Experimental Modular Prototype Construction for Isolated Hybrid Energy Systems in Alaska

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Total Project Cost:	$888,050.00
Grant funds requested:	$800,550.00
Match committed:	$ 87,500.00

Previous project title(s) for abstracts submitted to the Emerging Energy Technology Fund

Development/Deployment of Supervisory Controller and Secondary Load Controller for Wind-Diesel Hybrid Systems

Development of Controls for Demand Management by Electric Thermal Storage and Data Collection on Existing Wind-Heat Sites

Experimental Modular Prototype Construction for Isolated Hybrid Energy Systems in Alaska
Marsh Creek LLC in partnership with UAF

1. Project Summary

a. Project Description

Problem Definition

It is generally agreed that energy systems combining diesel with various renewable energy resources, especially wind power, are desirable in Alaska from both economic and environmental standpoints. However, the task of integrating energy sources of very different natures and high penetration presents many challenges to the power system designer. High variability and asymmetry of loads common on three-phase microgids is an additional complicating factor. Reviewing the history of hybrid power systems constructed in Alaska to date suggests that the problem was underestimated and that effective solutions for the integration of these complex power systems remain to be developed.

An analysis of hybrid energy projects points to two factors as being the most important for the success of the project; the system architecture and the control system that manages the sharing of the energy resources. Although architecture is in many ways restricted by the commercially available power equipment, the control system is the full responsibility of the system designer.

Proposed Solution

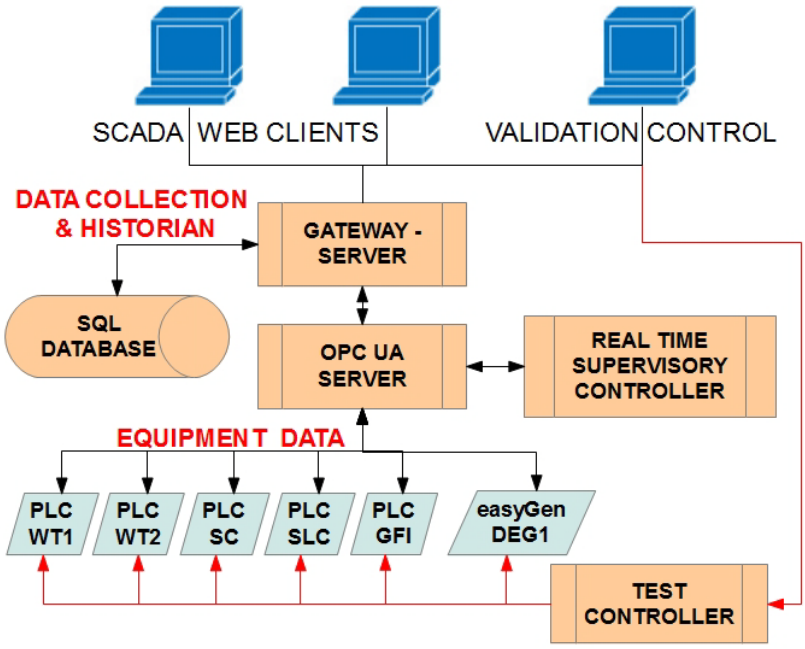
Technologies addressing development of high performance, robust, and maintainable systems have been under development at NASA and the aircraft and defense industries for many years. Such methodologies as comprehensive verifiable component specifications, interface control documentation, computer simulations of sub and full systems and the experimental validation of designs, using prototyping, have ensured the successful execution of numerous cutting edge endeavors. As bitter experience showed that their neglect was very costly, these methodologies have become established as mandatory within these industries.

This project proposes to introduce and demonstrate the application of these technologies to the development and validation of complex hybrid power projects. The goal is to achieve the full potential of hybrid renewable energy resources, while lowering maintenance and operational costs and the resulting cost of power in rural Alaska.

The proposed effort is to construct a modular prototyping platform together with the associated set of test procedures needed for the validation of the design of a complete hybrid power plant, including its full dynamic and fault mode characterization. This will provide the system designer with the means to perform system customization and then the validation needed for any individual hybrid power plant.

The demonstrational prototype platform, one possible configuration of which is shown in Figure 1, is to be located at March Creek's facility in Anchorage. It is to have a modular, reconfigurable, plug-and-play design capable of reproducing the multiple possible architectures of a hybrid power system that is either in the design stage, under construction or in operation. To achieve the capability to test multiple different architectures at minimal cost the major power components: wind turbines, diesel electric generators, etc., are to be either scaled to low power (fractional horsepower versions of the desired type of machine/component) or represented by real time computer simulations (virtual devices). Every virtual power component will provide data by either emulating the actual power device (computer model) or by the use of historical data. Test planning and control will be exercised from a validation and control computer. Software will be developed to allow for the complete dynamic and fault mode testing of the system and its components on the platform. Modern commercial off-the-shelf supervisory control and data acquisition (SCADA) systems will be responsible for the experimental data collection and logging.

Figure 1: Conceptual configuration of a hybrid energy project prototype



b. Project Eligibility

The prototype platform is expected to be operational at a fundamental level (being able to evaluate simple systems) within a year, and to reach maturity (being able to evaluate complex site relevant control topologies) within three years. It will facilitate:

- Achieving the full potential of energy resources and reducing fossil fuel consumption by enabling the design of optimized power generation systems in terms of architectures and controls;
- Reducing the total cost of ownership over the power system lifespan through improved reliability and planned maintainability achieved with the help of new design and validation technologies;
- Deployment of modern design and validation technologies used in defense and aerospace;
- Creation of intellectual property relevant to Alaska, thus supporting the state manufacturing and construction industries.

c. Project Innovation

The project is intended to be a platform facilitating creation of new intellectual property covering hybrid power plant development from concept through implementation to training:

- Introducing the use of a modular experimental prototyping platform with scaled power components and computer simulated components as a tool for the evaluation and validation of various hybrid energy architectures under a range of conditions without jeopardizing an actual community and their power system.
- Introducing the use of computer modeling of components and systems as a tool for testing, validation and optimization of hybrid system architectures and control systems, and to allow for the programming of controllers from validated models bypassing manual coding.
- Demonstration of the project performance and addressing anticipated challenges on a prototype thus providing greater project transparency and customer confidence.
- Allow for the configuring, optimizing and tuning of equipment in Anchorage before shipment to the rural community, greatly reducing the time (and cost) of on-site commissioning.

- Provide a relevant training experience for energy professionals, engineering students, and rural power plant operators.

d. Project Priority Qualifications

The project satisfies qualification requirements of AS 42.45.375, in particular:

- The applicant is an Alaskan organization.
- The project demonstrates partnership with the University of Alaska Fairbanks.
- The project applicant provides matching funds.
- The project has a potential of wide applicability in the state.

For promoting technical cooperation with ACEP and training of energy professionals it is proposed to install a copy of the prototyping bed at the University of Alaska Fairbanks Energy Technology facility managed by ACEP.

2. Technology Validation and Research Methodology

a. Objectives

The project objectives are to provide a modern technical basis for the design, optimization and control of hybrid power plants utilizing Alaska's considerable renewable energy resources.

b. Methodology

Industry proven combinations of theoretical and hardware modeling in conjunction with actual control hardware will be used to accomplish the project goals. The first stage will consist of devising a detailed set of verifiable requirements for the control system, its hardware and the virtual (or model) power system components, followed by computer modeling and then experimental validation. Industry best practices test procedures will be generated from the requirements set. This critically important part of system qualification will minimize the probability of technical errors and help identify system vulnerabilities. Computer code will be automatically generated for the selected controller hardware platforms using software such as Mathworks. The utilization of the ACEP test bed is anticipated for the testing of control system functionality.

3. Summary of Project Schedule and Summary of Project Budget

The project estimated schedule and budget timeline are presented in the table below:

	Project Tasks	Start date	Finish date	Duration	Cost
1	System architecture, requirements definition	11/5/2012	11/24/2012	15	$62,468
2	Prototype system modeling and programming	11/26/2012	8/31/2013	200	$242,977
3	Prototype design and component procurement	12/3/2012	1/12/2013	45	$68,977
4	System integration and SCADA deployment	2/4/2013	3/9/2013	40	$68,116
5	Prototype test and design revision	4/1/2013	9/21/2013	125	$293,890
6	Project demonstration and final report	9/30/2013	11/2/2013	30	$151,625

Marsh Creek services - $656,479, UAF services - $144,071. UAF services include 10 days of testing at the ACEP testing facility in Fairbanks. Matching funds will be provided in a form of in-kind in amount of $87,500 …….

4. Project Team Qualifications

The project team includes people who have practical experience implementing similar projects or elements of such projects:

John Lyons, Marsh Creek LLC, electrical engineer with nearly 30 years of Alaskan experience in power generation and distribution design, construction, maintenance and operations. John brings extensive hands on experience to the team with the integration of wind energy and hydroelectric energy with diesel plants in rural Alaska. John has pushed the envelope for displacing diesel fuel with renewable energy by utilizing electric thermal in integration designs.

Vladimir Leonov, Marsh Creek LLC, electrical engineer, PhD, 15-years of experience in BAE SYSTEMS implementing projects involving computer modeling and prototyping of discrete control systems, power electronics, high frequency, microwaves, and fiber-optical systems for defense and aircraft industries.

Richard Wies, Ph. D, P. E., University of Alaska Fairbanks, Associate Professor of Electrical and Computer Engineering, registered Electrical Engineer in the State of Alaska with over 12 years of experience focused on standalone hybrid electric microgrid systems. Richard's current research interests encompass the development of smart grid control and distribution strategies for the stable and efficient operation of standalone hybrid wind-diesel-battery-thermal storage microgrid systems in rural Alaska villages. He also has an interest in the development of medium and high voltage DC transmission and distribution systems for connecting rural villages and exporting stranded energy resources in Alaska. Richard's main research contributions to date are the development of standalone hybrid wind-diesel-pv-battery electric power system performance and stability models to investigate techniques for reducing diesel fuel consumption and maintaining system stability with high penetration and highly variable wind resources.

5. Discussion of Commercialization of Funded technology

The proposed experimental prototyping is anticipated to become a part of the typical development process for hybrid energy projects as has happened in other industries (aerospace) where highly dependable operation is the first priority. Eliminating blackout and interruptions of energy delivery to consumers is a cornerstone goal of the electric power utility industry. Increased utilization of renewable energy resource will automatically result in lower use of fossil fuel and substantial saving without additional investments. Prototyping can be effectively used for retrofitting existing hybrid energy projects.

At the end of the first year the project is expected to reach TRL level 6. The project is based on the teams' solid theoretical and experimental background supported by successful power components and systems modeling and functioning of the Kokhanok hybrid project.

It is anticipated that the prototype platform (both hardware and software) will be packaged as a commercial product and offered to the market. Its use will provide critical know-how to Alaska's industrial base and grow the hybrid power industry.

6. 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.

Signature: John Cameron Date: 03/09/2012

By: John Cameron Title: Vice President & General Manager