Flywheel-Based Frequency Regulation Demonstration Projects[1]

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***Abstract*-- Grid frequency regulation function addresses the balance between a grid network load and power generated. The system operator generates a frequency regulation signal based on the difference between these two parameters. The goal is to keep the system near nominal 60 or 50 Hz. Traditionally, frequency regulation is managed by varying the output of fossil fuel or hydro generators connected to the electric grid. As an economical alternative, energy storage can be used to provide this service, first, absorbing energy when it is in abundance, then discharging the same for the desired frequency regulation effect. Two flywheel based pilot projects are supported by DOE, California Energy Commission and NYSERDA in NY. The California system has been delivered and connected to the grid at PG&Es DUIT development facility in San Ramon CA. The NY system is in final assembly and will be delivered to Power and Composite Technologies, an industrial user in Amsterdam NY near the end of a distribution feeder. This paper describes the installations and the complementary objectives of these two projects.**

I. Introduction

One of the most challenging aspects of today's electric grid is the constant balancing of power demand and production to maintain a stable grid frequency within a narrow band of the target frequency (60 Hz in the US). This is referred to as frequency regulation [1]. If the imbalances, (or excursions from the target frequency), are too large, generators and equipment attached to the grid suffer from a loss in performance and sometimes disconnect from the grid to protect themselves. These unplanned events add to the existing level of imbalance and reduce the grid stability. In extreme cases, this cycle of imbalance and dropping of loads and generators, can lead to blackouts. The Beacon Power Smart Energy Matrix is a flywheel-based energy storage system combining high power flywheels with power electronics for the purpose of supplying frequency regulation services to regional grid operators. These fast acting systems are designed to instantly deliver electricity when demand exceeds supply and absorb electricity when supply exceeds demand. It is a high performance, long-life, environmentally friendly solution for frequency regulation, with no fuel consumed and no emissions generated.

Today, frequency regulation is addressed using generators controlled by a regulation signal which reacts to the load imbalances. This is inherently a slowly responding system to a rapidly changing input. This has limitations to both effectiveness and system cost. Where an auction type of regulation market exists, (i.e. PJM, CAISO, NYISO and NE RTO) the major cost components is lost opportunity cost for generating power, since the power from the generator must be reduced to allow regulation resulting in lost sales. Additional costs come from maintenance required for the generator from the increased cycling, and higher fuel consumption and emissions due to transient operation that tax the entire output of the generator, not just the incremental regulation portion.

Flywheels can be designed specifically for the harsh cyclic requirement of regulation. Their operating costs are very low, with no downtime maintenance required. They can respond very quickly, within seconds, to changing loads, and allow generators to do what they do best – generate power at peak efficiency and low emissions without cycling.

This paper describes the performance of two pilot grid connected flywheel based systems called Smart Energy Matrix (SEM). These pilots are sponsored by DOE, California Energy Commission (CEC) and New York State Energy Research and Development Authority (NYSERDA). The California project is connected to a transmission line at a substation installation at PG&E's DUIT Facility in San Ramon CA. The New York pilot is connected in an industrial site at Power and Composites Technology (PCT) in Amsterdam. NY. PCT is connected to a distribution feeder and will allow the system to demonstrate some Power Quality capability in addition to the regulation primary function.

II. Pilot description & Results

Preliminary analysis using PJM and CAISO data indicated that the storage device used for regulation needs to both charge and discharge at rated power for about 15 minutes continuously. Hardware and bid requirements further defined the system to be 1MW rated and be capable of continuous operation for 20 years. These specifications require a 1 MW storage device capable of continuously charging and discharging at rated power. Depending on system parameters, this could be as many as 350,000

[1] This project is part of the Energy Storage Collaboration between the California Energy Commission (CEC) and the Energy Storage Systems Program of the U.S. Department of Energy (DOE/ESS), and managed by Sandia National Laboratories (SNL).

cycles. Beacon Power’s solution to the lowest system cost design was to combine ten 100kW/25kWh flywheels into a transportable container shown in Figure 1.

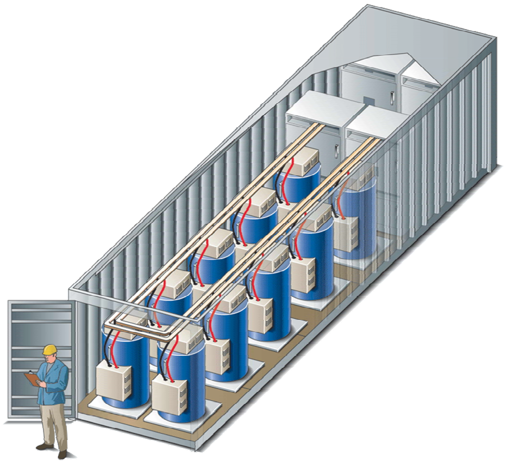

Fig. 1. 1MW Smart Energy Matrix (SEM)

In order to verify the design and capability, a pilot design was proposed using a modified version of Beacon Power’s telecom back-up flywheel design. Seven 15kW/4kWh flywheels can deliver 100 kW for 15 minutes. This pilot would demonstrate full scale controls, input signal management, communication system and interconnect features. Once the operation is demonstrated and a new 25 kWh flywheel is qualified, the 1/10th scale demonstration project can be upgraded to the full MW using the new flywheels.

Figure 2 shows the pilot installation at the DUIT facility in San Ramon.

Fig.2 Pilot SEM Installation

Figure 3 shows the demo SEM system architecture. There are only two interfaces to the outside. The first is an internet connection to receive a signal from the system operator, and the other is a 3 phase 480VAC connector to interface with the grid transformer.

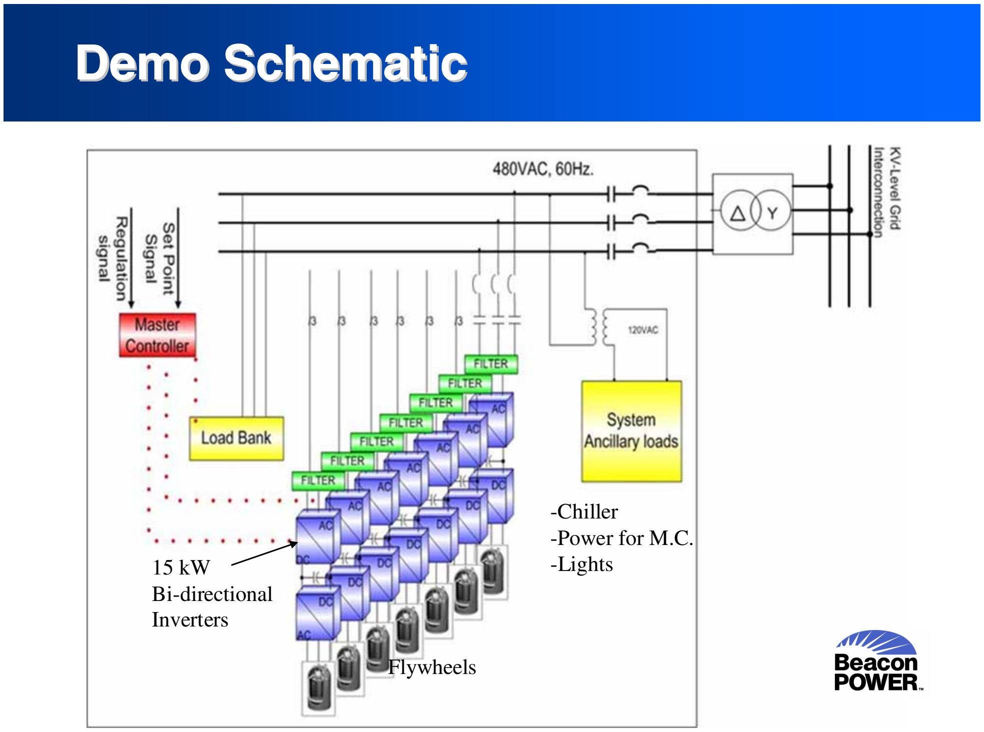

Fig.3. SEM Pilot project Schematic

Data and performance conclusions collected in the 1st six months of operation will be presented will be presented. Results will be validated by DOE through monitoring by Sandia National Laboratory, EPRI Solutions and Enernex.

Preliminary data shows the system can follow command signals very quickly. Today's performance standard is to achieve the change in power level called for by the regulation signal in 5 minutes. The flywheel based system an actually comply with the demanded power level within seconds. Figure 4 shows a signal used in the acceptance test (red) and the response shown in blue. The coincident signals prove the system capability to follow a commanded signal very quickly.

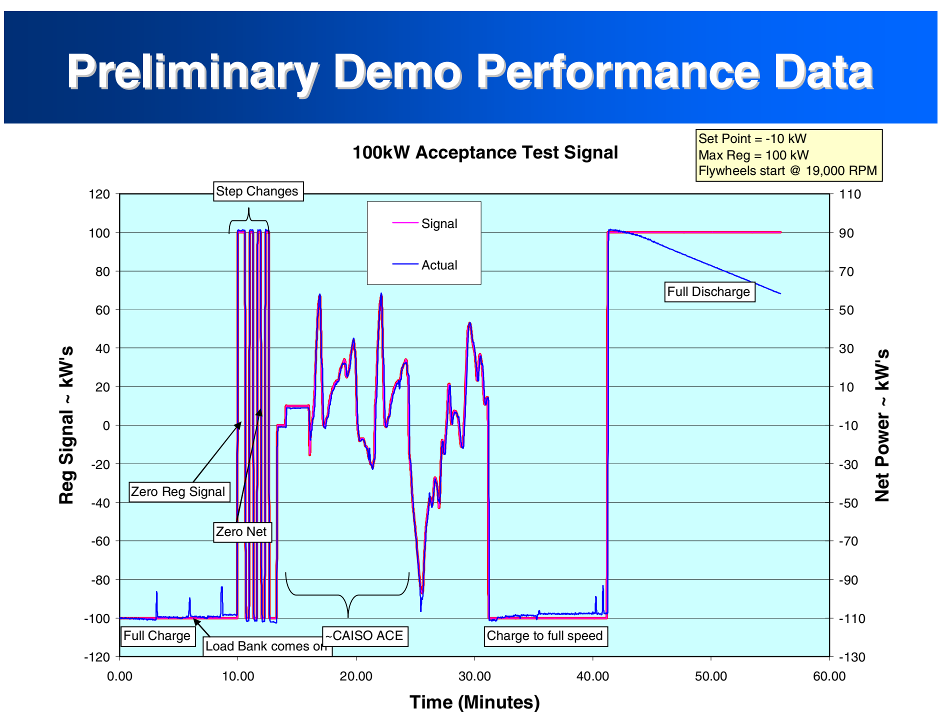

Fig. 4.   SEM performance characteristics

In the limiting case where the response exactly offsets the input load imbalance, the grid would be balanced and more stable. The benefit would be a significantly reduced regulation requirement which would be less costly to the system. One of the options being evaluated is using the actual system frequency as the input signal to the SEM. The advantage would be a more direct control of frequency and a simpler passive control methodology. The two projects will be evaluating the benefits of these fast acting schemes.

III. References

[1] M. Lazarewicz and A. Rojas "Grid Frequency Regulation by Recycling Electrical Energy in Flywheels" presented at the IEEE-PES 2004 General Meeting, Advances in Distributed Resources Panel Session, Denver, Co, USA June 2004.

[2] M. Lazarewicz and J. Arseneaux "Flywheel-Based Frequency Regulation Demonstration Projects Status" PowerPoint presentation, EESAT 2005, San Francisco, CA. web location for slides: http://www.beaconpower.com/products/EnergyStorageSystems/DocsPresentations.htm

IV. Biographies

Mr. Lazarewicz is a Registered Professional Engineer in the Commonwealth of Massachusetts and received both Bachelor's and Master's Degrees in Mechanical Engineering from the Massachusetts Institute of Technology. Mr. Lazarewicz also completed his Master's Degree in Management at the Massachusetts Institute of Technology Sloan School of Management.

Mr. Lazarewicz served as Vice President of Engineering at Beacon Power from February 1999 to February 2002 when he was named Vice President & Chief Technical Officer. Prior to joining Beacon Power, Mr. Lazarewicz worked for 25 years in the General Electric in various capacities in Power Systems and Aircraft Engines. He is a member of ASME and the IEEE Power Engineering Society, the Energy Development Subcommittee (EDS) and serves as Vice-Chairman of the Distributed Generation and Energy Storage Working Group within the EDS.

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Mr. Arseneaux is the project director for two groundbreaking flywheel energy storage systems, which will be deployed to demonstrate grid frequency regulation in California and New York this year. He is responsible for overall system integration, flywheel and component design, testing and field demonstrations. For the last few years he has been responsible for the design of various flywheel components including the rotor, bearings and structures in Beacon's 2kWh and 6kWh flywheels, which have demonstrated high performance and outstanding reliability. Prior to joining Beacon Power, Jim worked at General Electric for 24 years in a variety of engineering and management roles, developing components for high-speed turbo-machinery and aircraft engines. He has a track record of bringing new technology from concept to production for military fighter engines, commercial turbofans, helicopter installations, and tank engines. Jim has a B.S. degree in Mechanical Engineering from Tufts University, and an M.S. in Mechanical Engineering from Northeastern University.

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