Sandia National Laboratories

Hardware Validation of a Direct DC-AC Dual Active Bridge Converter for Single-Stage Energy Storage Interfacing

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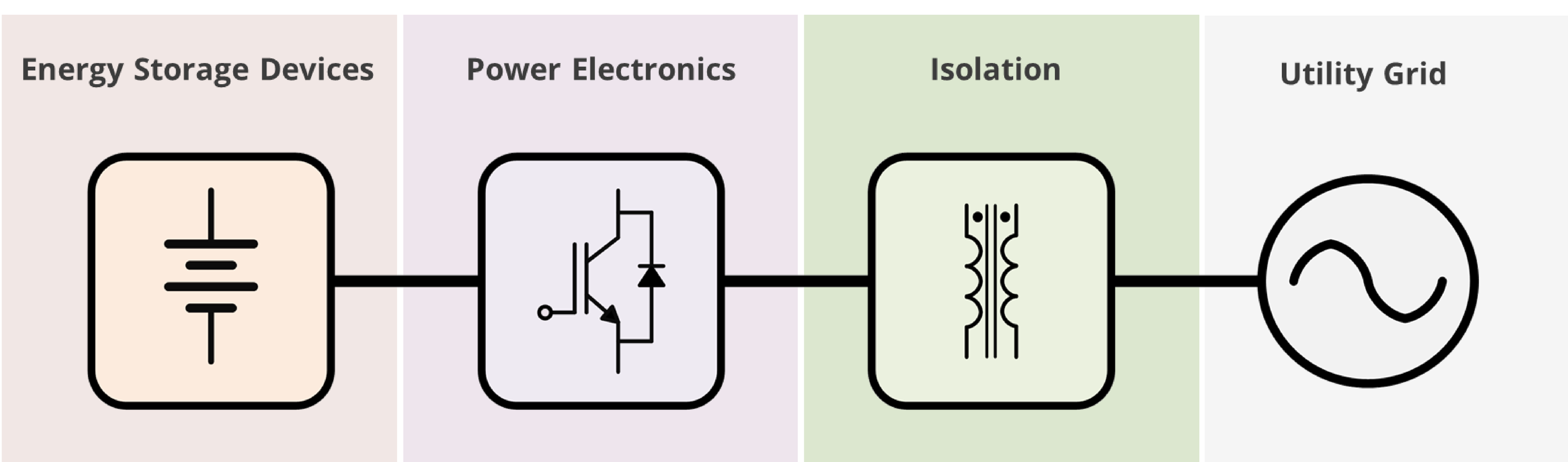
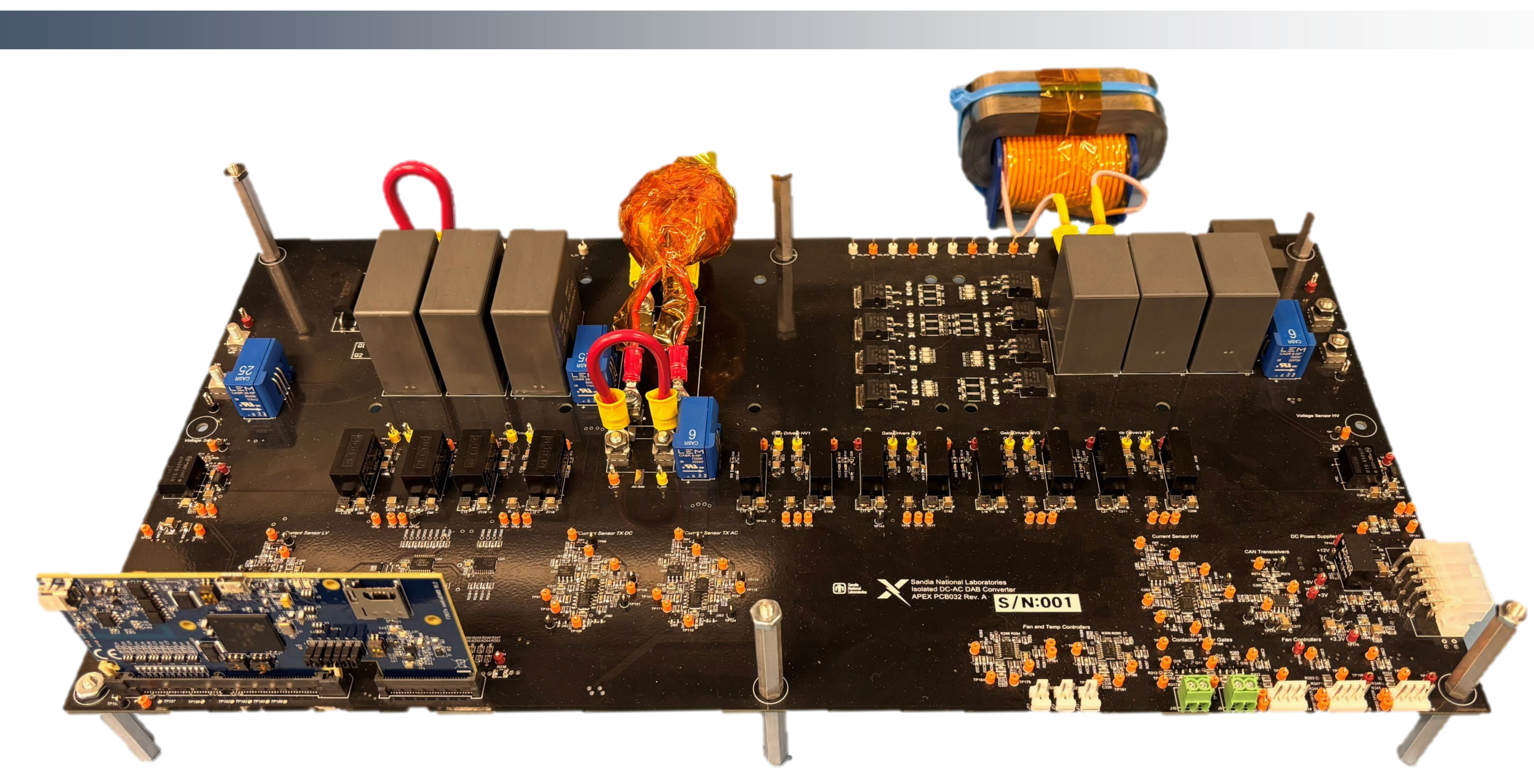
Objectives and Impacts



- This project aims to design an **isolated DC-AC converter** for integrating **energy storage systems at the module level**
- The converters' AC outputs are cascaded to achieve higher AC voltages for interfacing with the grid, **eliminating the need for a centralized inverter stage** and **large, costly LFTs for inverter grid connection**
- This module-integrated solution enables flexible interconnection of disparate storage resources within a single modular and scalable installation
- Through the use of modular power electronics systems each battery module connects to a dedicated DC-AC converter to optimally manage its charge and discharge cycling

DC-AC Dual Active Bridge Converter



Full Converter Ratings	
Nominal DC voltage, V_{dc}	48V
Nominal AC voltage, $V_{ac,pk}$	240 V
Output power, P_o	1.2 kW
Switching frequency, f_{sw}	50 kHz
Transformer Turns Ratio, n	1:6

Low Voltage Test Ratings	
Nominal DC voltage, V_{dc}	12 V
Nominal AC voltage, $V_{ac,pk}$	30 V
Output power, P_o	90 W
Switching frequency, f_{sw}	50 kHz
Transformer Turns Ratio, n	1:3

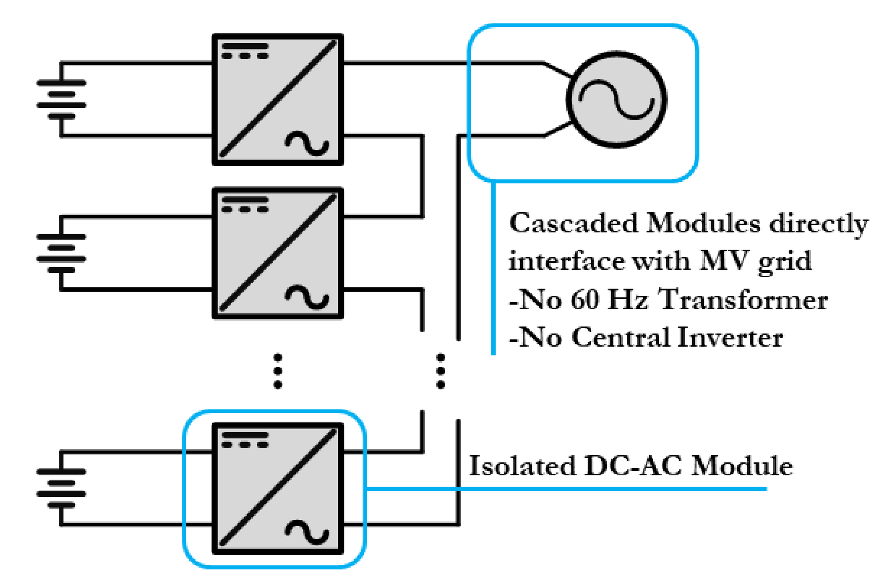
Summary & Future Work

- The **improved discharge mode DC current performance** demonstrated in simulation will be validated in hardware; its steady-state and transient performance will then be evaluated via closed-loop control
- Next, **charge mode simulation results** will be verified with hardware testing
- **Future research will focus on cascading several modules –** demonstrating resilient performance at each converter's battery port as well as the cascaded stack's AC port through simulation and experimental prototype validation

System-Level Motivation

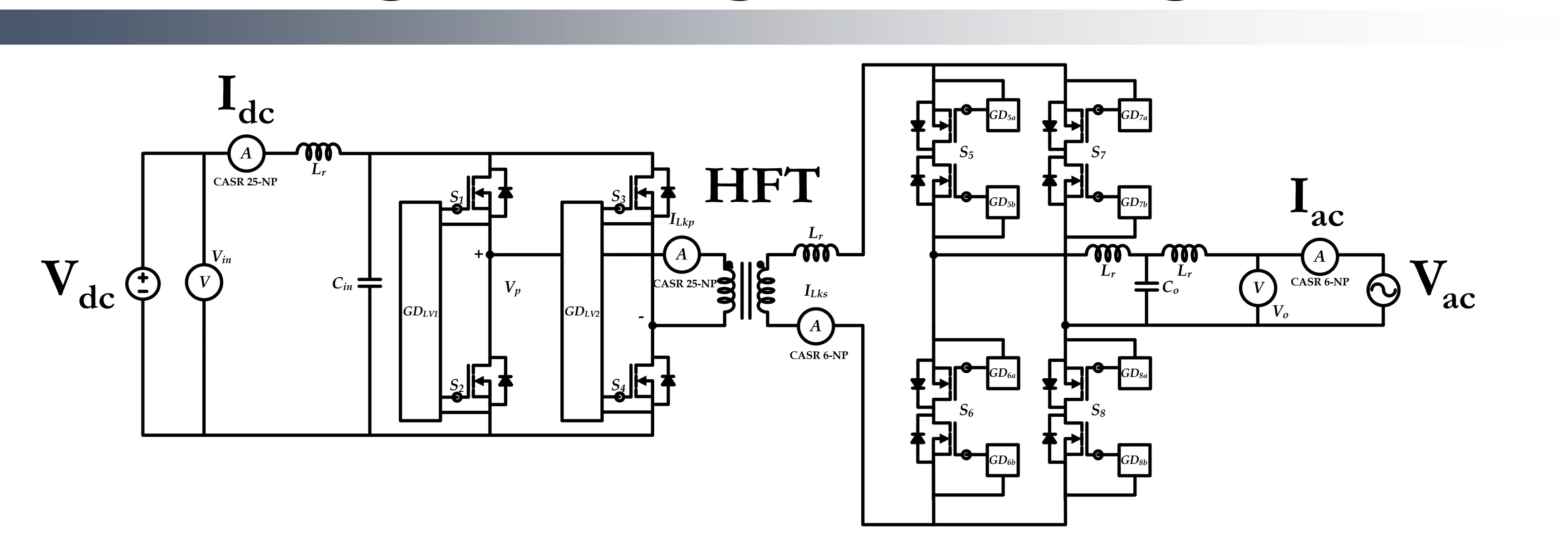
Combine traditional DC-AC conversion stages into a cascaded single-stage topology – reducing cost and increasing system reliability, while distributing individual control of energy storage devices

- **Leverage new technologies (i.e. bidirectional switches)**
- Incorporate sophisticated controls at the module- and system-levels

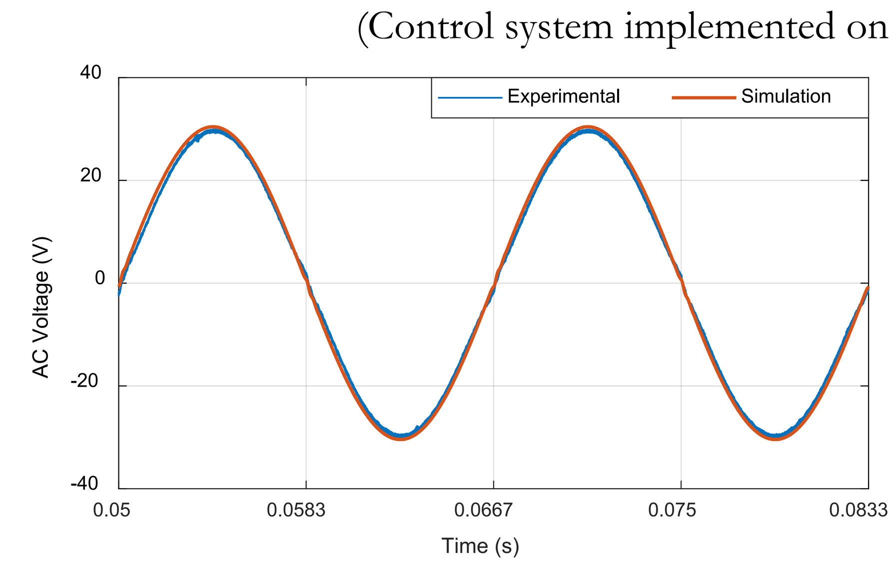


Cascaded Configuration

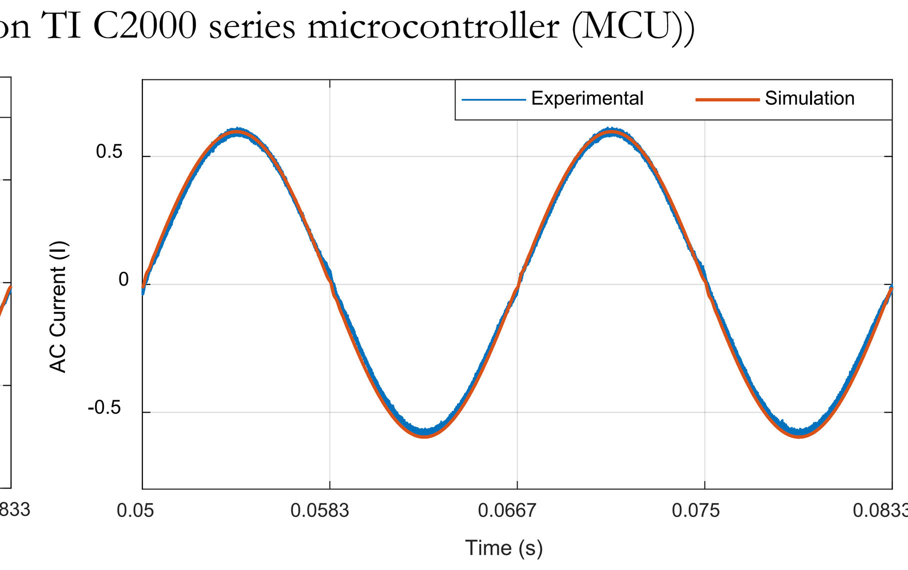
Low Voltage Testing – Discharge Mode



DC-AC DAB Experimental Prototype Circuit Diagram
(Control system implemented on TI C2000 series microcontroller (MCU))



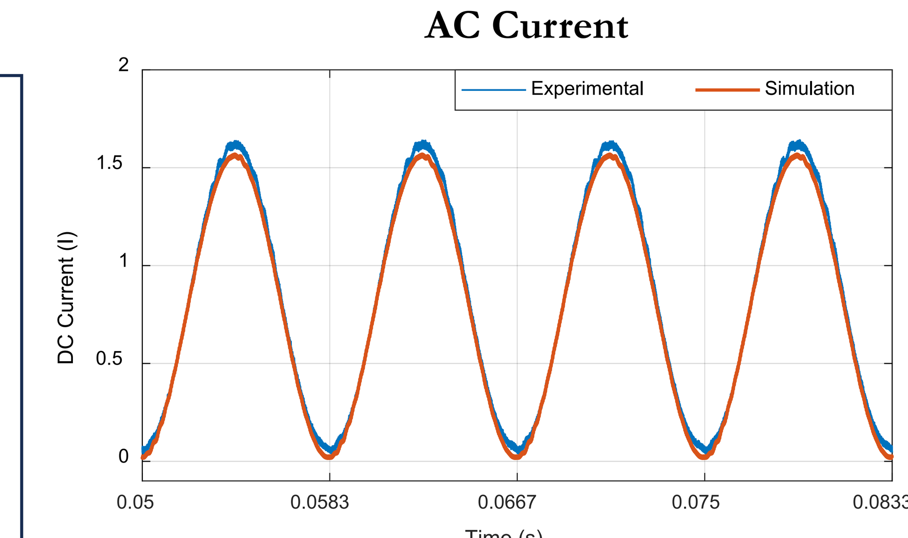
Experimental Prototype vs Simulation Results
AC Voltage



Experimental Prototype vs Simulation Results
AC Current

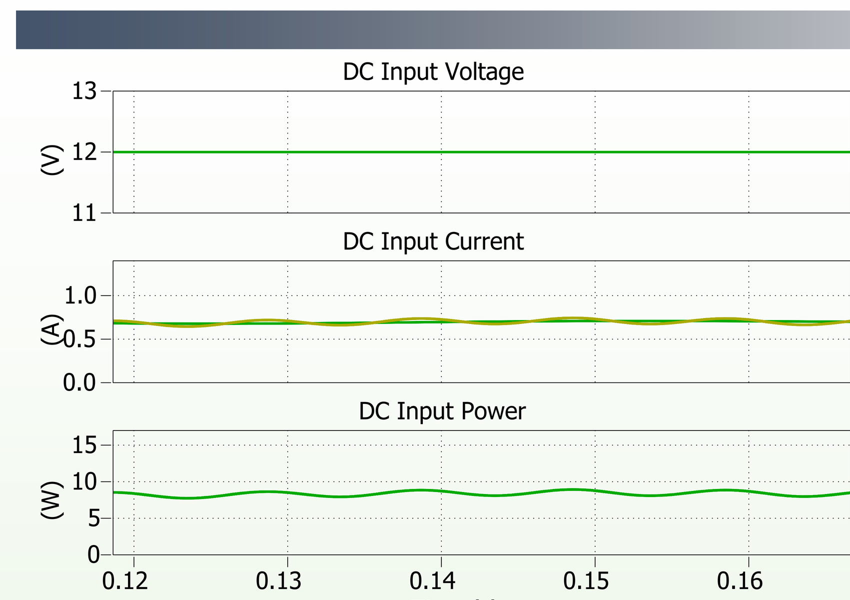
Key Takeaways

- Open-loop control experimental results demonstrate **performance parity** with the DC-AC DAB simulation model for discharge mode of operation
- This increases confidence in the experimental prototype's design…
- … and reinforces that modifications to simulation controller performance will be similarly seen in experimental testing

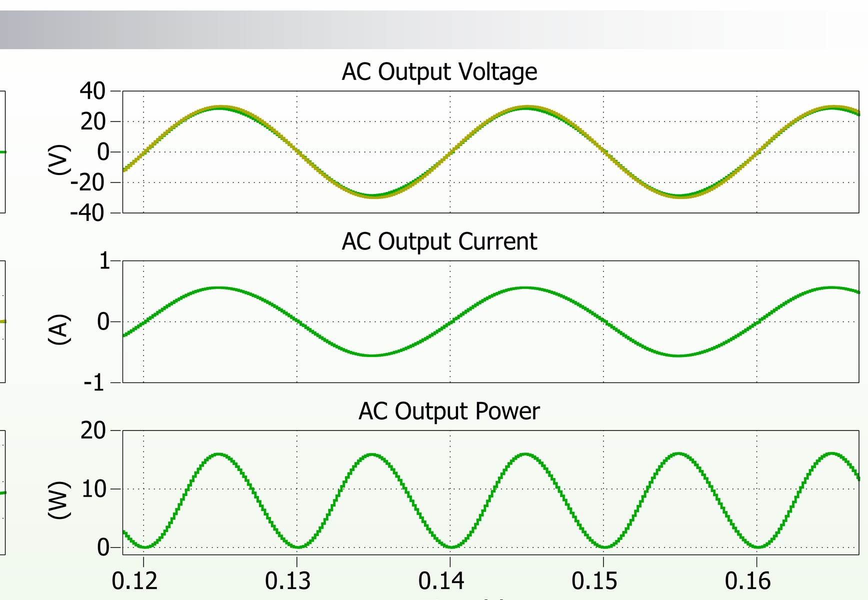


Experimental Prototype vs Simulation Results
DC Current

Improving DC Filtering Performance



Simulation Results: Improved DC-side filtering provides a better DC current waveform



Simulation Results: Improved DC-side filtering does not negative impact AC-side waveforms

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