Flywheel Based Energy Storage for Grid Services

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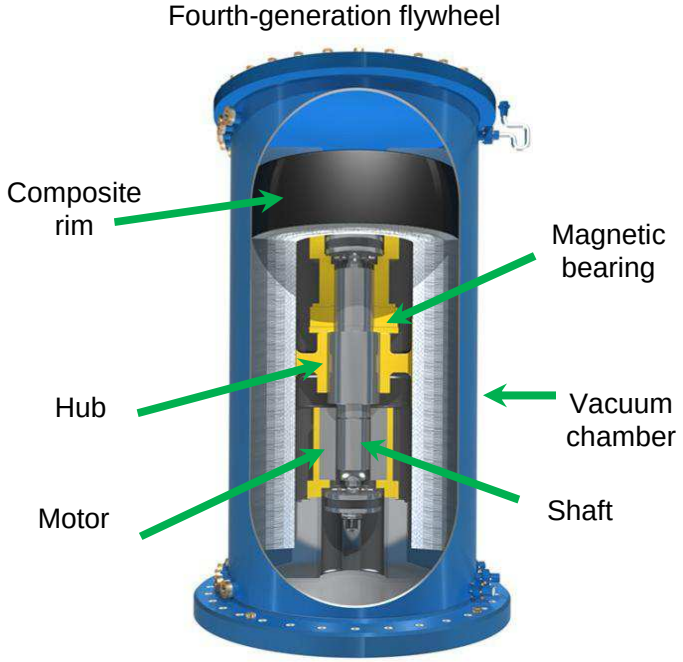
Beacon Power Overview

- Manufacturer and developer of flywheel energy storage plants
- 100kW demo in NY & CA (2006-2007)
  - NYSERDA and CEC support ~ $1M each
- November 2008 started commercially operating up to 3 MW in ISO-NE
- First 20 MW Merchant plant operating in Stephentown, NY in 2011
  - $43M DOE loan guarantee
  - $2M NYSERDA contribution
- Next 20 MW plant to be built in Hazle Township, PA
  - Local permitting is in process
  - $5 million PA RACP grant

20 MW plant in Stephentown, NY

Flywheel Storage Technology



- **Proven grid technology**
- Extremely fast accurate response
- Low operating cost: Recycles electricity
- Low O&M: 20-year design life – 125K cycles
- Zero CO_2 or other emissions

Flywheel Product Development

2000

Gen 1

2001

Gen 2

2004-05

Gen 3

2007-08

Gen 4

- Gen1 and Gen2 addressed telecommunication applications
- Over 1,000,000 hours of operation in the field without mechanical failure
- Only flywheel technology capable of addressing grid-scale applications

2006/2007

Successful demonstrations in CA and NY

2008 - present

Commercial operation and service revenue

Typical “Regulation” Profile

ISO Goal:

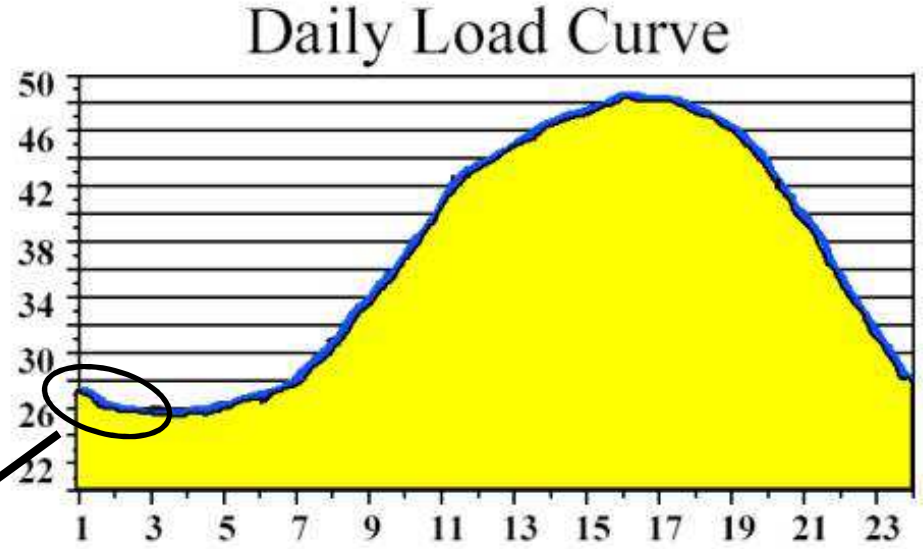
Load = Power Generated

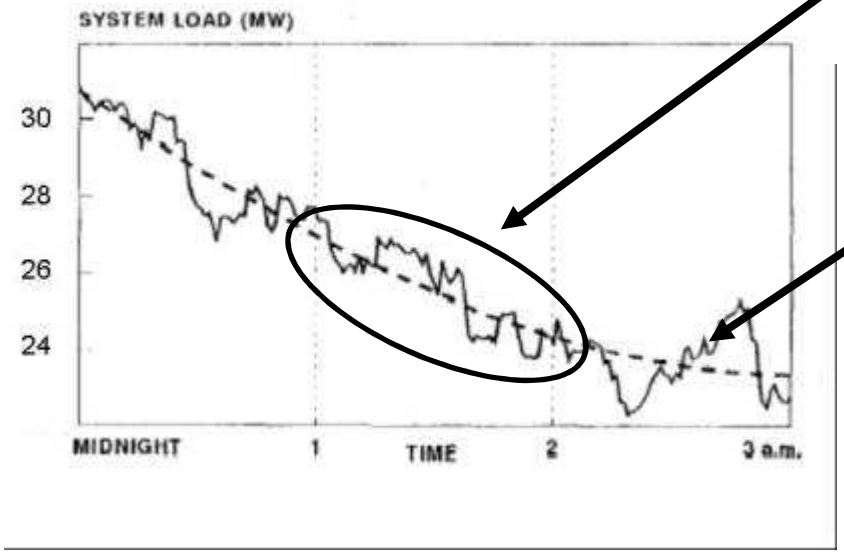
Power < Load:

– Frequency drops under 50/60 Hz.

Power > Load:

– Frequency rises over 60 Hz.



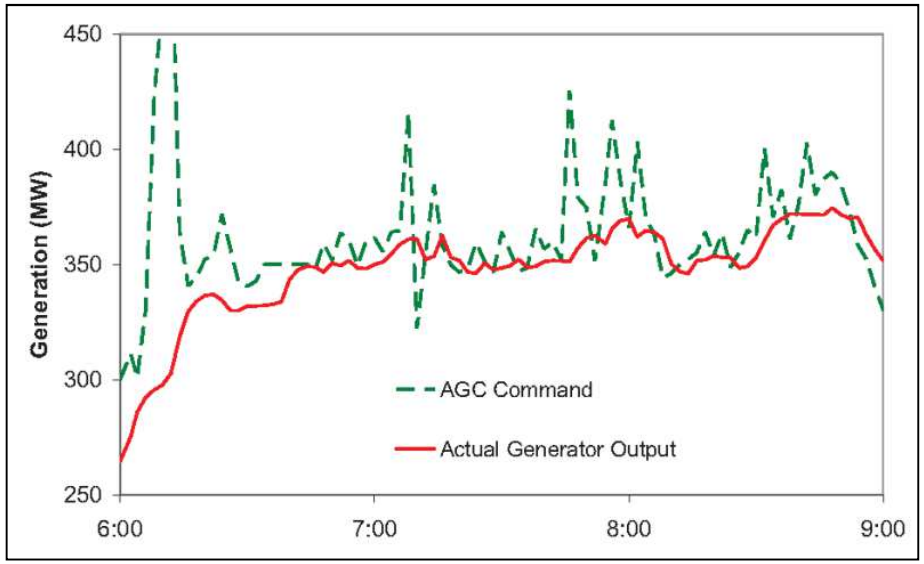


Short term variation

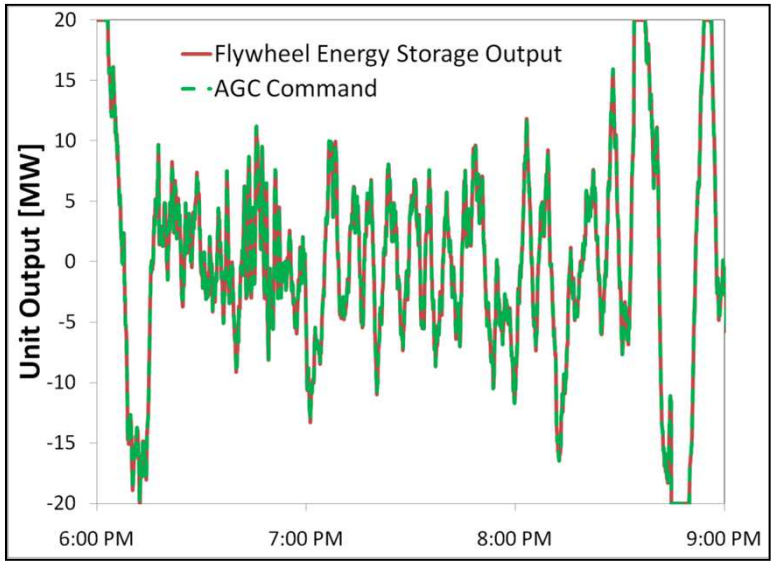
- ~ 1% of daily load
- Managed via regulation
- Fluctuation is net zero

Video available www.beaconpower.com

Fast Regulation: Speed Matters…



Slow ramping
Generator



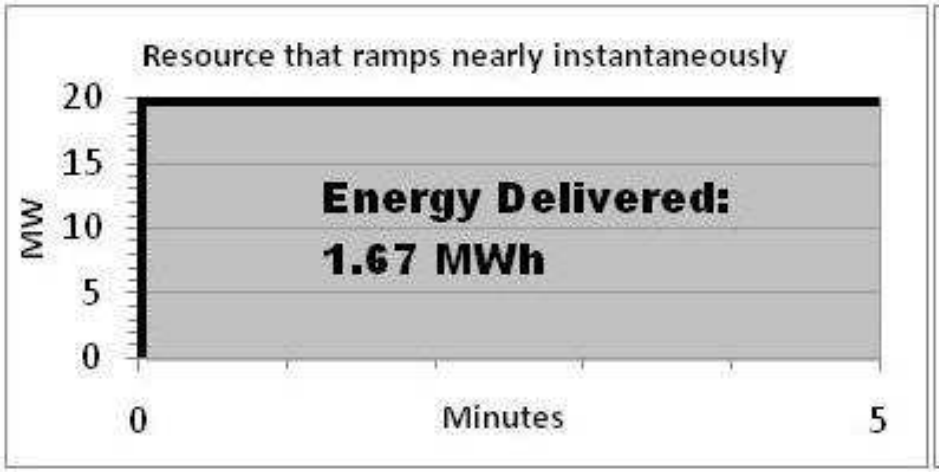
Fast response
Flywheel Energy Storage

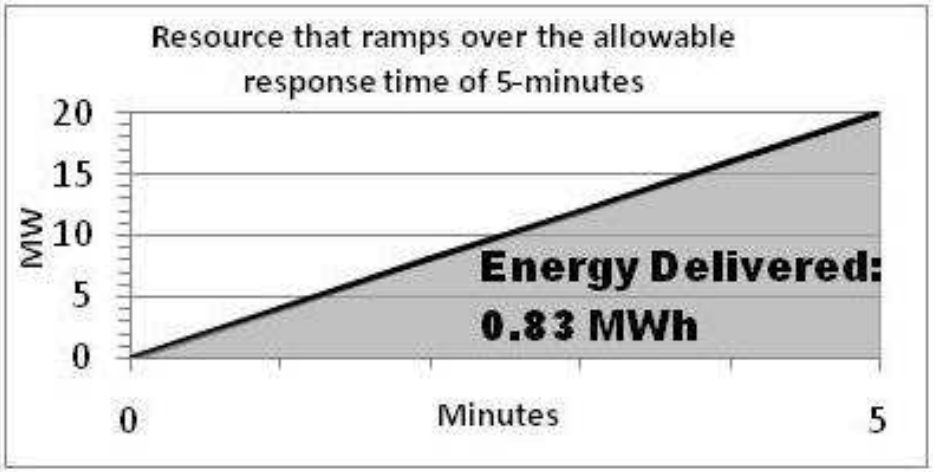
Advanced Storage provides fast accurate response
Provides Reliability and Cost Benefits

Sources:
- Kirby, B. "Ancillary Services: Technical and Commercial Insights." Wartsilla, July, 2007. pg. 13

Value of Fast Regulation

- Frequency error is function of the amount (MW) of imbalance and the time it takes to correct the imbalance
  - The sooner ACE is corrected the less amount of regulation needed
- Faster response can lower regulation procurement
  - Faster ramp will reach target more quickly
  - Faster ramping resources will recover more quickly for re-dispatch
  - Will not be caught in wrong direction requiring another resource to be dispatched to counteract it

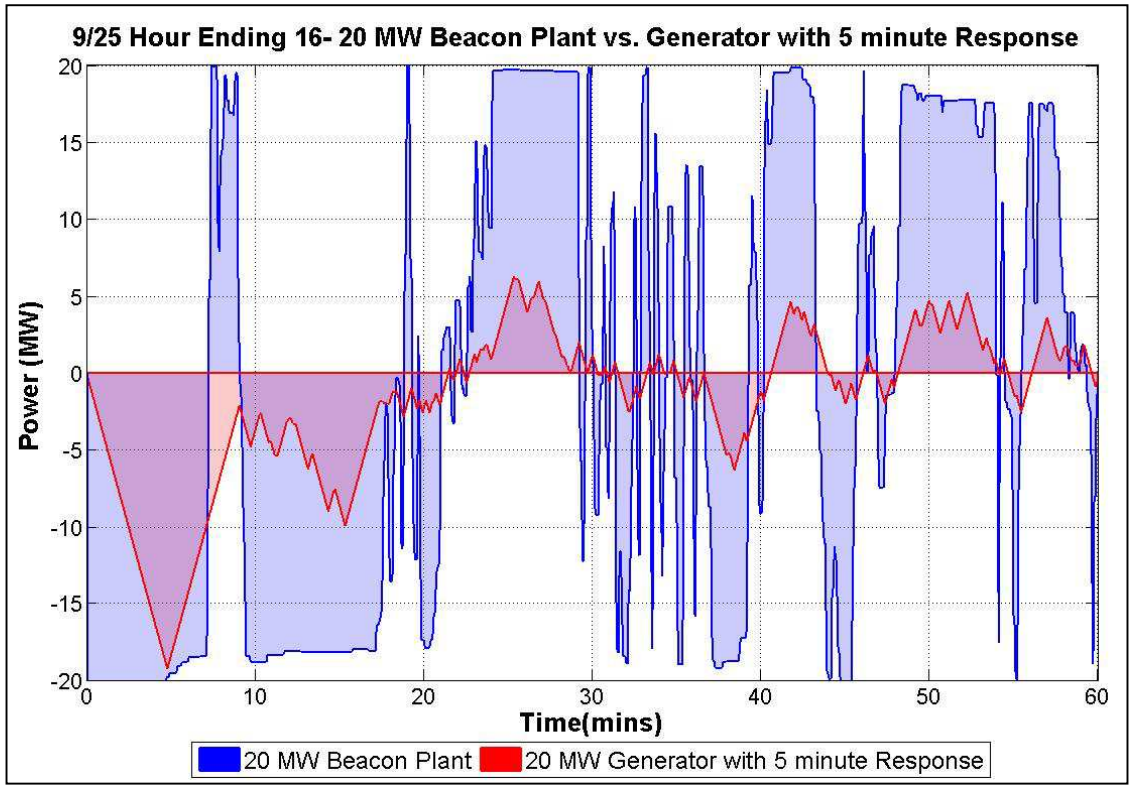




Fast Regulation: Speed Matters

Data from Beacon Power's NYISO plant

- **NYISO utilizing advanced storage as "first responders" to Area Control Error (ACE) – operating at full rated power**



Regulation Market Data*	ACE Correction (MWh)	%
20 MW Generator	3.7	8%
20 MW Flywheel	14.2	32%

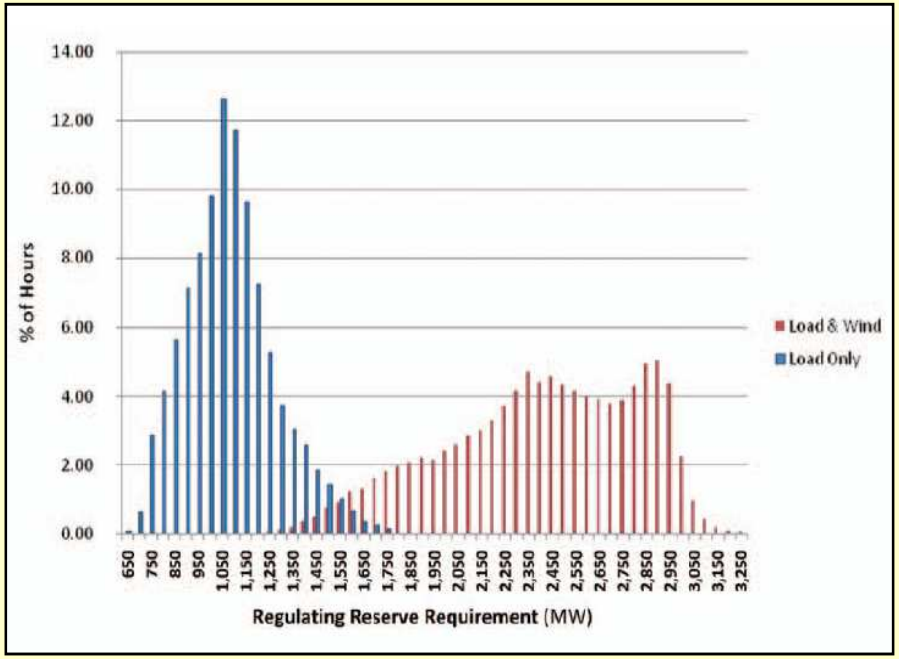
Storage provides 2 - 4x more Regulation Service per MW

On average Beacon's 20 MW flywheel plant provides 25% of NYISO's ACE Correction with only 10% of the market capacity

PJM Forecasts Need for More Regulation with Increased Renewables

- PJM expects the **<u>regulation requirement to increase by 200%</u>** when reach 20% wind penetration
  - From 1,000 MW to 2,000 MW
- Other ISO/RTOs:
  - CAISO increase by 300% with 33% wind
  - ISO-NE increase by 280% with 20% wind
  - NYISO increase by 60% with 10% wind

Eastern Wind Integration and Transmission Study
Distributions of PJM hourly Regulation Requirements
Load only vs. PJM Scenario 3 (20% Wind)



Source: EWITS Figure 5-11, page 152.

"Wind plants …make it imperative to look for new sources and new technologies for these services."

-NYISO Integration of Wind into System Dispatch, October 2008

Market and Regulatory Issues: FERC

- **FERC Order No. 890 in 2007 set the stage for opening Regulation market to energy storage**
- **Continue progress to remove barriers to advanced storage**
  - NYISO, Midwest ISO, PJM are open; have revised tariffs
  - ISO-NE has pilot program; developing permanent rules
  - CAISO tariff filed at FERC August 2011
- **FERC now focusing on compensating the value of fast regulation, i.e. "pay-for-performance"**
  - In all ISO/RTOs (except ISO-NE) resources paid on $/MW Capacity not on actual amount of Regulation Service provided
  - NOPR issued in February 2011 to change Regulation compensation to pay resources based on the actual amount of Regulation "work" (ACE Correction) provided

FERC NOPR: Potential Cost and Reliability Benefits

"Use of faster-ramping resources for frequency regulation has the potential to improve operational and economic efficiency and, in turn, lower costs to consumers in the organized markets"

1. **Allows RTOs and ISOs to use less regulation capacity to meet current NERC standards, thus lowering regulation costs**
   - right market signals encourage fast-ramping technologies for regulation market
   - ISO-NE uses performance payment, has lowest Regulation as % of load
     - On average 60% less than other ISO/RTOs
2. **Commission anticipates secondary effect of lowering Energy market prices**
   - Slower-ramping generators displaced by storage in the Regulation market can operate at constant output levels and at more efficient heat rates
3. **Allows new technology to improve profitability**

Wins for all four: RTO, generator, rate-payer, new technology

Regulating the Grid of the Future

Conventional Regulation


+


- Regulation provided by generators varying output
  - Decreases efficiency
  - Increases fuel consumption
  - Requires more maintenance
  - Increases emissions

Smarter Solution: Storage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- Store energy when supply exceeds load; inject energy when load exceeds supply
  - High round trip efficiency
  - Low operating cost
  - Near instantaneous response
  - Zero direct emissions

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