Development and Testing of the Neptunea Marine Hydrokinetic Energy Turbine

A collaborative proposal between The University of Alaska Fairbanks Alaska Center for Energy and Power & Real NewEnergy

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Total project cost:	$1,022,052
Grant funds requested:	*$747,896*
Match funds committed:	*$274,156*

Previous projects/applications: None

Previous abstracts: None

Abstract: Neptunea Marine Hydrokinetic Energy

Project Description

Marine hydrokinetic (MHK) energy is a promising energy resource for remote locations in Alaska if the technology can be deployed reliably and affordably. This project will demonstrate that the technology is a well suited for remote Alaska locations.

The PAX Rotor is a biomimetic rotor that harnesses more hydrokinetic energy in 40-60% shallower waters than conventional horizontal axis MHK rotors adding excellent debris handling properties, non-fouling characteristics and non-cavitation properties, all leading to higher capacity factors, reduced maintenance and repair costs and increased up-time.

The Alaska Center for Energy and Power (ACEP) and Real NewEnergy (RNE) will use the PAX Rotor to develop and test a new method of generating MHK energy. Combining the new rotor with an ingenious deployment strategy marks a major improvement over existing technology. A bottom-mounted, concrete cradle will support an off-the-shelf horizontal axis MHK turbine. The cradle allows for slight turbine movements, to align itself with the motion of the PAX Rotor. The PAX Rotor will be connected to the turbine generator via a flexible tethering cable. Due to the slight buoyancy of the PAX Rotor and its shape, the Rotor establishes vertical and horizontal equilibrium in the area of greatest flow, maximizing energy production. Additionally, the enhanced flexibility allows for large, subsurface debris to glance off the sides of the Rotor with smaller debris passing through.

The current Technology Readiness Level (TRL) is estimated to be 5 as the MHK turbine itself has been successfully deployed in real operating conditions and the PAX Rotor has been validated in a laboratory (flume) environment; however, the combination and deployment strategy is novel. At the completion of the project, the team anticipates that the Neptunea system will progress to TRL 7 or 8 and subsequent commercialization will result in TRL 9 by year five.

In order to advance this technology, the team will improve upon the existing designs of the PAX Rotor by conducting extensive computational fluid dynamics (CFD) analysis. A full-scale, PAX Rotor will then be used with a proven Tocardo 50kW permanent magnet direct drive generator turbine. This system will be deployed at the AHERC test site on the Tanana River in Nenana, AK (the TRTS) and monitored using the specialized equipment available at the site.

The team believes this deployment scheme to be feasible since most of the components are proven and/or simple in nature. Previous MHK deployments in AK have been cut short by damage from debris. The PAX Rotor has already demonstrated excellent debris handling properties and in combination with added flexibility (tether) and avoidance (bottom-mount), this system can succeed where other MHK deployment strategies have failed.

Remote villages in Alaska could in many cases benefit from mid-scale (100-200 kW) MHK turbines. Robust MHK solutions pose a variety of advantages over traditional and non-traditional forms of electricity generation. Namely:

- No fuel costs, compared to rates in excess of $0.30/kWh for diesel-based electricity in Alaskan villages
- Baseload electricity generation reduces energy storage/management needs
- Can bring sizable quantities of power, capable of supporting “Western” lifestyle
- Produces also in winter (under the ice), although flow speeds are less than in summer
- Adds to reliability of local energy system; MHK should prove to be more reliable than diesel internal combustion engines which often fail as a result of internal glazing

Project Innovation

The PAX Rotor is derived from shapes and properties existing in nature, bringing the efficiencies of natural flow to fluid-handling technology. Also known as biomimicry, this engineering practice adapts natural solutions to

human technical problems. The shape of the PAX Rotor allows the turbine to convert energy from a longer stretch of water, leading to power increase, efficiency gains and the ability to operate in up to 60% shallower water than conventional MHK rotors. This is of interest to MHK developers as many fast-flowing tidal and in-river sites are too shallow for MHK deployment. Neptunea will significantly increase the number of viable sites for MHK development, allowing the industry to reach the economies of scale necessary to reduce cost.

PAX's 2008 testing revealed unique rotor characteristics which lead to increased availability of MHK turbines:

- The leading edge of the PAX Rotor recedes as it rotates, greatly reducing the damaging effects of debris. Small debris passes easily through the turbine; larger objects will glance off the side of the blades
- The biomimetic rotor is non-fouling, increasing efficiency and reducing maintenance
- For high flow sites, this rotor will greatly reduce the effect of cavitation which is known to cause cyclic stress to propellers, leading to surface fatigue and damage to the device

The concrete cradle will be heavy enough to remain fixed to the bottom while still easily deployable and salvageable via either a common barge-mounted crane or flotation. The cradle also protects the generator from potentially harmful subsurface debris. The flexibility in the tether-rotor connection reduces debris impacts to the PAX Rotor. In this way, direct strikes to the PAX Rotor should be rare and benign. The easily deployable concrete cradle and the expected resiliency to damaging debris impacts should lead to lower capital costs, less operating expenditures and longer lifetimes.

Project Site and Demonstration Environment

ACEP operates the AHERC test site on the Tanana River in Nenana, AK. AHERC is a fully permitted testing center that has specialized equipment and instruments along with experienced researchers and engineers to conduct detailed testing campaigns. AHERC has completed a detailed characterization of river bathymetry, current flow, fish population, bed-load and suspended sediment transport, and riverbed conditions at the TRTS.

Summer flows at the test site are favorable, averaging 2 m/s. However, these strong flows push large debris down the river, presenting a threat for turbine destruction. Alaska has already seen three MHK projects prematurely ended due to damage from debris. Overcoming this obstacle is a vital step if Alaska is to realize its vast MHK resources[1]. Icing in winter is another problem that has confounded MHK developers, while energy security in the winter is a real priority in rural villages. The flows are significantly less in the winter, but even a small amount of energy production will help offset diesel consumption and prevent depletion of personal or community supply. The bottom mounted Neptunea will not be removed during the winter and the monitoring campaign will continue.

Priority

This project fulfills all four priority considerations. ACEP is the lead project organization and will effectively use its resources across the campuses of the University of Alaska to develop and test this new solution. ACEP is partnering with RNE, a renewable energy innovation company that is making available a 50kW horizontal axis MHK turbine through its partnership with leading turbine manufacturer, Tocardo. Additional matching funds will be provided by RNE through in-kind labor while ACEP will provide a cash contribution to the project in the form of days at the AHERC test site. Most importantly, this solution has the potential for widespread use in the state

[1] *Assessment and Mapping of the Riverine Hydrokinetic Resource in the Continental United States*. EPRI, Palo Alto, CA: 2012. 1026880

through in-river and tidal deployments. Many communities located on navigable waterways could benefit greatly from MHK energy generation.

Technology Validation and Data Collection

The performance will be measured using the following parameters:

- Electricity production (kWh)
- Power output (kW)
- Debris handling (uptime, visual & sonar)
- Fish monitoring (observation & sonar)
- Winter output (kWh in winter)
- Deployment (cost and time)
- O&M ($ and time)

A successful project would be characterized by near-constant electricity production, full power output (50kW) at peak flows and debris diversion confirmed by 100% uptime. Electric output during the winter and continued survivability would also be viewed as a ground-breaking achievement.

A time-lapse camera system will be used to monitor surface debris and high-resolution sonar, a mechanical debris detection device and direct observation will be used to detect subsurface debris.

All equipment and labor necessary for the testing campaign has been included in the budget which will be strictly monitored to determine valuable indicators such as development, capital and operating expenditures (DEVEX/CAPEX/OPEX) and total cost of electricity including seasonal fluctuations.

Project Schedule and Project Budget

	Months after Award											
Gantt Chart & Budget	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
Project Management	$140,000											
Testing development & project preparation	$25,000											
Development of PAX Rotor design	$55,000											
Final Neptunea design		$130,000										
Implementation			$325,000									
Monitoring, analysis & reporting					$240,000							
Evaluation						$110,000						

The project has been estimated to cost $1,022,052 including matching funds of $274,156 (27%). The Tocardo turbine has been valued at $150,000 and match of $124,156 will be provided by AHERC, in the form of time at the TRTS and salary support for researcher G. Roe.

Go/no-go milestones will occur after (1) the PAX Rotor has been designed to ensure it is ready for manufacture of a full-scale Rotor; (2) following the final Neptunea design but before procurement of expensive components; and (3) prior to the winter freezing to determine whether the team feels confident to leave the Neptunea system deployed indefinitely.

Additionally, the project schedule will be reevaluated throughout the course of the project to determine whether the project can be completed in less than 24 months.

Project Team Qualifications

The AHERC team has been conducting hydrokinetic-related studies since 2008 and has established the TRTS' capabilities to conduct HKD testing. Dr. Jeremy Kasper will guide the overall project direction with special focus on debris evaluation, site hydrodynamics and TRTS usage. Mr. George Roe will assist with project evaluation and report preparation. Mr. Roe has 35 years of experience at Boeing, where he worked in research and development efforts for a range of technologies (e.g., thermal management, vehicle subsystems, crew protection, energy harvesting, energy storage, alternative energy) and their integration with products sold by Boeing and its teammates. Mr. Roe is currently a research professor with University of Alaska Fairbanks Alaska Center for Energy and Power.

Real NewEnergy executed a worldwide license with PAX Scientific for further development and marketing of PAX Rotors. Jay Harman, co-founder and CEO of PAX Scientific, will assist the team with engineering work and greater understanding of the PAX Rotor's capabilities. RNE founding partner, Joris Benninga, will be the project manager. Joris is a sustainable energy economist and strategist with a strong track record in the development of renewable energy companies and projects.

Discussion of Commercialization of Funding Technology

While innovative and capable of solving very important Alaskan MHK challenges, Neptunea consists in essence mostly off-the-shelf components. The PAX Rotor can be used on any horizontal axis MHK turbine and a number of those turbines are entering the market as we write this. Once the team can prove the concept through testing, Neptunea can be rolled out for rapid commercialization and has a large market potential in Alaska.

The Rotor itself can most likely still be optimized further for maximizing energy conversion, but 2008 testing already put the current design at par with the performance of other classic lift based rotors with similar blade surfaces. We also expect that the tether system can be refined after the project, but all further improvements qualify as good engineering, rather than new necessary inventions.

The technology will be competitive. Tocardo turbines are extremely robust, requiring virtually no maintenance and making them suitable for use in remote locations. The current price for the Tocardo machines (including the classic rotor and power electronics) is around $3500/kW. These costs are very likely to come down with increased production numbers, leading to combined turnkey CAPEX/DEVEX levels of less than $5000/kW. In such cases power will be produced for between 10-20 cents/kWh.

Alaska has many remote communities located on the shores of rivers. For many of them the MHK resources can be a source of reliable, clean and affordable power year round. The earlier mentioned EPRI study translates roughly into 4 GW of installed capacity potential. Neptunea brings harnessing this potential several steps closer.

Signed Applicant Certification

"By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered"

09/04/13

Andrew M. Gray, Director, UAF Office of Sponsored Programs