs
- Meets IEC TC-114 standards and will be subject to 3rd Party review
- Provides data for model validation improvement

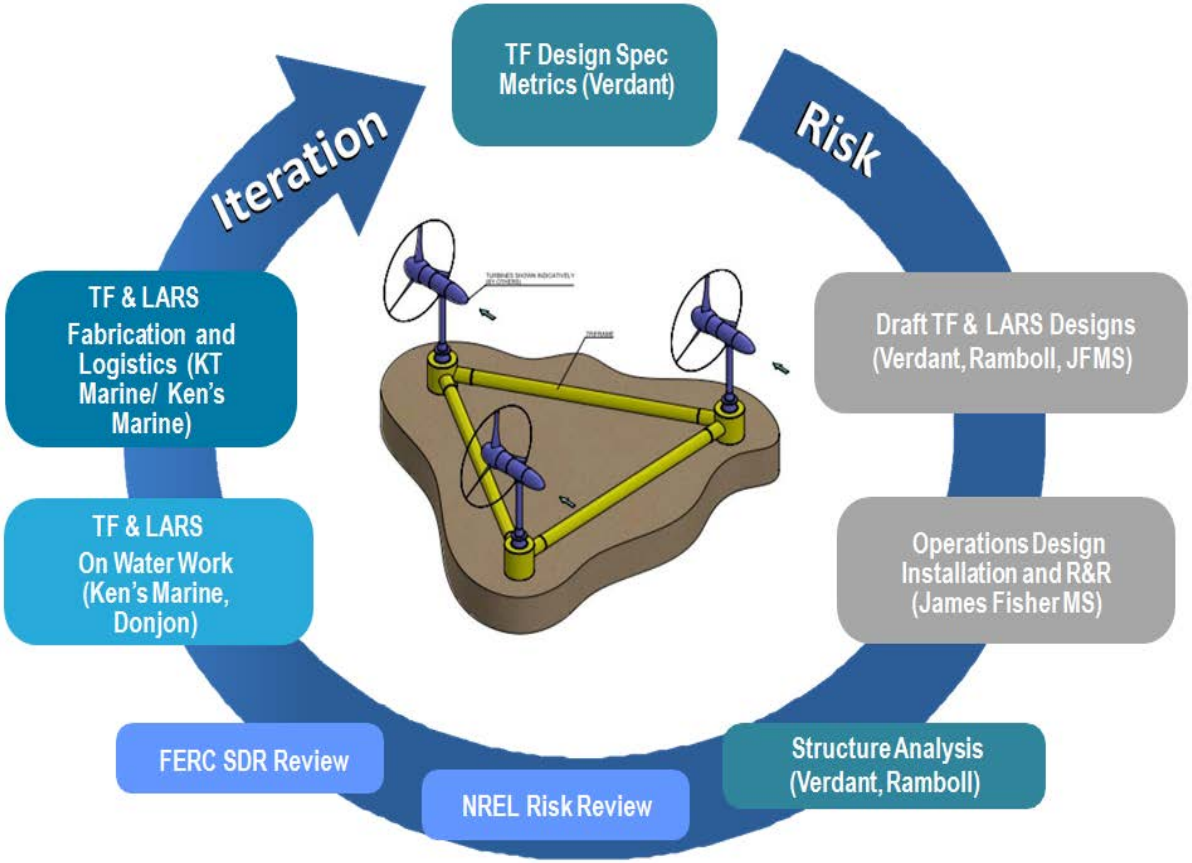
Project Budget

Total Project Budget – Award Information			
DOE	Cost-share	Total	
$4,145,035	$3,854,362	$7,999,397	
FY17	**FY18**	**FY19** (Q1 & Q2 Only)	**Total Actual Costs** FY17–FY19 Q1 & Q2 (October 2016 – March 2019)
Costed	Costed	Costed	Total
$433,325	$1,334,793	$542,502	$2,310,620

- No discrepancies
- Major fabrication costs underway
- Cost-share partners: NYSERDA, Con Edison, Ramboll

Management and Technical Approach

- Integrated Design Process driven by LCOE components
- Risk Management, with 3rd Party NREL review
- 3-year process with down-select and Go/No-Go
- Technical, economic, and performance milestone reporting



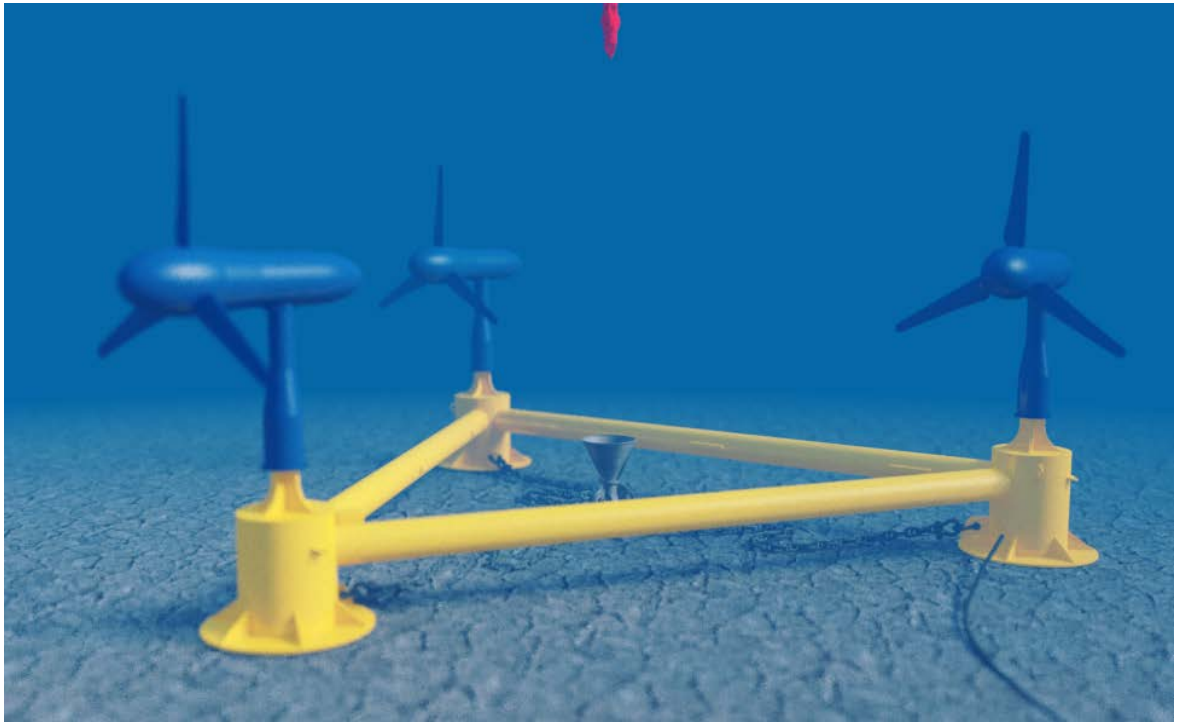
Ultimate success will be determined by CAPEX and OPEX cost metrics, technical performance, and regulatory compliance.

End-User Engagement and Dissemination Strategy

- US-based marine services contractors and fabrication vendors were engaged throughout the design process.
- Their MHK experience gained by will enhance their ability to support the broad range of MHK devices.
- A lower-cost system for deploying MHK devices will help advance the entire industry.
- The project involved overall a large group of engineer designers at the partner firms and NREL staff twice provided an independent review of the risk management plan including risk register and FMEA.
- The regulatory process, including FERC and the other resources agencies involved information to the public and NGOs for their input.
- Verdant personnel have presented the project at several conferences, including Annual IMREC/METS, 2019 Ocean Technology Conference, 2018 AORES
- Several papers based on the project and related subjects have been published in technical journals and at annual Marine Energy Technology Symposiums
- Data from the project will be shared with NREL for use with Hydro-FAST.
- Data from the project will be uploaded to the MHKDR for dissemination throughout the MHK industry.

Technical Accomplishments

- **Design objectives Met:**
  - Structural loads
  - geotechnical adaptability
  - buildability
  - deployability
  - scalability
- **IDP Iterations:**
  - reduced costs
  - reduced risks
- **Plans detailed:**
  - Fabrication & testing
  - Deployment, Installation, and Maintenance
  - Risk management
  - FERC SDR

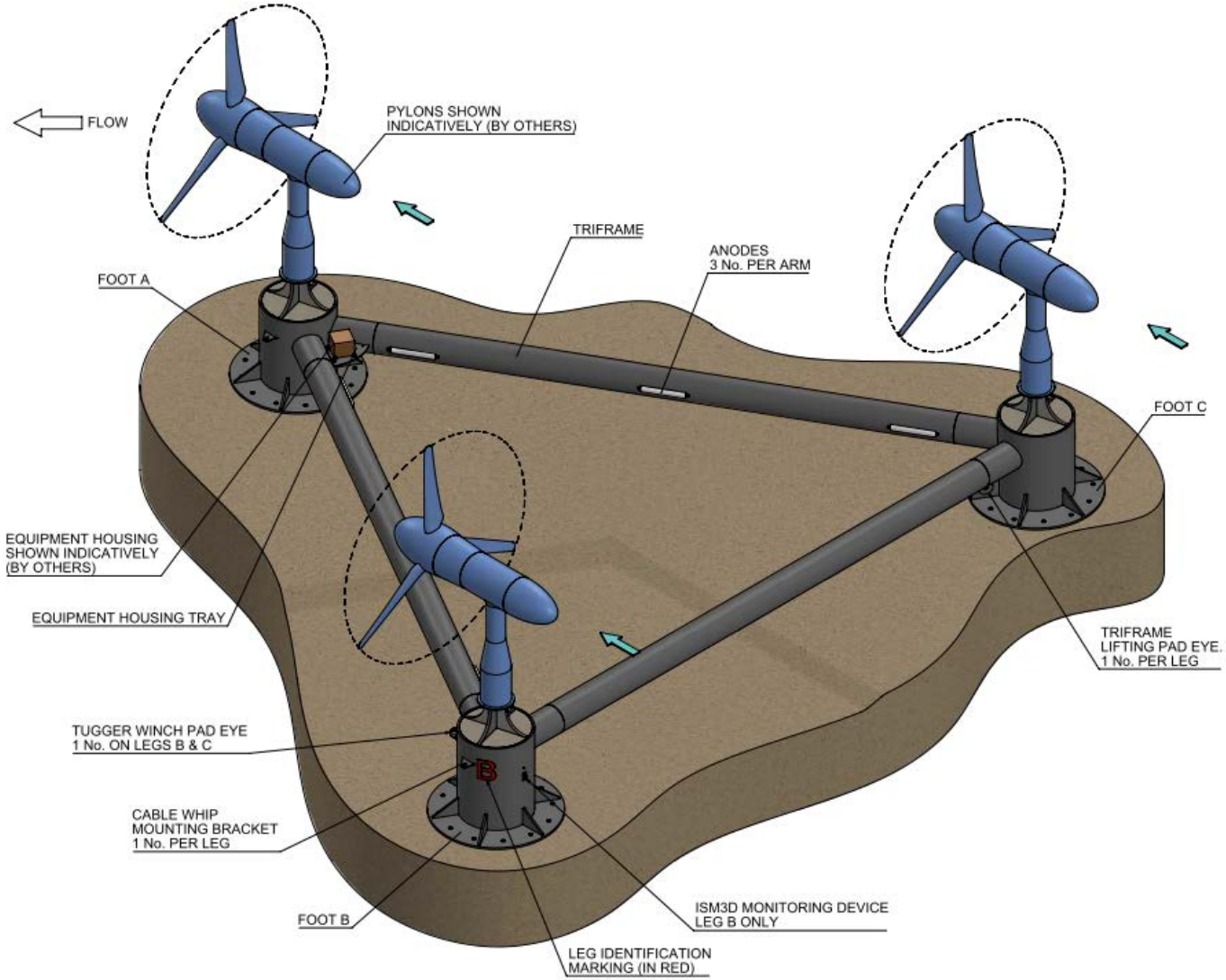


Technical Accomplishments (Cont.)

- All Quarterly Assessment overall project health indicators: Green
- Technical papers, peer-reviewed journal articles:
- *Advancement of a Tidal Energy Converter Mount through Integrated Design Process and Risk Management,* Colby, J.; Corren, D.; Adonizio, MA; Hernandez, A.; Offshore Technology Conference; May 2019
- *Application of the IEC Tidal Energy Resource Assessment and Characterization Technical Specification to the Roosevelt Island Tidal Energy (RITE) Site,* Hass, K.; Xu, T.; Colby, J.; Neary, V.; Marine Energy Technology Symposium; April 2018
- *Accelerating Marine Energy Commercialization through Standards and Certification Development,* Colby, J.; Adonizio, MA.; Hernandez, A.; Corren, D.; Marine Energy Technology Symposium; April 2018
- *Added-Mass Effects on Verdant Power's Gen5B Horizontal-Axis Tidal Turbine,* Murray, R.; Colby, J.; Marine Energy Technology Symposium; April 2018
- *Achieving Cost Reduction in the MRE Industry; Integrated Design and O&M Efforts at RITE,* Adonizio, MA.; Colby, J.; Corren, D.; Marine Energy Technology Symposium; April 2017
- New IP generated, no patent applications yet
- Custom instrumentation packages developed:
  - TF Installation & retrieval (TFPS)
  - TF structural performance monitoring (LTTFMS)

Progress Since Project Summary Submittal

- Final TF drawings approved for manufacture
- Major RITE site preparations completed (MS9B)
- Preparation for testing LARS TF lifting devices



Future Work

- Complete TriFrame and LARS fabrication
- Prepare turbines (4) and integrate to TF
- Installation of site, TF, and turbine instrumentation
- Coordination with NREL RMC Project
- Perform site environmental studies
- Perform all other regulatory requirements
- Deploy TF with turbines
- Monitor TF structural performance for 120 days
- Perform maintenance cycle (R&R) and install 4th turbine
- Corelate all TF, Resource, and Turbine data
- Provide all MS reports and final report

	2018	2019				2020			
Task	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1C	*Project Management & Tech Transfer*								
2C	*Deployment Planning & Risk Management*								
4C	*Regulatory & Environmental*								
5C	*System Fab/Assembly (MS9A)*					**Final System Integration**			
6C	*Site Preparation (MS9B, 10, 11)*					**Site Ready**			
7C							**Installation (MS12)**		
8C								**System Operation**	
9C								**R&R Cycle (MS13, 14)**	
10C									**Final Report & Data (MS15)**