Low-Cost Flywheel Energy Storage

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Objective
The purpose of the proposed research program is to develop technology that drastically reduces the cost of energy stored in and delivered from utility-scale flywheels, specifically for the benefit of renewable power generation. A material development program focuses on enabling up to a tenfold decrease in the cost of kinetic energy storage through innovations in topology, design and materials.

Background
Conventional flywheel devices store energy in a high-speed rotor that is levitated by mechanical or magnetic bearings positioned on both ends. Flywheels have potential use in utility-scale storage and could even supplant gas or coal-plant ramping to manage the intermittent nature of solar and wind power. Flywheels are modular and easily sited. They have a relatively small footprint and low greenhouse gas emissions. These advantages make installation socially and economically attractive. Challenges with the technology remain, such as rotor dynamic limits arising from bearing span and bearing stress issues, requirements for massive stationary structures to provide support stiffness for the bearing mounts, complex motor and generator thermal management issues, and frictional losses from bearings and windage.

Approach
The first objective is to develop nanomaterials that are guided by revolutionary flywheel energy storage designs. The goal is to develop technology to store electric energy at grid scale. This involves developing nanotube materials to improve performance, and novel designs to make maximum use of the new material technology. Increasing the specific strength of the carbon nanotube yarns and sheets will require a better understanding of (a) the structural characteristics of nanotube “forests”, (b) the topological transformations that convert a nanotube forest into an aerogel sheet or ribbon, and (c) the relationship between the forest structure and the structures and properties of drawn sheets and twist-drawn yarns (Figure 1).

Figure 1. Scanning electron microscope images of yarns spun from carbon nanotube forests
To make a transition of the novel materials into commercial applications possible, two primary goals will be evaluated with respect to the flywheel design. The first goal is to evaluate the necessary design specifications for flywheel energy storage located at various points within the grid and at wind generation sites. In contrast to electrochemical batteries, flywheels can have flexible peak power and energy storage configurations which are not tied to electrochemically dependent thermal and life degradation limits. Using data from NREL’s Western Wind Integration Study, as well as real-world data from the Austin, TX Pecan Street Project, which records daily home consumption and generation data from PV installations, an optimal flywheel energy storage system may be sized for increased penetration of renewable sources within the grid (Figure 2).

The second goal is to use the flywheel sizing results to evaluate, optimize, and include game-changing technologies and approaches into the flywheel design. Such technologies will include using high temperature superconducting bearings to reduce losses for long-term energy storage and high strength nanocomposite materials to increase energy storage capacities. Alternate design approaches will include a subsurface hubless flywheel design which increases specific energy storage capabilities by integrating bearing and motor generator components into the energy storage rotor structure and eliminates massive and costly stator containment (Figure 3).