PACIFIC ENERGY

ADVANCED ENERGY STORAGE SYSTEMS

CUSTOM ENERGY TECHNOLOGY GRANT REQUEST

Philip Schaefer, CEO
Pacific Energy
7490 Jurupa Avenue
Riverside, CA 92504
philip@pacificenergyinc.com
(951)-588-1630

Table of Contents

Table of Contents	Page
Executive Summary	3
Background and Objective	4
Research to Date	5-6
Research Plan	7-9
Detailed Budget Summary	10-11
Biographical Sketches	12
References	12

EXECUTIVE SUMMARY

Pacific Energy is seeking a "Custom Energy Technology Grant" from Riverside Public Utilities in the amount of $100,000 to develop a demand response and peak shaving Advanced Energy Storage system (AES). The AES system will greatly benefit both RPU and the end user through optimal management of peak loads. Excitement and a growing sense of promise accompany energy storage in the electrical power industry from generation to the end user. Recently, a series of circumstances including technological breakthroughs, legislative and regulatory mandates, and the challenges associated with intermittent renewable generation have propelled energy storage to the forefront of industry consciousness [6].

Pacific Energy developed its first energy storage based product, a Grid Optimized (GO) PV System, to mitigate the disruptiveness of integrating intermittent renewables into the power grid. This system unites PV and energy storage, resulting in reliable and smooth output power throughout the day. The AES system was modeled around the structure set forth in Southern California Edisons SGIP program.

This grant proposal is for a design, engineering and construction of a 100 kilowatt-hour peak shaving, advanced energy storage system to be integrated into an existing commercial building connected to RPUs power distribution network. This energy storage system will be used by commercial or industrial end users to reduce peak demand usage. It will give Riverside Public Utilities the capability to strategically reduce stress on their grid. We believe that the outcome of this project will be a system which will address energy demand issues in Riverside and provide a clear benefit to RPU's customers as well as to RPU itself.

From RPU's perspective, this system can function as much more than a simple peak demand shaver. Because of the rapid real-time response of our system, it can cause the end users load to be perceived as almost completely flat throughout the day. This will contribute to frequency and voltage regulation. Additionally, this system will be able to generate reactive power at request to assist in stabilizing the grid.

Energy storage can be used for many different applications in the power grid. Our system will be equipped with algorithms for determining the best possible choice of action given real time measurements and a set of priorities entered by the user. For example, if the end user's current demand is low, but the power being imported from the utility grid is of poor quality, our system may inject reactive power or take some other action to increase the stability of the grid and its overall power quality.

All recent research completed by Pacific Energy has been completed in collaboration with students from California Baptist University and the University of California Riverside. Research for the proposed system will follow suit and provide an excellent academic opportunity for both universities.

BACKGROUND AND OBJECTIVES

History & Background of the company

Pacific Energy, founded in 2008, is the renewable energy and energy storage subsidiary of TSJ Electrical & Communications founded in 1997. It was formed initially to perform engineering and installation services for PV systems. The engineers at Pacific Energy quickly realized the importance of energy storage, especially in the stabilization of potentially disruptive photovoltaics. Additionally, we have explored how the same type of system could be effective as a distributed system. We are currently involved in research and development of several power electronics projects. Pacific Energy's goal is to cost effectively optimize renewables and energy storage for integration into distribution grids.

How It Makes a Difference

Southern California Edison predicts that time of use energy services alone have a benefit $1226/kW (over ten years) of installed energy storage. If this application is coupled with voltage support that number is upped to 1626$/kW [7]. Many different applications can be coupled and prioritized so that the energy storage could serve many different functions. This is where the true value of our system lies. The algorithms that we develop will allow our energy storage to serve various functions to both the end user and utility grid. These services include energy shifting, wholesale price arbitrage, avoiding the need to "dump energy" and minimum load issues, provide "in-basin" generation, distribution system power quality improvements, and power outage mitigation. The inverter, control algorithms, and power electronics in the system will make a robust and cost-effective system that can meet these needs with an estimated system lifetime of 20 years.

Objectives

Pacific Energy plans to accomplish the following objectives with the grant money:

1. Create a grid connected lithium-ion based, energy storage power control unit that is modularized and scalable.
2. Reduce the power and cost burden on Riverside Public Utilities during peak demand times by peak demand at the utilization point.
3. Use energy storage to mitigate the negative impact caused by peak demand on Riverside Public Utilities and end users.
4. Collaborate with Riverside Public Utilities to integrate storage systems into their distribution system with maximum benefit.
5. Partner with students and professors at California Baptist University (CBU) and the University of California Riverside (UCR) to study and prototype energy storage systems.
6. Create a user-friendly graphical user interface (GUI) to control and monitor the energy storage system.
7. Increase the viability of distributed renewable generation in the grid
8. Create cost-effective systems to aid Riverside Public Utilities in meeting the AB2514 CPUC state mandate.

RESEARCH TO DATE

Pacific Energy has been researching the use of energy storage in other areas for several years. The first product developed was specifically designed to optimize solar electricity generation (See Figure 1. below). This system uses Lithium-Ion storage to buffer PV output so if the system would sense the drop in power and use stored energy to “fill in” for the PV. By running smoothing algorithms this system greatly reduce the disruptiveness of PV to the power grid. In addition our system would allow the grid operator the ability to utilize production at a peak demand time vs non peak production.

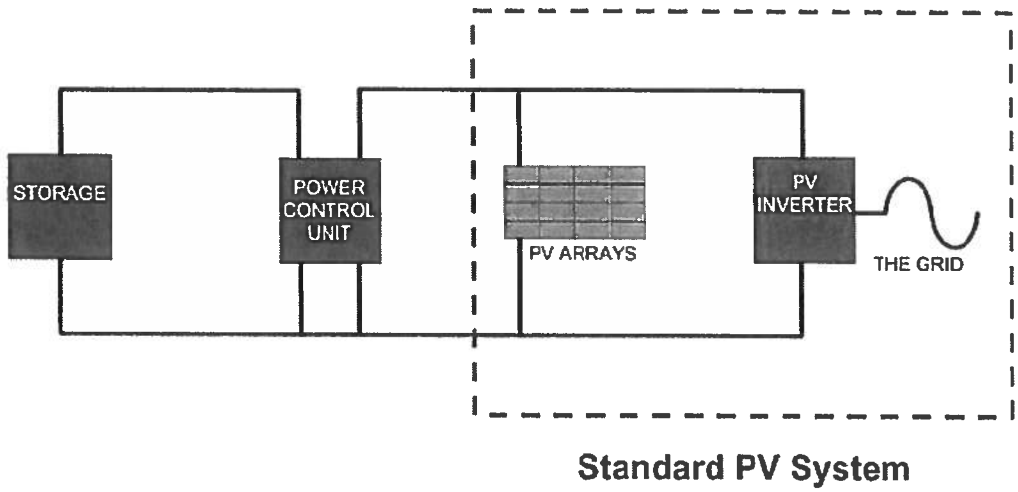

Figure 1: GO PV System Block Diagram

Currently the problem of integrating renewables is solved by keeping spinning reserves online. When a renewable source starts to produce less power these spinning reserves are activated and produce power for the grid. Essentially, the renewables cannot be “trusted” to output power in a predictable fashion. This leads to needing a backup option constantly. 100% of “non-firm” imports need to be backed up by just as much reserve power. However an energy storage solution could store energy from times of overproduction and hold it, waiting until it is needed to bolster non-firm imports. In this way no money or energy are wasted to buy and keep backup generators running, and the renewables can be “trusted” to produce a certain power profile each day [5].

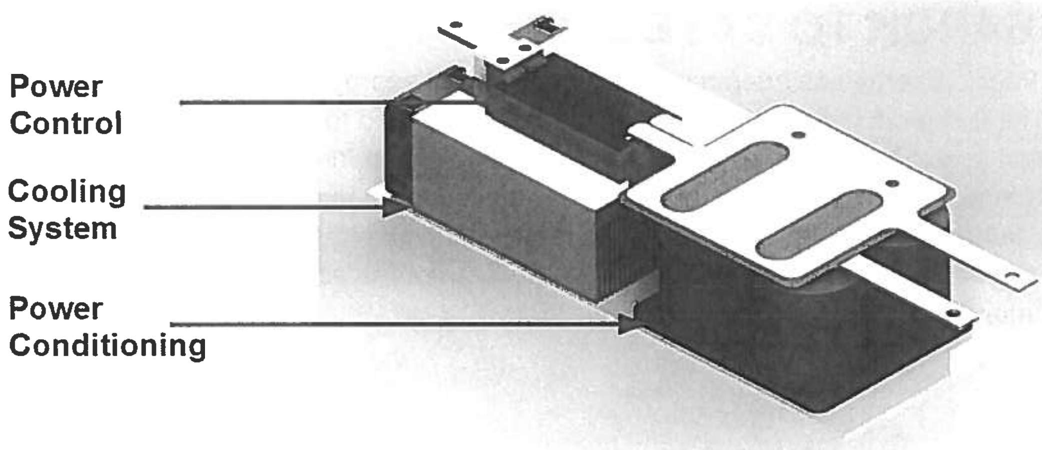

Figure 2: Modularized IGBT based power pole.

In creating the GO PV system we learned to successfully and safely control Lithium Ion storage and the utilization of the stored power to optimize the output of renewables. The project also provided us with a high tech state of art, multifunction research, development and prototype laboratory for other energy storage and power electronics projects. Finally, in the creation of GO PV system, Pacific Energy has created the cost-effective and modular power-pole shown in Figure 2. This power-pole is the building block for DC/DC converters, chargers, inverters, and motor controllers.

RESEARCH PLAN

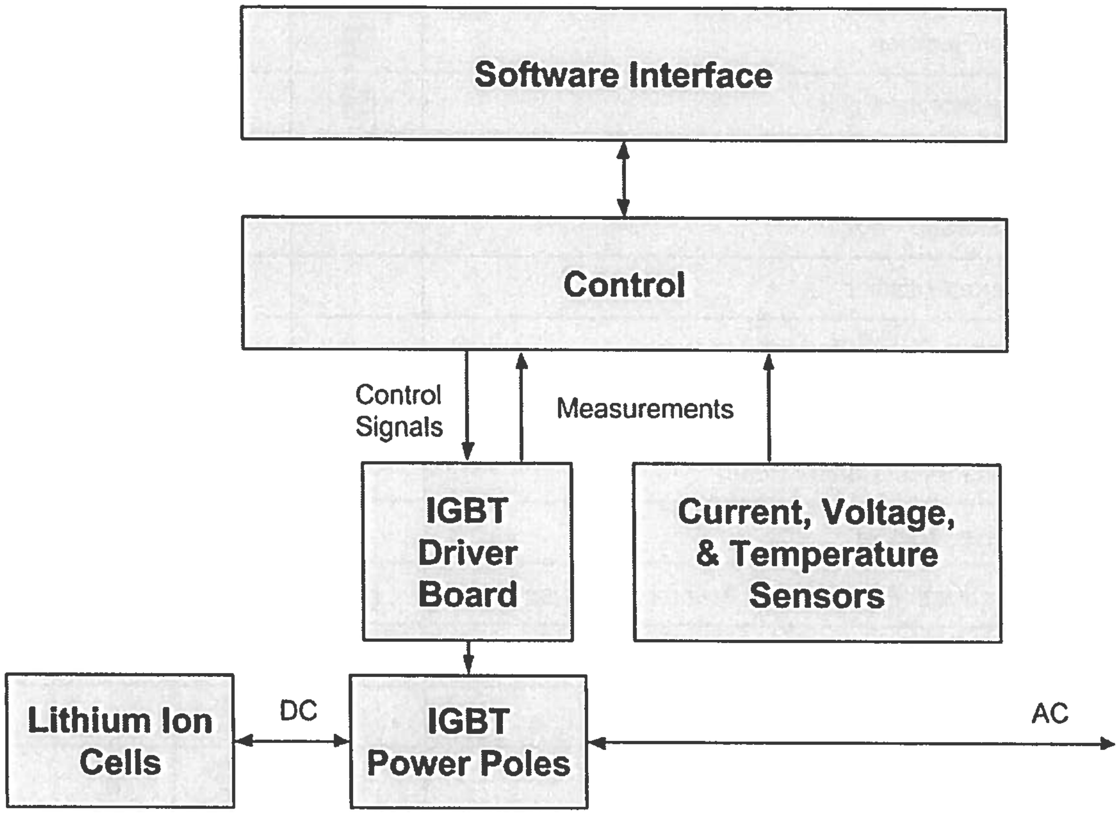

Figure 3: Pacific Energy AES System

Figure 3 shows the storage system block diagram. Below, each element is outlined briefly:

- The Lithium Ion storage will be used to store and discharge energy on demand
- The Power Control Unit consists of a bidirectional inverter/rectifier utilizing an Insulated-gate bipolar transistor (IGBT) based power pole. This unit will control the conversion of power from AC to DC and from DC to AC. It will also control the amount of power flowing to and from the battery.
- The IGBT Gate Driver Board will control the power electronics. It contains measurement and error checking circuitry.
- The control layer will communicate with the software as well as run the smart-grid algorithms.
- The software interface will be designed by engineers at Pacific Energy to run on typical Windows Operating Systems. It will allow the user to easily monitor the system in real time, view logs of previous days, and control the system as it runs.

Quarter	1	2	3	4
Hardware Milestones				
Design Inverter/Rectifier	■			
Design Energy Storage Pack	■			
Buy Parts	■			
Build Energy Storage Pack		■		
Prototype Inverter/Rectifier		■		
Install Prototype at Pacific Energy		■		
Hardware Verification		■		
Design and Order Final Control Board			■	
Software Milestones				
Research and Design Algorithms to Accomplish Objectives	■			
Simulate Circuitry and Control	■			
Implement Algorithms		■		
Software Alpha Testing		■	■	
User Interface Design				■
Software Beta Testing & Verification				■
Validation Milestones				
Test Basic System Functionality			■	
Worst Case Scenario Analysis			■	
Run System Autonomously				■
Analyze Real World Effectiveness				■
Documentation Milestones				
Data Sheet and System Specifications				■
Quarterly Report	■	■	■	■
Final Evaluation Report				■

Table 1: GO Energy Storage Project Timeline

The first step in our research plan is a simulation of the complete system model using Multisim. Next, a Multisim/LabVIEW co-simulation will be created as a platform to test different functionalities and algorithms. The co-simulation feature built into these tools allows us to simulate hardware in Multisim and control software in LabVIEW. This will reduce the cost of prototyping and allow us to quickly test many different control algorithms. During this time we will also be using our experience creating utility scale energy storage for PV systems to design and build a Lithium-Ion pack capable of storing enough energy to be effective.

This topology has been carefully designed to allow for the maximum amount of grid stabilization functionality while keeping the battery safe and maximizing its lifetime. The power electronics have been designed efficiently and with cost and battery lifetime in mind. For example, this system will be able to compensate for reactive power using only the power electronics, independently of the energy storage. This will increase the storage lifetime. Using the energy storage the system could achieve peak power shaving, transmission and distribution network support, voltage support, and upgrade deferral. It can also be used as a reserve supply.

As the designs are proven in simulations we will begin buying the parts necessary to prototype and build a proof of concept. We will install this prototype in our power electronics test bed at Master's Electric in Riverside (a grid connected fully integrated lab to log all system functions). Using Master's load profile (peak usage) and the test bed we will begin the testing phase (peak shaving), and verify that all of our objectives have been accomplished. Throughout these final phases, special attention will also be paid to the software used to control the system. Features will include user friendly browser based graphical user interface (GUI) for data logging, and control.

DETAILED BUDGET SUMMARY

Project Title:	Pacific Energy's AES Peak Shaving System
Sponsor:	Master's Electric/Pacific Energy
Principal Investigator:	Zachariah Taylor
Department:	Research and Development
Electrical Engineering Institutions:	Pacific Energy/California Baptist University/UCR
Period of Performance:	12 months

Personnel:	**No. of People**	**Totals**
Software Engineer	1	18,300.00
Embedded Systems Engineer	1	18,300.00
Power Electronics Engineer	1	30,000.00
Electrical technician	1	14,000.00
Project coordinator	1	30,000.00
Parts:		
Battery Management Systems		4,000.00
Lithium Ion Cells (100 kWh)		60,000.00
PCBs		4,000.00
Miscellaneous Electronics and Controls		3,500.00
Enclosures		7,000.00
Inductors, Relays, Wire		4,000.00
Subcontract:		
Powerex Power Electronics Devices		11,000.00
Total Direct Cost:		**204,100.00**
Portion Directly Paid by Pacific Energy		**104,100.00**
Total Grant Requested Year 1:		**100,000.00**

Salaries

The salary is based on the cost of 4 engineers, 1 project manager, and 1 electrician working 40-70 hours a week thru the year.

Parts

Battery Management Systems (BMS) and Lithium Ion Cells

The BMS and Lithium Ion prices are based on the cost for 100 kilowatt hours' worth of 100Ah cells (384 cells). Vendor to be Elite Power.

PCB/Case/Electronics

The system will require a printed circuit board to hold the control electronics. The entire energy storage unit, power electronics, and control will then have to be housed in a case. These numbers are based on various vendors' prices, a complete vendor quantity and cost list will be provided if requested.

Subcontract

The power electronics required for this project would be provided by POWEREX, a leader in high power semiconductor solutions including IGBTS and custom power modules. A preliminary quote from POWEREX listed a single power pole at $2,250. For this prototype we would plan to buy 4, http://www.pwrx.com/

BIOGRAPHICAL SKETCHES

Philip Schaefer is the CEO and general manager of Pacific Energy, Inc. His company has done general electrical contracting jobs both for government and private organizations since 1997. Four years ago, Philip decided to take his company into the renewables and advanced energy storage industry. His goal is to cost-effectively develop grid optimized (GO) systems that can provide relief to the electrical grid while supplying clean energy to end users.

Zachariah Taylor is a University of California Riverside student currently pursuing a Master's degree in Electrical engineering with a concentration on smart-grid technology. His background is in research and development and circuit design He received his bachelors of science in electrical engineering at California Baptist University (CBU). It was at CBU that he met Dr. Seunghyun Chun, a power electronics expert. For a year Zach learned under Dr. Chun before coming to work for Pacific Energy in January of 2013.

Jonathan Nichols is a senior student in Electrical & Computer Engineering at CBU. He joined Pacific Energy in January, 2013 as an R&D Electrical Engineering Intern to work on the GO PV system. His research specialty includes control system and software design using LabVIEW. He has developed many proprietary algorithms for Pacific Energy including new power injection methods and energy storage control.

REFERENCES

[1] California Solar Statistics. http://www.californiasolarstatistics.ca.gov/. Web. 13 Sep 2013.

[2] California State Profile and Energy Estimates. http://www.eia.gov/state/?sid=ca. Web. 12 Sep 2013.

[3] Southern California Edison High-Penetration Photovoltaic Project- Year 1. National Renewable Energy Laboratory. NREL/TP-5500-50875. June 2011.

[4] Eyer, Jim & Corey, Garth; Sandia National Laboratories, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*, SAND2010-0815, February 2010.

[5] Spinning Reserve and Non-Spinning Reserve. CAISO, 2006. Web. 15 Sept. 2013. http://www.caiso.com/docs/2003/09/08/2003090815135425649.pdf

[6] Rittershausen, Johannes & McDonagh, Mariko; Southern California Edison, *Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage.* DOCKET 11-IEP-1N. May, 2011.

[7] Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide. DOE Energy Storage Systems Program.