

Technical Background

Fifth Generation (Gen5) Tidal Power Technology, TriFrame™ Mounting System, Roosevelt Island Tidal Energy (RITE) Project, and Marine Renewable Energy (MRE) Industry Leadership



Technology Advancement

1. Technology Development Approach and Objectives

- Focus on maximizing system power performance, increasing availability and reliability, and reducing project costs
 - Components: Project and installation and retrieve and replace (R&R) for operations and maintenance (O&M)
- Advancement through technology readiness levels (TRL)
 - At present – TRL 8-9
 - TRL-8: System Commissioning – actual system completed and qualified through test and demonstration
 - TRL-9: System Operations – actual system to be operated over the full range of expected mission conditions
- Simple, robust, and scalable technology; suitable for varied tidal project sites, multiple arrays of turbines, and riverine applications

2. Gen5 Tidal Power Turbine System

- System design focused on maximizing power performance, scalability, and simplicity of design for long-life (20-year) underwater operation with extended service intervals.
 - Proprietary design
 - Customized components for efficient integration and performance, and ease of assembly, sound rehabilitation strategy in an array, and scalability
 - Conduct comprehensive component and system testing and validation for function, and lifecycle
 - Manufacturing and assembly
 - Under an established quality management system (QMS), established robust supply chain of 20 suppliers and test facilities to conduct fabrication inspections
 - Performance
 - Using evolving international standards for tidal generator power performance, the European Marine Energy Centre (EMEC), as a third-party contractor, will validate the performance of the Gen5 turbine

3. TriFrame™ Mounting System

- System design focused on maximizing deployment strategy to effectively mount three turbines for operation in a hydrodynamic configuration, suitable for ease of maintenance in a long-life (20-year) underwater configuration and scalable to larger sizes
 - Proprietary design
 - Gravity-based hybrid steel triangular design (~97 tons) evaluated for tidal flow forces through multiple design cycles by Ramboll Environ and approved by U.S. regulatory agency, Federal Energy Regulatory Commission (FERC)
 - Designed to maximize turbine array power performance in water currents
 - Carefully integrated with seabed with specialty feet suitable to geologic conditions and precise placement to achieve level specification using high resolution bathymetry
 - Installation and retrieve and replace (R&R) strategy
 - Executed using precision GPS and coordination of marine contractor's multi-vessel deployment sequence over a 4.5-hour window during installation
 - Lifting, placement, and retrieval (at maintenance) executed using a custom-designed "Launch & Retrieval System" (LARS), which demonstrates repeatability and scalability of maintenance strategy
 - Performance
 - TriFrame™ mounting achieves cost reduction through installation and operation and maintenance of three turbines simultaneously
 - LARS install and R&R achieves metrics of no underwater diver intervention and precise placement; both keys to lowering economics in arrays
 - TriFrame™ placement and foot design scalable and adaptable to sites

4. Quality Management of Supply Chain and Project

- Under an evolving Company QMS system, a cycle of methods and criteria, execution and recordkeeping, analysis, and implementation, focuses on continual improvement of all technology and project development
 - Component design and system testing and validation at three levels – supplier, subsystem, and system
 - Gen5 turbine system assembly conducted under proprietary QMS developed in conjunction with Dovetail LLC by tracking assembly, inspections, verifications, and tests (IVT) and resolving non-conformances
 - TriFrame™ assembly conducted under FERC Quality Control Inspection Program
 - Project QMS includes comprehensive documentation of standard operating and exceptional operation procedures, documentation and reporting of power performance (under the International Electrotechnical Commission [IEC] standards), and regulatory/environmental performance in compliance with regulatory license and permit for the project

The Roosevelt Island Tidal Energy (RITE) Project – NYC's East River

Following a successful multi-year demonstration (2007-2019) of the Verdant Power technology at the RITE Project, the Company embarked on a pre-commercial phase to design the Gen5 tidal power turbine system, optimize the economics of installation and maintenance of arrays, and prove performance (power and environmental) with a 5-meter diameter rotor/generator system as a one-half scale demonstration at the RITE Project site. The Project (2020-2021) will achieve metrics for full scale or utility-scale sites; and with an operating grid-connected array of tidal power turbines showcased in New York City, demonstrates MRE - the new renewable energy, hydropower as distributed generation, and alternative market opportunities that address the Blue Economy

5. Verdant Power Funding, Design, Equipment, and Marine Operations Partners

- Funding - Public and private funding support through the New York State Energy Research and Development Authority (NYSERDA), the U.S. Department of Energy Water Power Technologies Office (WPTO), New York City, and Con Edison-New York
- Design - Powertrain Engineers, Inc. and Manufacturing Resources, Inc.
- Equipment - Milwaukee Gear Company (drivetrain/integrated mechanical assembly and custom gearbox), ABB-Baldor Electric Company (generator), and Stearns Brake
- New Jersey Marine Operations - Ken's Marine Services Inc., K-T Marine Inc., and Donjon Marine Company, Inc.

6. Control and Integration

- Real-time online monitoring at the RITE Project site of the Gen5 tidal power turbine systems, including power production from the turbines and grid operations, will be conducted through a proprietary state-of-the-art supervisory control and data acquisition (SCADA) system,

which simultaneously logs both the condition and the performance of the turbine systems, and allows for engineer/operator control of the power plant

- Turbines' power operation is integrated with real-time water velocity, allowing for operation when flow exceeds one meter per second (m/s), and operation on both predictable flood and ebb tides for approximately 4.5 hours, four times per day
- Project power is integrated with local community/utility electricity grid-connection – Con Edison-New York under a specialty tariff for distributed generation

7. Regulatory and Environmental

- RITE Project received the first U.S. Federal Energy Regulatory Commission (FERC) license for an MRE project in January 2012
- FERC compliance and implementation of "RITE (Project) Monitoring of Environmental Effects" or RMEE plans that provide knowledge and leadership innovation of the minimal effects of Verdant Power's tidal turbines on aquatic and avian species (including ESA listed Atlantic Sturgeon) as well as on sound emissions and recreational use of the River

Verdant Power & MRE Industry Leadership

8. Contributions, Awards, and Recognitions

- National Hydropower Association (NHA) and Marine Energy Council (MEC)
 - Chair of Research & Development Committee and NHA Advisory Board
 - Recipient of NHA's "President's Award"
 - Energy Ocean International's "Company Pioneer Award"
 - Founding member of NHA/MEC
- American Council on Renewable Energy (ACORE)
 - Founding member of ACORE
 - Veteran Wireless Operators Association's "Innovations Award"
 - American National Standards Institute's "Next Generation Award"
- Renewable Energy and Energy Efficiency Advisory Committee to the U.S. Secretary of the Department of Commerce - serving 12 years representing MRE
- Ocean Energy Europe (OEE) - first and only U.S. based company to become a member
- International Electrotechnical Commission (IEC)
 - IEC's "Young Professional Leaders Award"
 - Chair of International Industry Standards IEC Technical Committee (TC)-114: Marine Energy: Wave, Tidal, and Other Water Current Converters
 - Leadership in development and adherence to industry standards, leading to independent review and certification to international standards
- European Marine Energy Centre (EMEC) - the first marine energy test laboratory to have been designated with Renewable Energy Testing Laboratory (RETL) status by the IEC
 - The Company's Gen5 tidal power turbines in 2020 will be the first system to be assessed for power performance verification and validation by EMEC as an RETL and to receive an internationally recognized Renewable Energy Test Report (RETR), verifying compliance with formulated international standards
 - Receiving an RETR will serve to underscore buyer, financial, and insurance confidence in Verdant Power's Gen5 tidal power systems

9. Commercialization Approach

- Verdant Power will be building utility-scale commercial projects at already identified sites, beginning with on-site pilot commercial projects consisting of multiple Gen5 tidal power turbines of three to six full-scale systems on one to two TriFrames in order to maximize learning of a project's site; initiate scale-up manufacturing processes, procedures and learning curve; ensure intensive documentation; build and perform to standards; and provide independent certification for the project
- The Company's Gen5 tidal power turbine is Verdant Power's "Commercial Standard System" that is tailored to sites to maximize annual energy production (AEP). Commercial projects will be sited nearest to where power is needed as utility- and village-scale power, and as a distributed energy resource. Customers of the Company's technologies and services are end-users or project sponsors including utility companies, independent power producers, investor sponsors, and other owner/operator entities

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