AEA Emerging Energy Technology Grant Application AEA-12-047

for

Application of Composite Flywheels and Development of Controls Platform for the Integration of Wind-Diesel Hybrid Systems

March 9, 2012

Prepared For:	Alaska Energy Authority, Emerging Energy Technology Grant Application AEA-12-047
Project Name:	Application of Composite Flywheels and Development of Controls Platform for the Integration of Wind-Diesel Hybrid Systems
Applicant:	Hatch 1225 East International Airport Rd., Suite 110 Anchorage, AK 99518 USA Daniel Hertrich DHertrich@hatchusa.com Phone: 907 223 0678
Proposal Number:	12-0719, Rev. 0
In Partnership With:	Williams Advanced Engineering Williams F1 Grove, Oxfordshire, Ox12 0DQ United Kingdom Doug MacLennan Doug.MacLennan@williamsf1.com +974 44193 770
Total Project Cost:	$1,189,500
Grant Funds Requested:	$672,500
Applicant Match Committed:	$517,000

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Project Summary

a. Project Description: The focus of our project will be:

1. The continued development and testing, for applications in isolated wind-diesel hybrid generation systems, of the Williams Composite Flywheel, an innovative high efficiency, light-weight, cost-effective, state-of-the-art flywheel technology with high power density tailored for wind-diesel micro-grid voltage and frequency regulation and,
2. Development and optimization of a control system using a novel, patent-pending, dynamic control and optimal energy management system for wind-diesel generating systems including hybrid energy storage technologies.

The development of these technologies will foster the realization of highly-reliable smart grids in Alaska, using cutting edge technologies to maximize diesel fuel savings and ensure stable operation of the grids despite the intermittent nature of wind energy. This project depends on collaborative work and contribution from Hatch and Williams Advanced Engineering with assistance from the Alaska Center for Energy and Power (ACEP) at the University of Alaska, Fairbanks (UAF).

b. Project Eligibility:

i. The flywheel proposed in this project utilizes a patented technology known as Magnetically Loaded Composite (MLC). The advantage of MLC technology is its ability to provide cost effective, continuous, deep power cycling with a very fast response time, not possible with steel flywheels. Key differentiators of this technology compared to other flywheels are:
High Power Density – The high strength to weight ratio of the carbon fibre composite, and the use of hydrodynamic and magnetic bearings, allows the flywheel to operate efficiently at rotational speeds exceeding 37,000 rpm resulting in a very high power density and a compact size. This characteristic results in higher power to energy ratio which is critical for stabilizing hybrid wind-diesel systems. This also results in significantly lower rotational losses of the flywheel.
High Duty Cycle and Long Life – The rotor of MLC flywheels are manufactured of a carbon fibre composite with a magnetic powder mixed into the matrix on the inside diameter of the cylinder which forms the permanent magnet rotor for the motor/generator. The absence of large metallic structures found in conventional flywheels minimizes eddy current losses and the associated heat gains. The MLC flywheels have a design life of 20 years with 1150 charge-discharge cycles per day at 75% duty cycle. This feature is critical for isolated Alaskan communities with limited accessibility and harsh weather conditions.

This technology was developed, to date, for connection to DC bus systems such as electric rail traction systems and has not been used widely in AC power generation applications. As such, this project represents both an improvement of an existing energy technology as well as the deployment of a technology not previously demonstrated in Alaska. It is expected that this technology will be commercially viable for wind-diesel applications within one to two years. The proposed scope of work develops the readiness of this technology from TRL4 to TRL8 scales.

ii. The patent-pending dynamic control and optimal energy management system is a technology targeting remote micro-grids with a high wind penetration ratio and realizes the implementation of smart hybrid wind-diesel systems. The controller ensures dynamic stability of the micro-grid via millisecond control resolution while minimizing diesel fuel consumption in the second resolution frame through an online optimization technique utilizing load and wind prediction. Such a system is not available commercially to date. Key features of this technology are:

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- Predictive dispatch of the generation and energy storage components based on forecasted load demand, wind data and predetermined operational characteristics of its components.
- Online energy management optimization to minimize diesel fuel consumption.
- Fast dynamic control of active and reactive power to maintain the voltage, frequency and power angle stability of the power system at all operating conditions.

This technology will maximize the fuel savings of existing and planned wind-diesel hybrid systems in Alaska. It is planned that the technology will be commercially viable within 2 to 3 years. Proposed scope of work develops the readiness of this technology from TRL4 to TRL8.

c. **Project Innovation**: Increasing the utilization of wind energy in Alaskan Hybrid Wind-Diesel grids is critical in order to maximize diesel fuel savings. However, maintaining the voltage and frequency stability of the power grid becomes very challenging. Despite being considered a short-term storage device, the flywheel can be used in conjunction with long term storage devices, such as batteries, to reduce the batteries electrical current charge/discharge rate, reduce the batteries charge/discharge cycles and therefore extend the batteries lifetime and help undersize the battery system cost, footprint and power rating. This feature will be tested and demonstrated in ACEP Diesel Test Bed.

   The implementation of the MLC flywheel technology and advanced control system will serve to optimize the utilization of wind generation in order to offset fuel costs and reduce carbon emissions, while providing improved power stability at competitive economic scales. This will have the further benefit of reducing the wear of the diesel generators, thus reducing maintenance requirements and extending the useful life. The fast millisecond dynamic control feature ensures stabilizing the voltage and frequency of the micro-grid despite the variable nature of wind generation. As part of this project we intend to quantify this benefit, using field data supplied by the ACEP and by experimentally testing the components at the ACEP Diesel Test Bed and Hybrid Applications Laboratory. The study will entail a dynamic MatLab/Simulink model of the wind-diesel system, including the flywheel and will serve as the basis for the control system development. This combination of features are not offered in any commercially available product.

d. **Priority**: This project will be managed from our Hatch office in Anchorage (please see the included Certificate of Authorization in the Appendix) and will be supported by a global organization of 12,000 people in 65+ countries. As part of our project scope, we intend to work closely with the UAF ACEP's wind-diesel simulation facility for testing of the control system and flywheel integration. Both Hatch and Williams will provide match contributions as detailed in the budget section below. Finally, our intended goal is for widespread deployment of the technology throughout the many existing and potential wind-diesel hybrid sites within Alaska.

Technology Validation and Research Methodology

Objectives and Methodology: The project will be executed in three distinct phases as described below. Each phase of the project will be monitored and reported by the Hatch Project Manager Daniel Hertrich.

a. A conceptual integration study will be performed by developing models of the micro-grid to estimate diesel fuel savings using micro-grids operation simulators such as HOMER and investigate dynamic voltage/frequency disturbances of the micro-grid using SimPowerSystem (SPS) blockset under MATLAB / Simulink. This will help determine preliminary parameters for incorporating the flywheel with the control system and assess its performance. The models will be validated using field data measurements. Through a discussion with Brent Sheets, we understand that ACEP has data from

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at least two sites with the intention of collecting additional data sets. Hatch has significant experience conducting this type of study for wind-diesel systems in remote communities.

b. The controller hardware architecture and software will be developed. The development will be carried out utilizing the models created in the previous phase to determine the requirement for testing the control systems and its algorithms. The work in the first two phases will be performed in close collaboration with ACEP.

c. In the third phase, the controller and flywheel will be experimentally tested at the ACEP Diesel Test Bed and Hybrid Applications Laboratory. The objective will be to demonstrate the robustness and applicability of the proposed technologies on actual wind-diesel micro-grid setup. The scope of the test will include, but is not limited to, verifying the dynamic model, testing the control system, and confirming performance of the flywheel and testing the power electronic interface with the AC grid.

Summary of Project Schedule and Budget

Item	Budget	Match Funds	Grant Funds
Conceptual Study	73,500	25,000	48,500
Development of Control System	430,000	147,000	283,000
Controls Hardware, Shipping and Travel Expenses	216,000	100,000	116,000
ACEP Test Facility (50 days @ $4,500)	225,000		225,000
Williams Flywheel and Installation	245,000	245,000	
TOTALS	**1,189,500**	**517,000**	**672,500**

Schedule	Date Complete
Final Project Selection / Grant Award	08/17/2012
Conceptual Study	10/26/2012
Control System	03/01/2013
ACEP Test Facility	05/10/2013

Project Team Qualifications

ABDEL HAGAR, PhD – Electrical Studies Specialist, Hatch.

Abdel has 7 years of experience in electrical engineering practice, research and technology development. His engineering experience is centered around renewable energy projects and covers power electronics, power system analysis, protections, control theory, instrumentation and process control. He worked as an electrical engineer and researcher in Egypt and Canada.

AMGAD EL-DEIB, PhD – Electrical Studies Specialist, Hatch.

Amgad has 9 years of experience in electrical engineering practice, teaching and industrial research projects. His engineering experience covers the areas of electrical power systems, power electronics, process modeling and control, instrumentation, and PLC/SCADA systems. Amgad has successfully completed multiple R&D projects with industrial partners including optimal sizing of PV and energy storage, design and control of industrial DC/DC power supplies.

GLENN HOLDEN – Discipline Practice Lead – Electrical Engineer, Hatch.

Glenn is an Electrical Engineer with an electronics technician background and an M.B.A. in operations management. He has more than 35 years experience in the consulting industry, of which 31 years has been with Hatch Energy, formerly Acres. Glenn has been involved in all aspects of the design,

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specification, supervision of manufacturing, construction and commissioning of hydroelectric plants, solar and wind farm developments. He is also experienced in industrial power distribution and control and SCADA type systems.

DANIEL HERTRICH – Senior Civil/Hydro Engineer, Hatch.

Daniel is an Alaska registered PE with 18 years of experience in Alaska in remote hydroelectric developments and rural Alaska municipal engineering and planning. Mr. Hertrich has extensive experience in hydroelectric assessments and feasibility studies, hydrology data collection and analysis, hydroelectric design, and construction management.

IVOR SHAW – Manager Wind – Senior Project Manager, Hatch.

Ivor has 32 years experience in infrastructure and energy projects, including extensive worldwide experience in wind project evaluation, management, design, rehabilitation, construction management and review. Ivor has served as senior civil engineer and project engineer/manager and has worked on many significant projects, including the Ripley and Prince Wind farms, Niagara River and Rankin hydro projects. Ivor has managed all phases of small, medium and large projects and is currently Manager, Wind Eastern Canada and USA.

DAVID DELVES – Technical Partnerships Coordinator, Hatch.

David is a Mechanical Engineer with 20 years of experience in machinery design, product development project management and technology commercialization. His focus at Hatch is to work with external partners to explore new technologies which will benefit Hatch clients.

Discussion of Commercialization of Funded Technology

The proposed project will develop technologies which maximize the wind energy utilization in remote diesel generation grids while maintaining the grid stability and power quality with the goal of reducing the cost of power generation, diesel fuel use and carbon emissions at these sites. Successful completion of the research and experimental validation of this project will lead to applying these technologies in existing wind-diesel system in Alaska.

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.

Signed on behalf of Hatch by: Proposal prepared by:

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Name:	Ray Kavanagh	**Name:**	David Delves
Title:	Director, Wind Power	**Title:**	Technical Partnerships Coordinator
Date:	March 9, 2012	**Date:**	March 9, 2012

This proposal is subject to Hatch standard terms and conditions.

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