

Session II – Storage in Transmission and Distribution Infrastructure

Flywheels for Frequency Control

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Beacon Power – Who we are



Focus on Fast Acting, Short Duration, High Cycle, High Value Storage Applications



Global leader in flywheel energy storage systems

- Develop, design, build, and operate flywheel energy storage systems
- Offer one of the largest commercially available composite flywheels
- Designed, built, and operate the largest flywheel energy storage plants in the world
- Most experience:
 - More than 40 MW installed; and
 - Over 7 million operating hours
- Member of ESA. Working with Sandia on standards and material developments. Recipient of DOE and APRA-E funding

Owner: Rockland Capital



Operating Facilities



Over 40 MW & 7 Million Hours In Commercial Operation



Tyngsboro, MA
0.5 MW
Operating since 2008



Stephentown, NY
20 MW Facility
Operating since Q1 2011



Hazle, PA
20 MW Facility
July 2014



Beacon Power – fourth largest deployed ES capacity in 3Q 2013*

*excluding traditional pumped storage, CAES and solar thermal, Navigant Research “Stationary Storage in Utility Applications”, May 2014

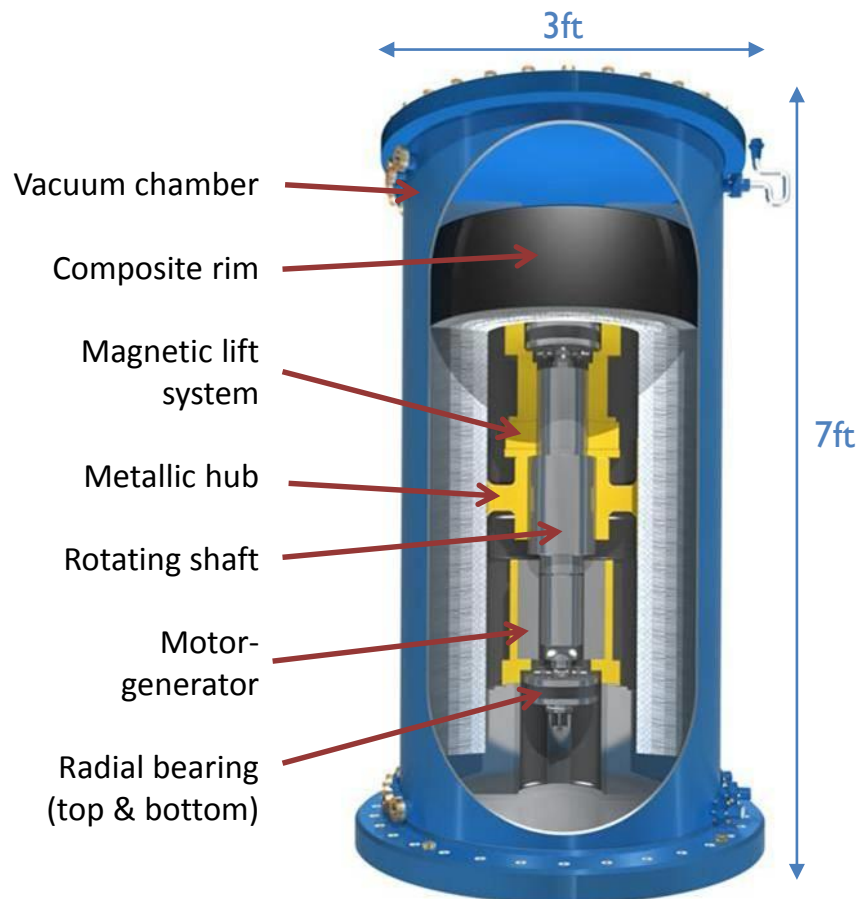


Series 400 Flywheel Description



Largest composite flywheel in commercial operation

- Large patent portfolio supports Beacon's flywheel technology and applications
- Flywheel is a large mechanical spinning device – see diagram to right
 - 2,500lb carbon fiber rotor can spin up to 18,000RPM
 - Rotor suspended by magnetic bearings in a steel vacuum chamber
 - Total weight ~ 8,000lbs
- Capable of continuous absorption and injection of energy from a grid or power system
- Over 100,000 full depth of discharge cycles (~10X greater than highest work load electrochemical batteries)





Installed Flywheel Cutaway



New modular design simplifies installation

Modular design being tested in Alaska demo projects

- TDX Wind Diesel System
- Chugach Battery Hybrid System

Easy Installation

- 3 piece concrete foundation provides stability
- Moderates climate conditions
- Allows service access

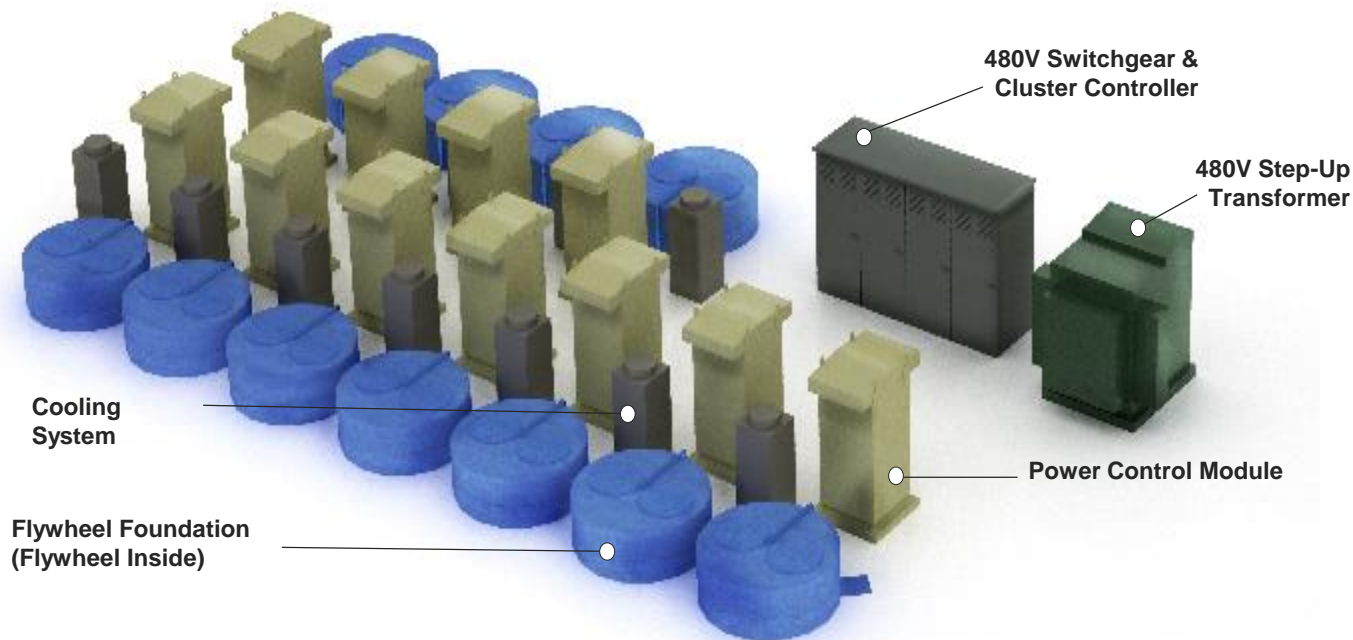




Representative Flywheel Energy Storage System



2 MW Configuration



- Fully distributed architecture facilitates permitting & siting
- System operation at any size from 100 kW to multi-MW power blocks



Flywheel Energy Storage System



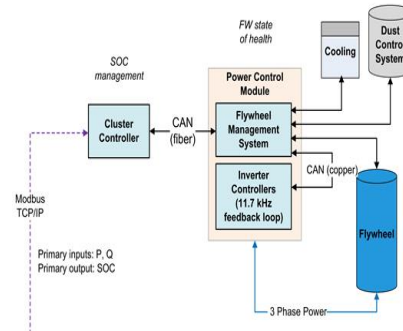
Fully integrated system – facilities operate without onsite personnel



Storage device

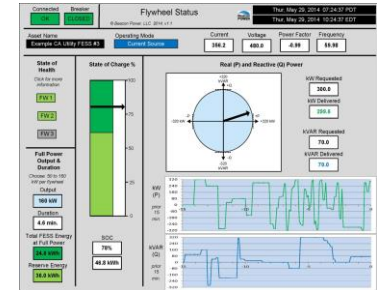


PCM is the connection interface of each flywheel and allows stored energy to be coupled quickly and seamlessly with a power grid or system



Manages the flywheel storage system by translating and distributing signals from the power grid or system.

Monitors the status of critical operating parameters.



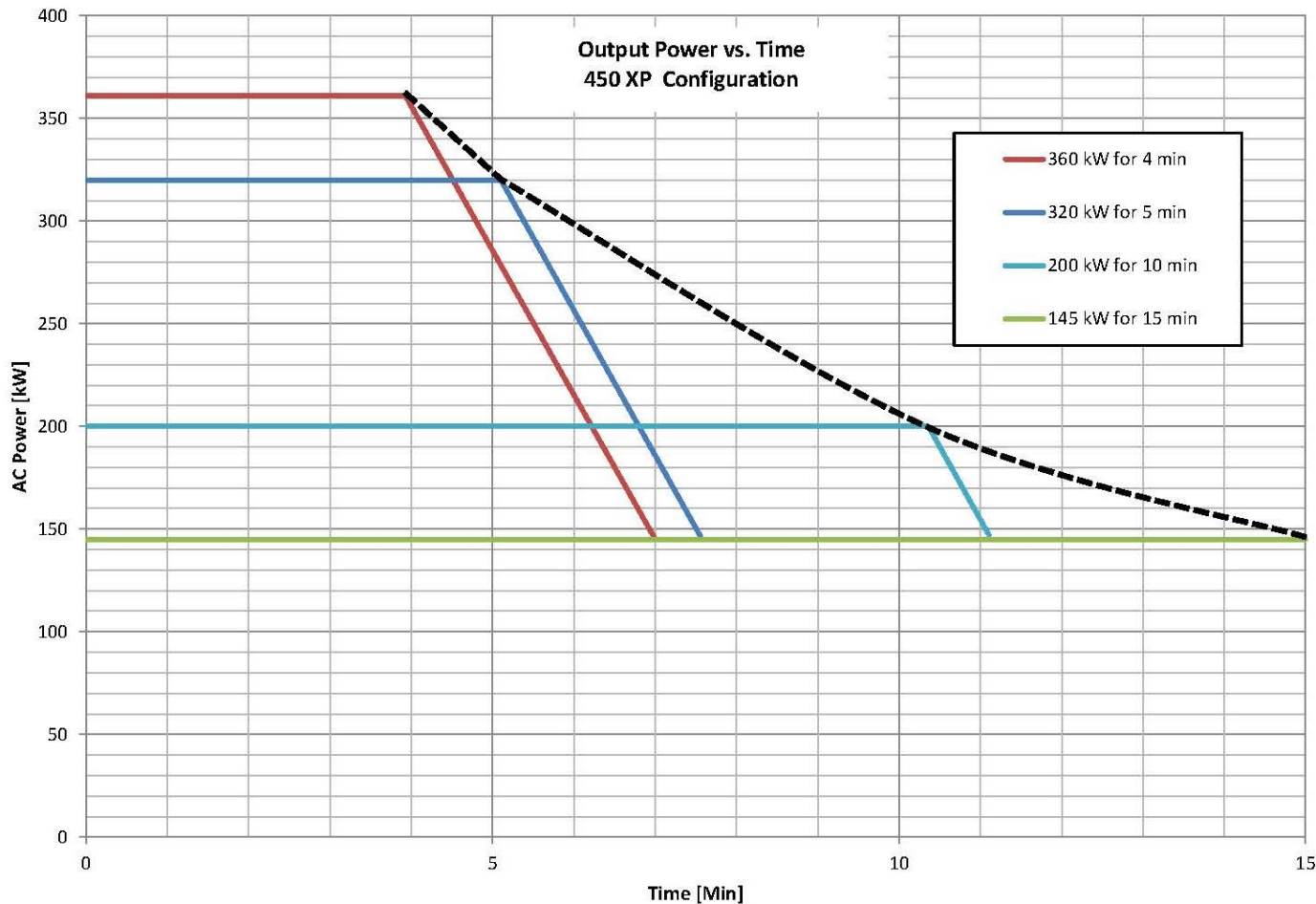
System operators able to monitor system performance



Beacon 450XP Flywheel



Power and Energy



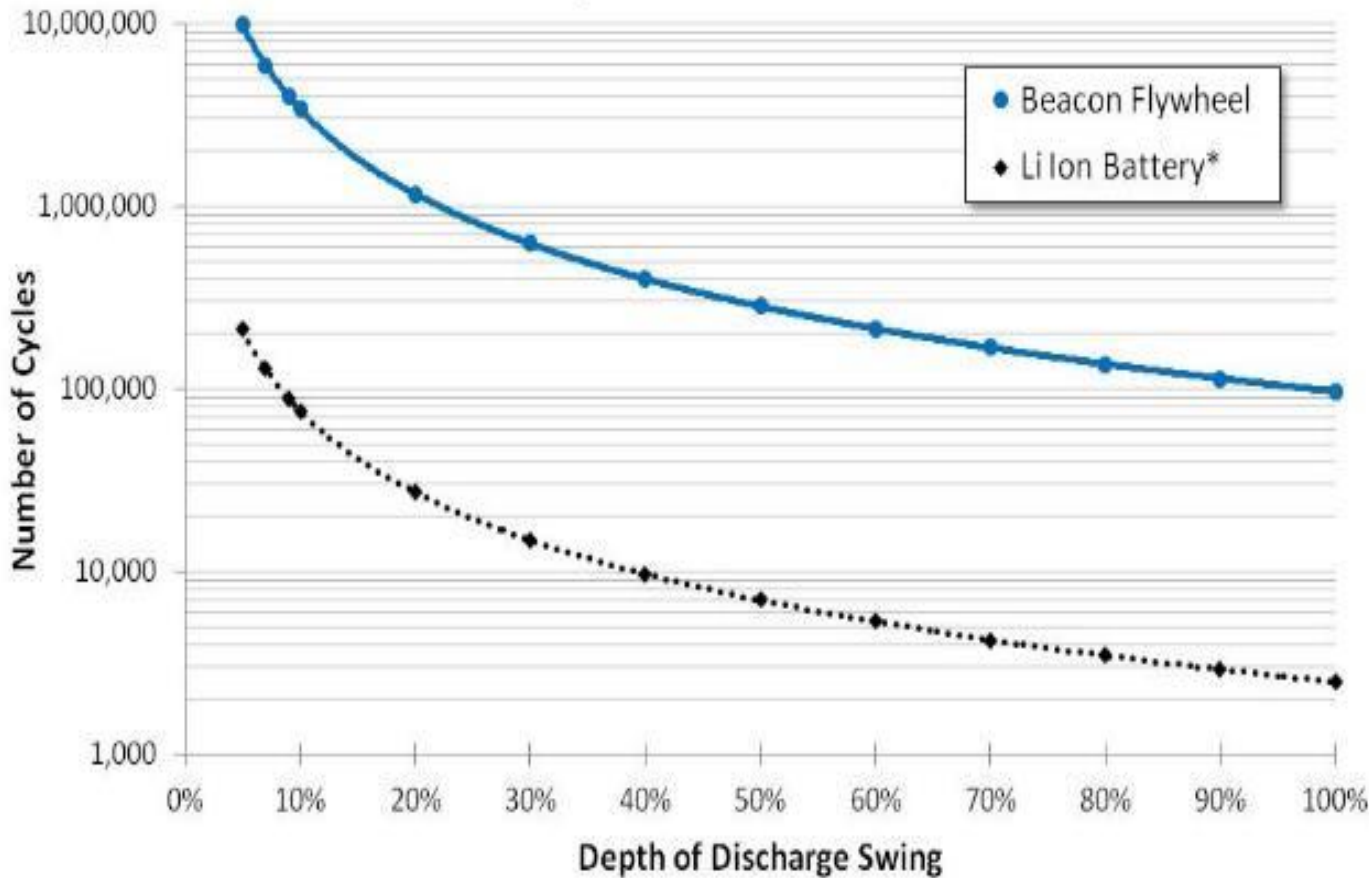
- Power output up to 360 kW
- 36 kWh of energy deliverable over up to 15 minutes
- Constant throughput at any state-of-charge within recommended operating range
- Symmetrical discharge/recharge rates for maximum flexibility



Flywheel vs. Battery Comparison



High cycles enables lower lifetime cost



Our flywheels experience 1,700 to 4,000 full depth cycles per year in utility grid stability operations



What is Frequency Regulation



Process used to balance the difference between load, generation and energy transfer between control areas

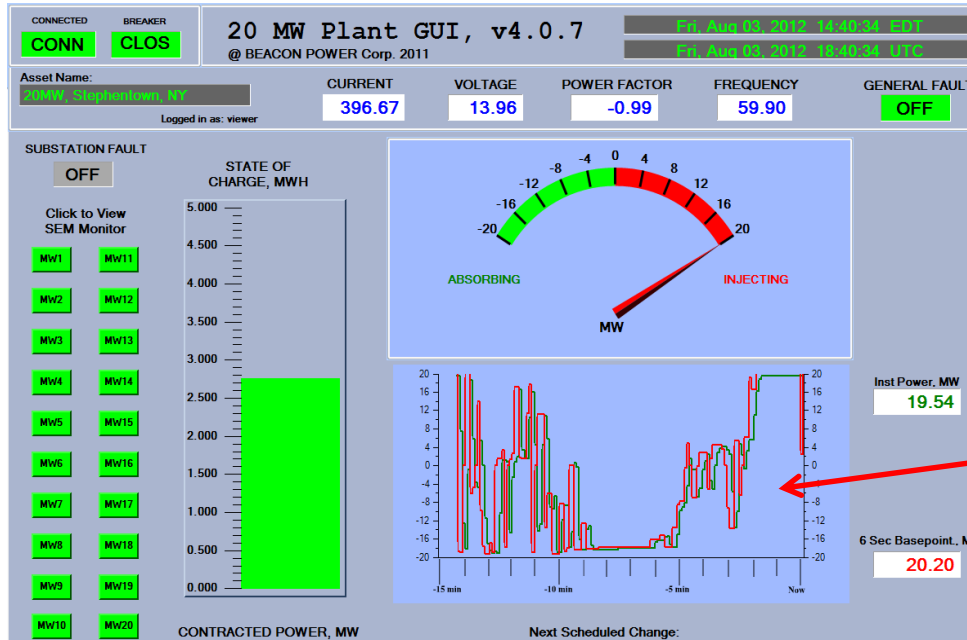
- High Cycles
- Short Duration (Typically 5 Minutes or Less)
- Highest Value Energy Recycling (Imbalances That Were Not Predicted)



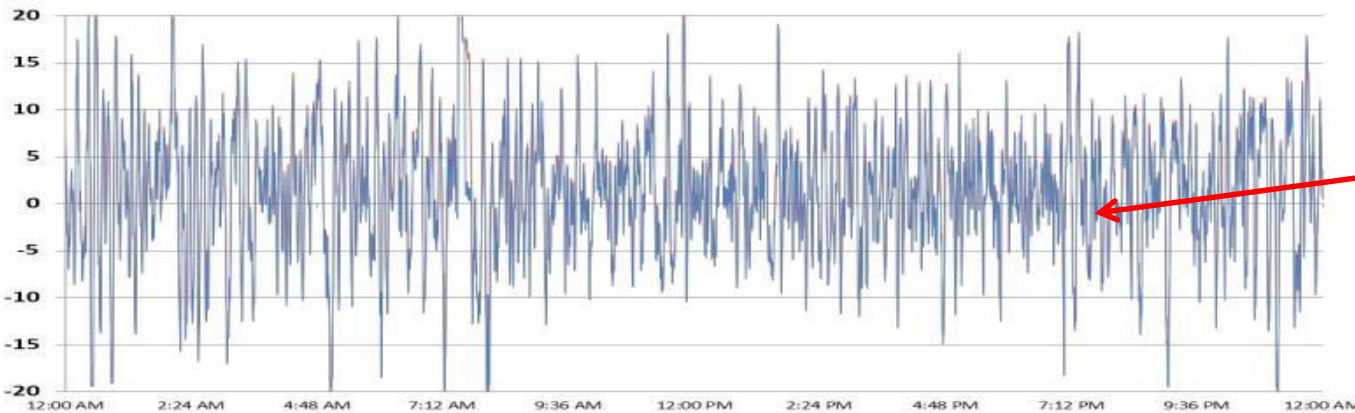
Similar to Primary and Secondary Reserves



Typical Regulation Cycles



15 minute History

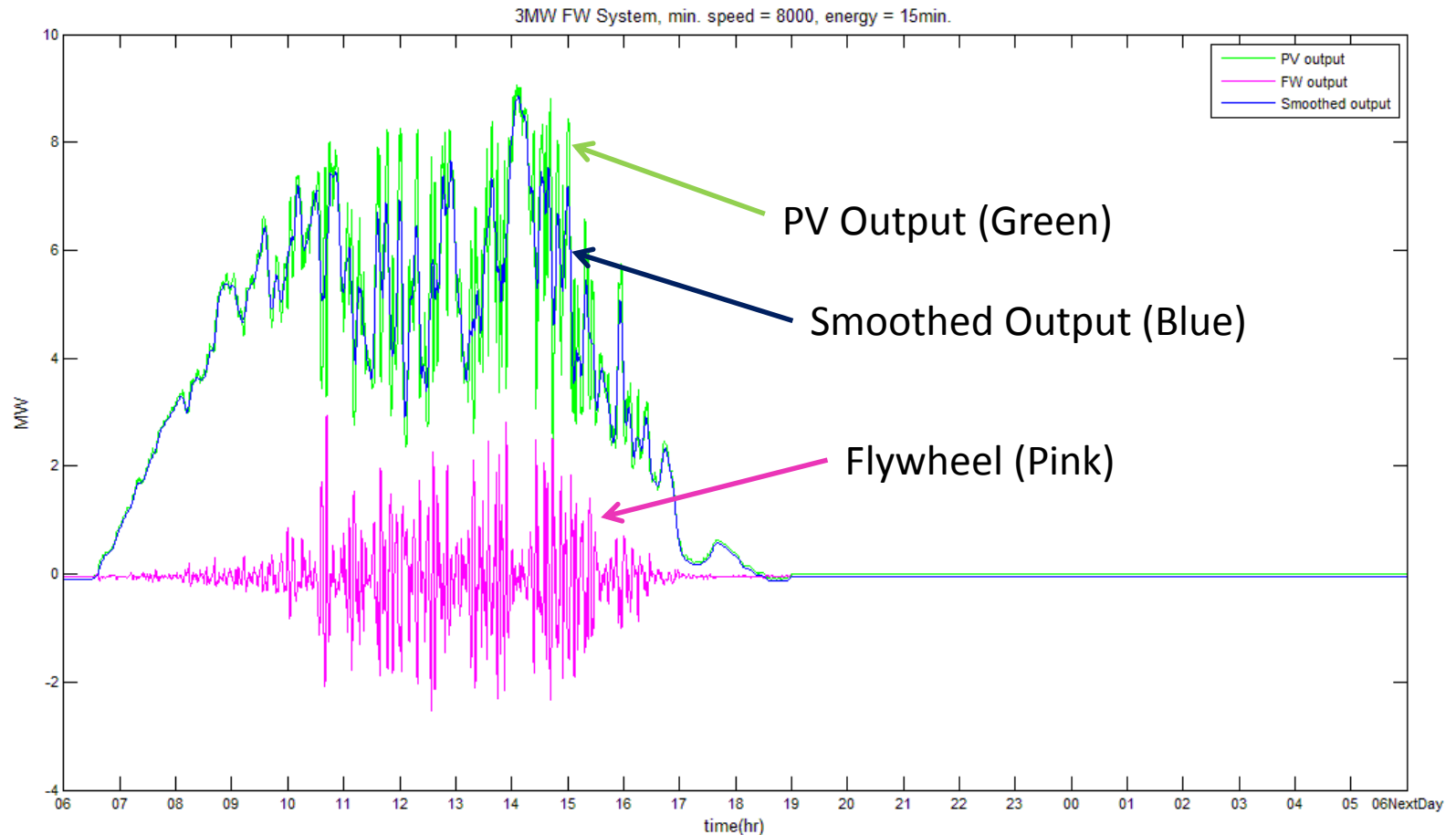




Renewable Smoothing



Fast acting flywheels can also provide smoothing for intermittent wind and solar output





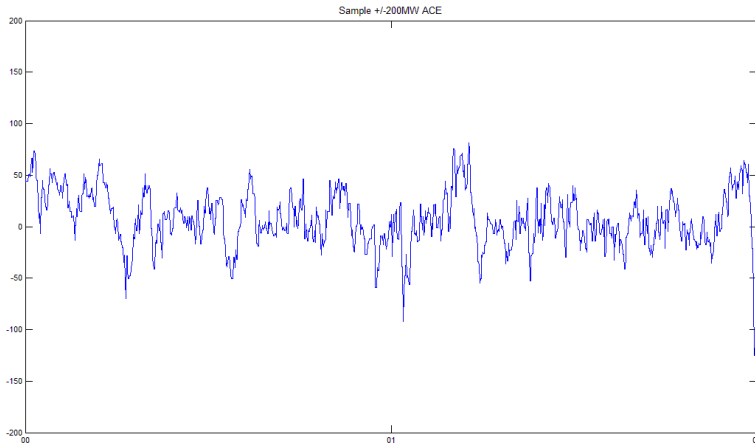
Fast Storage Resources are Part of a Total Grid Stabilization Portfolio



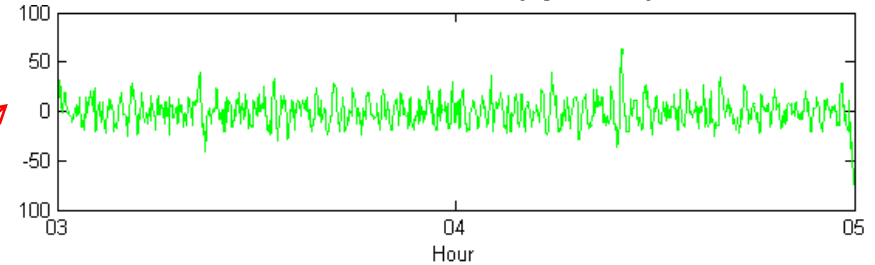
Challenge: MW supply/demand imbalances

Solution: Break into pieces and add fast storage

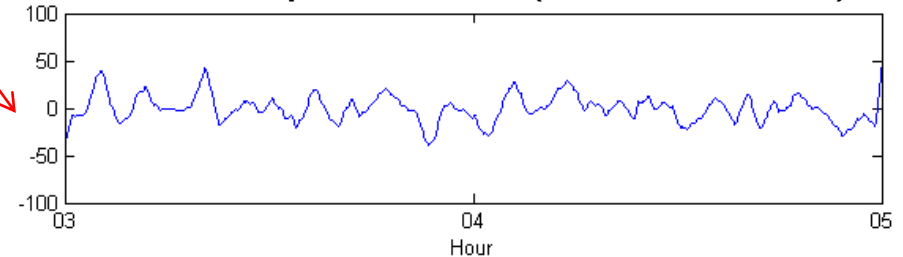
Total Imbalance (MW over 2hours): actual NY data



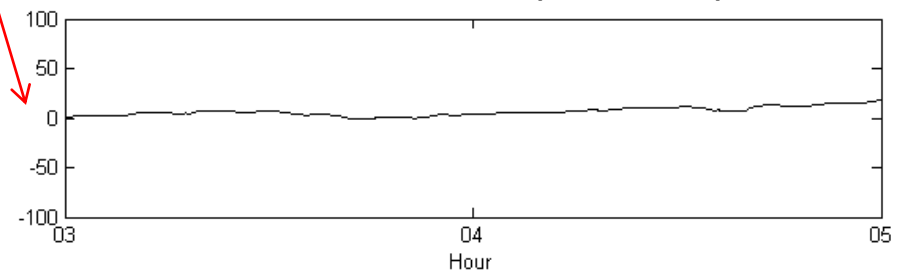
Fast Resources (flywheel)



Medium Speed Resources (combustion turbine)



Slow Resources (steam units)



Grids break down the problem and assign response to generators in line with their capabilities.

- Improves accuracy and system efficiency
- Best matches capability with services needed
- Reduces fossil generator ramping



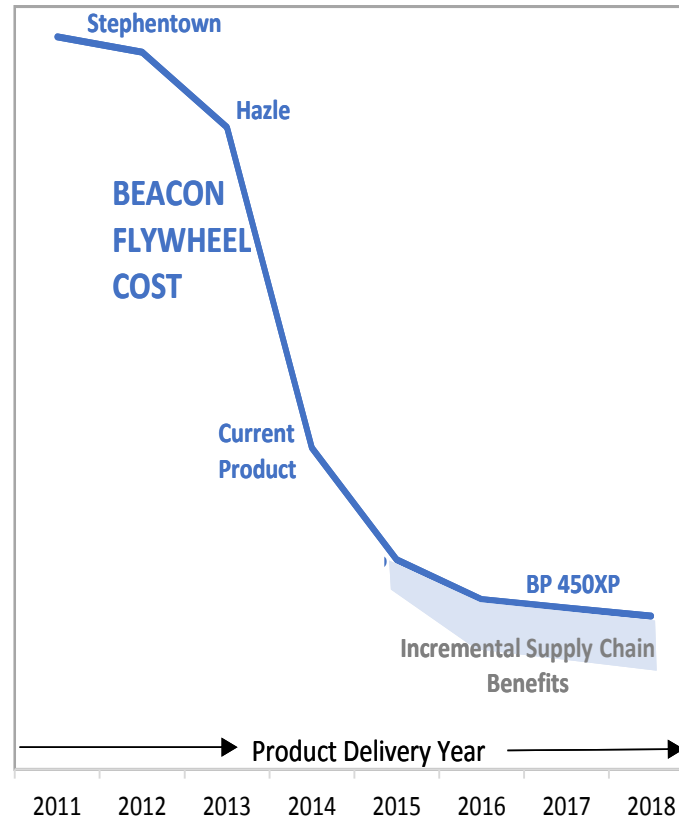
Beacon Product Development



$\$/KW$ decreasing with each new installation

- ▶ Beacon flywheel capital cost decreasing rapidly
- ▶ $\$/KW$ now similar to Li-ion with long life
- ▶ Learning from existing operations and market discussions
- ▶ Improvements in
 - ▶ storage device
 - ▶ system controls and
 - ▶ balance of plant
- ▶ Incremental supply chain and manufacturing potential

$\$/kW$ Cost Reduction Roadmap
PJM Interconnect Type Installation



Energy Storage Conference

Explaining | Exchanging | Enabling
Paris | 19th to 21st November 2014



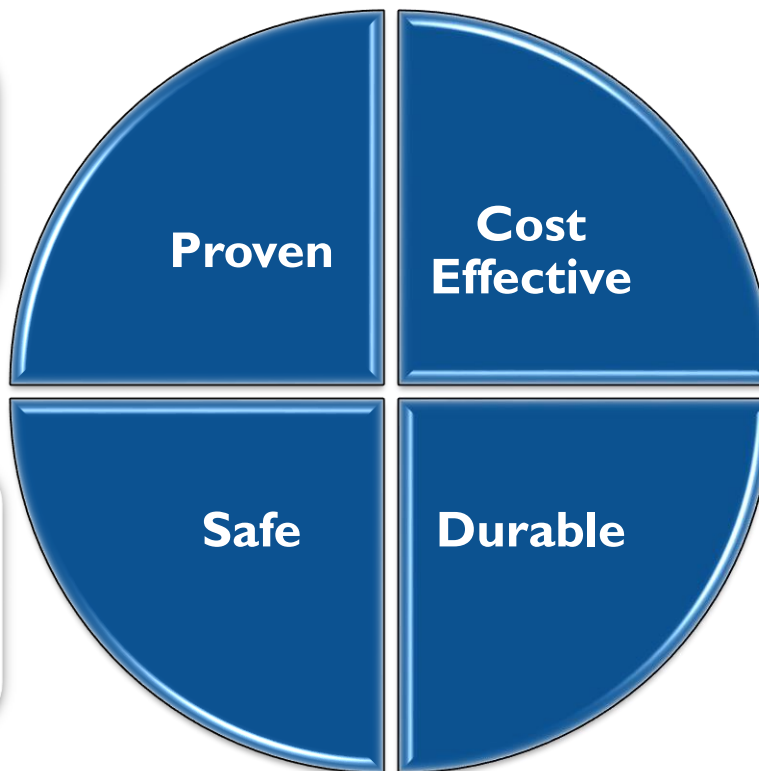
The Beacon Advantage



Realizing benefits of fast responding mechanical energy storage

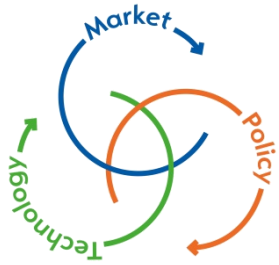
Over 40 MW and
7.0 million hours in
commercial operation

Excellent safety record
No harmful chemicals
or hazardous materials
No emissions



Competitive capital
cost plus greater
durability and low
operating costs
means ...
Lowest lifetime cost
20+ year design life

Does not degrade with
cycling, DOD, time or
temperature
No need to limit SOC to
manage cycle life



Thank you for your attention