Sandia National Laboratories

Design of a Storage System Testbed for Refinement of Rack-Scale Thermal Models

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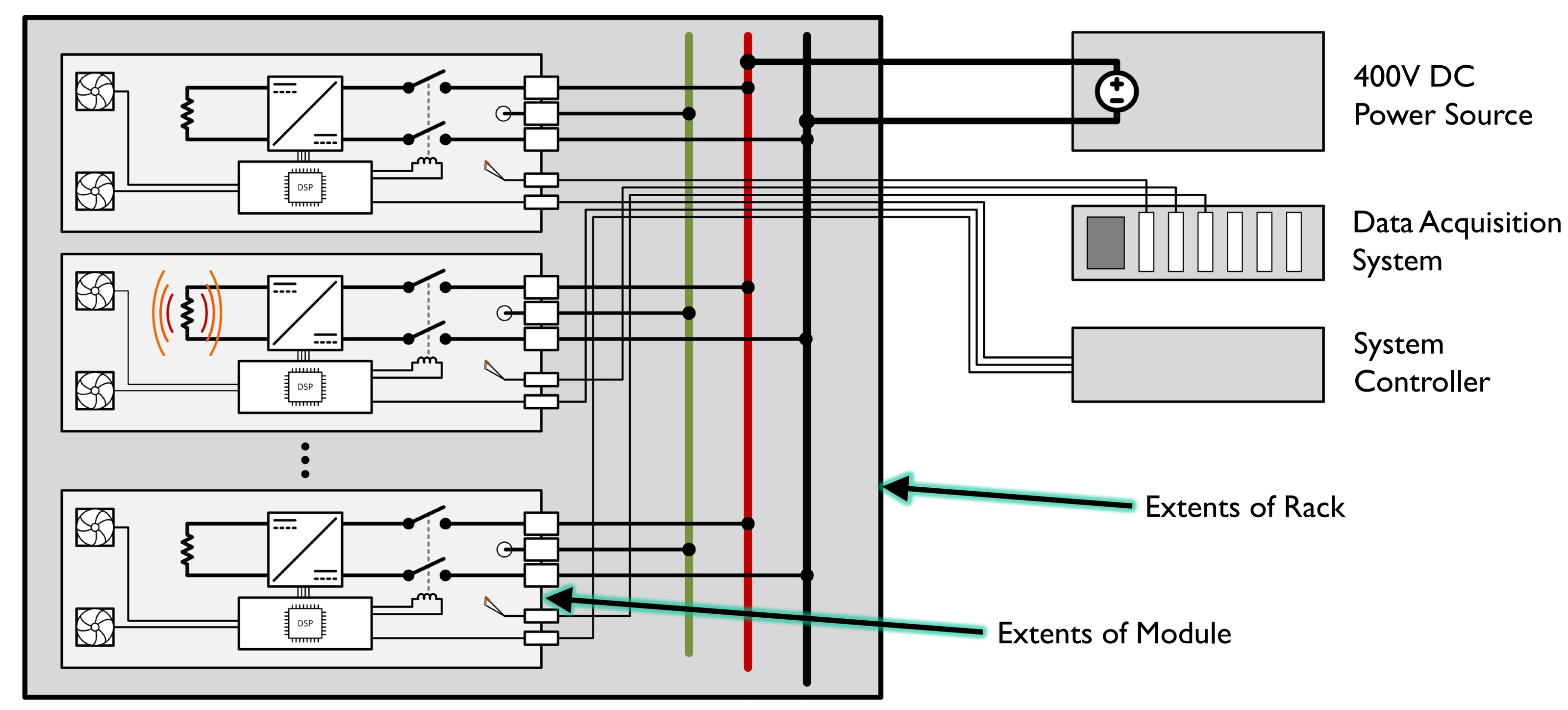
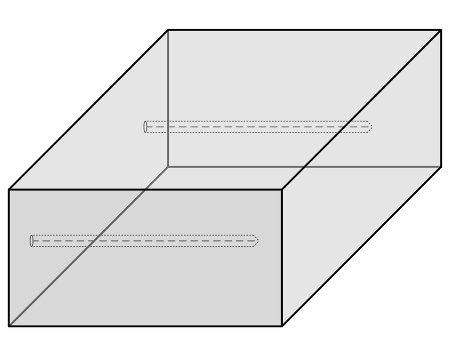
Introduction

- Integrating DC-DC converters into storage system modules opens new possibilities for system operation, including active response to cascading thermal runaway events.
- Previous work has show the feasibility of active electrical response to thermal runaway events: strategic dispersion of stored energy reduces the propagation rate and overall severity of cascading failures.
- The algorithm that orchestrates the response depends on accurate and computationally efficient models of thermal energy transfer within the storage system.
- The goal of this project is to design and construct a deeply instrumented energy storage system testbed to support the development, validation, and calibration of the thermal models that underlie energy dispersion algorithms.

System Concept



Module Design

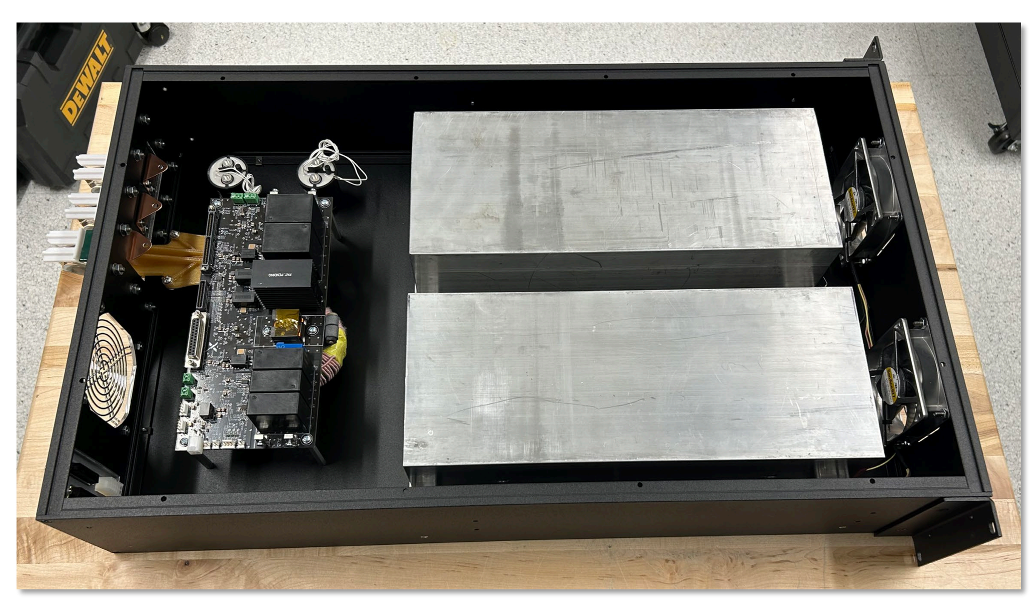


Heater Blocks: 6061 Aluminum blocks with embedded cartridge heaters emulate size, weight, and thermal conductivity of a Li-ion battery pack. Block dimensions are based on a 7.5kWh pack composed of prismatic cells. Cartridge heater power is regulated to emulate battery heat release profiles for different charge/discharge rates.

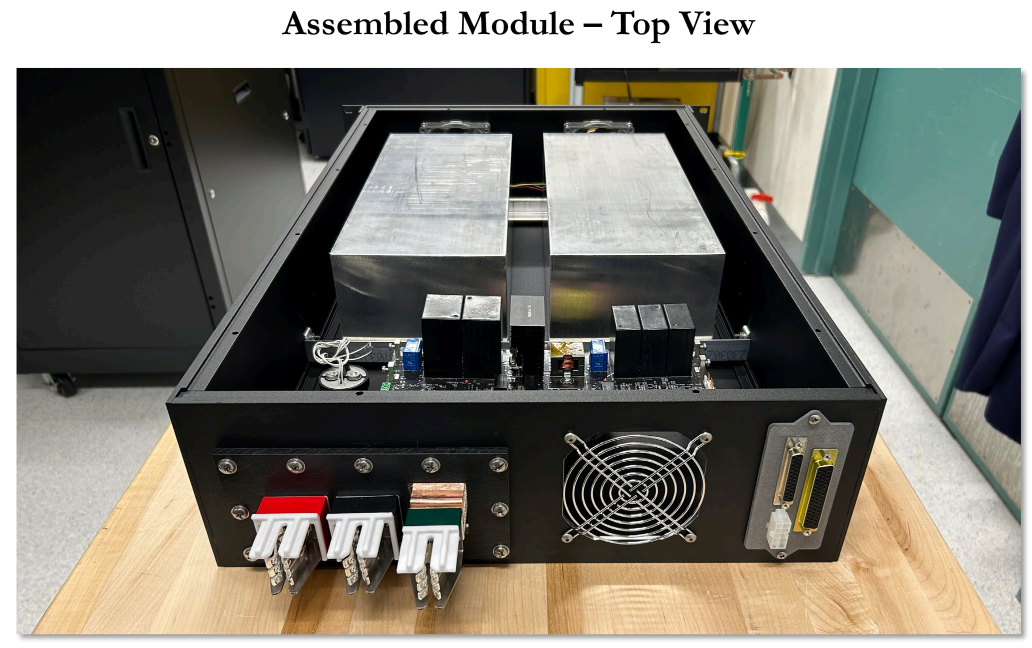
DC-DC Converter Specifications

Parameter	Value
Nominal Input Voltage	400V
Nominal Output Voltage	200V
Rated Power	1.6kW
Switching Frequency	100kHz
Max Temperature (Ambient)	85˚C

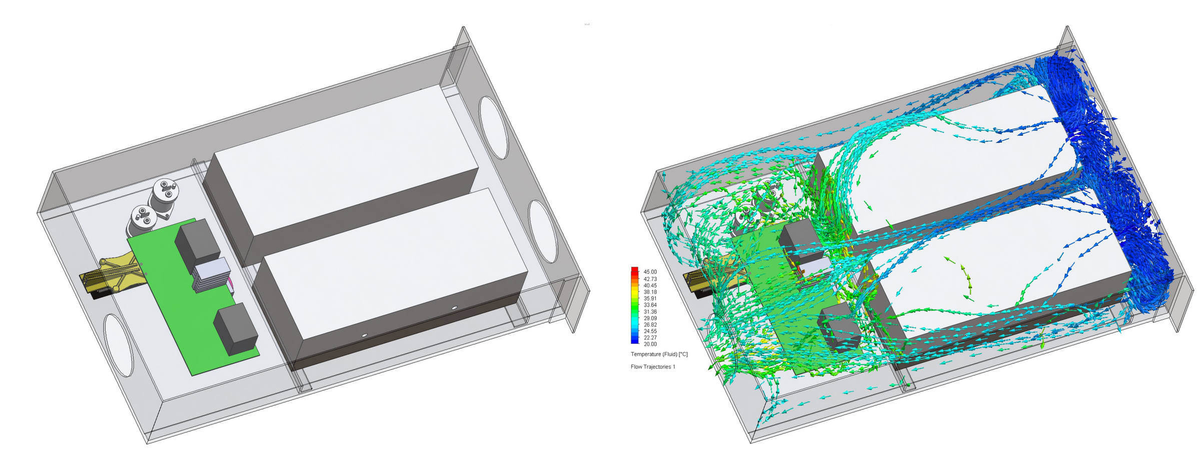
DC-DC Converters: Synchronous buck converters within each module regulate power delivered to the heater blocks. Converter control may be implemented locally with an on-board DSP or through a central system control board. The latter approach enables higher maximum operating temperatures.



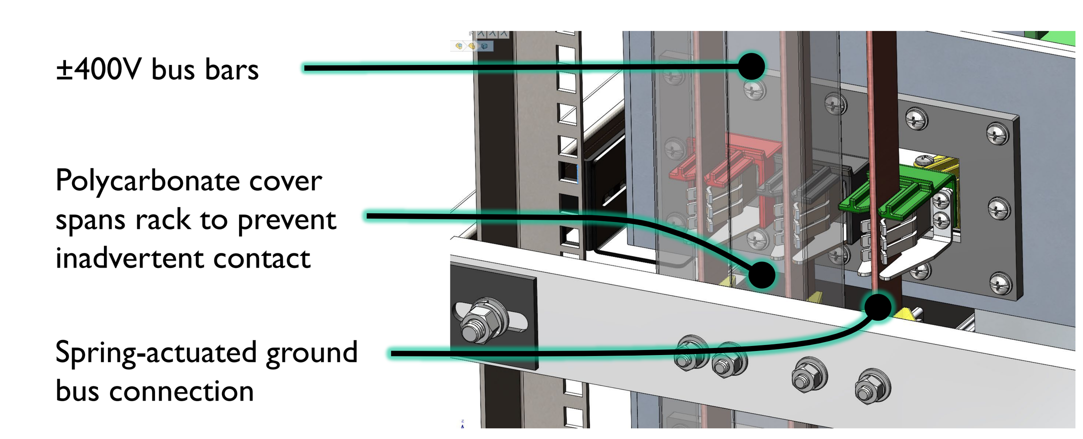
Assembled Module – Top View



Assembled Module – Rear View



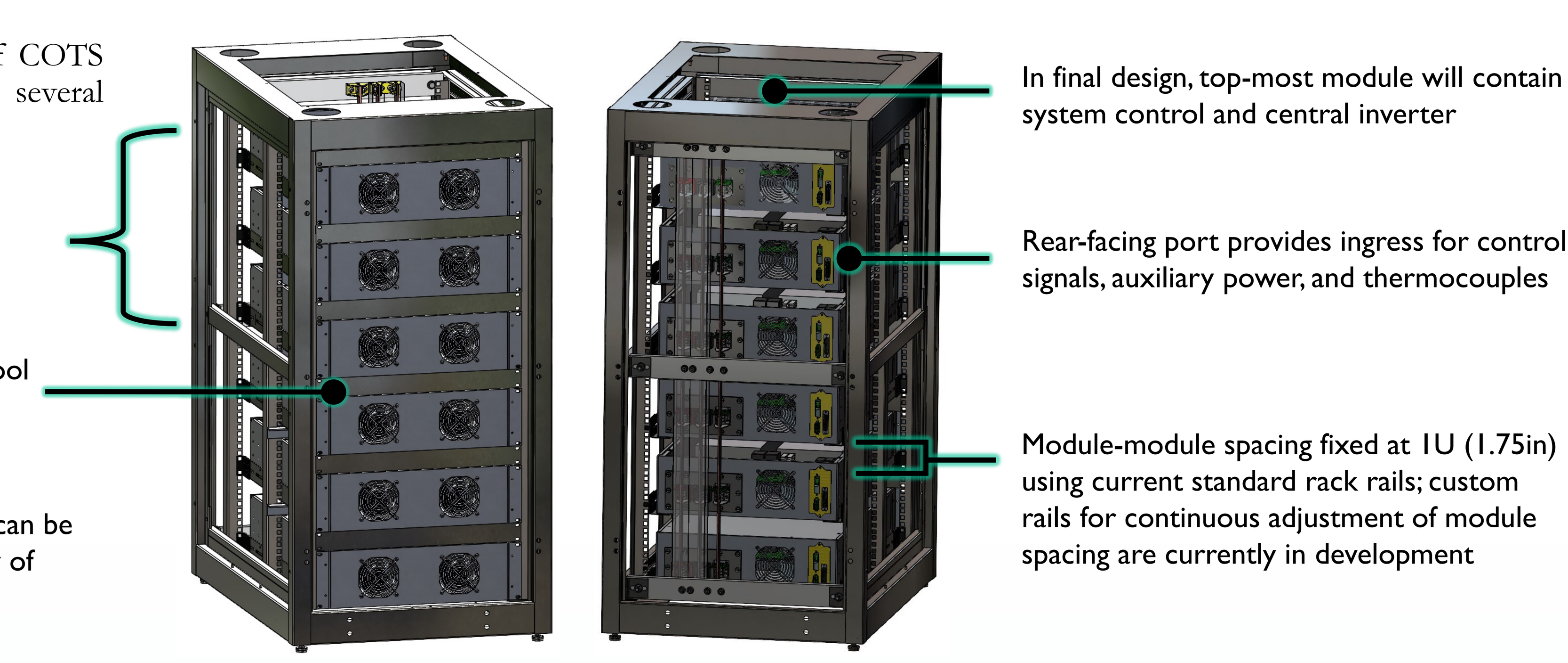
Module-Level Thermal Management: Forced air cooling within modules can be activated or disabled according to the needs of the experiment. Single-module CFD simulations were performed with simplified internal geometry to level-set forced air flow rate requirements for specific temperature rise values.

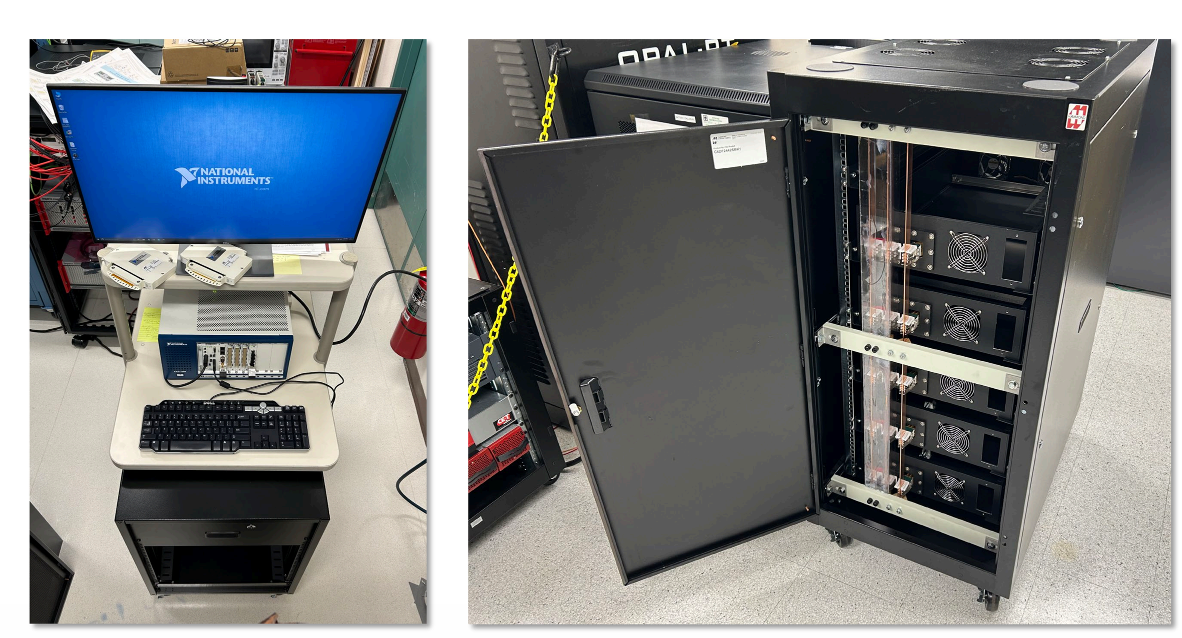


Bus Bar Interconnections: A custom make-first/break-last bus bar grounding solution was developed to ensure operator safety during module hot swap replacements.

Rack System Integration

Rack Structure: System primarily consists of COTS rack components, but is augmented with several custom machined or 3D printed elements





Thermal Instrumentation: Temperatures are logged during experiments using a dedicated National Instruments PXI data acquisition system. System contains a total of 192 T-type thermocouples: 25 per module and 42 distributed through rack.

Summary & Future Work

- Primary system function is to inform the development of rack-scale thermal models; next steps are to perform the experiments.
- Module-module spacing is a critical factor in determining likelihood of propagation. A design revision will include custom rack rails for precise control over module spacing within rack.
- Heater blocks emulate heat release during normal storage system operating conditions and are appropriate for experiments performed in general-purpose lab facilities. A solution for emulating conditions of thermal runaway is currently in development.
- Key design elements from this project will be incorporated into a rack-based hybrid storage system to be constructed in FY24.

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