20 MW Flywheel Energy Storage Plant

Hazle Spindle – Hazle Township, PA
Acknowledgements

Thanks to the following who supported this project

• DOE’s Office of Electricity and Dr. Imre Gyuk, Program Manager of the Electrical Energy Storage Program
• NETL – Ron Staubly, Project Manager
• Pennsylvania PUC
• PPL
• PJM
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Purpose of Hazle Project

- Develop additional experience in performing frequency regulation in different locations.
- Speed the deployment of fast response flywheel-based frequency regulation
- Build on experience of 20 MW plant in NYISO
- Validate modifications in FESS design from Stephentown
- Obtain experience interconnecting into a different Utility and ISO
- Gain experience in PJM Fast Response Regulation Market
- Continue to explore additional applications and revenue streams
Third Plant in Commercial Operation

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
Operations from Sep 2013
Full COD 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
Changes from Stephentown to Hazle

• Design Improvements
  – Hub material improvement
  – Improvements to rotor lock to prevent bearing damage
  – Simplified cooling system
  – Vendor process improvements
  – Software updates
• Interconnection to PPL transmission system at 69 kV
• Participating in PJM Fast Response Regulation Market
Hazle Project Milestones

- Groundbreaking – Spring 2013
- Began operation at 4 MW – Sept 2013
- Major site work complete – April 2014
- Last flywheel delivered – July 2014
- Full commercial operation at 20 MW – July 2014
Beacon BP-400 Flywheel

- ~7’ tall, 3’ in diameter
- 2,500 pound rotor mass
- Spins up to 15,500 rpm
- Max power rating 100 kW, 25 KWh charge and discharge
- Lifetime throughput is over 4,375 MWh
- Capable of charging or discharging at full rated power without restriction
- Beacon flywheel technology is protected by over 60 patents
BP - 400 Flywheel in Production
System online 24/7 with >98% Availability and >97 % Accuracy
Substantial differences in how ISOs dispatch fast resources currently. Markets are still developing on how to best fully utilize these plants.
# Flywheel vs. Battery Comparison

<table>
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<tr>
<th>Power Applications</th>
<th>Energy Applications</th>
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<tr>
<td>265 kW</td>
<td>100 kW</td>
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<td>160 kW</td>
<td>100 kW</td>
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<tr>
<td>100 kW</td>
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<td>22 kwh</td>
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<td>12.5 kwh</td>
<td>400 kWh</td>
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<td>25 kwh</td>
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<td>4,400 MWh*</td>
<td>720 MWh**</td>
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<td>4,375 MWh*</td>
<td>2,880 MWh**</td>
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<td>5,000 MWh*</td>
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<td><strong>Lifetime Throughput</strong></td>
<td><strong>Cost Metrics</strong></td>
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<td><strong>Power-to-Energy</strong></td>
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<tr>
<td><strong>Cost Metrics</strong></td>
<td><strong>Power-to-Energy</strong></td>
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<td>Cost per lifetime kwh of throughput or cost per KW</td>
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**Beacon flywheel: 100,000 to 175,000 full depth of discharge cycles**

**Battery technologies: 1,000 to 10,000 full depth of discharge cycles (estimated)**

(*Beacon throughput. **Assumes 5,000 cycles, 80% useable SOC, 10% avg. lifetime degradation)*
Beacon BP-400 Flywheel: Power & Energy

Same flywheel with more power now available

Output Power vs Time
BP-400 Operating Configurations

Current Production

Hazle Flywheel

160 KW
100 KW
50 KW
Potential configuration

Output Power @ 480V/AC (KW)

Time (Min)
Current Production Modular Design

**Lower Cost**
- Eliminates containers
- Less on site construction
- Higher power means less flywheels per plant

**Easy Installation**
- Smaller components
- Moderates climate conditions
- Allows service access

**Less Land Required / Smaller footprint**
Representative Flywheel Energy Storage Systems

2 MW Configuration

- Fully distributed architecture facilitates permitting & siting
- System operation at any size from 100 kW to multi-MW power blocks
Next 20 MW Plant Site Layout
Product Development Road Map

- Beacon flywheel capital cost decreasing rapidly
- 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

Cost decreasing rapidly with each project
Summary

• Hazle Township construction complete
• Plant online at 20 MW
• Changes from Stephentown to Hazle being validated and resulting in lower maintenance cost.
• Performance of plant continues to meet expectations
  – Availability >98%
  – Accuracy >97%
• Lessons on market needs being reflected in next generation products.
Thank you.

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978-661 2097