Future Power Solutions for Exploring Hypothesized Surfaces: Hybrid Energy Storage System

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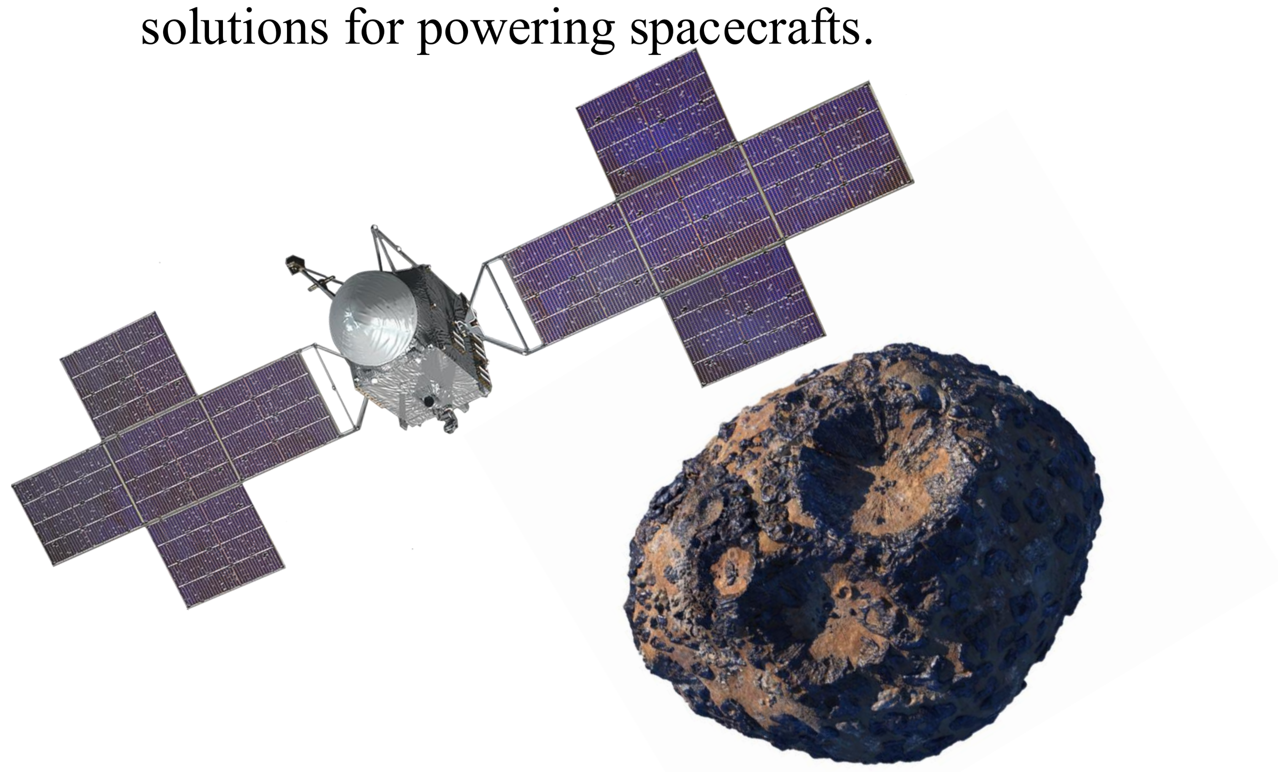
Sponsor: NASA Psyche Mission

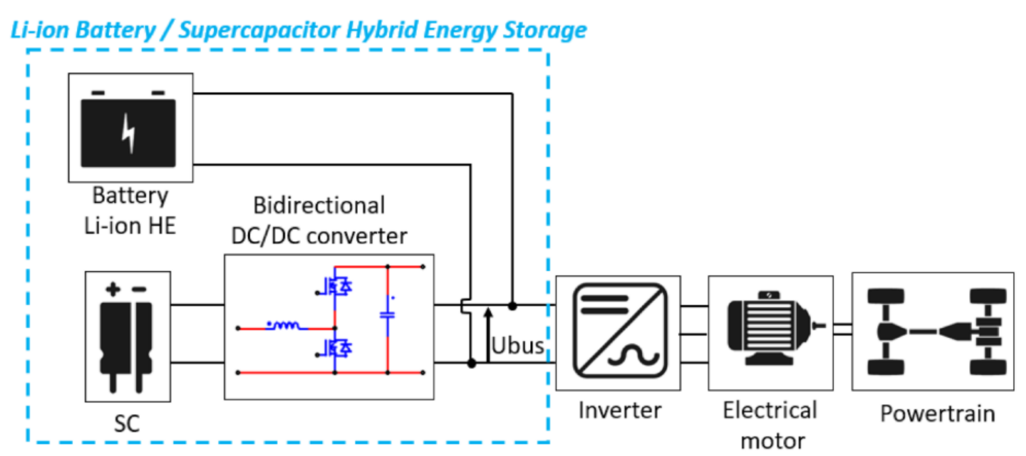
Introduction and Problem Statement

The NASA Psyche mission launched in 2023 and is slated to arrive at the (16) Psyche asteroid in 2029, where it will remain in orbit for 2 years studying and observing the asteroid. With Psyche's unique makeup and distance from Earth, it poses a unique challenge for designing systems that may function within its conditions. Future potential missions may require new, improved, or unique power solutions for powering spacecrafts.



Concepts and Theory

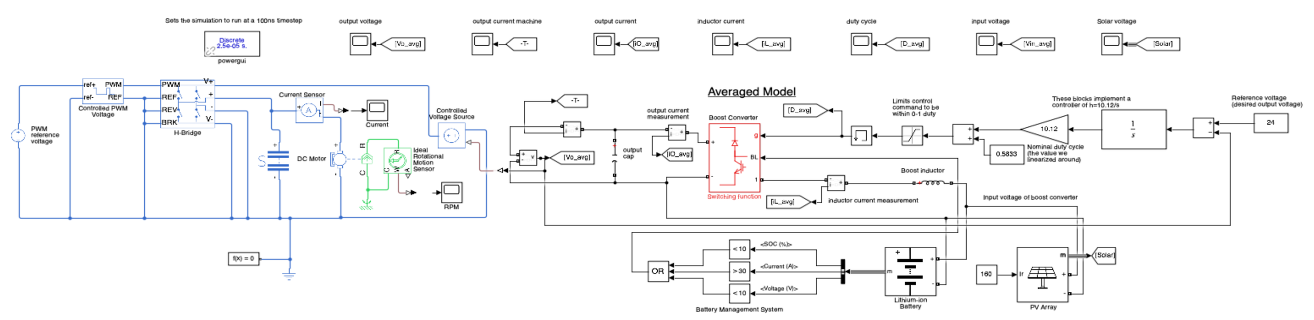
A hybrid energy storage system (HESS) makes use of super-capacitors in conjunction with lithium-ion batteries. Lithium-ion batteries and super-capacitors have been used in an extensive array of electronics for small and large scales. The lithium-ion batteries work as bulk energy storage but are limited in their discharge rate as well as operation conditions. Super-capacitors are limited in their energy storage capacity but have a quick discharge rate. Together, the capacitors and battery work to provide adequate storage and a discharge rate fast enough to handle inrush current and transience in the power -



Concepts and Theory Continued

-system. Overall, HESS increases power system efficiency. Furthermore, increasing the efficiency of the power storage can increase the viability of solar power in decreased sunlight conditions like those around the Psyche asteroid.

Simulation



The simulation shows the model of the Hybrid Energy Storage System (HESS) . The model includes the boost converter, the Battery Management System (BMS), the solar panel and the and the motor with the supercapacitor.

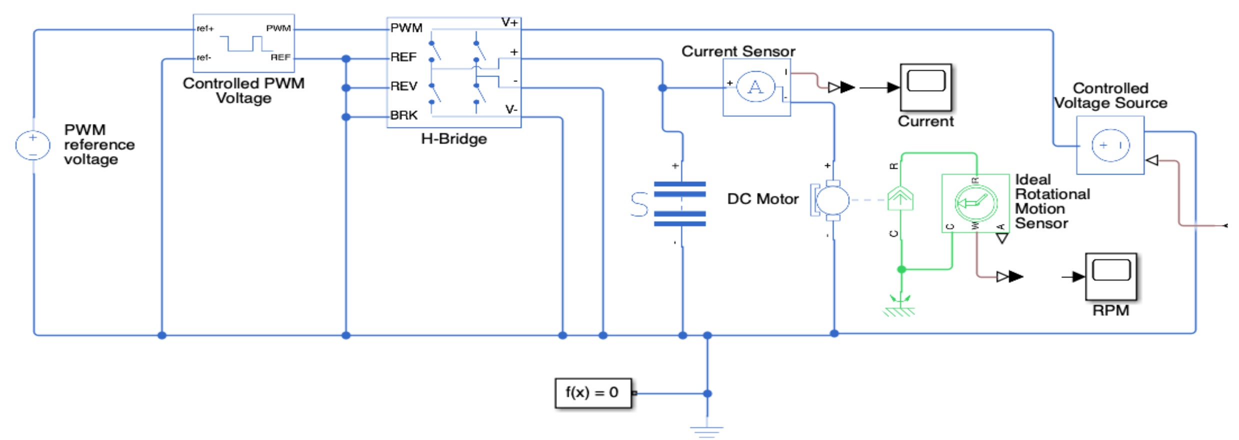


Image of the DC motor w/ Pulse Width Modulation (PWM) implemented, and the supercapacitor connected in parallel.

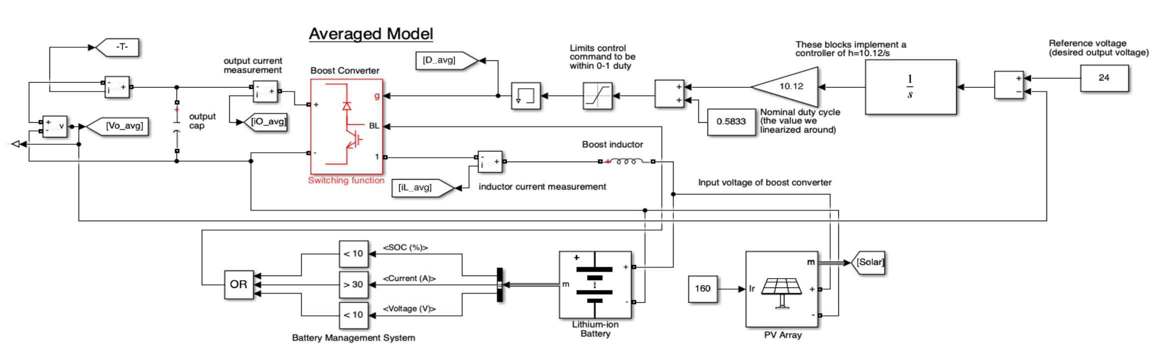
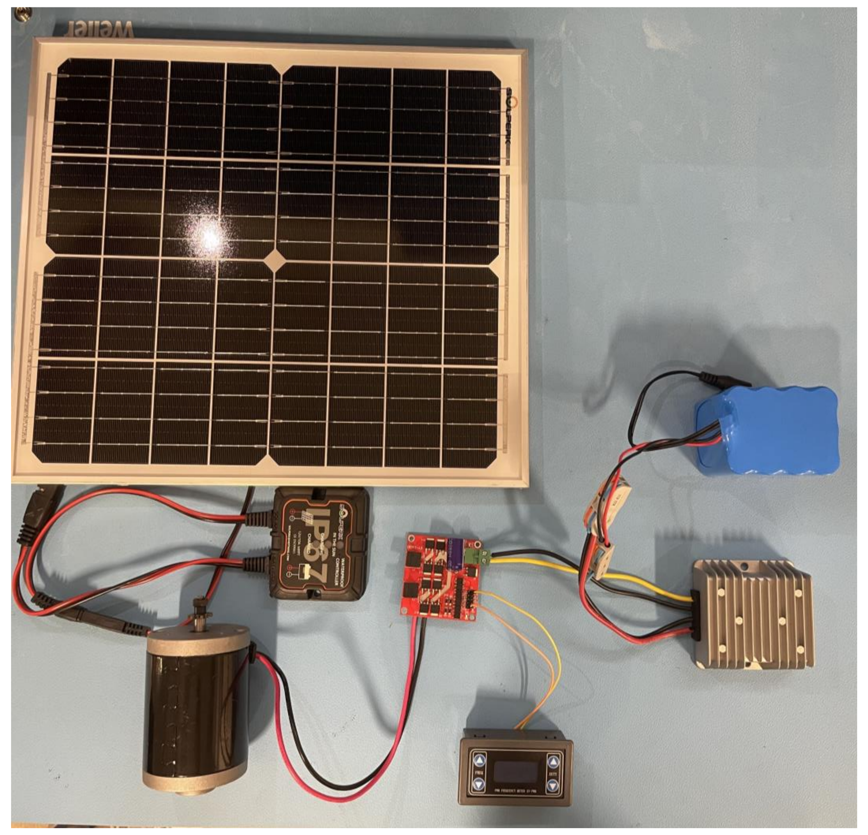


Image of the Boost Converter; Design derived from Prof. Mike Ranjram
https://faculty.engineering.asu.edu/ranjram/

Physical Prototype

The physical prototype represents a technical proof of the HESS system. With paired DC motors providing a load, super-capacitors and lithium-ion batteries provide power. A small solar panel is used for power generation and a DC-DC converter to convert between 12v storage and 24v loads. The super-capacitors successfully handled inrush current and any transience in the circuit while the lithium-ion batteries provide steady state power. A MPPT/BMS are integral to the solar panel for controlling charging. The capacitors are sized in order to supply power to the motors when there is inrush current and any transience.

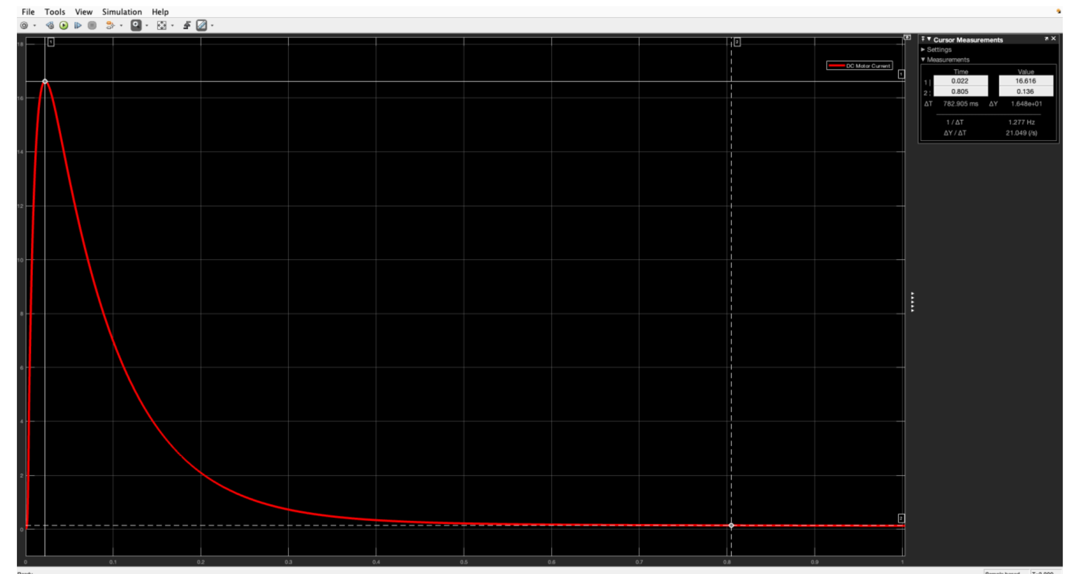


Limitations and Restrictions

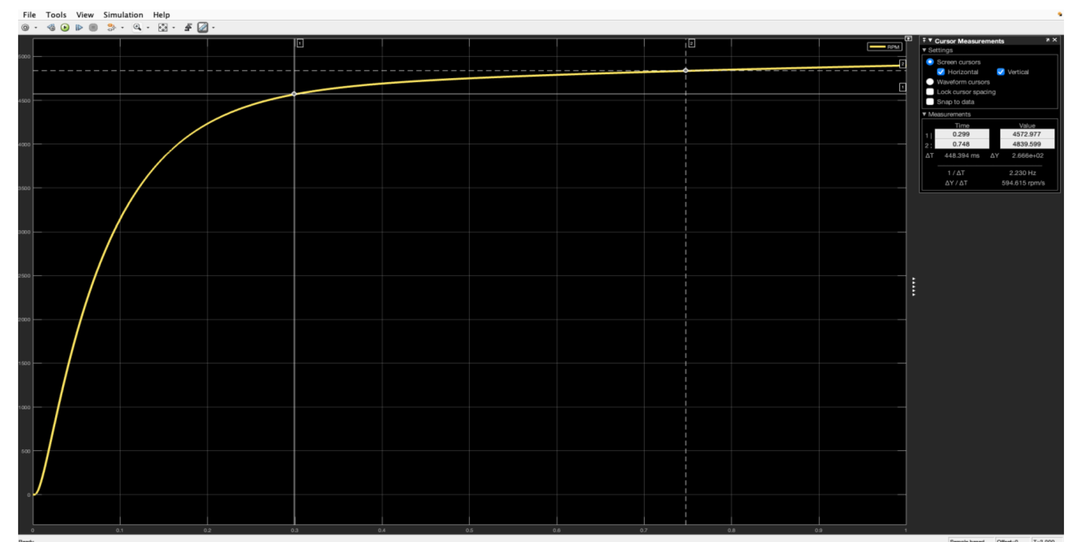
The physical prototype was limited in scale, component availability, and time. Ideally, a bidirectional DC-DC converter would have, for example, allowed for regenerative breaking. With additional time and resources, more custom components could have been designed from scratch to better suit our prototype. Furthermore, budget restricted the scale of the physical prototype to being a technical proof. Final implementation of the HESS design would require scaling in order to support the final load and power requirements. The physical prototype was built will scalability in mind.

Simulation Results

The motor current exhibited a peak value of 16.6 A during startup, and stabilized at a steady-state value of 136 mA.



The motor RPM began to saturate at approximately 4572 rpm and eventually reached a steady-steady speed of 4839 rpm.



Conclusion

A hybrid energy storage system, using lithium-ion batteries and super-capacitors, can successfully handle transience and supply DC loads. The HESS system allows lithium-ion batteries to be used for bulk energy storage and as a steady state energy source. The super-capacitors successfully handle inrush current and transience, preventing sudden or high discharge from the batteries. The HESS system is scalable to be able to supply variable loads. In the conditions of space and surrounding Psyche, the HESS system should work to increase the viability of solar panels by increasing the ability to store and use electrical power. The HESS should be capable of operating in the conditions of space and around Psyche. A HESS power solution increases the viability of solar power in low sunlight conditions, and the HESS viability will increase as solar technology increases.