UTC Project Information	
Project Title	Advanced Energy Storage System for Electric Vehicle Charging Stations for Rural Communities in the Pacific Northwest
University	University of Idaho
Principal Investigator	Herbert Hess
PI Contact Information	hhess@uidaho.edu
Funding Source(s) and Amounts Provided (by each agency or organization)	University of Washington PacTrans $40,000 University of Idaho $ 40,000
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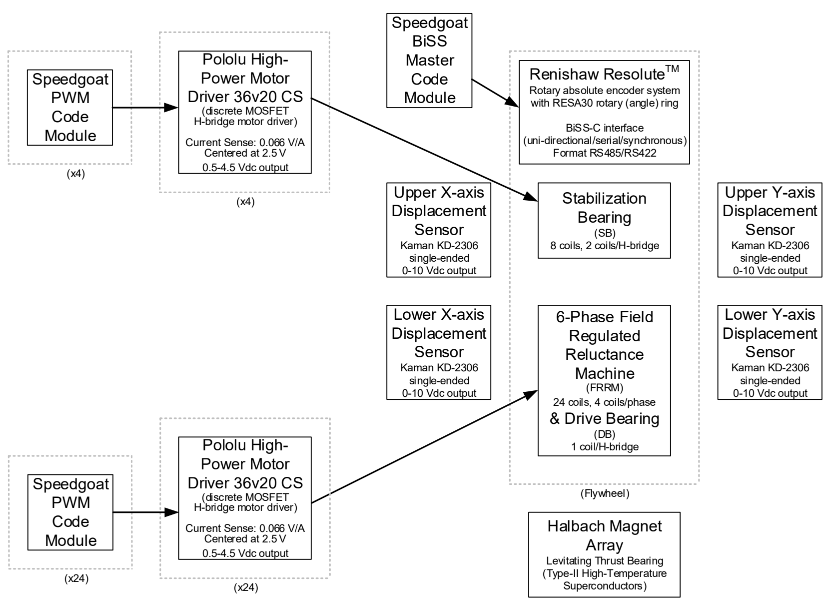
Agency ID or Contract Number	69A3551747110
Start and End Dates	August 16, 2020-August 15, 2022
Brief Description of Research Project	As electric vehicles (EV) become more available, a pervasive and dependable charging network must be built. The electric power grid serves many remote places, but EV charging stations are not widespread and electric distribution is not always reliable in rural areas. This project builds on a previous NASA investigation that we performed to create the FRRM as an energy storage device on the surface of the moon. At NASA Technology Readiness Level (TRL) 2 (concept formulation, simulation of basic properties and algorithms, and elementary experimental investigation of underlying science), our data-driven solution[†] appears promising. Our FRRM forms the basis of exceptionally energy efficient storage in support of remote EV charging in an effective and reliable manner. The FRRM's rotor itself is the rotating energy-storing mass, making for a compact bidirectional machine. Using advanced power electronic converter technology, we store energy and recover energy using the FRRM's unique topology. Although a prototype based on this design was not finished, our FRRM design has been documented in three Masters theses.

Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	This project developed mathematical models, appropriate computer simulations in MATLAB Simulink, and hardware functional testing of the sensor and actuator subsystems for a flywheel energy storage system. The mathematical models describe ideal sensor and actuator behavior. The simulation uses these models in relevant computations to evaluate the effectiveness of the proposed energy storage system. After the fabrication of appropriate hardware prototypes of this energy storage system, initial real-time hardware in the loop testing enabled verification of modeling assumptions and limitations. The electrical current sensor is well defined in the mathematical model and is based on the manufacturers' data for the actual hardware. The current sensor is successfully implemented in a one-dimensional prototype. The electrical current actuator is mathematically modeled using H-bridge PWM current control. A proportional-integral control algorithm then provides stable operation of the prototype in one dimension. The position or displacement sensor is also well defined in the mathematical model and is based on the manufacturers' data for the actual hardware. The physical hardware testing was notably consistent with the mathematical model and MATLAB Simulink simulations. For all three sensors and actuators subsystems, the physical interface is described and documented in our report for integration into the flywheel energy storage system. A functional block diagram of the control for the energy storage system is shown in the figure below. This has been implemented in simulation. Experimental implementation in one dimension has been accomplished.



	The hardware for the six-dimensional energy storage system is nearly complete. A completed stator for the machine is due back from the contractor in early April 2023. The remaining components are on hand. We have fabricated an air bearing as a means of temporarily supporting the rotor structure until we are able to support the rotor in four dimensions. We expect to assemble the machine in April 2023. This completes what we expected to accomplish in the PacTrans proposal. Work will continue with funding from other sources.
Impacts/Benefits of Implementation (actual, or anticipated)	The research establishes the feasibility of the Active Magnetic Bearing control software and hardware for our Flywheel Energy Storage System (FESS). --A single-axis active-magnetic-bearing academic test fixture, used to test the sensor and actuator subsystems, proves that the concept of an active magnetic bearing can be implemented in a stable fashion. --The appropriate modeling is proven effective, reliable, and fast enough to accomplish the physical hardware support for the selected machine topology. --Construction of the physical hardware shows that the concept of a shaftless flywheel is feasible. Expansion to four axes, then six axes will be realized with a strong likelihood of success, employing follow-on funding. --We have established a reliable means of storing energy in remote locations using only the hardware and control software. This is a feasible alternative to battery storage, valid over a wider range of environmental conditions.
Web Links • Reports • Project Website	Hess, Herbert L., "Advanced Energy Storage System for Electric Vehicle Charging Stations for Rural Communities in the Pacific Northwest," Final Project Report, April 2023.