INTERIM PROJECT REPORT

Commissioning and Initial Technical & Economic Data Collection in FY06 of Three Pioneering Energy Storage Systems in the DOE Collaborations with CEC and NYSERDA

A Study for the DOE Energy Storage Program

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Acknowledgement

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Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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INTRODUCTION

The DOE / ESS Program supports the development of a large portfolio of storage options for a wide spectrum of applications. Of note among them are the current DOE partnerships with the New York State Energy Research and Development Authority (NYSERDA) and the California Energy Commission (CEC). California and New York State contain large urban centers with transmission constraints and both states have mandates for renewable energy, which makes them ideal venues for demonstrating the technical, economic, and security values of electrical energy storage (ESS).

DOE's broad goal in the separate agreements with each state is to demonstrate ESS as a technically viable, cost-effective, and broadly applicable option for increasing the reliability of the US electricity system and for electric energy management. Both partnerships are meeting, if not exceeding, DOE expectations.

Through technical oversight provided by Sandia National Laboratories, the programmatic goal for both programs is the collection, analysis, and dissemination of data relevant to near-commercial electric energy storage applications, systems and products.

Six commercial demonstration projects, three from each state, are in various stages of development:

NYSERDA/DOE Joint Energy Storage Initiative

- New York Power Authority — *NAS BESS at the Long Island Bus Facility*
- Beacon Power — *Scaled Demonstration of a Flywheel Energy Storage System for Grid Frequency Regulation*
- Gaia Power Technologies — *Energy Storage Device in Edge-of-Grid Application*

CEC/DOE Joint Energy Storage Collaboration

- ZBB Energy Corporation — *Demonstration of a 2 MWh Zinc-Bromine Battery System*
- Beacon Power Corporation — *Demonstration Project Utilizing Flywheel Energy Storage System [FESS] for Utility Grid Frequency Regulation*
- Palmdale Water District — *Energy Storage-Enabled, Renewable, MicroGrid Power Network*

During Fiscal Year 2006, three of the six began producing technical and economic data for collection and evaluation: the two Beacon demonstrations and the Gaia demonstration. This report summarizes that data.

NYSERDA / DOE — *Energy Storage Device in Edge-of-Grid Application*

This project, part of an MOU between DOE and the New York State Energy Research and Development Authority (NYSERDA), demonstrates a demand reduction and load leveling device for edge-of-grid scenarios that will provide economic benefits to the local utility and the rural electricity user. DOE funds the data management, collection and analysis activities through contracts with EnerNex Corp, out of Knoxville, TN.

The demonstration centers on the *PowerTower,* an 11-kW/20-kWh Energy Storage System developed by Gaia Technologies. The PowerTower is installed at a residence in the Delaware County Electric Cooperative (DCEC) territory of New York state. Gaia's PowerTower is a total energy management system that incorporates electricity storage, power electronics, and communication and control modules. The unit is used for an array of applications, from load shifting and peak shaving to backup power and enabling alternative energy sources.

The project is being conducted in multiple phases and will evaluate the usefulness of electricity storage technology in two applications. The first application was *fuel-cell demand reduction*, during which the PowerTower provided energy to a load supplied by a 5-kW fuel cell, as needed. The second application, currently being demonstrated, is *grid demand reduction*; the PowerTower is providing energy when the electricity load at the residence exceeds a preset threshold.

Under technical guidance from Sandia National Laboratories (Sandia), Gaia selected and installed the data acquisition system (DAS) monitored by EnerNex. On a daily basis, EnerNex collects and compiles for analysis an extensive file of data based on parameters and data protocols supplied by Sandia. As illustrated in the schematic below, the DAS and other hardware for the demonstration are installed between the electrical meter and the main power panel of the home (Figure 1). Figure 2 shows the PowerTower and the communications equipment installed in the basement of the home.

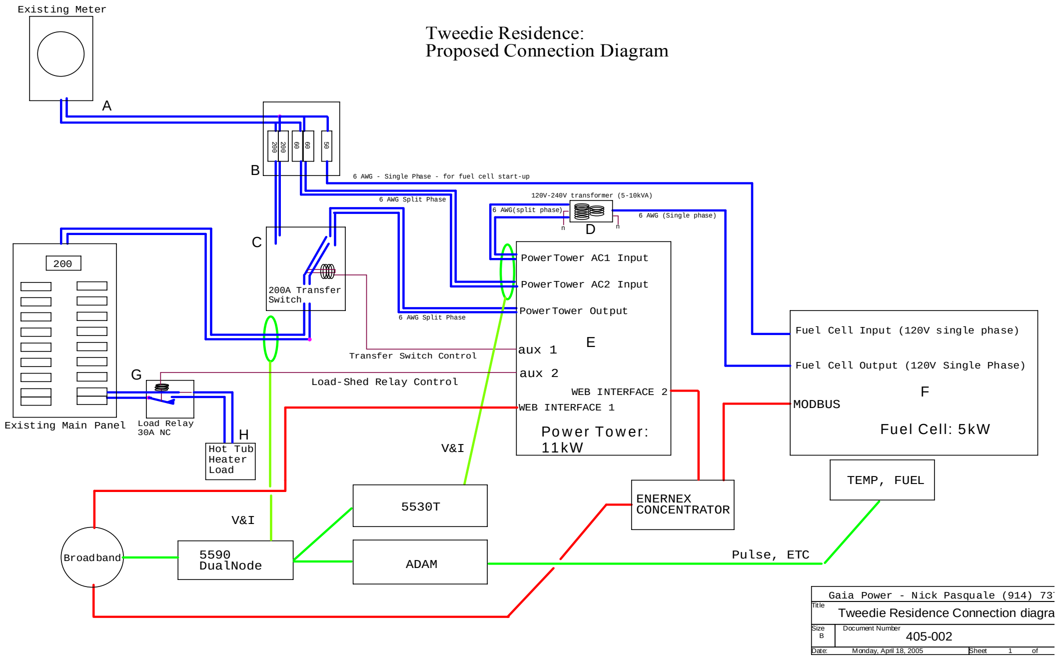

Figure 1. Schematic of the DAS Located Between the Homeowner's Electrical Meter & Main Power Panel.

Figure 2. *PowerTower* and Main Communications Panel

For the first year, the system ran primarily either in grid parallel/net metering or off-grid mode. In the grid parallel set-up, the fuel cell output was connected in parallel with the grid output. Hence, when the fuel cell was operating as the primary source of power to the Power Tower, the grid was redundant, except in cases where it was used for providing back-up power or in damping the output of the fuel cell.

During this first phase of the demonstration, from August 2005 through May 2006, the Power Tower portion of the battery/fuel cell installation supplied battery power for over 557 hours (7.7% of the time). Over the same period, the fuel cell portion of the installation operated for 5,496 hours (76% of the time), until commencement of the second phase. The results illustrated that a combination battery energy storage device and fuel cell can power an edge-of-grid application.

Figures 3 and 4 depict power and current during the last week of September, the second phase of the demonstration. Figure 5 illustrates how the input/output affected the battery voltage. To serve the increase in load, the batteries were used more extensively during this period which illustrates that a battery energy storage device in an edge-of-grid application, can provide grid demand reduction.

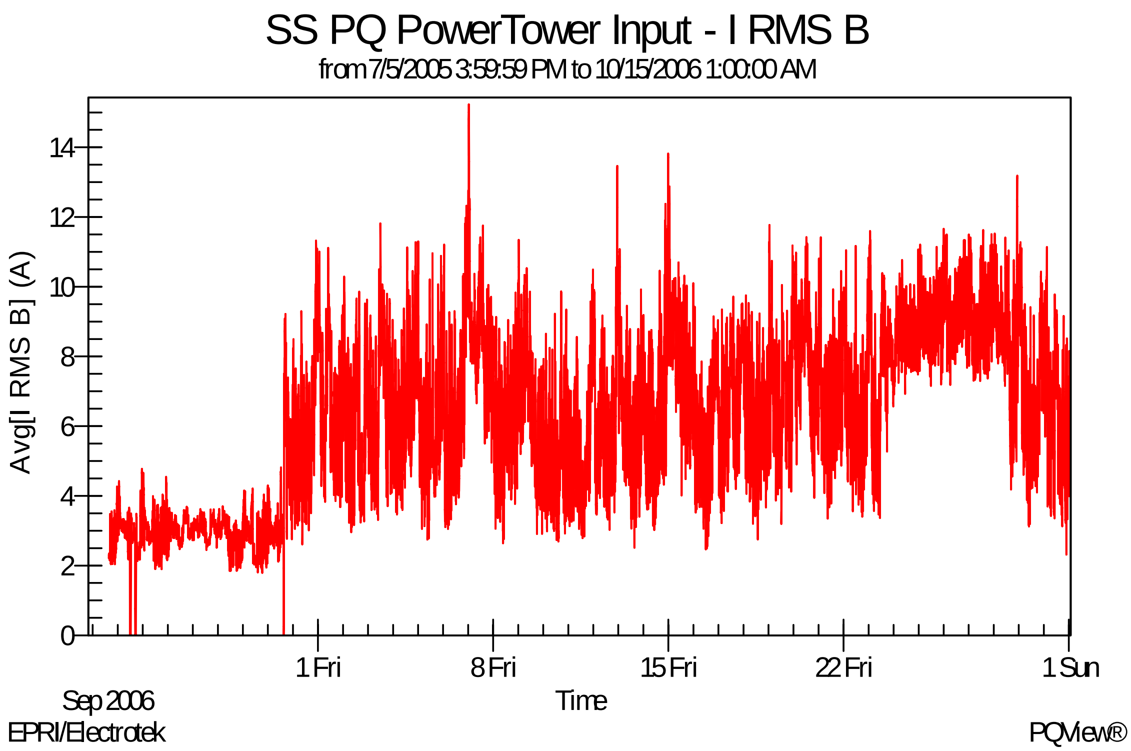

Figure 3. Power Tower Input Current

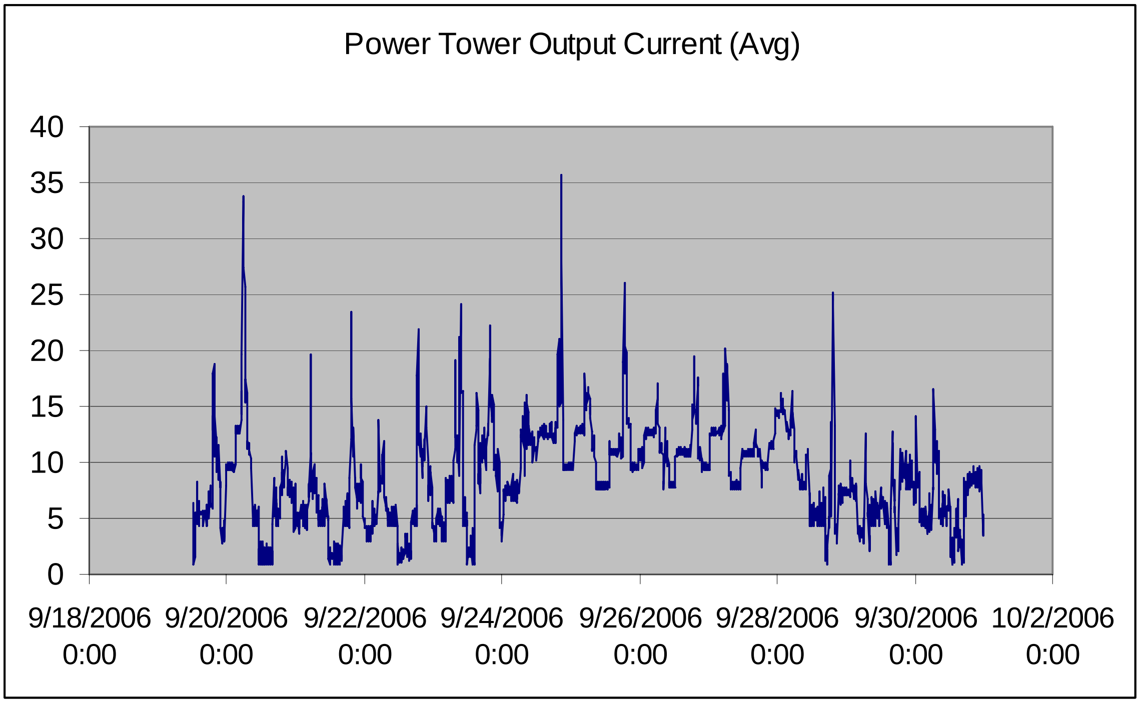

Figure 4. Power Tower Output Current

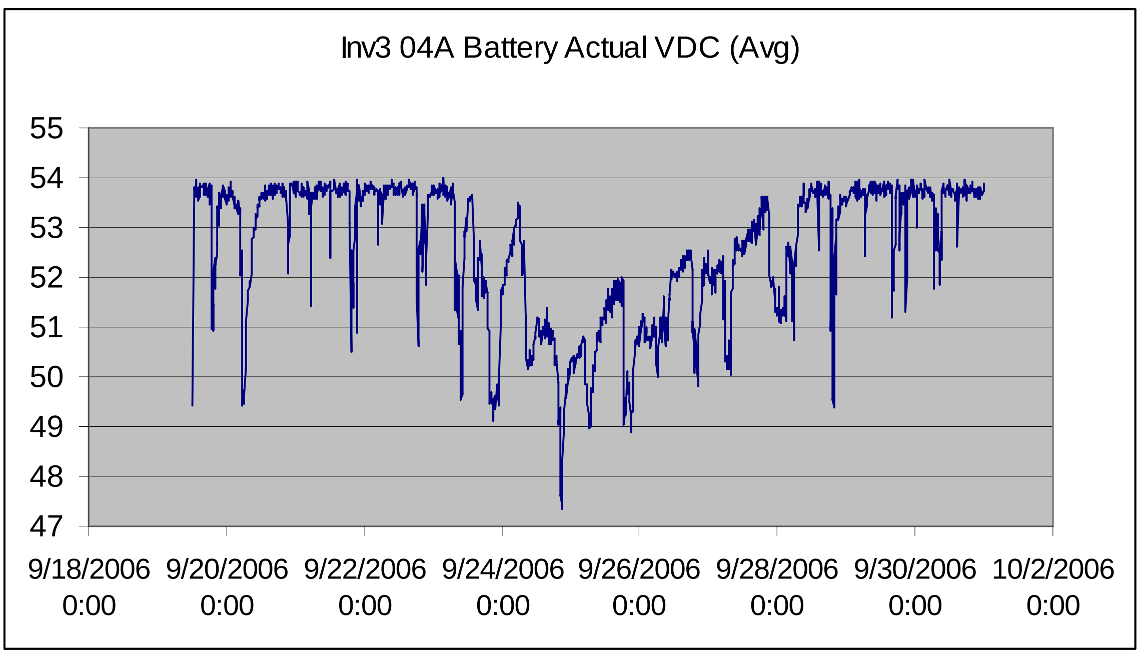

Figure 5. Battery Operation in September 2006

The PowerTower system, whether charged by the electricity grid or the fuel cell, has functioned as intended and the entire operation has been transparent to the homeowner.

In September, EnerNex completed implementation of graphical, web-based data access. The full data logging package and trends for all system hardware can be viewed online at http://www.storagemonitoring.com/nyserda-doe/storage-home.shtml.

An opportunity to test the PowerTower system with a diesel generator has recently arisen, which will constitute a third phase of the demonstration.

CEC / DOE — *Utilizing Flywheel Energy Storage System (FESS) for Utility Grid Frequency Regulation*

DOE is sponsoring this project in an effort to determine the relative benefits of achieving electricity generation resources that respond faster to demands. In addition, understanding the response time of a flywheel storage system as compared to traditional generator response time will provide a better determination of the required sizing for flywheel and other fast response systems. Analysis of currently-used frequency regulation signals indicated that an energy storage module that can store or deliver 1 MW for 15 minutes would provide regulation services superior to services currently provided by generators.

The project, part of an MOU between DOE and the California Energy Commission (CEC), involves a Beacon Flywheel Energy Storage System (FESS) that is demonstrating the feasibility of using a flywheel to provide frequency regulation services to the California Independent System Operator (CaISO). DOE funds the data management, collection and analysis activities through contracts with EPRI Solutions, Inc. (EPRI), located in Knoxville, TN, and Distributed Utility Associates (DUA) in Livermore, CA. The data management activities are directed by Sandia National Laboratories.

The Beacon FESS is designed to demonstrate how a flywheel energy storage system can be utilized to respond to a regional transmission operator's signal to quickly add or subtract power from the grid in a frequency regulation support mode. Using this concept, the flywheel recycles energy (stores energy when generation exceeds loads; discharges energy when load exceeds generation), instead of trying to constantly adjust generator output, as would be the case in a grid scenario.

Beacon has provided seven 15 kW flywheels in a parallel configuration. The FESS follows the regulation signal with errors less than 10% (typically 3-5%), depending on power demand. Unlike generation-based frequency regulation, which typically experiences errors in the 15-25% range, no fuel is consumed and no emissions are generated.

Figure 6 is a line drawing of the system configuration and Figure 7 illustrates a conceptual layout of the FESS system.

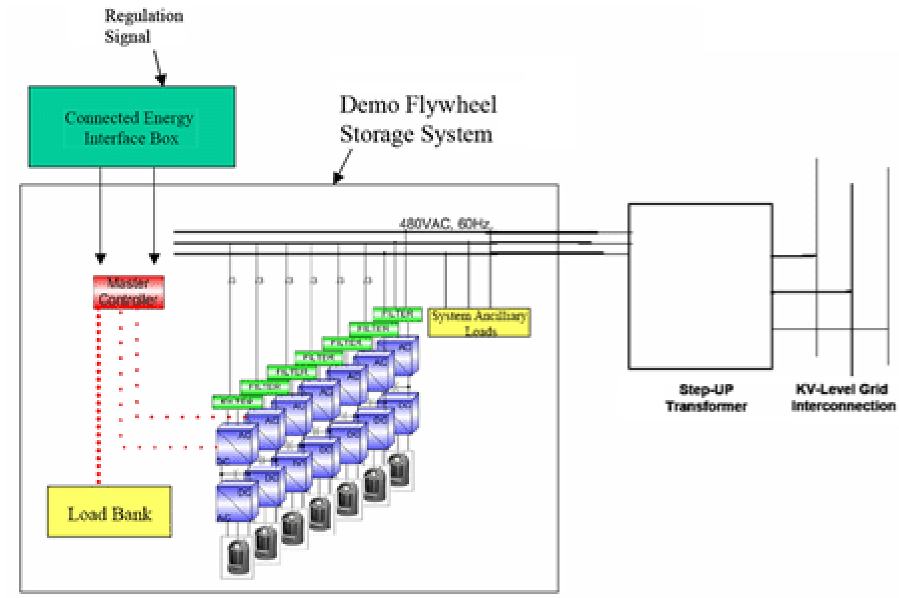

Figure 6. Diagram of the Scaled *Smart Energy Matrix* FESS System Configuration

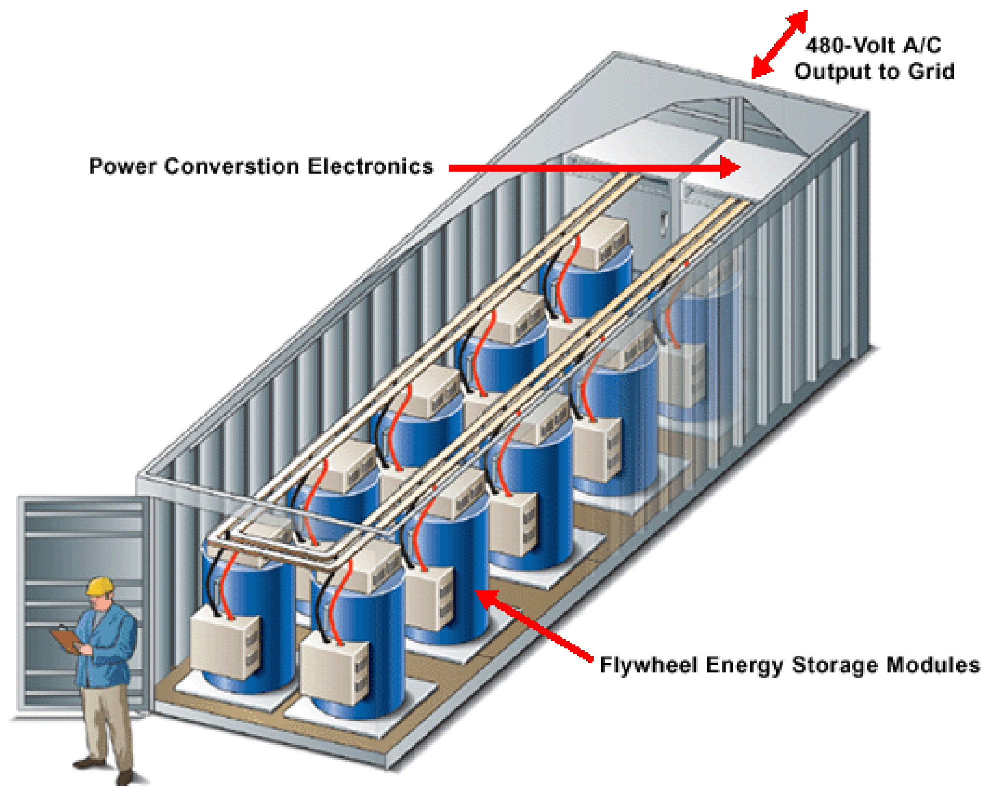

Figure 7. Conceptual Illustration of the Physical Packaging of the *Smart Energy Matrix* FESS

The FESS was assembled in Massachusetts and then transported to the PG&E Distributed Utility Integration Test (DUIT) Facility in San Ramon, CA, where it was installed and commissioned for this demonstration. EPRI Solutions Corp. recently began data collection to validate the original analysis. When aggregated to reach appropriate input/output levels, a flywheel energy storage system can offer many benefits to the US electric grid. The primary benefits are:

- **Increased Available energy**: Generators are not able to provide their maximum power because, for safety considerations, they must be operated below their maximum capability to provide regulation. Typically, the generators in use today must operate below their maximum capacity by twice the amount of regulation. If all regulation were provided by FESS, the grid would experience an additional 2-4 % generation capacity, without adding new generators.
- **Support of Distributed Generation with Local Voltage Support**: Several projects have already shown the benefits of using flywheels for local voltage support. Included among them is a project on the NY City transit system, where ten 1.6 KWh flywheels provide support between train stations. As flywheel storage increases, as will be demonstrated by this project, the feasibility of larger scale application of FESS for local voltage support will be more practical.

The FESS at the DUIT facility will be operated under test for six months to prove its demonstrated ability for interfacing with ISO signals and the grid.

The demonstration phase of this project began August 1st 2006 and full analysis of the complete data should be available by the end of CY 2006. Meanwhile, daily, weekly and monthly energy data can be viewed on a password-protected CEC website (www.energystoragedemo.net/cec). Figure 8 is a capture of real-time web site data being produced by the FESS.

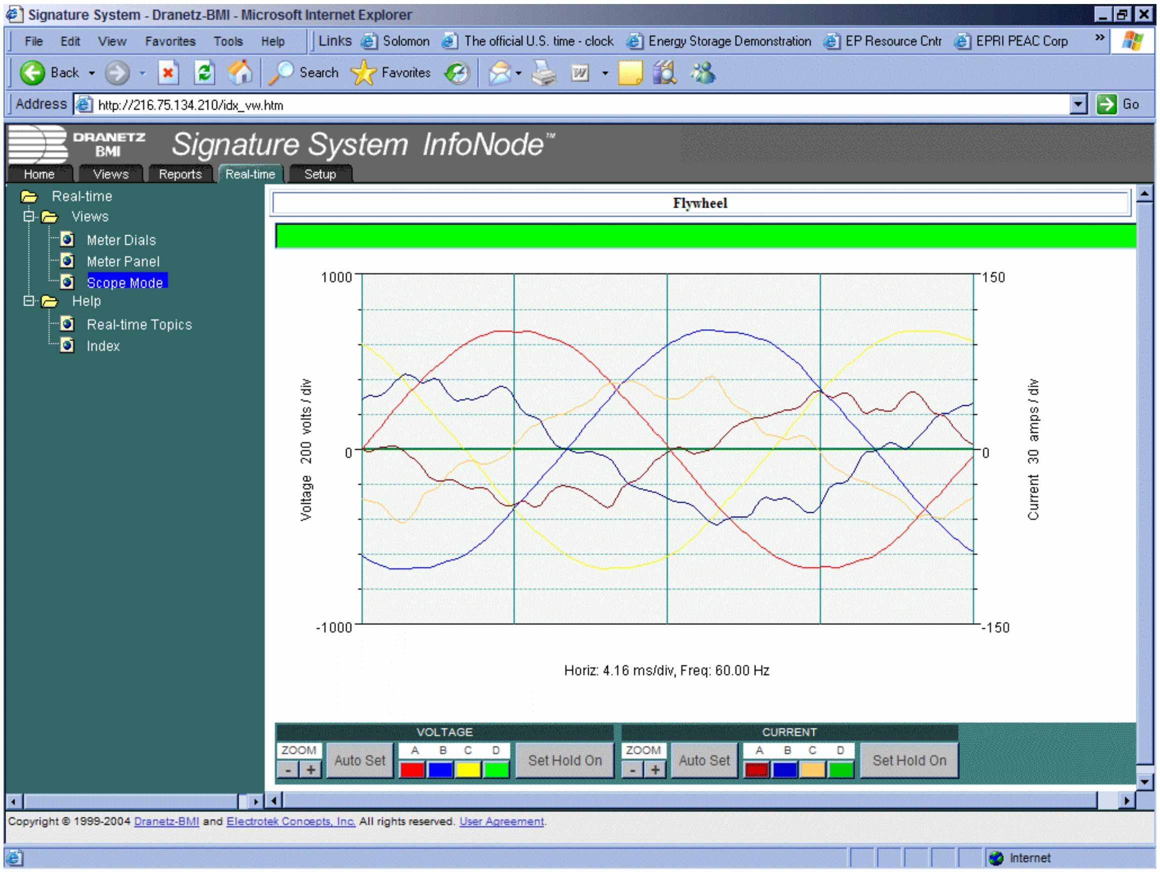

Figure 8. Sample of Real Time Data Produced Daily on the Internet by EPRI Solutions

NYSERDA / DOE — *Scaled Demonstration of a Flywheel Energy Storage System for Grid Frequency Regulation*

Part of an MOU between DOE and the New York State Energy Research and Development Authority (NYSERDA), this project is demonstrating grid frequency regulation using a scaled-down version of the Beacon *Smart Energy Matrix* commercial flywheel energy storage system (FESS). DOE funds the data management, collection and analysis activities, through a contract with EnerNex. For this demonstration, Beacon adapted the FESS to operate on the Niagara Mohawk distribution grid, at an existing industrial site belonging to Power and Composite Technologies, Inc. (PCT) in Amsterdam, New York. In addition, the New York Independent Operator (NYISO) has committed to support to support the demonstration.

The primary goal is to determine whether the *Smart Energy Matrix* FESS can respond directly to changes in grid frequency, as opposed to following an ACE signal, by either injecting or absorbing power from the grid. An additional goal is to demonstrate that the FESS can provide reactive power to improve the power factor at an industrial plant.

The scaled *Smart Energy Matrix* FESS is comprised of seven, Model BHE6, Beacon flywheels that were modified with a larger motor, assembled in a transportable container, and installed at the demonstration site. The FESS is operating at 480Vac and supplying up to 100 kW for fifteen minutes. The full-sized, commercial version of the *Smart Energy Matrix* will be rated at 1 MW/ 250 kWh.

With technical guidance from Sandia National Laboratories (Sandia), Beacon installed an extensive data acquisition system (DAS) that is being monitored by EnerNex Corp. On a daily basis, EnerNex collects and compiles for analysis an extensive file of data from the DAS, based on parameters provided by Sandia. Graphical summaries of the data can be viewed on the demonstration website.

Figure 9 shows various views of the scaled *Smart Energy Matrix* FESS installed at the PCT demonstration site. The upper right photo is the seven flywheels inside the container. Figure 10 is a one-line diagram of the DAS for this demonstration.

Figure 9. The Beacon Smart Energy Matrix FESS Installed at the PCT Site

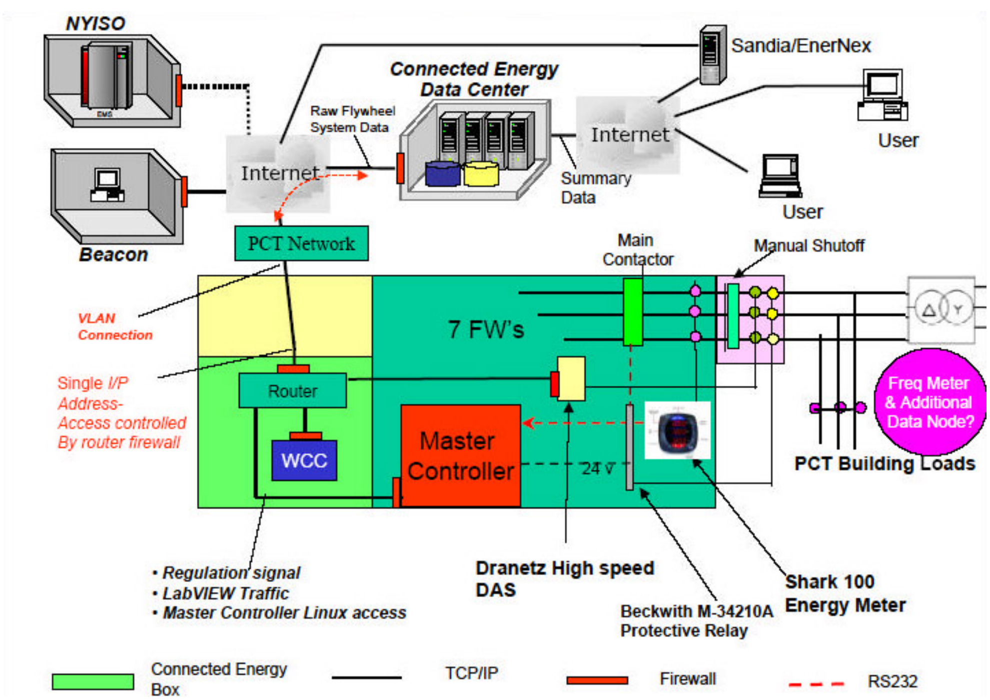

Figure 10. Diagram of the Data Acquisition System (DAS)

Figure 11 is an example of a daily output graph that shows the response of the flywheel system on July 25th. The pink trend line is the frequency. The dark blue line is the regulation signal (in kW) being fed into the flywheel system as a result of the frequency variations. The green line is the regulation effect. As shown by the graph, the flywheel generally follows the frequency signal. The instances of dark blue are periods when the flywheel does not have enough stored energy to respond to the frequency signal.

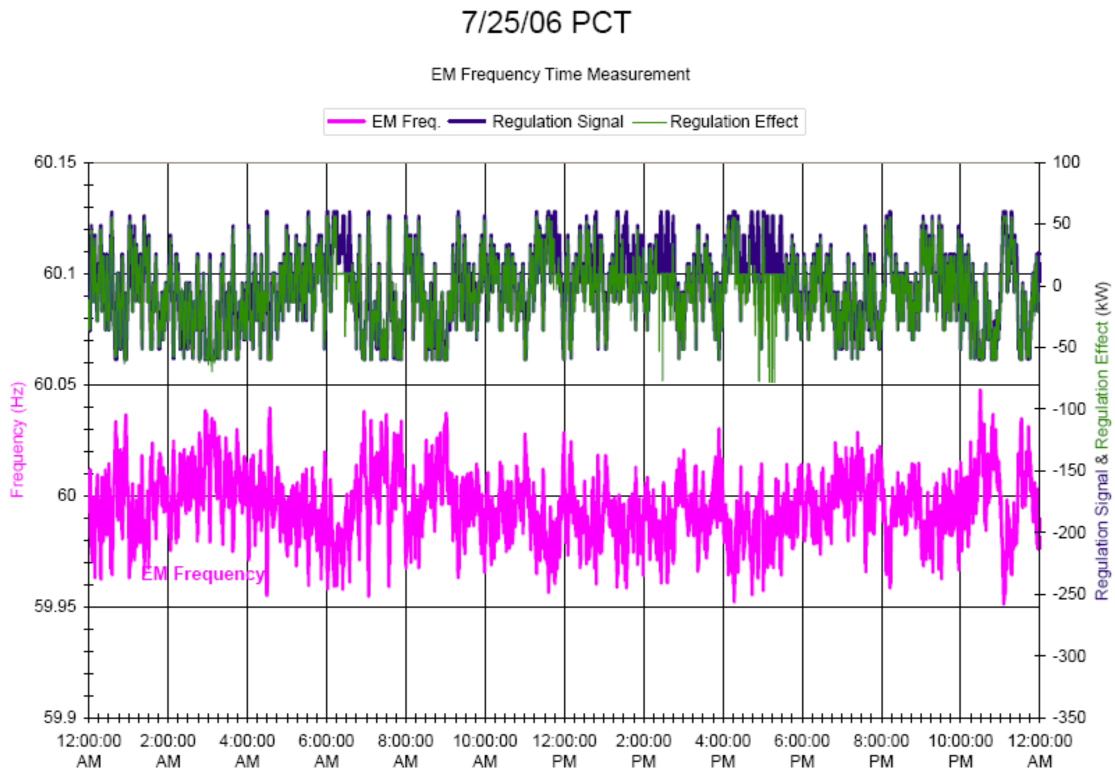

Figure 11. Sample Daily Output Graph of Data Provided by EnerNex

A real-time interface with the internet has been implemented that shows the current status of the *Energy Matrix* flywheel system. The interface shows whether the Beacon FESS is injecting energy to the grid or absorbing it, the number of flywheels operating at the time, etc. Figure 12 is a screen capture of a typical interface that can be viewed on the DOE/NYSERDA Initiative web site: http://www.storagemonitoring.com/nyserda-doe/storage-home.shtml.

Overall, the application by Beacon Power is progressing well and has proven to be successful in responding directly to changes in the grid frequency.

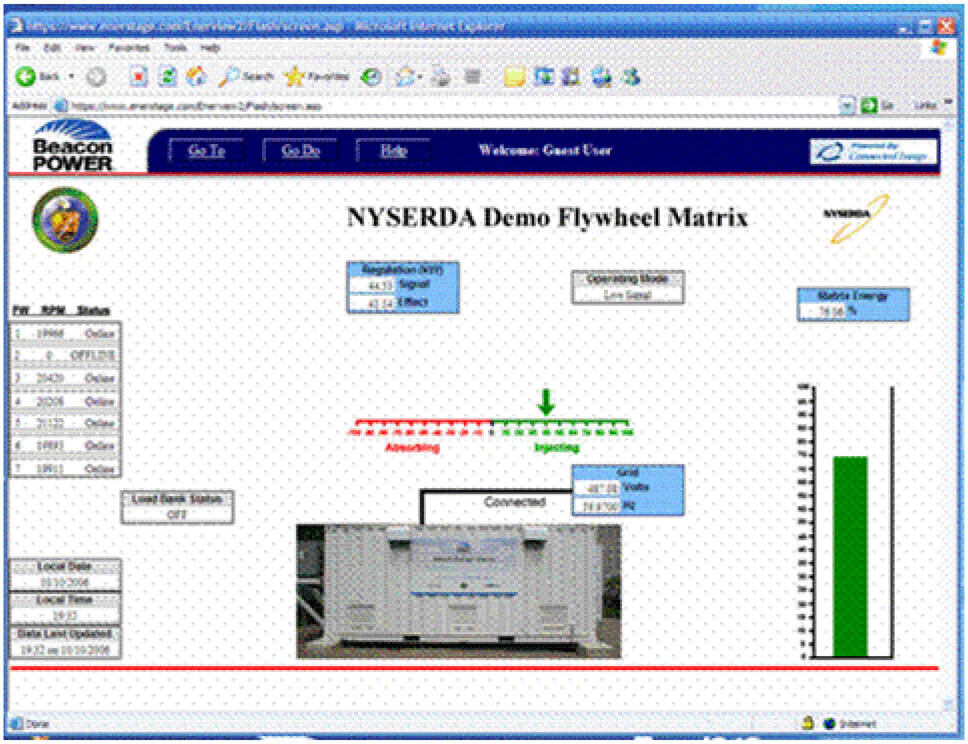

Figure 12. A Typical Data Interface from the DOE/NYSERDA Initiative Web Site

Appendix A — EnerNex: Final FY06 Quarterly Monitoring Report

Quarterly Monitoring Report: NYSERDA/DOE Energy Storage Demonstration Projects – June 2006 Through September 2006

EnerNex Project Number 3005

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Executive Summary

In 2004, the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA) commissioned three energy storage research projects. The three projects are as follows:

- Gaia Power Technologies/Delaware County Electric Cooperative – Edge of grid residential application that includes an 11 kW Power Tower battery-based energy storage and delivery system fed by a Plug Power 5 kW fuel cell in Delhi, NY
- Beacon Power – Grid frequency regulation demonstration at an industrial facility in Amsterdam, NY, using 7 flywheels producing 100 kW for 15 minutes
- New York Power Authority/ABB – Peak-shaving and emergency backup application utilizing a 1 MW/7.2 MWh commercial-scale sodium-sulfur (NAS) battery system at a Long Island Bus facility

Gaia Power Technologies/Delaware County Electric Cooperative

The first project mentioned above is the application of a Gaia Power Tower energy storage device at a residential location to illustrate an edge-of-grid application. Construction and installation was completed in June, 2005. Figure 1 on the following page shows the connection diagram of all of the equipment including the data acquisition system. The data acquisition system installed at this site includes the following equipment:

- Drantez-BMI Signature System DualNode (Combination InfoNode (data concentrator) and DataNode) at Service Entrance collecting power quality and steady-state values
- Additional DataNode on Power Tower Input (also Fuel Cell Output)
- Advantech ADAM modules for environment (temperature, humidity) and flow (gas and water) data from thermocouple and pulse counter meters
- EnerNex Data Concentrator (ETRAX 100LX MCM 2+8 chip and device server) to download Power Tower currently and Fuel Cell Operational Data (future)
- On board DAS systems on Power Tower and Fuel Cell
- Communications through secure VPN to VPN satellite link provided by Skycasters, LLC

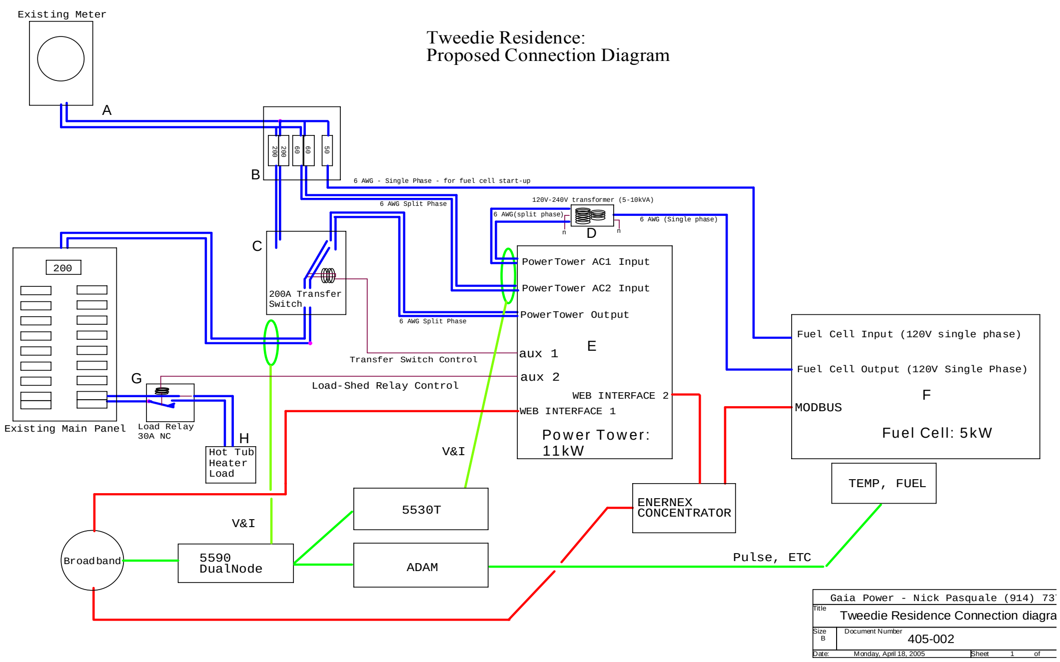

Figure 1 – DAS System for Site 1

The Power Tower consists of a 24-battery (6 strings of 4 batteries) based input configured with power electronics to obtain power from any source and output 11kW of continuous power with up to 25kW in surge power. This system also provides state of the art load management capabilities with power modules offering a 120V single phase connection or a 120/240V split phase mode. It has an on-board ampere hour (AH) counting meter for the battery pack that is updated per second for the entire period when the Power Tower supplies the energy during peak load demand.

Also included in the system for the first year is a Plug Power fuel cell. The Plug Power fuel cell is propane fueled to generate a rated 5kW power output. It consists of on-board batteries and a 60 Hz inverter and can be programmed to output 1.25kW, 2.5kW or 5kW. For starting operation however, the fuel cell is fed from the grid in order to minimize the risks of false starting and also to keep it synchronized with the grid, in a more efficient constant power mode. Several points are of importance and worth discussing in regards to operating the fuel cell at the constant power mode. The fuel cell ran until June 5th and was physically removed on July 27th, 2006.

For the first year, the system ran primarily either in grid parallel/net metering or off-grid mode. In the grid parallel set-up the fuel cell output is connected in parallel with the grid output. Hence, when the fuel cell is operating as the primary source of power to the Power Tower, the grid is almost redundant except in cases where it is used for providing back-up power or in damping the fuel cell's output. In the Off-Grid mode, the fuel cell's output is connected directly to the power tower input (AC1) while the grid is fed into the secondary input of the power tower (AC2).

After the fuel cell was removed the system was placed in bypass mode until August 30th. After August 30th, it was then configured as the grid feeding the Power Tower and the Power Tower feeding the loads. It is expected that another energy storage device (15 kW Briggs generator) will be installed later in the year to replace the fuel cell. Table 1 is a summary of the system configuration during the first 17 months of the installation.

Table 1 – Summary of System Configuration

Month	**System Mode**
July, 2005	Fuel Cell ON (But new stack was installed during the last week of month)
August	Fuel Cell ON (Net metering but back to full mode on Aug 30th)
September	Fuel Cell ON
October	Fuel Cell ON (Until Oct 26th when outage occurred)
November	Fuel Cell ON (Primarily netmetering then set to OFF position followed by brief operation on Nov 22nd)
December	Fuel Cell OFF
January, 2006	Fuel Cell OFF (Set back to ON position on Jan 15th)
February	Fuel Cell ON (Net metering)
March	Fuel Cell ON (Net metering, Power Tower switched ON March 23rd)
April	Fuel Cell ON (Net metering)
May	Fuel Cell ON (May 20th, switched to Bypass)
June	Fuel Cell OFF (June 5th), Bypass
July	Fuel Cell Removed (July 27th), Bypass
August	Bypass
September	Grid Feeding Power Tower, Power Tower Feeding Loads

The system did illustrate that a residence on the edge of the grid could in fact power his/her home with a combination battery energy storage device and fuel cell. During this phase, from August 2005 through May 2006 the Power Tower portion of the battery/fuel cell installation supplied battery power for over 557 hours or 7.7% of the time. The fuel cell portion of the installation operated over 5496 hours or 76% of the time until commencement of the second phase of the project. However, as you can see from the table above, the system was in bypass mode for extended periods of time. The reason for this is that the homeowner experienced severe voltage flicker which caused a lot of annoyance. A lot of analysis was done by Gaia, DCEC, Sandia and others, with the current understanding summarized below.

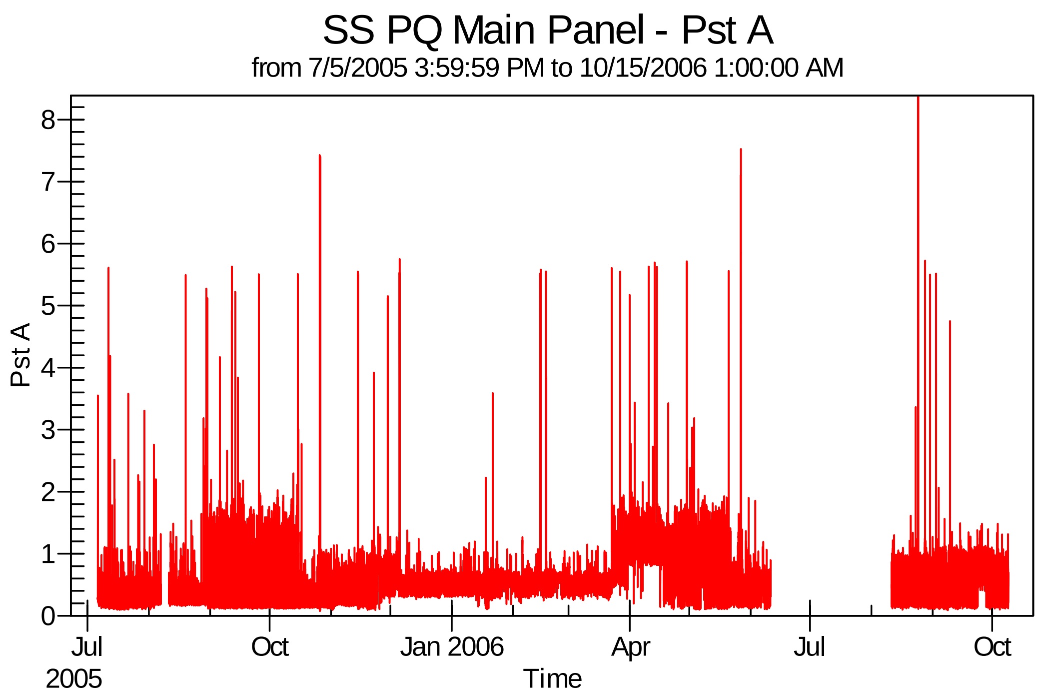

Figure 2 – Short Term Flicker Trend for Project Duration

It turns out unlike most standalone installations (Off grid) the Power Tower was connected as a peak shaver. The generator (fuel cell) was connected and operating all the time at 1.5 or 2kW. In the event the load demand is over 2kW, the power tower would provide power to compensate for the load.

In typical installations, the generator is only brought on to charge batteries in the absence of solar energy. The batteries would always satisfy the entire load, and when the batteries could not, the generator would satisfy all of the load and charge the batteries.

It is currently believed that the flicker problem exists because of the way the Power Tower inverters are configured. They are using (2) Xantrex SW55XX inverters. The Xantrex inverter can produce 5.5kV 120Vac @ 60Hz, but when configured in series, they produce the 240Vac required to satisfy the Tweedie residence. The problem is the inverters are always in charge mode until the load rises above 1.5kW. This can happen often during the day, hence the frequent flicker. Before the load reaches 1.5kW, the fuel cell (Beacon inverter) is satisfying the load. The transition of the Xantrex inverters switching from charge to discharge (invert) is when the flicker is observed. We think that the Xantrex 240Vac and the Beacon 240Vac are not exactly at the same potential and that causes the flicker.

The suggested solution was to connect the Xantrex inverters in series, but have one always in discharge (invert) mode and the other in charge mode. This eliminates a costly component in the current installation, the step up transformer. The Beacon inverter is a 120Vac inverter, but to connect to a 240Vac connection it needed to be stepped up. They can connect directly to the 120Vac Xantrex inverter in charge mode, and the frequent flicker problem should not exist because the Beacon and the Xantrex inverters are always inverting and not switching back and forth. We have not been able to test this solution. This change is a large change and might not help the current time line.

The DAS system installed has worked fairly well. We have had ongoing difficulties with the satellite communications but have been able to get it up and running before any significant data loss. There was a 2 month stretch from June 11 to August 11, 2006 where the entire system was down and no data collection occurred. It has been agreed that the project will continue for an additional 2 months as a result.

Beacon Power

The energy storage system used in this demonstration project is a scale-power Smart Energy Matrix designed and manufactured by Beacon Power. The unit was installed at PCT in Amsterdam, NY, during the first week of June. The system consists of seven four-rotor flywheel units. The system operates at 480Vac and is capable of supplying up to 100 kW for fifteen minutes. An extensive data acquisition system has been installed by Beacon Power. Prior to June, the service entrance of the facility was monitored for approximately three months. They are also using Connected Energy for data acquisition and presentation. There is a Shark 100 Energy Meter as well as a Dranetz-BMI Signature System monitoring the input/output of the entire Smart Energy Matrix. There is an extensive DAS system within the Smart Energy Matrix (EM). Figure 3 is a one-line diagram of the DAS system for this site.

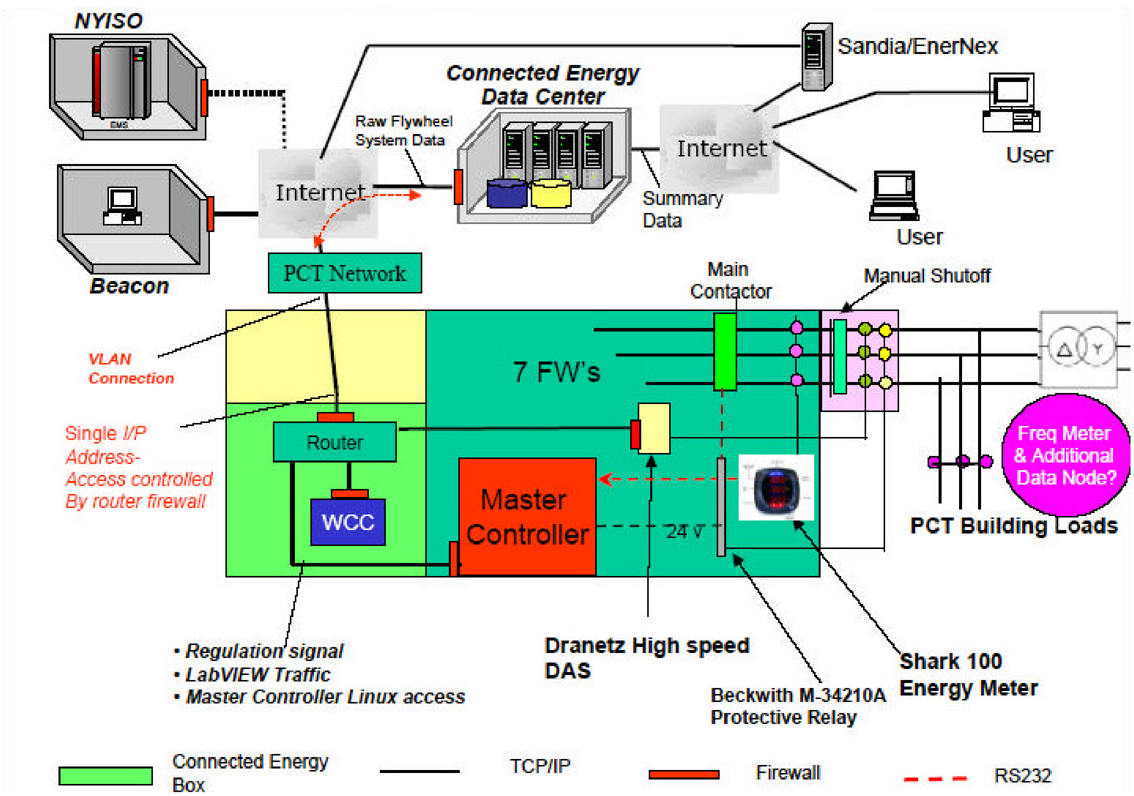

Figure 3 – DAS System for Site 2

The goal of this energy storage project was to see if the Smart Energy Matrix flywheel system could respond to changes in frequency by either injecting or absorbing power from the grid. The last week of July was used as the test signal. The frequency during this week was recorded and is being played back over and over again to view the response and operation of the flywheel. On a daily basis an extensive file is collected by the DAS system and summary graphs are prepared. Figure 4 is an example of a daily output graph. This graph shows the response of the flywheel system on July 25th. The pink trend line is the frequency. The dark blue line is the regulation signal (in kW) being fed into the flywheel system as a result of the frequency variations. The green line is the regulation effect. As you can see, the flywheel is able to follow the signal quite well. The instances where you see blue are when the flywheel does not have enough stored energy to respond to the signal. On this day, it amounts to about 8% of the time and corresponds to prolonged negative frequency signals. Overall, the application by Beacon Power has been proven to be successful.

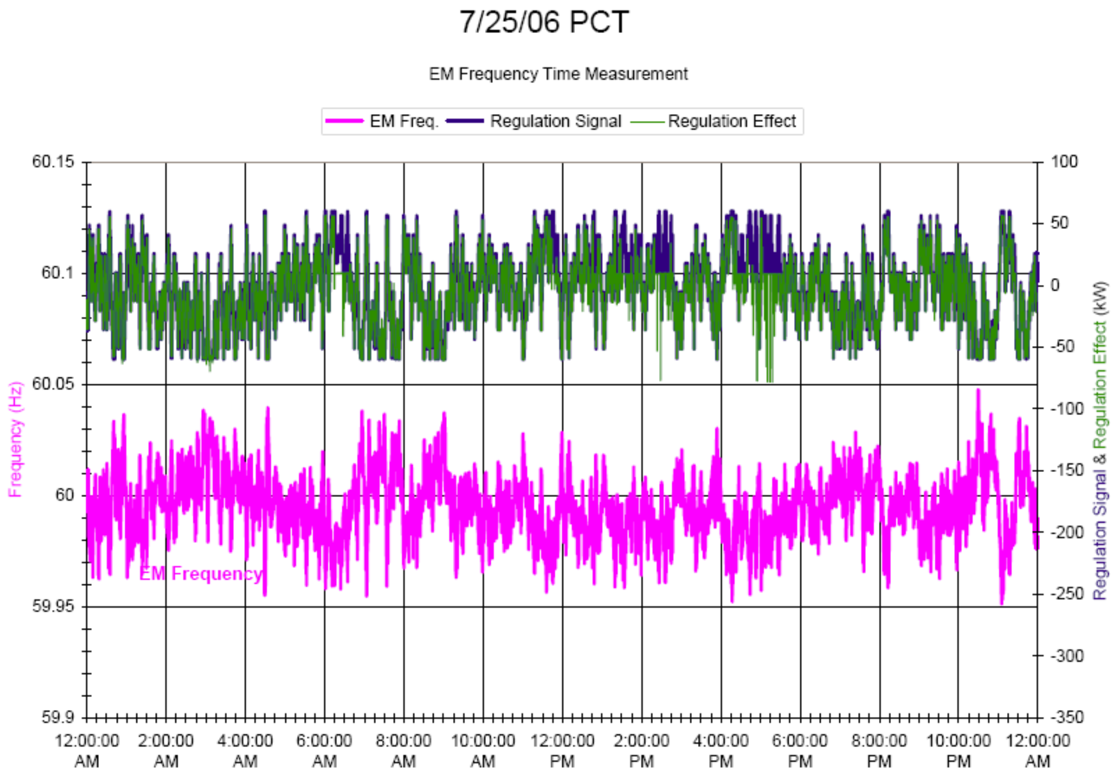

Figure 4 – Flywheel Performance for July 25th

The additional Dranetz instrument is being used to verify the accuracy of the overall DAS system. Figure 5 is a three hour period on September 19th that shows the Dranetz DAS system and the EM DAS system. As you can see, the recorded trend data matches up very well, verifying the accuracy of the on-board EM DAS system. The on-board system is collecting data at a much higher resolution than the 1 minute resolution of the Dranetz which can be evident when the signal moves around a lot, but overall this is a good comparison.

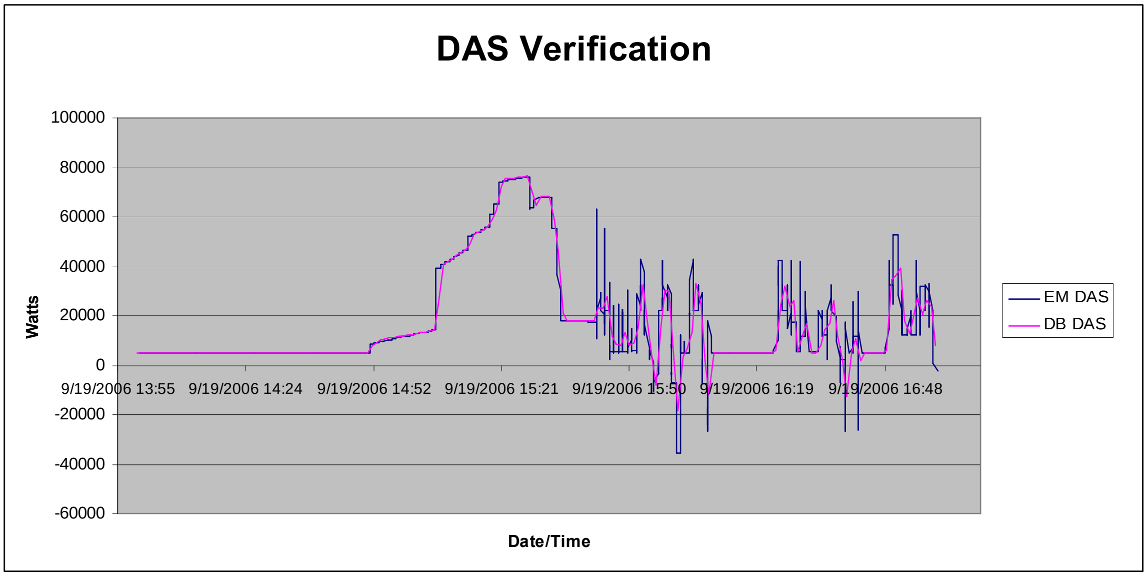

Figure 5 – DAS Verification

There is a real-time interface that has been implemented that shows the current status of the EM flywheel system including whether injecting or absorbing, number of flywheels operating, etc. This is available off the project web page. A screen capture is shown in Figure 6.

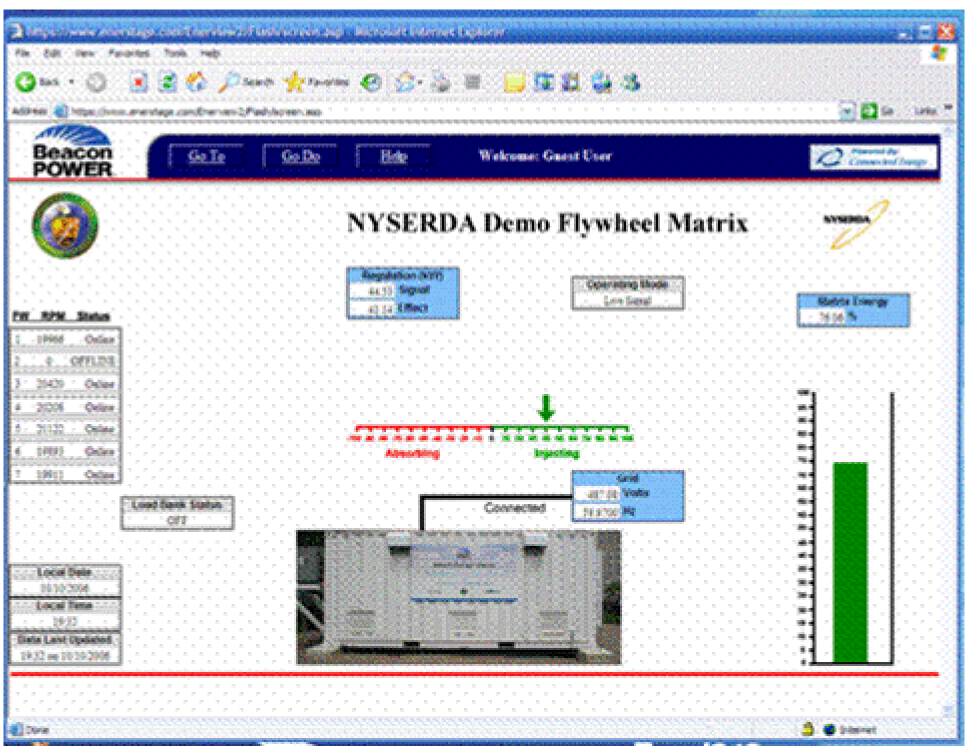

Figure 6 – EM Flywheel Real-Time Interface

New York Power Authority/ABB

This project demonstrates the utilization of a sodium-sulfur (NAS) battery system to shift compressor peak load to off-peak capacity and provide emergency backup power at a Long Island Bus depot facility. The primary application will be to supply up to 1 MW/7.2 MWh of power to a natural gas compressor for six to eight hours per day, seven days per week, especially during the summer peak period. The natural gas compressor provides fuel for buses that will replace diesel-powered buses. The NAS batteries are being supplied by NGK Insulators of Japan.

ABB is supplying an on-site data acquisition system that will sample a variety of parameters at 1 second intervals and will be able to store up to 365 days worth of data. The signal list was finalized by ABB and the project team on July 10th, 2006. Table 2 contains a copy of the signal list as provided by ABB. ABB will provide a high speed connection into the on-site DAS computer so that a file can be retrieved periodically and then archived for later analysis and long term trending.

Startup of the entire system is expected in December, 2006.

Table 1 – DAS PCS Signal List

Signal	Description	Range
Grid RMS Voltage	Actual AC Voltage, measured at 4160 V PCC	0 – 4200.0 Volts AC
Grid RMS Current	Actual AC Current, measured at 4160 V PCC	0 – 500.0 Amps AC
Grid Real Power	Actual AC Real Power, measured at 4160 V PCC	0 – 4000 kW
Grid Reactive Power	Actual AC Reactive Power, measured at 4160 V PCC	0 – 4000 kVAR
Grid Apparent Power	Actual AC Apparent Power, measured at 4160 V PCC	0 – 4000 kVA
PCS Real Power	Actual AC Real Power, Calculated by PCS Control System.	0 – 1500 kW
PCS Reactive Power	Actual AC Reactive Power, Calculated by PCS Control System.	0 – 1500 kVAR
PCS Apparent Power	Actual AC Apparent Power, Calculated by PCS Control System.	0 – 1500 kVA
Load Real Power	Actual AC Load Real Power, Calculated by PCS Control System	0 – 4000 kW
Load Reactive Power	Actual AC Load Reactive Power, Calculated by PCS Control System.	0 – 4000 kVAR

Load Apparent Power	Actual AC Load Apparent Power, Calculated by PCS Control System.	0 – 4000 kVA
PCS Real Energy Accumulated – Absorbed Real Energy	Actual Accumulated AC Real Energy absorbed by the PCS, Calculated by PCS Control System.	0 – 65,536 MWHr
PCS Reactive Energy Accumulated – Absorbed Reactive Energy (Inductive)	Actual Accumulated AC Reactive Energy absorbed by the PCS, Calculated by PCS Control System.	0 – 65,536 MVArHr
PCS Real Energy Accumulated – Discharged Real Energy	Actual Accumulated AC Real Energy discharged by the PCS, Calculated by PCS Control System.	0 – 65,536 MWHr
PCS Reactive Energy Accumulated – Discharged Reactive Energy (Capacitive)	Actual Accumulated AC Reactive Energy discharged by the PCS, Calculated by PCS Control System.	0 – 65,536 MVArHr
System Charge / Discharge Cycle Counter	Counter for tracking Charge / Discharge Cycles. Counter increments by 1 after each completed Discharge Cycle.	0 – 10,000
System Operational Mode	Power Supply Mode of operation	0 = Shutdown 1 = Standby 2 = Charge 3 = Discharge

Quarterly Monitoring Reports

The following sections present DAS updates and/or results of the three energy storage system sites.

Gaia Power Technologies/Delaware County Electric Cooperative – July through September, 2006

The homeowner accidentally hit the satellite dish with his tractor on June 11th. This knocked the DAS completely off-line and in fact the entire system was shutdown in July when the fuel cell was removed from the property. The site was restarted in August. The DAS started operating around August 11th. The system was in bypass mode until August 30th when it was reconfigured again. It was configured this time to have the grid feeding the Power Tower and then the Power Tower feeding the loads. The before and after configurations are shown in Figure 7 and Figure 8 below. Figure 9 shows the upcoming installation where a 15 kW Briggs generator is used to feed the Power Tower. Finally, in Figure 10, is an illustration of the long term configuration which includes just the 15 kW generator which will provide backup power.

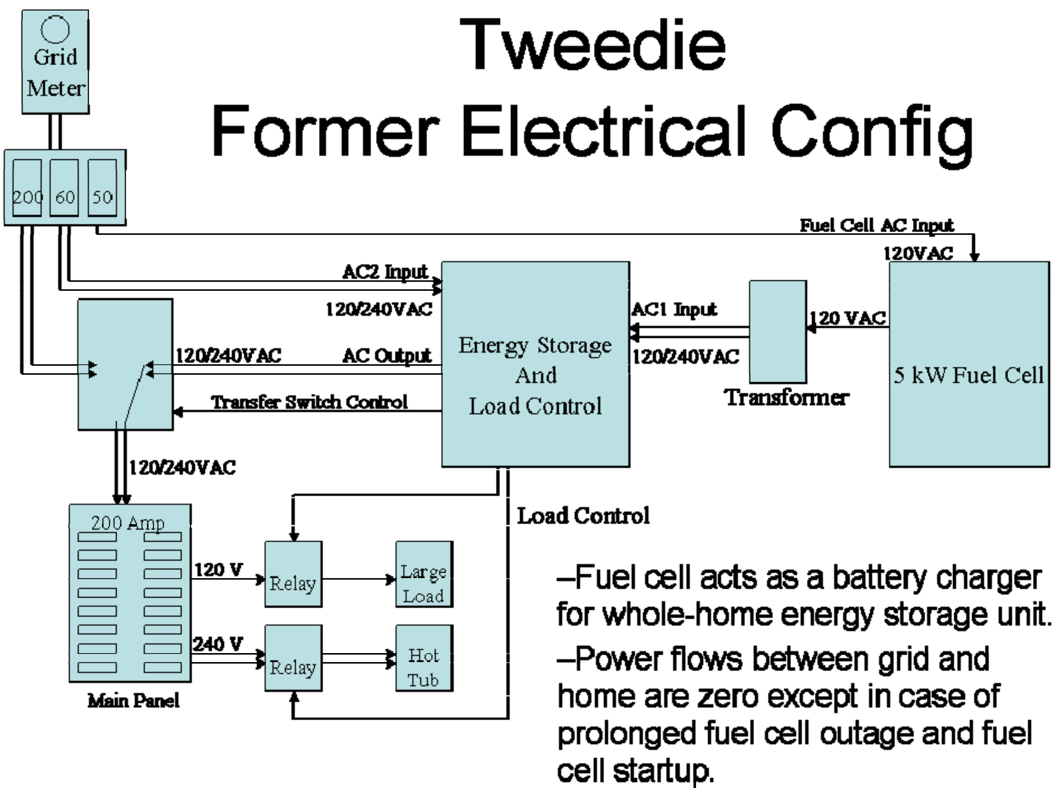

Figure 7 – Former Electrical Configuration

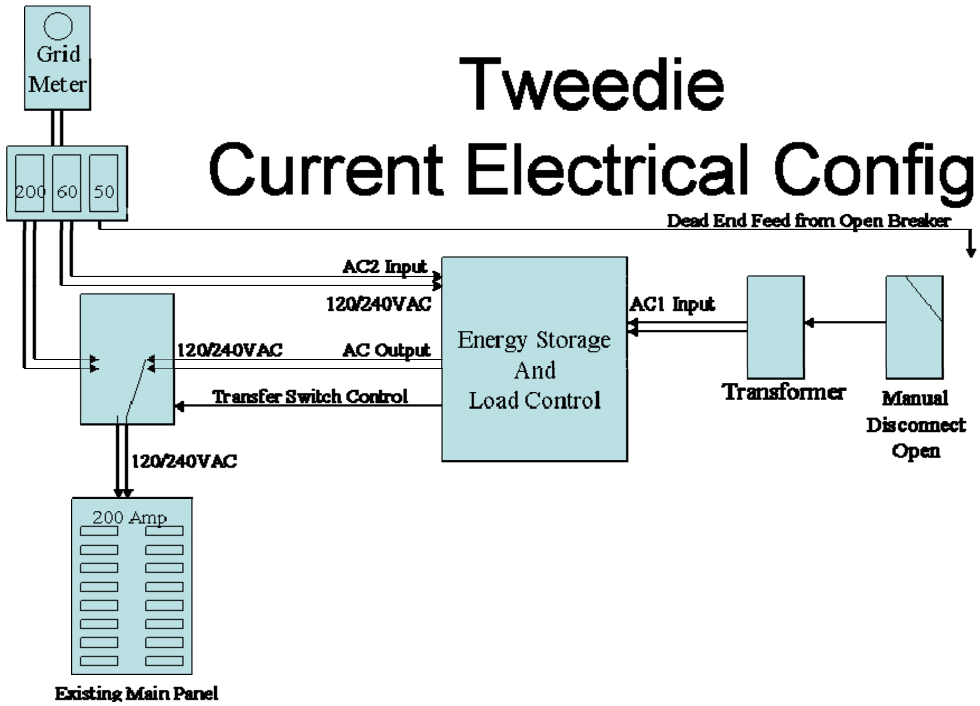

Figure 8 – Current Configuration

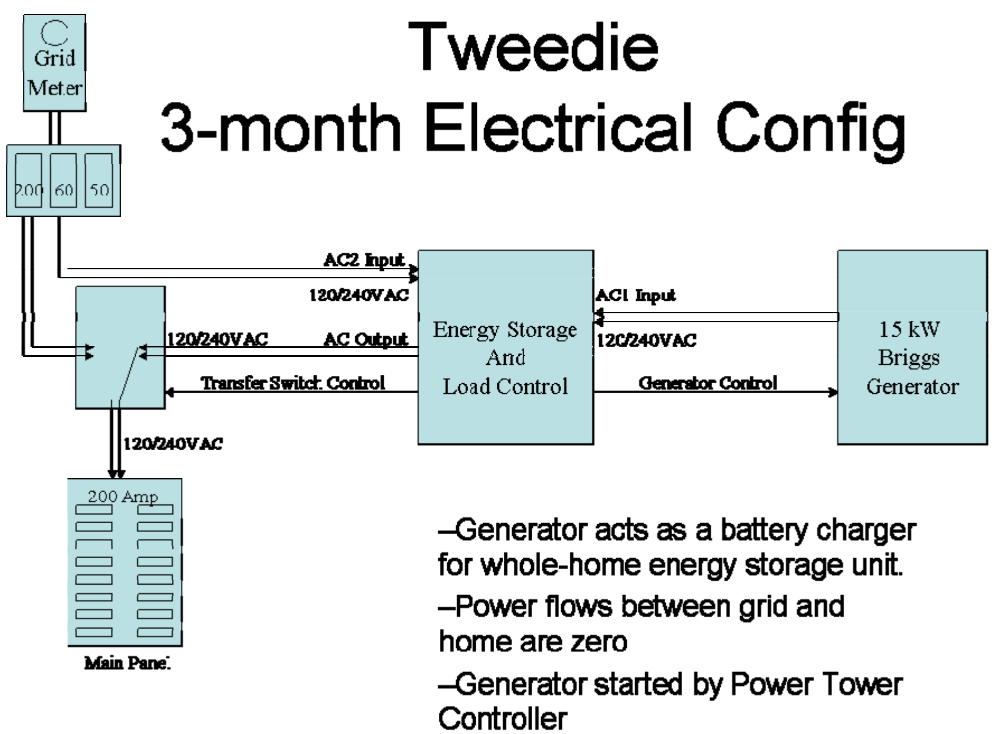

Figure 9 – Upcoming Configuration with 15 kW Generator

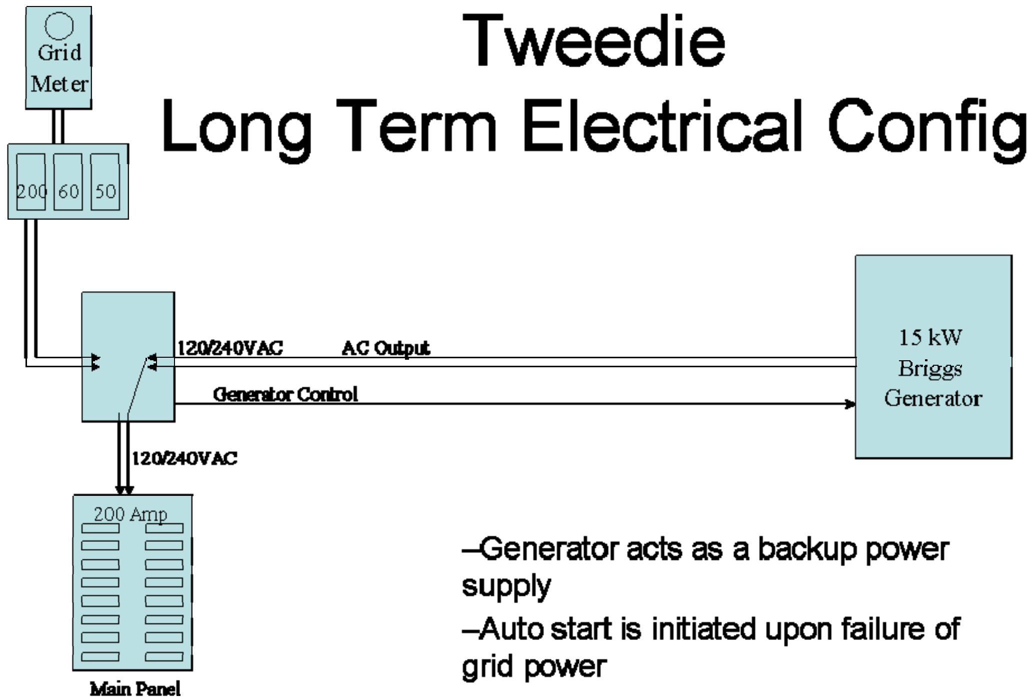

Figure 10 – Long Term Configuration

As mentioned earlier, the DAS system came back online around August 11th. Service entrance data has been successfully downloaded and appears correct since then. Figure 11 shows the main panel real power from August 11-September 30. As you can see it remains pretty steady even when the Power Tower is switched in on August 30th.

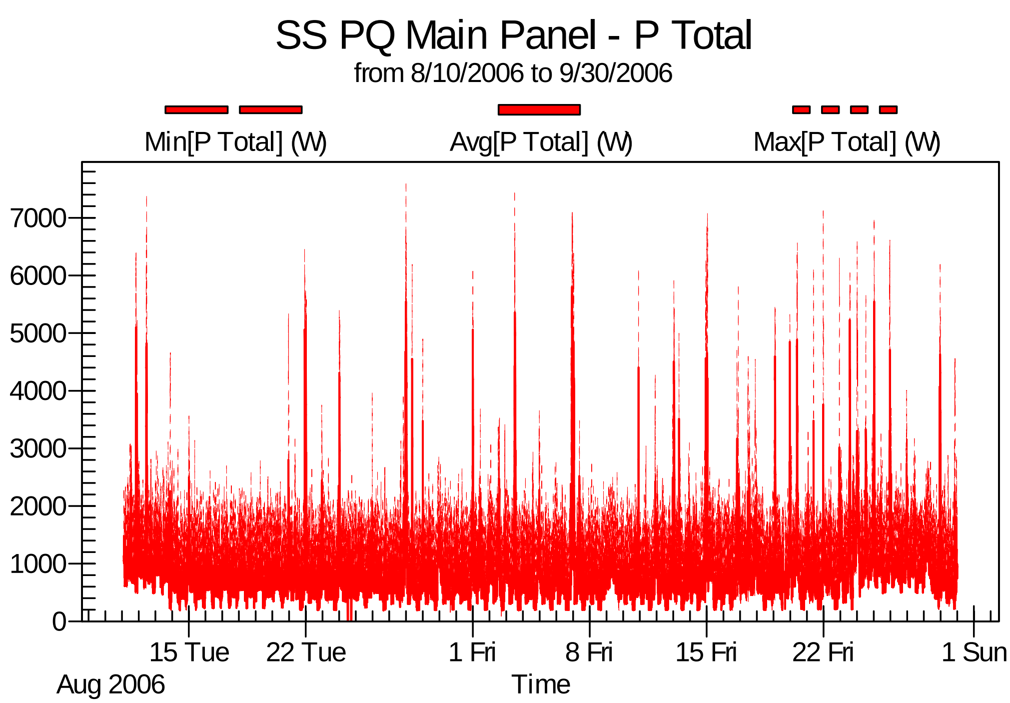

Figure 11 – Main Panel Real Power

On the Power Tower input Datanode, you can clearly see the increase in current as shown in Figure 12. On both Figures, note the increase in power and current during the last week of September.

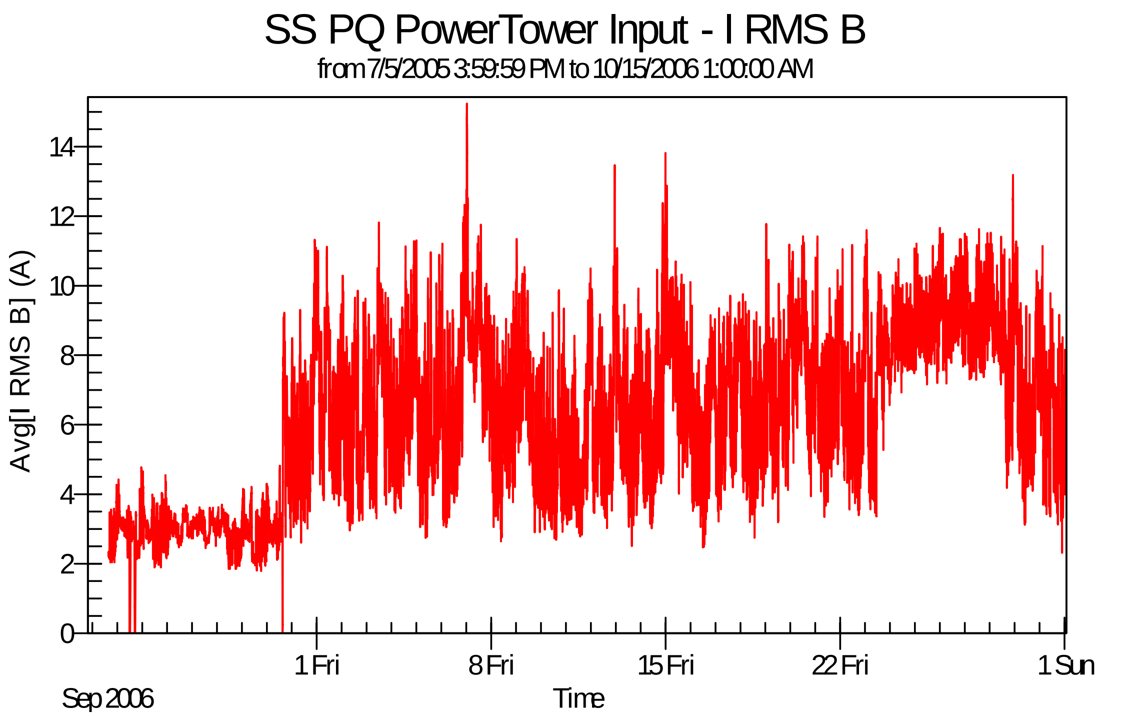

Figure 12 – Power Tower Input Current

We have Power Tower output data starting from September 19th. Figure 13 shows the corresponding output current and Figure 14 shows how this affected the battery voltage. As you can see the batteries were used more extensively during this period to serve the increase in load. We are unsure as to what caused this increased load current.

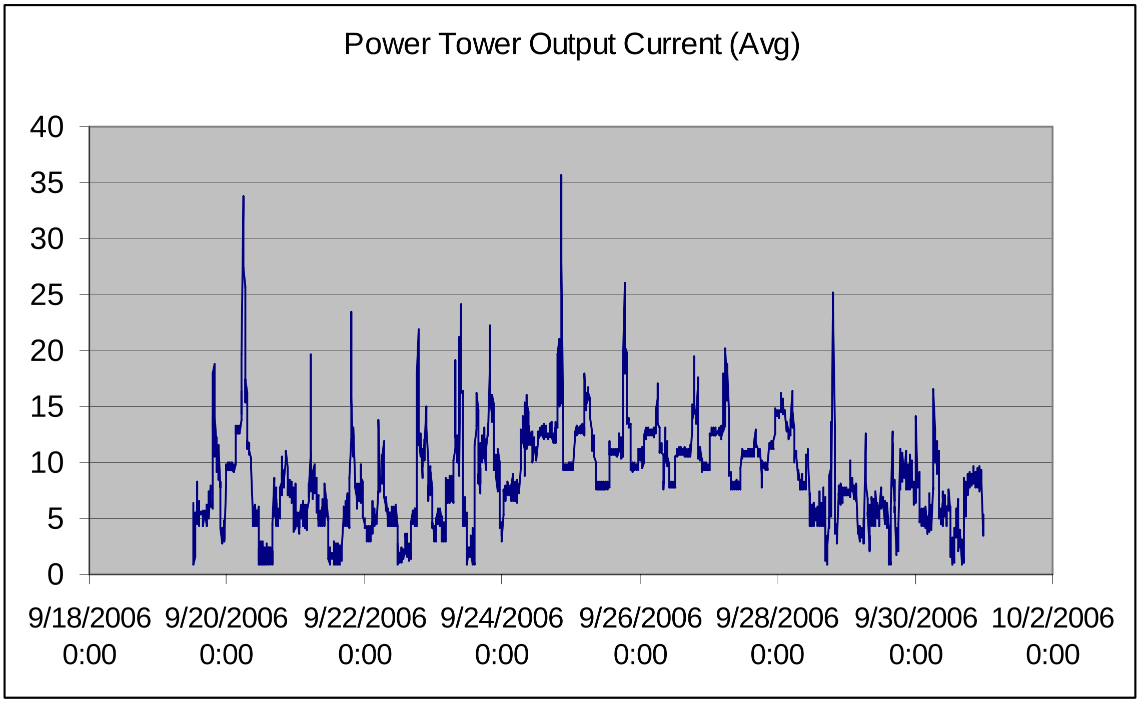

Figure 13 – Power Tower Output Current

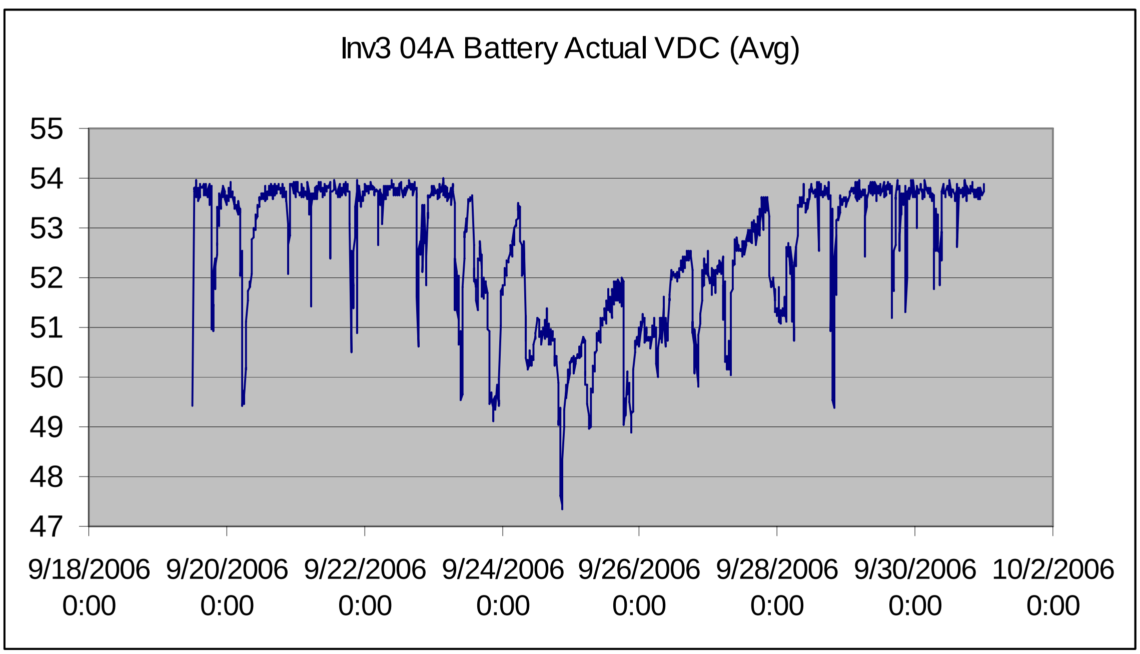

Figure 14 – Battery Operation in September

Interestingly, the short term flicker did not increase with the Power Tower was switched on as can be seen in Figure 15. The average value did increase during the last week of September when the load was higher and battery usage was higher. Generally throughout the first phase of the project, the flicker increased when the Power Tower was switched on. It should also be pointed out that the home phase currents are quite unbalanced which may also contribute to the flicker. We can observe from Figure 16 that the current on each phase (A & B) from the main panel to the Power Tower has an average current rating of 18A and 35A on phase A and B respectively. The 240V, two-phase configuration also implies that certain loads, such as the oven range and heaters require high startup current that will create high voltage drops, which leads to further disturbances in the system. As mentioned earlier, in order to achieve a 240Vac, both inverter legs have to be connected in series. Moreover, the Power Tower should be capable of producing a nearly constant DC to the inverter while charging and discharging. This is a very difficult task that requires a precise control scheme at the Power Tower interface. Ultimately, the result of such dynamics is high flicker potential at certain instances within the system especially when the dedicated loads in the residence are in operation.

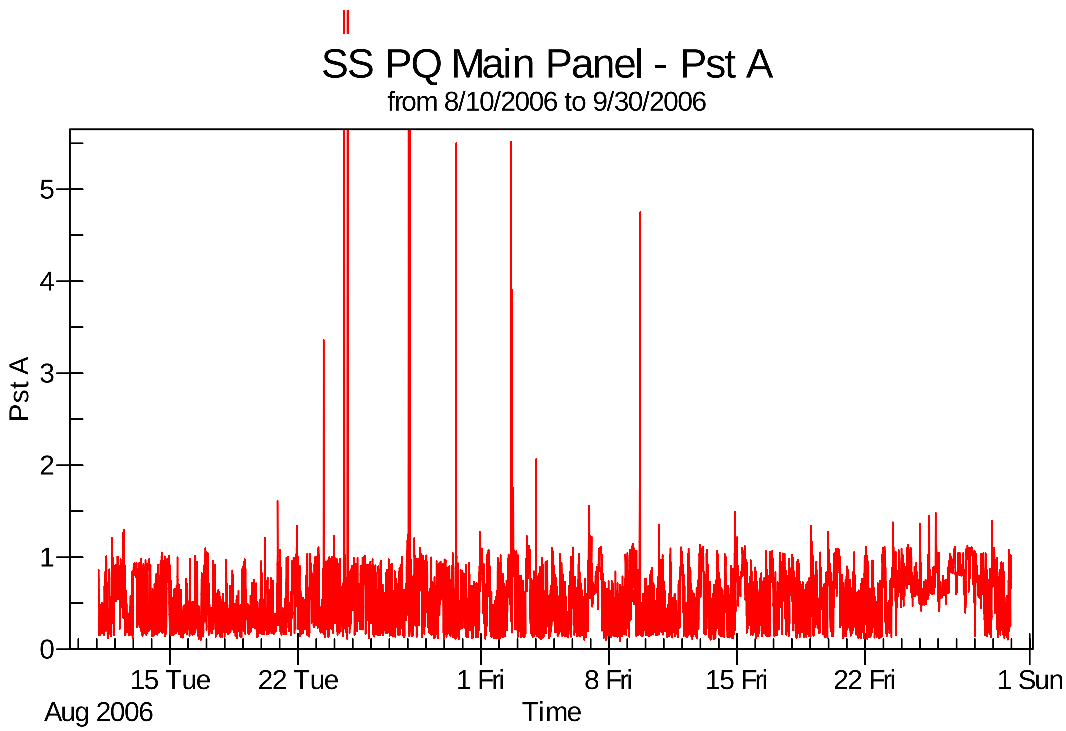

Figure 15 – Short Term Flicker During

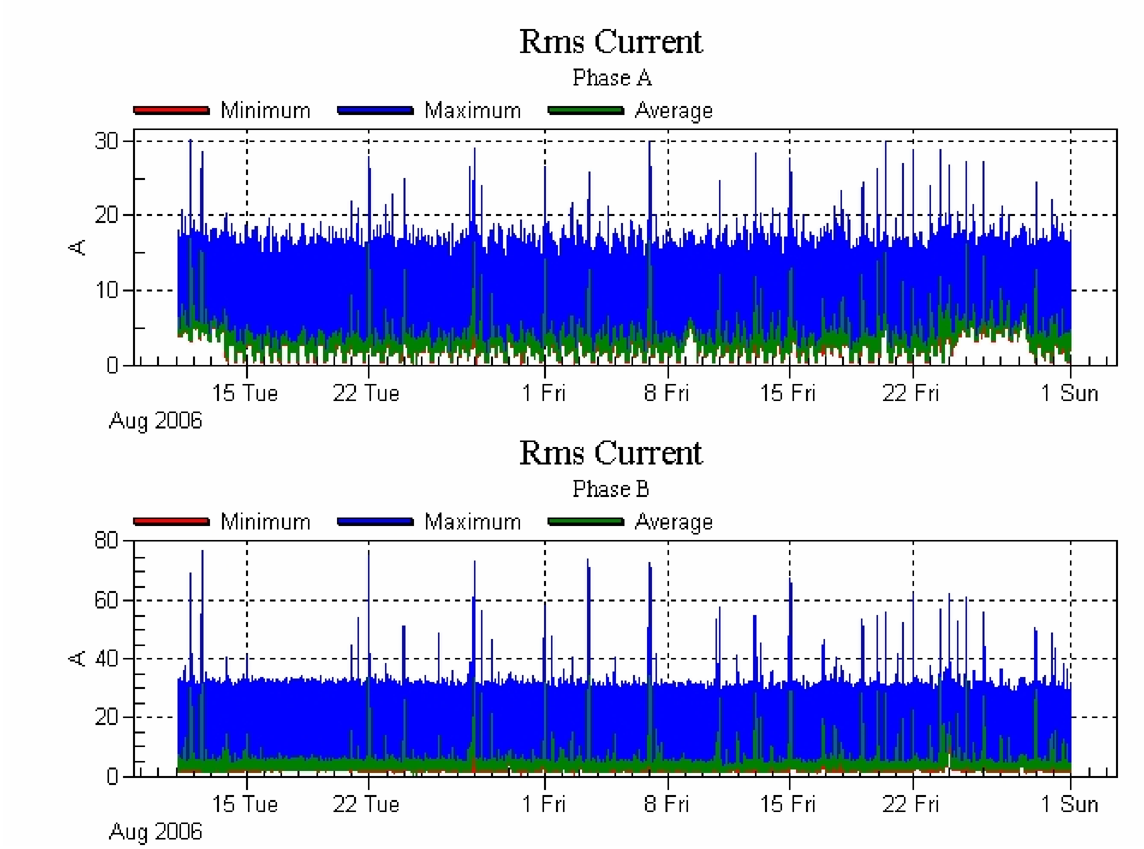

Figure 16 – Phase A and B Current (SS PQ Main Panel)

One thing that should be pointed out is that when the system was reconfigured, the voltage leads on the Power Tower input of the DAS system were mistakenly not reconnected. This makes the Power Tower input power readings meaningless and precludes doing any input/output analysis. The site manager was going to the site on October 10th to troubleshoot this problem.

Beacon Power – February Through September, 2006

The Dranetz DAS was installed at the service entrance in mid-February. Service entrance measurements were collected until the EM flywheel was installed in early June. The flywheel is installed at an industrial manufacturing facility called PCT in Amsterdam, NY. The real power trend recorded during this period is shown in Figure 17. It illustrates a typical 5 day a week cyclical load. In a typical day the frequency varies from about 59.94 to 60.06 as shown in Figure 18.

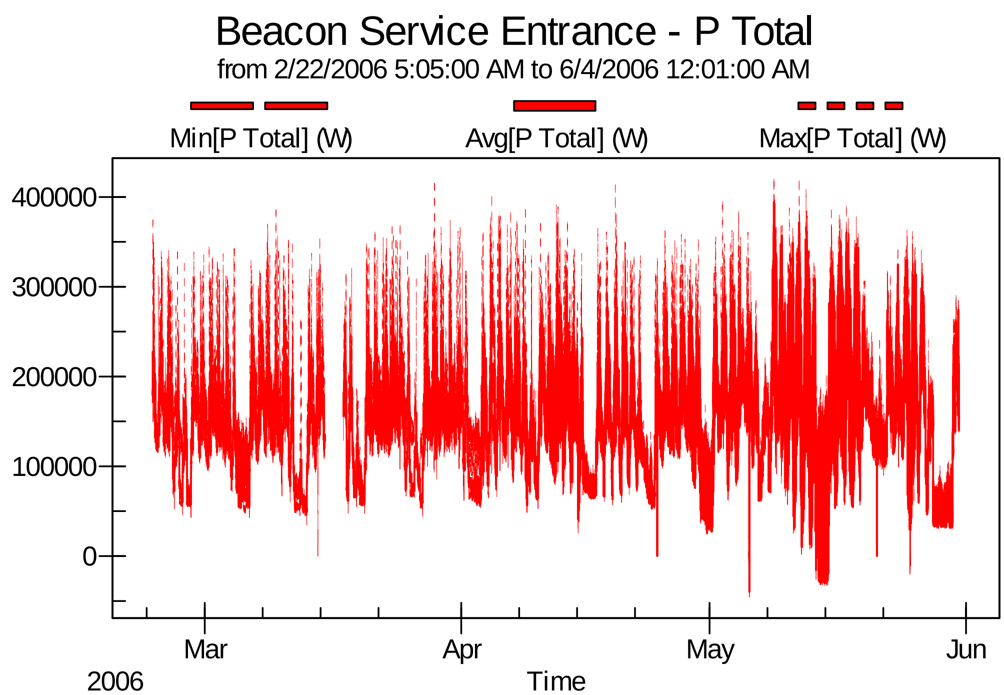

Figure 17 – Service Entrance Real Power

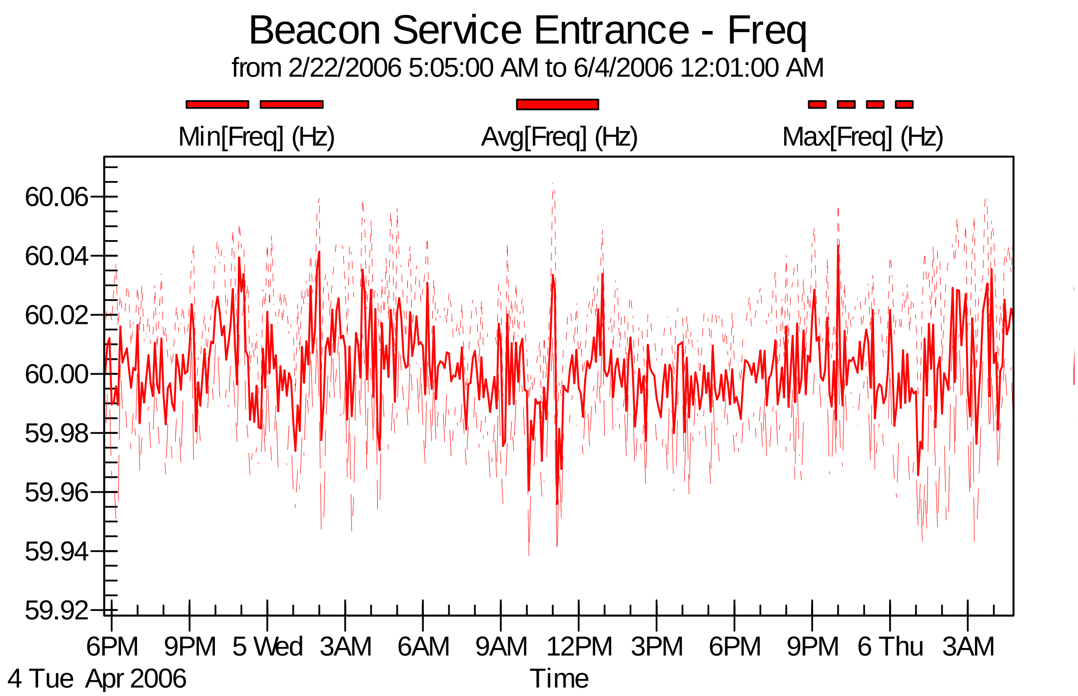

Figure 18 – Daily Frequency Variation

The EM flywheel system was installed at PCT in early June. As mentioned earlier, the first month encompassed startup and onsite testing. The first operational test occurred during the last week of July. The frequency was recorded during that week and has been used in playback mode since. The Dranetz DAS is being used to verify the DAS of the EM flywheel system. As mentioned earlier, the DAS systems are in agreement and several more correlations are shown in the following figures including a 40 minute timeframe on September 7th.

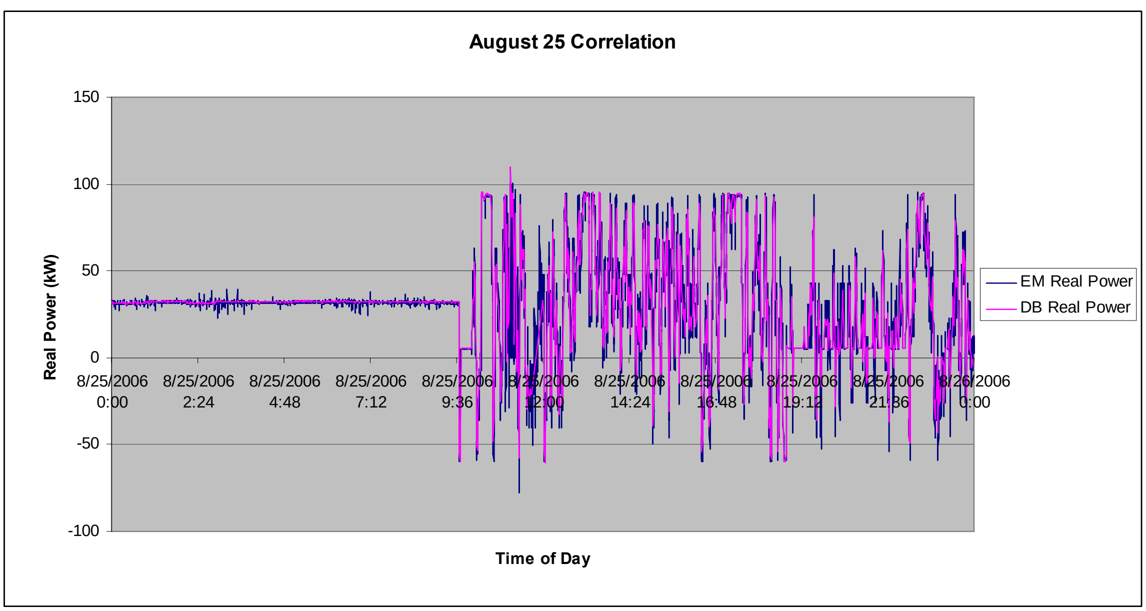

Figure 19 – DAS Correlation on August 25th

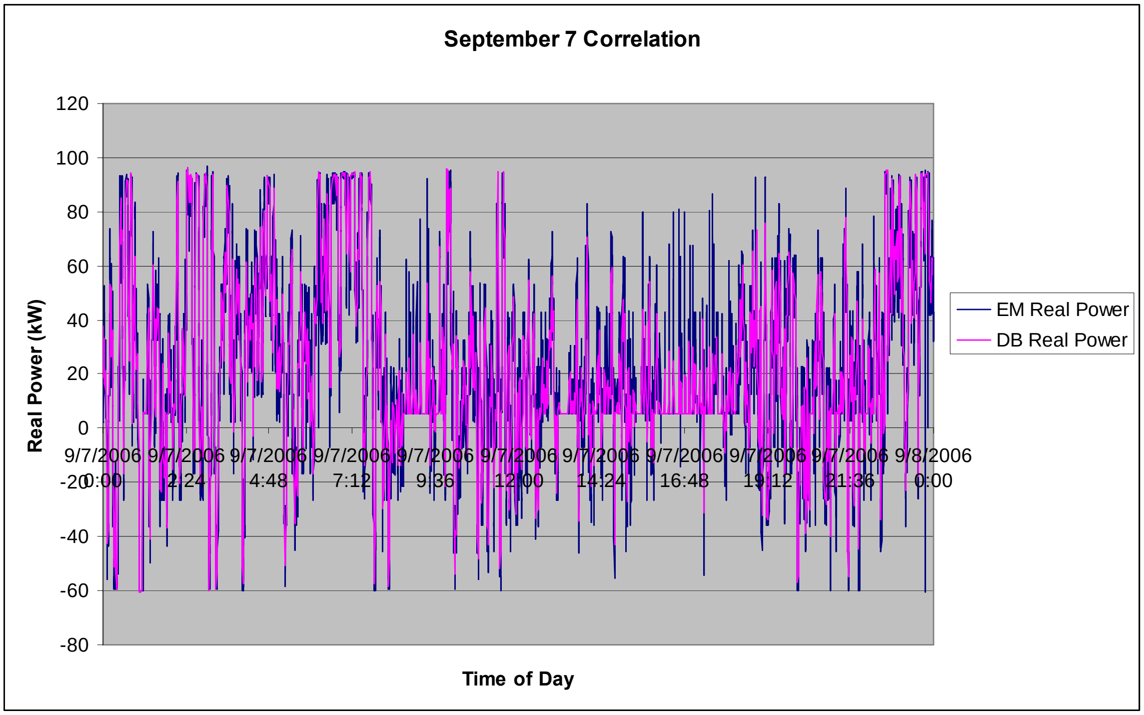

Figure 20 – DAS Correlation on September 7th

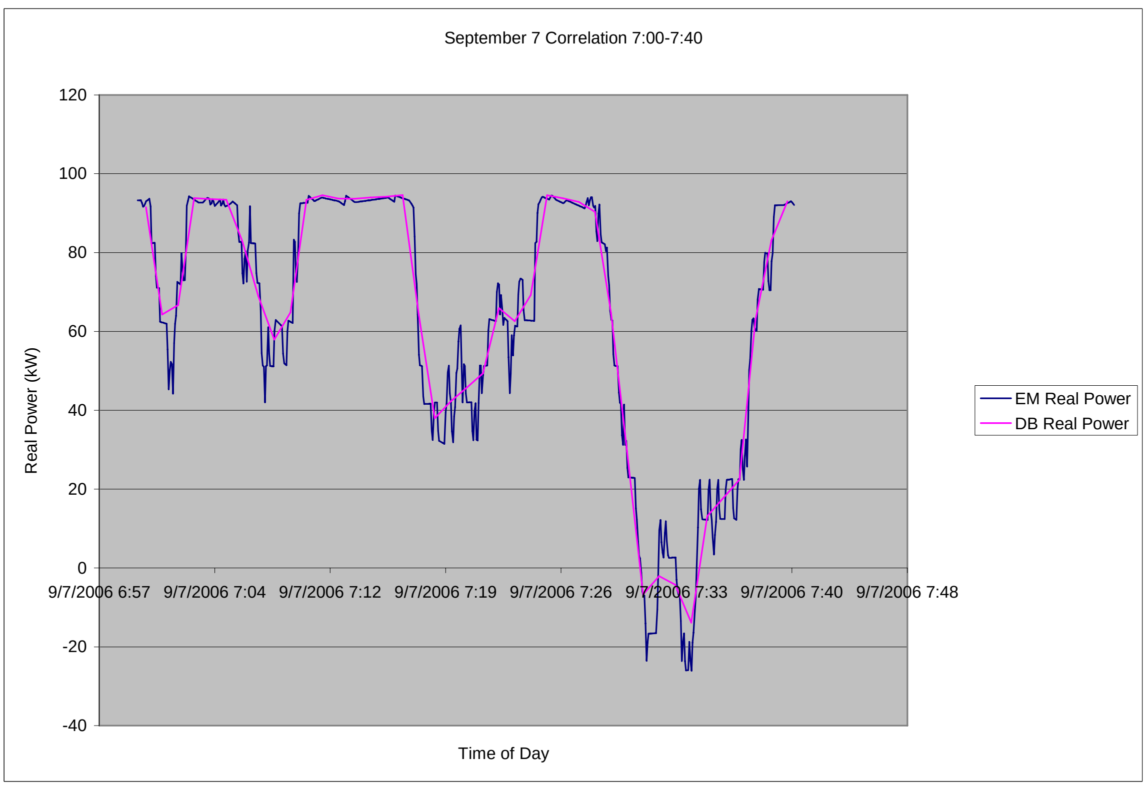

Figure 21 – DAS Correlation on September 7th 7:00-7:40

Now that we are confident that the on board DAS system is accurate, plots of Regulation Signal vs. Regulation Effect can be generated. Figure 22 is an example for the data collected on September 7th. Beacon Power is generating plots like these on a daily basis and calculating statistics in terms of availability, etc. These will become part of future quarterly reports. This data was not available at the time this report was written.

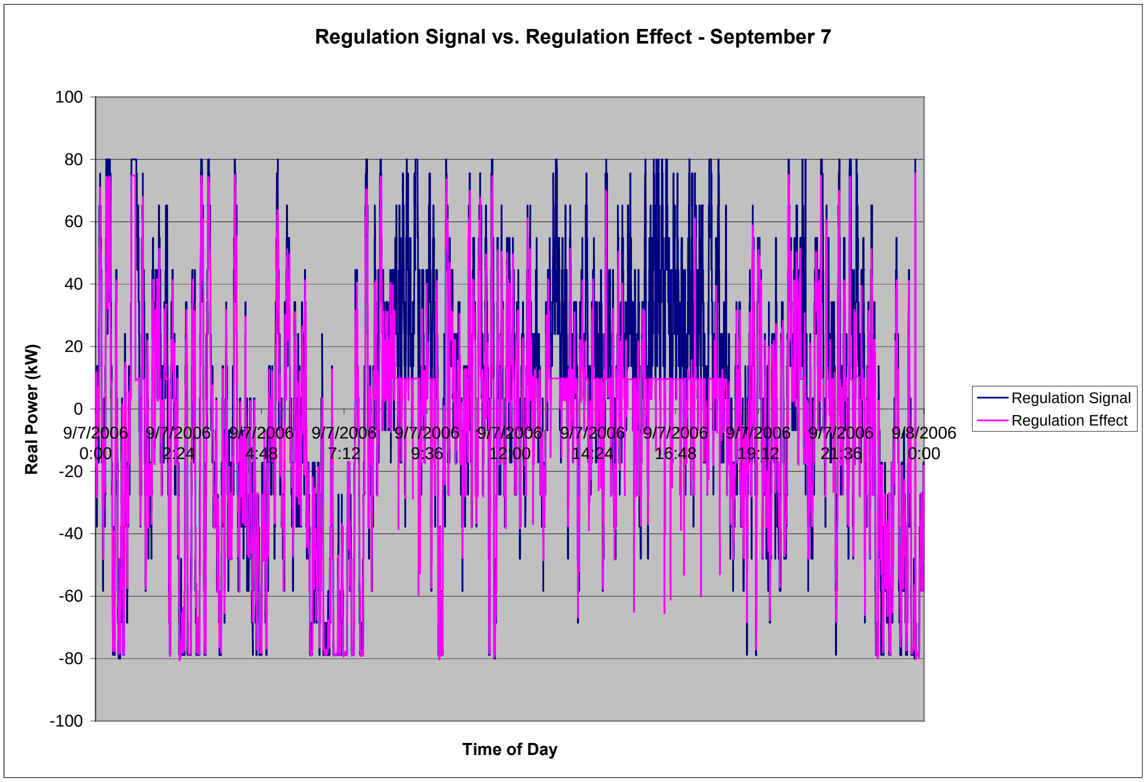

Figure 22 – Regulation Signal vs. Regulation Effect for September 7th

The period times above when the regulation effect does not match the signal is the time when the energy in the flywheel system is depleted. Overall though, Beacon Power has proven that they can follow a frequency signal and can inject or absorb power as needed as long as the power is available.

New York Power Authority/ABB – July Through September, 2006

The NAS battery system is not scheduled to be installed and commissioned until December, 2006. Therefore, there is nothing to report in terms of the DAS quarterly report. As mentioned earlier, the signal list has been finalized by the project team and this list can be viewed in Table 2.

Appendix B — EPRI: Final FY06 Quarterly Monitoring Report

Quarterly Report 07-01-2006 to 10-01-2006
DOE/CEC Energy Storage Data Management Project
Submitted by Doug Dorr EPRI Solutions Project Manager

The Energy Storage website continues to be available on-line at www.energystoragedemo.net/cec Changes to the website during this quarter include a new realtime viewable page for the FESS demo project and availability of historical data in the password protected areas for the Palmdale and FESS projects

Palmdale Demo

The Palmdale MicroGrid Project continued in the pre-demonstration monitoring stage. The information is available on the www.energystoragedemo.net website in a similar manner to that for the FESS data. The is a single data file that is viewable and sortable by day, week, and month. Presently there are no useful charts and graphs to view.

FESS Demo

During this quarter, the FESS project went from the testing phase to the demonstration phase. The demonstration phase began on September 1st 2006 and will commence on March 1st 2007. During this demonstration phase, daily, weekly and monthly energy data is viewable on the www.energystoragedemo.net/cec website. The password protected data analysis area of the website contains separate databases for each month of monitoring, along with the real time data (limited access) and the archived pre demo data (January 2006 to August 2006) referred to by the filename archive database #1. Each file set can be viewed sorted and analyzed by hour, day, week or month. The main page for the data collection is shown in Figure 1.

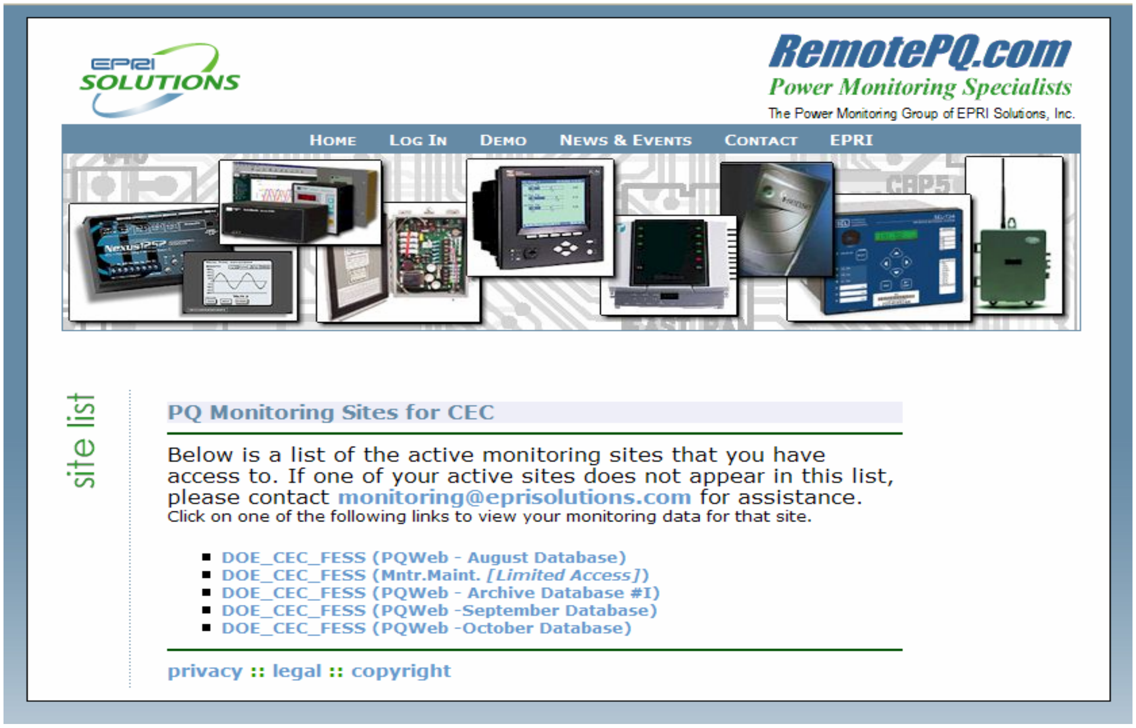

Figure 1. Password Protected Data Collection Main Page

Additional data files are supplied on a daily basis by Beacon Power. This enables correlation of the Dranetz energy data to system operational data and addition energy data collected by the Shark Energy Meter that resides on site at the same collection point with the Signature System monitor. The Shark meter provides a redundant backup of the energy information collected by the Dranetz meter. It is expected that this dual redundancy will enable more reliable data collection while accomplishing the DOE/CEC objectives of independent third party audit of the FESS energy performance.

As an example comparison, the following two figures show the two energy meters during a six hour period during the testing phase of the project. The objective of these figures is to compare the energy recordings from the two devices to prove that the readings correlate with one another in terms of power measurement accuracy. By viewing the figures, it is clear that this power correlation is nearly identical and the time resolution is accurate within a few seconds.

The red trace shown in Figure 2 comes from the (Dranetz meter) and is derived by selecting "Three Phase Power" from the pull down menu in the password-protected data section of the CEC/DOE www.energystoragedemo.net/cec/ web link. The blue trace shown in Figure 3 comes from the connected energy website (Shark meter). Both are from 05/23/2006.

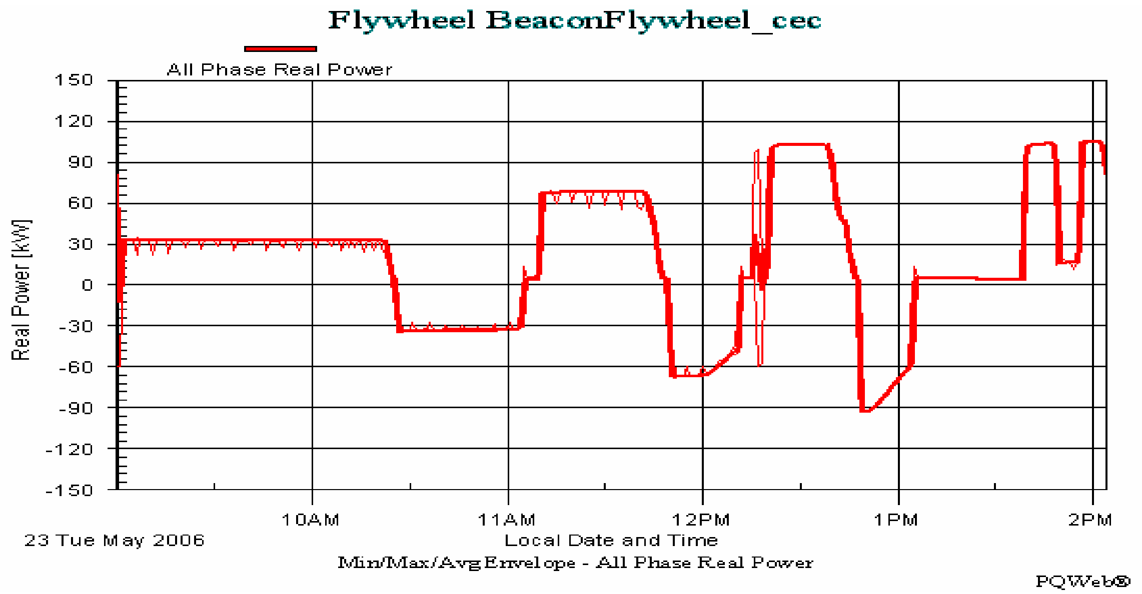

Figure 2. Power Delivered and Absorbed by the Flywheel Over a 5 hour Test Period as Reported by Dranetz Signature System Energy Meter.

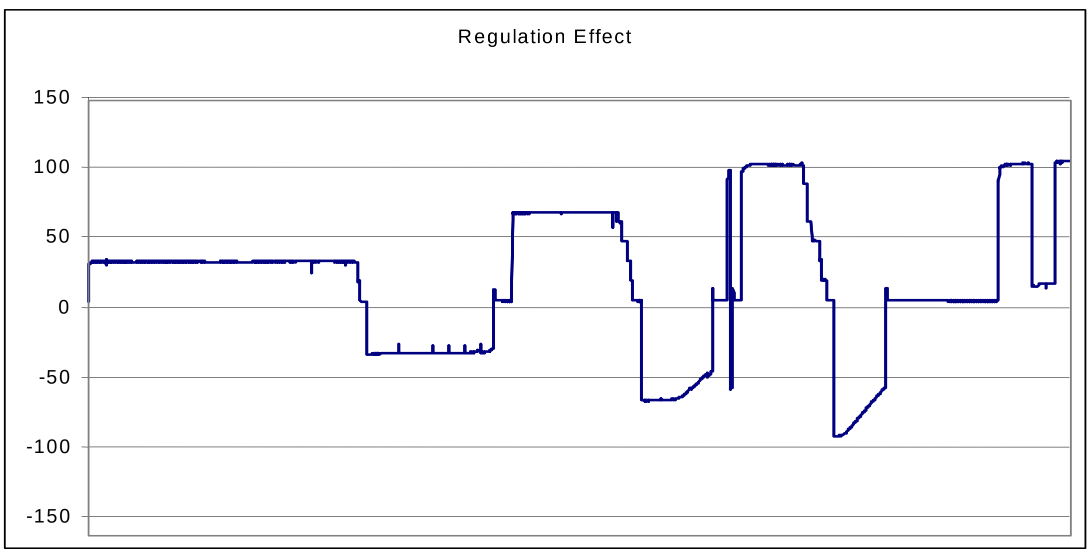

Figure 3. Power Delivered and Absorbed by the Flywheel Over a 5 hour Test Period as Reported by The Shark Energy Meter.

Figures 4 provides a snapshot of the types of high resolution waveforms that are available from the Dranetz monitor. The monitor has the capability to capture subcycle data such as that shown in Figures 4 and 5 and trend long duration power parameters such as those shown in Figure 2.

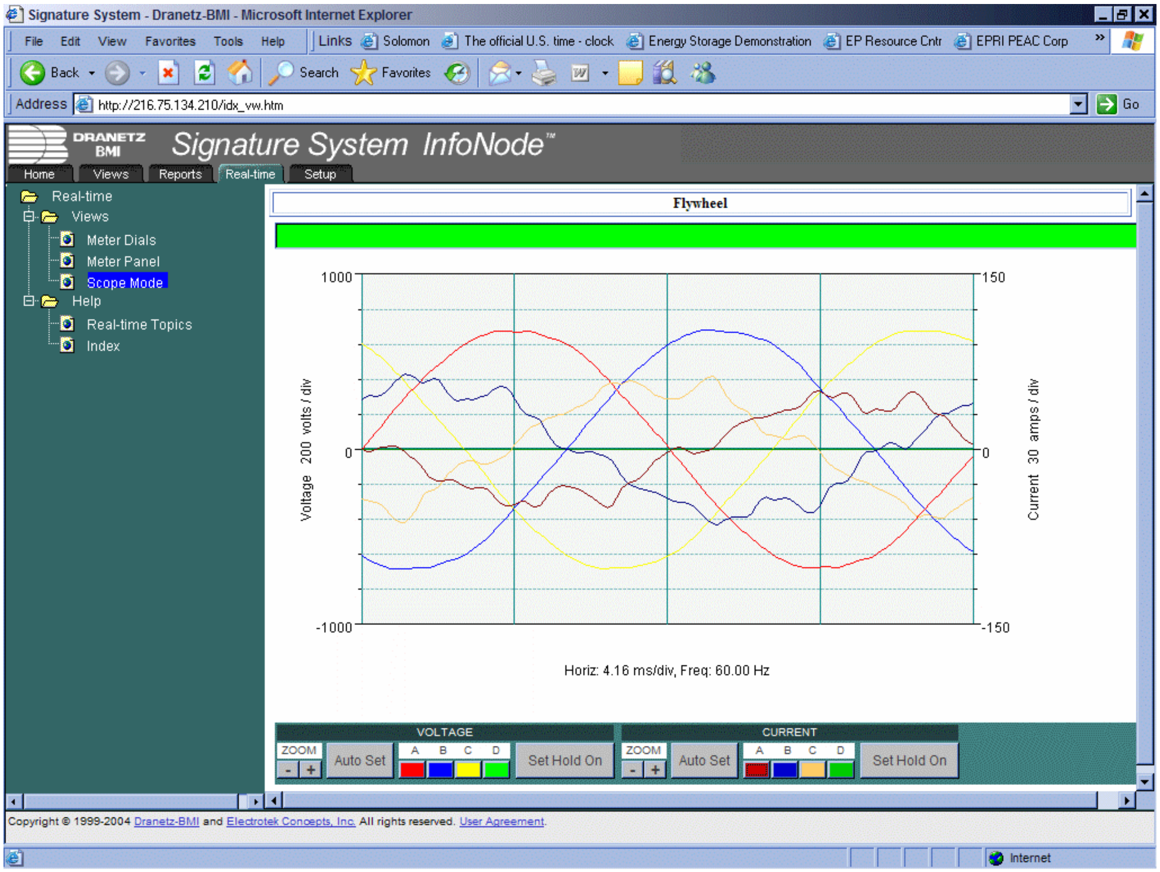

Figure 4. Three-Phase Voltages and Currents from FESS as Captured by the Dranetz Monitor (while operating in the "Oscilloscope Mode").

Note that the current is nearly 180 degrees out of phase with the voltage indicating the FESS is absorbing power as opposed to delivering power.

A new feature (link) was added to the data page for the FESS webpage to allow viewing of real time flywheel parametric and graphical interface information. The link goes to a special viewing page on the connected energy website and displays the real time information. Figure 5 provides a snapshot of this real time information.

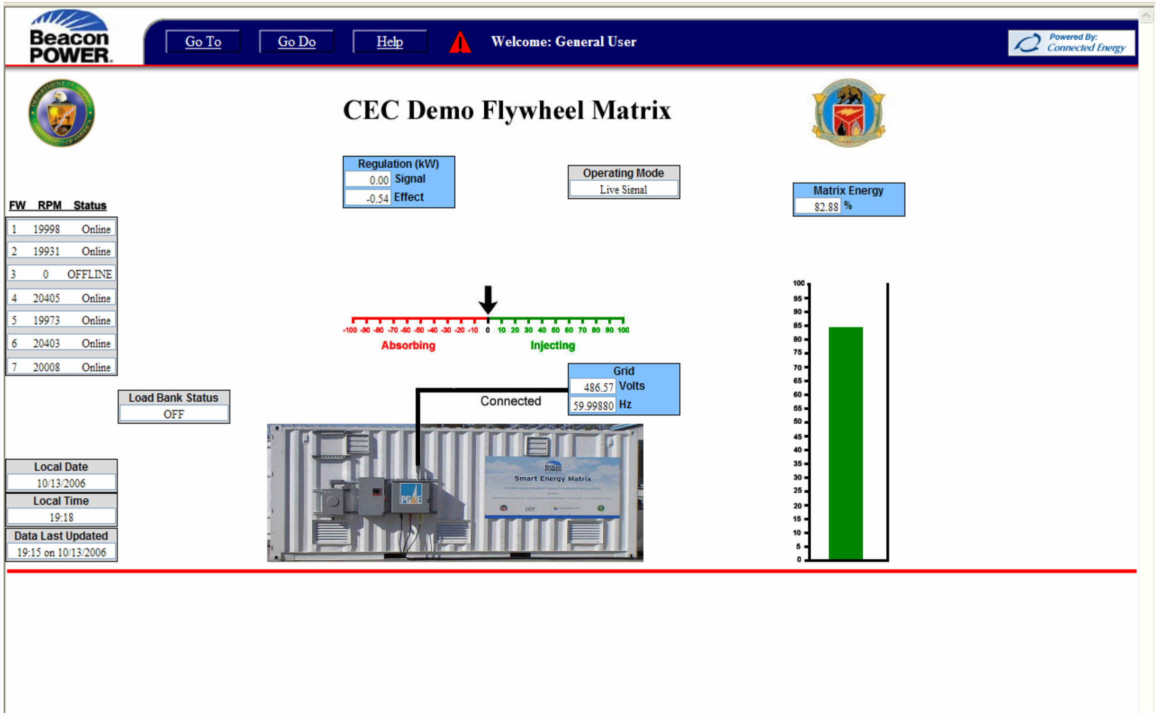

Figure 5. Real Time Data From the FESS.