NREL
NATIONAL RENEWABLE ENERGY LABORATORY

# Preliminary Structural Design Conceptualization for Composite Rotor for Verdant Power Water Current

## Cooperative Research and Development Final Report

## CRADA Number: CRD-08-296

NREL Technical Contact: Scott Hughes

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**CRADA Report**
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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI.A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA number: CRD-08-296

CRADA Title: Preliminary Structural Design Conceptualization for Composite Rotor for Verdant Power Water Current

Parties to the Agreement: Verdant Power

Joint Work Statement Funding Table showing DOE commitment:

| Estimated Costs | **NREL** Shared Resources |
|---|---|
| Year 1 | |
| *1. Design Requirements* | $ 15,000.00 |
| *2. Baseline Fatigue Testing* | $ 55,000.00 |
| *3. Blade/Rotor Performance Modeling* | $ 70,000.00 |
| *4. Hydrofoil survey and selection* | $ 20,000.00 |
| *5. Load Estimation* | $ 50,000.00 |
| *6. Develop Candidate Designs* | $ 90,000.00 |
| TOTALS | $ 300,000.00 |

Abstract of CRADA work:

Verdant Power has developed the Kinetic Hydropower systems (VP-KHPS). The VP-KHPS is based on an axial-flow turbine that is fixed for unidirectional flows, and yaws for tidal flows. Verdant recently deployed several of these 35-kW turbines into the East River near New York City.

NREL has been working with Verdant Power for the past year on structural testing of their cast AlMag 35 blade for the VP-KHPS at NREL's structural test facility after several earlier generation blade models suffered structural field failures. Based on Finite Element Analysis and stress estimations, the present cast AlMag blade is thought to be at the limit of its load capability with the 5m diameter at 2.5 m/s flow. To increase the rotor diameter or the rotor loading significantly, a new rotor design is required.

NREL/DOE plans to expand this partnership with Verdant through a cooperative research and development agreement (CRADA) that is planned to begin in the summer of 2008. The primary thrust of the CRADA will be to develop a new rotor design that will allow higher current flows (>4m/s), greater swept area (6-11m), and in the process, will maximize performance and energy capture.

The work embodied in this CRADA will enhance the probability of success of a proposal submitted by Verdant under Topic Area 1 of the Advanced Water Power Projects (AWPP) program. The scope of work defined in this CRADA is designed to be a precursor to work on the AWPP program, and will enable more refined rotor designs in a much shorter timeframe for work on the AWPP program. This CRADA will develop tools and methodologies including hydrodynamic modeling and load calculation methods which can be directly applied to the Verdant AWPP program.

Sandia National Laboratories (SNL) has also been recently working with Verdant Power on structural analysis of their cast AlMag blade for a 5m diameter rotor. The analysis was performed to coincide with testing that was performed at NREL. Under a separate CRADA, SNL will collaborate with Verdant Power.

The new improved structure must optimize the cost, durability and longevity of the blades and rotors to meet commercial electric price objectives. The needed changes will be significant enough to entail revisiting the fundamental blade design, and a complete blade hydrodynamic design cycle. The new design cycle will require multidisciplinary collaboration, including hydrodynamic and structural modeling, analysis and design along with design for manufacture and fabrication technique development. This must be followed by extensive strength and fatigue testing and full or near full-scale hydrodynamic testing.

NREL and SNL are likely to participate in many parallel stages of this development. The NREL cost share will be $300K with no funds exchanged. The Verdant Shared Resource contribution to this CRADA is $162,500.

Summary of Research Results:

- Developed HARPOpt [Horizontal Axis Rotor Performance Optimization] code internally using Verdant in-water data and experience to validate the code
- Code predicted Verdant in-water measured data with reasonable accuracy
- Fatigue testing of blade conducted in Flapwise and Edgewise directions. Tests based on 20-year equivalent loading. Loads supplied by Verdant
- Development of new composite-based blade design through HARPOpt, and NREL FAST code use. Modifications to TurbSIM for water inflow characterization. Blade and rotor design optimized for several site-specific locations

Subject Inventions listing: None

Report Date: 10/10/04 Responsible Technical Contact at Alliance/NREL: Hughes, Scott

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