FACT SHEET

Frequency Regulation and Flywheels

To ensure a functional and reliable grid, the Independent System Operators (ISOs) that operate regional grids in the U.S. must maintain their electric frequency close to 60 hertz (Hz), or cycles per second. When the supply of electricity exactly matches the demand, grid frequency remains at 60 Hz. But because supply rarely matches demand, grid operators need to continuously balance the two. Historically, they have done this by directing the grid's generation capacity to increase or decrease power output by approximately one percent in response to frequency deviations.

Beacon's flywheel is a mechanical battery designed for a minimum 20-year life, with virtually no maintenance required for the mechanical portion of the flywheel system over its lifetime. Of critical importance in performing frequency regulation with energy storage-based systems is their cyclic life capability. Beacon's experience to date in ISO New England shows that 6,000 or more effective full charge/discharge cycles per year are required. The system is capable of over 150,000 full charge/discharge cycles at a constant full power charge/discharge rate, with zero degradation in energy storage capacity over time. For the frequency regulation application, flywheel mechanical efficiency is over 97 percent, and total system round-trip charge/discharge efficiency is 85 percent.

At the heart of Beacon's Smart Energy 25 flywheel is a patented high-strength carbon-fiber composite rim, supported by a metal hub and shaft, with a motor/generator on the shaft. Together the rim, hub, shaft and motor/generator assembly form the rotor. To nearly eliminate friction, the rotor is sealed in a strong vacuum chamber and levitated magnetically.

The rotor spins between 8,000 and 16,000 rpm. When absorbing energy, the flywheel's motor acts like a load and draws power from the grid to accelerate the rotor to higher speed. When discharging, the motor switches into generator mode, and the inertial energy of the rotor drives the generator, creating electricity that is injected back into the grid as the rotor slows down. At 16,000 rpm, a single Smart Energy 25 flywheel can deliver 25 kilowatt-hours (kWh) of extractable energy at a 100 kW power level for 15 minutes. Multiple flywheels are connected in parallel to provide any desired megawatt-level power capacity. A 20 MW energy storage plant consists of 200 such flywheels.

A major benefit of fast-response flywheel-based regulation is that it is far more effective than slow-response resources of the same nominal capacity rating. Pacific Northwest National Laboratory (PNNL) studied the comparative value of fast-response versus conventional regulation resources. Researchers found that 1 MW of fast-response

storage-based regulation can be expected to deliver approximately twice the system regulation value of the average conventional regulation resource in California.

PNNL's detailed report is here: http://www.beaconpower.com/files/PNNL.pdf

Other benefits of fast-response flywheel-based regulation are that it produces much less CO_2 emissions than fossil-based regulation, and reduces dependency on fossil fuel. Even including the carbon footprint of make-up energy that flywheel-based regulation must buy to adjust for losses, KEMA, Inc. found that flywheel regulation can cut CO_2 emissions by about 50 percent versus base load gas-fired regulating generators, and up to 85 percent compared to coal-fired regulating generators.

KEMA's detailed report is here: http://www.beaconpower.com/files/KEMA_Report.pdf

(Above) Artist's rendering of Beacon's 20 MW flywheel plant, as seen in close-up. The plant consists of 200 Smart Energy 25 flywheels housed below ground in concrete cylinders (blue covers seen above), along with 20 steel containers (1 per MW) placed on concrete pads. The containers house electronics and communications equipment.

For more information visit www.beaconpower.com