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# Torsion Spring-Based Mechanical Energy Storage for Renewable Energy Systems: Design and Performance Evaluation

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## Extended Abstract

To combat climate change, economies around the world will need to rapidly transition away from fossil fuel-based energy. Renewable energy sources, such as solar and wind power, offer a path toward sustainability [1], but are susceptible to production fluctuations and cannot produce power on demand. To combat the intermittency of renewables, robust and reliable energy storage systems are needed to produce a stable energy grid system [2]. Current grid-scale energy storage solutions include pumped hydroelectric systems, and chemical battery systems, which have significant environmental and geographical impacts, disrupting natural ecosystems. New energy storage technologies will need to be developed to meet the demand of a transitioning energy grid, and mechanical energy storage systems show promise to address the issues with current energy storage technologies.

The present research examines the possibility of using conventional steel springs as a form of grid-scale mechanical energy storage. Springs were chosen as a potential energy storage solution as they offer promising energy density and can be scaled with modular design, allowing the system to meet the demands of various grid-scale energy storage applications. The proposed design stores potential energy using flat spiral torsion springs connected in series to form modular spring banks. This paper will investigate both the theoretical limits of steel torsion spring storage, as well as the practical design elements and physical performance of this storage technology with a prototype.

Factoring in the maximum possible packing efficiency of the spring banks, initial designs of a pilot scale spring mechanical energy storage system reach an energy density of up to 357 $kJ/m^3$. In addition to the analytical evaluation of a pilot scale spring energy storage design, a prototype has been created to experimentally evaluate the design elements and mechanical inefficiencies of the energy storage device. The device's springs, structural elements, and gears were 3D printed to enable quick design iterations. A stepper motor doubles as both a motor and a generator for the device, and solenoids are used to regulate charging and discharging. The prototype demonstrates the functionality of a spring energy storage system, while also enabling a quantitative analysis of system efficiency.

Testing of the prototype revealed a peak system efficiency of 1.24%, with the device storing 164 Joules and discharging 2.04 Joules. This efficiency does not include the energy used by solenoids and control systems. While the efficiency of the prototype is low, an abundance of factors could have led to this result. It's likely that scaling the design down to the prototype scale and using almost entirely 3D printed components rather than precision machined ones resulted in much greater losses owing to friction. The stepper motor used for the prototype also has a very low efficiency as a generator, significantly reducing the system efficiency. Additionally, various electronics such as the motor controller, rectifiers, and relays would have contributed to further losses. Using higher quality components and materials coupled with a motor/generator better suited for this application would undoubtably increase the system efficiency for a pilot-scale system.

## References

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