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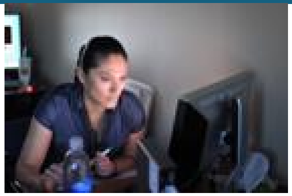
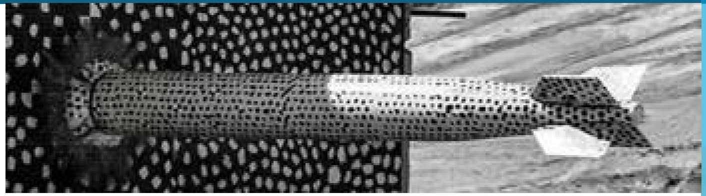
Dispersion of Stored Energy in Response to Thermal Runaway





PRESENTED BY

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Project Concept and Motivation

Cascading thermal runaway (TR) events present significant risk to large-scale utility battery storage installations

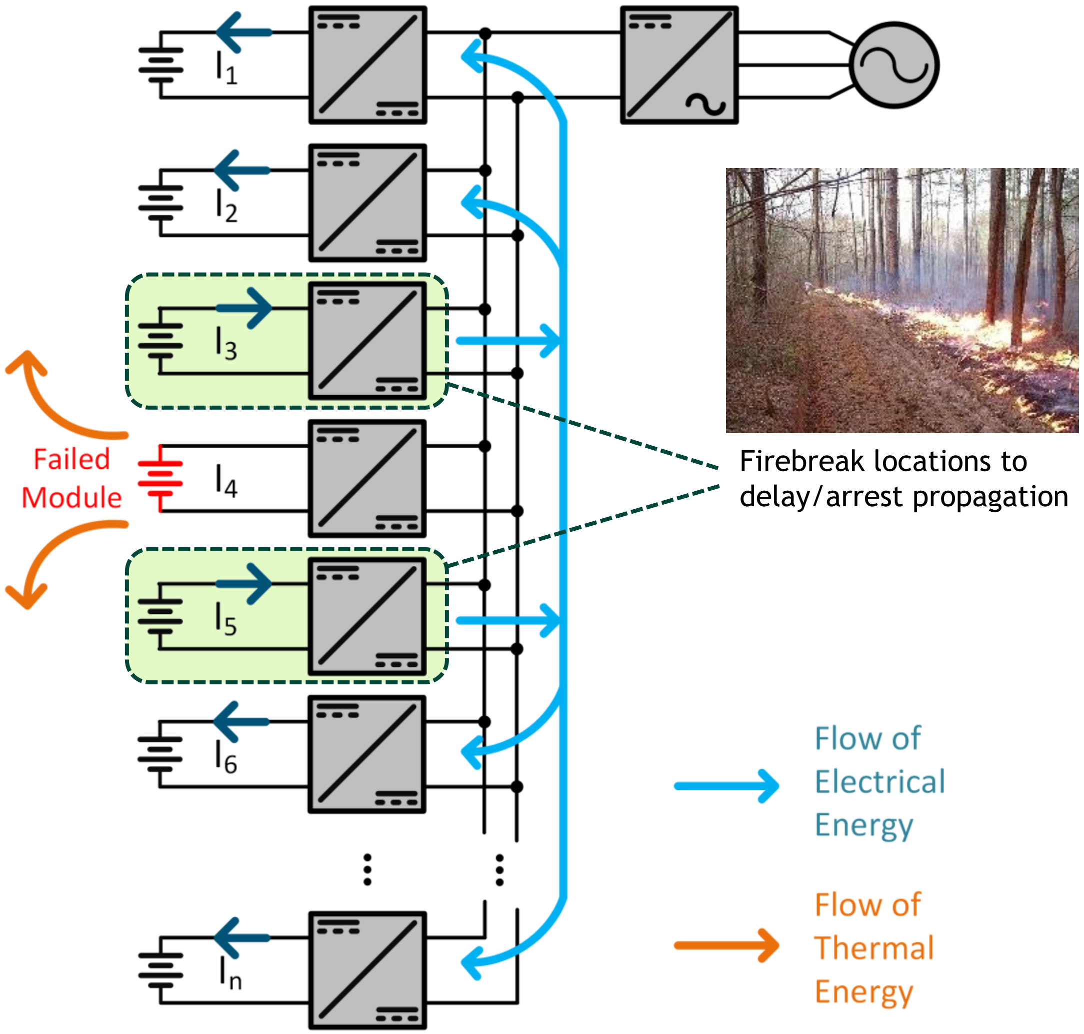
Current approaches to mitigating this risk involve electrical isolation, cooling, and fire suppression

Electrical isolation strands energy in subassemblies adjacent to the TR event, and does nothing to stop TR events once in progress

The likelihood of propagation of TR between subassemblies can be reduced through judicious dispersion of stored energy within the system, effectively placing "firebreaks" in the event's path

The goal of this project is to develop the electrical intervention mechanisms necessary to accomplish rapid energy redistribution in response to TR events

Rate of energy transfer is critical to response efficacy; goal for electrical system is to redistribute stored energy as rapidly as possible without damaging power conversion hardware



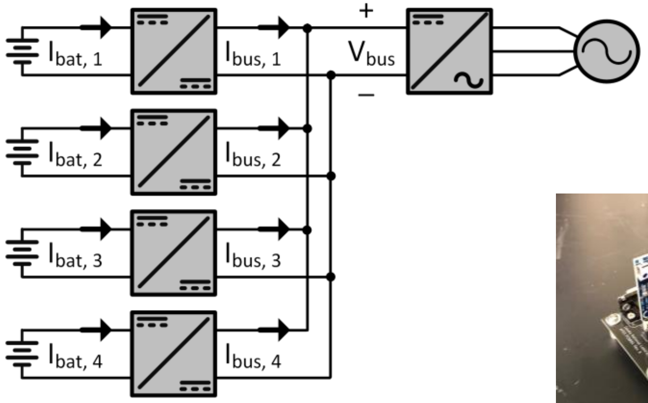
System Under Consideration

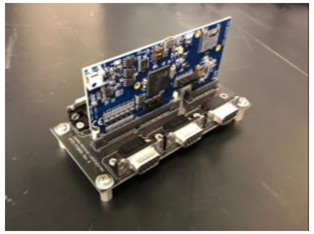
Two structural requirements for energy redistribution:

- Subassembly-level charge/discharge control
- A shared bus through which energy is exchanged

Simple example – Module-interfaced storage with parallel DC bus connection

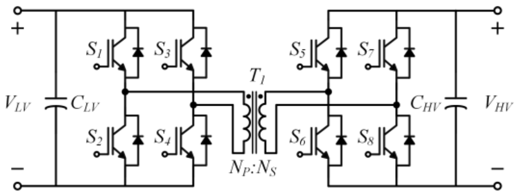
- A common system architecture for hybrid storage, "second-life" battery systems, etc.
- DC-DC converters perform charge control, DC link acts as shared bus after inverter disconnects





Controller Board

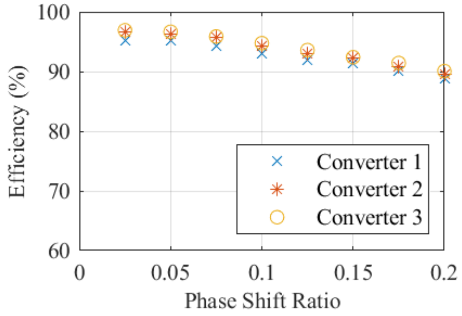
Low-Voltage Demonstration System

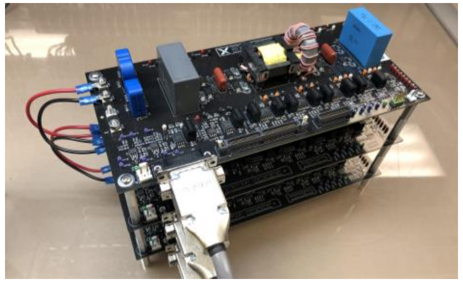


Dual Active Bridge DC-DC Converter

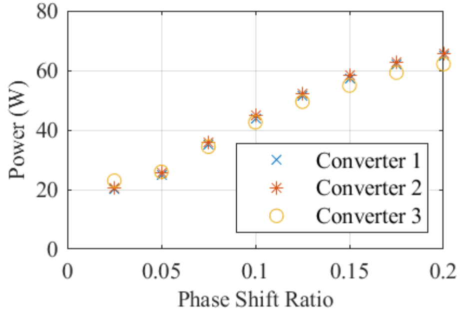
Converter Specifications	
Low-Side Voltage (V_{LV})	11V-15V, 12V nom
High-Side Voltage (V_{HV})	88V-120V, 96V nom
Switching Freq (f_{sw})	100 kHz
Rated Power (P)	±60W
Turns Ratio (N_P:N_S)	5:40

Experimental Prototype





Multi-Converter Stack



Results From Low-Voltage Prototype System

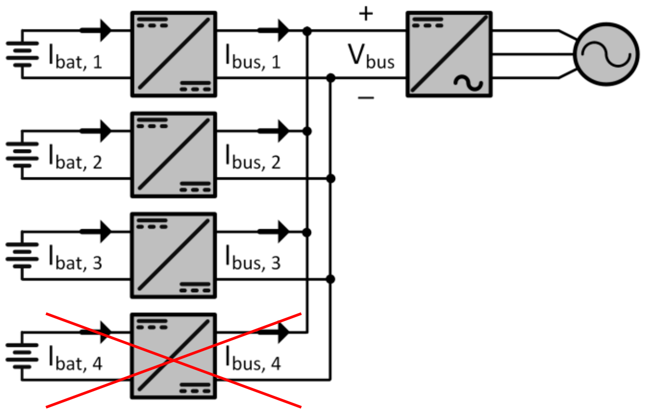
t < 0ms	TR event detected. Inverter has isolated from local grid connection and bus voltage has dropped to 0V.
t = 0ms	Subassembly 3 is to be depleted. Its converter begins regulating the DC bus voltage at 120V.
t = 200ms	Subassemblies 1 and 2, which are able to receive dispersed energy, begin operating in controlled current mode, charging their respective storage devices at 2.5A.
t = 1000ms	Subassembly 2 reaches maximum capacity and is no longer able to receive energy; its charging current drops to 0A. Charging current for subassembly 1 increases to 5A.

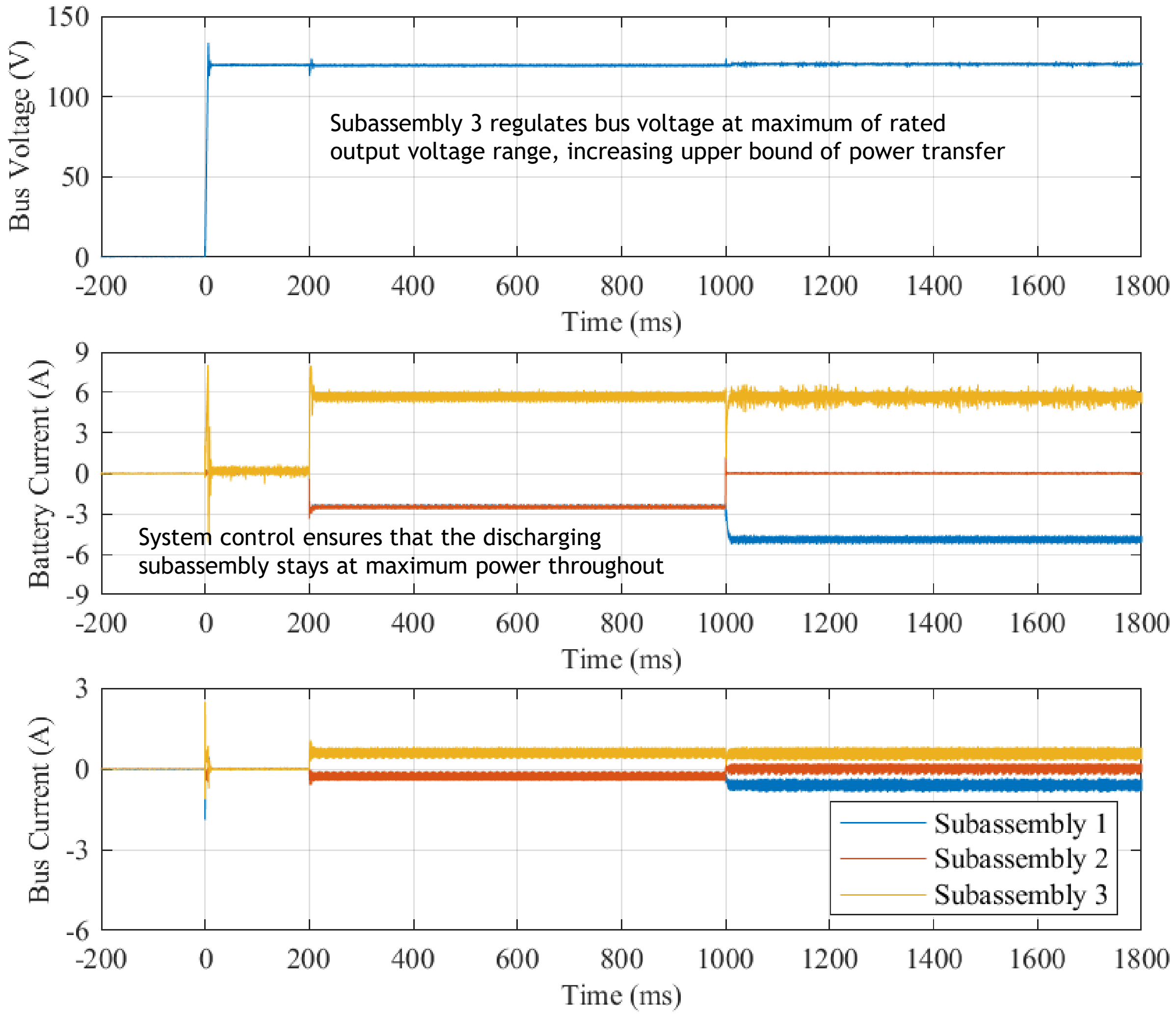
Storage Subassembly 1
Recipient of dispersed energy

Storage Subassembly 2
Recipient of dispersed energy

Storage Subassembly 3
Discharged to form firebreak

Storage Subassembly 4
Location of TR Event

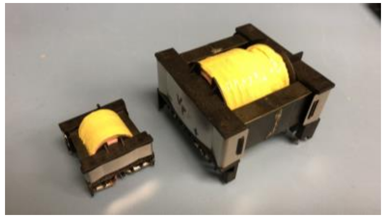




Conclusions and Next Steps

Key Outcomes:

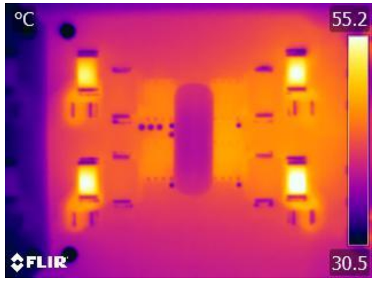
- Results from simplified low-voltage prototype system indicate feasibility of rapid charge transfer between battery subassemblies through shared bus
- Identified requirements for electrical system stability during large-signal transients resulting from energy dispersion actions (i.e. 0 to >100% power output)
- Developed multi-converter hardware and control platform, which will be used in the coming year to further study dynamic behaviors of paralleled converters and optimize rates of response
- Filed nonprovisional patent application on energy redistribution concept

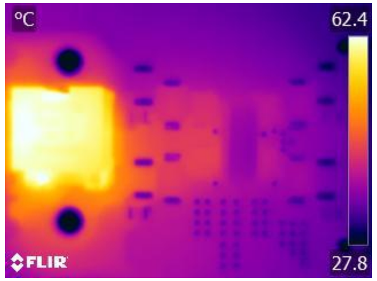


High-frequency transformers for current prototype (60W) and forthcoming converter revision (600W)

Next Steps:

- Replicate results at practical scale
- Quantify risk acceptance problem for operating converters beyond rated limits in emergency response scenarios
  - How far do you push a converter beyond its normal limits if it could potentially prevent cascading failures and total system loss?
  - How far can normal operating limits be pushed, and for how long?
- Implement control algorithm for optimal redistribution based on system configuration, location of fault





Component temperatures in DAB converter at low side (left) and high side (right) H-bridges when operating at 50% above max rated power

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