Safety Enhancement of Energy Storage Systems Through Power Electronics Integration

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PROJECT PROFILE

Topic: Safety & Reliability
Strategic Pathway: Grow
Project start and finish: FY2025 – FY2026

PROBLEM

- Battery ES is considered an always-energized component (shock and arc flash hazards)
- Maintenance challenges: need to de-energize systems (insulated tools and PPE, LOTO), physical inspection of cables and connectors
- The objective is to build a power electronics system technology that can be integrated into BESS that supports bi-directional energy conversion providing inductive coupling between the battery/cells and the DC bus.
- A power electronic converter is required to interface a BESS with the power distribution bus; however, conventional solutions rely on hardwired physical connections
- An integrated inductive coupling solution enhances ES system safety and enables disconnection even during active power transfer.

APPROACH

- Interface power electronic converter designed with two inductively coupled stages for wireless power transfer
- Topology: double-sided LCC converter (supported by simulations and prior ORNL experience)
- Coupling configurations investigated: loosely coupled and tightly coupled (core-based).

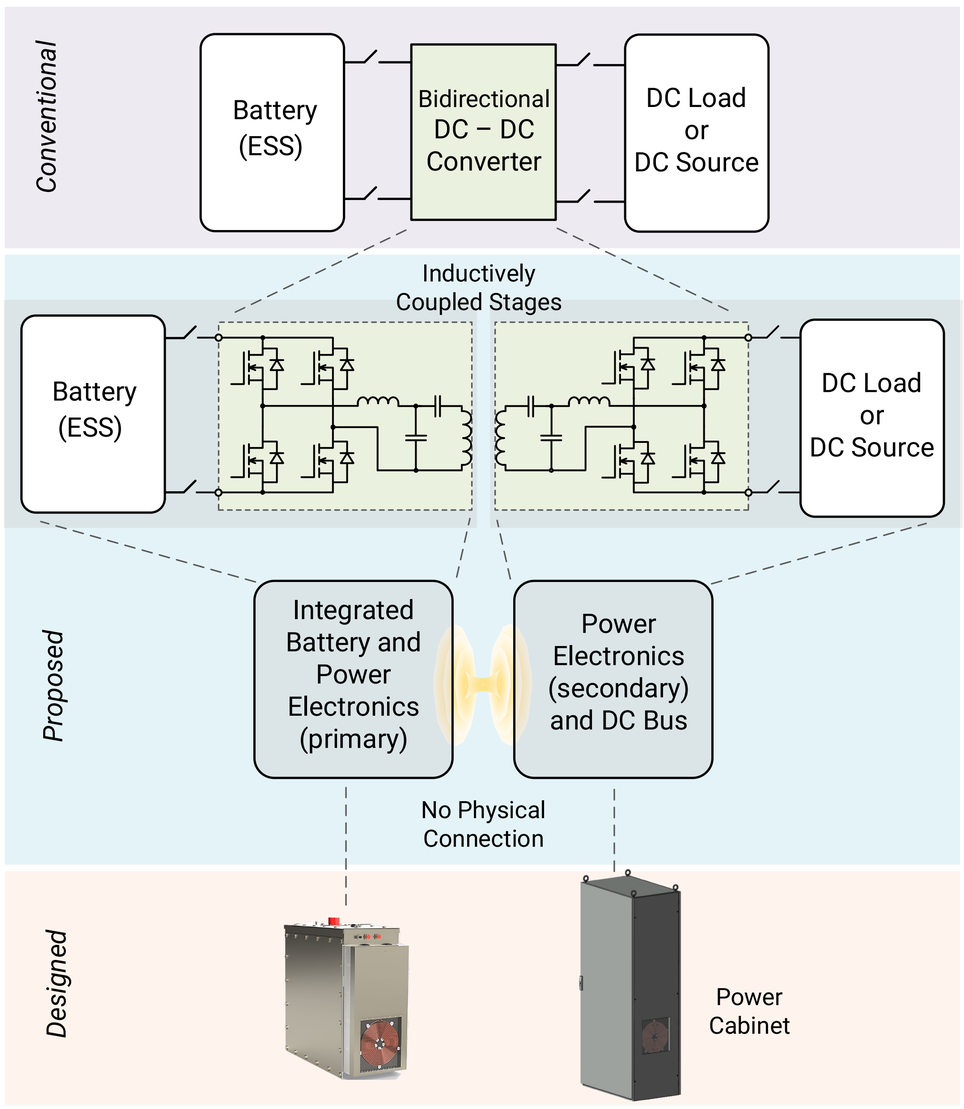
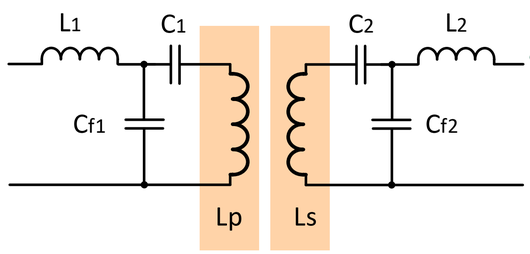


Fig. 1. System architecture.

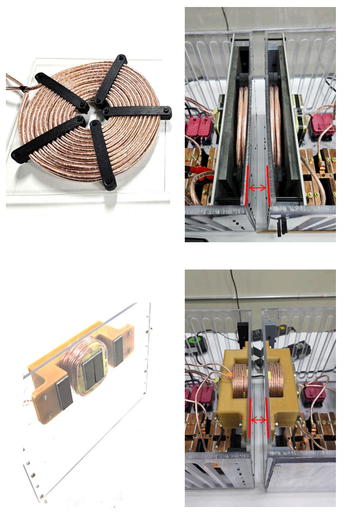
RESULTS

System Design and Analysis → Simulation Analysis → Hardware Development and Assembly → Experimental Tests

LCC – LCC Topology



Parameter	Value
Power	30 kW
DC input	600 V
Freq.	20 kHz
Resonant Tank	L = 116 µH
	C = 1.3 µF
	Cf = 0.5 µF



Planar coils
Turns: 24 (double layer)
L = 126uH

AMCC 400 cores
Turns: 28 turns
L = 174uH

Fig. 2. Magnetic Couplers.

- Magnetic couplers designed and built
- Developed and validated hardware components (full-bridge power stage, control board, power supply, resonant inductors, sensing boards, enclosure
- Developed control firmware
- Tested up to 10 kW

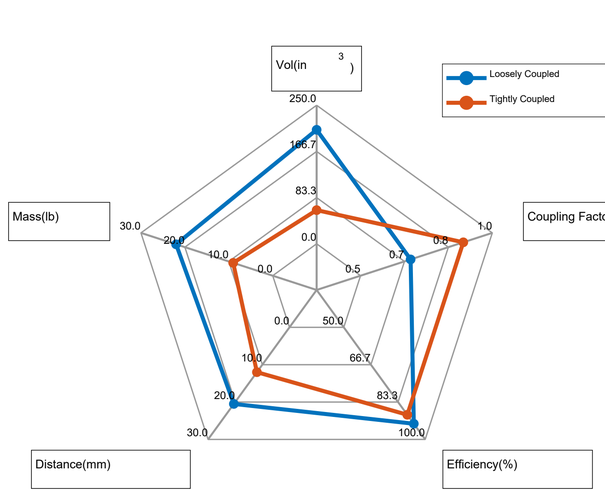


Fig. 3. Parameters comparison.

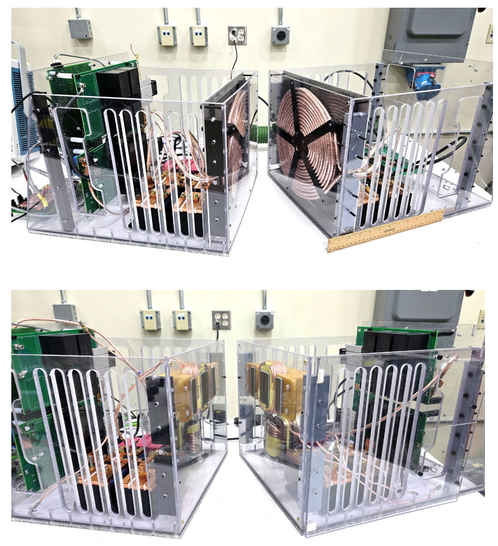


Fig. 4. Hardware prototypes.

CONCLUSIONS & IMPACT

- Design is highly modular and provide easy maintenance of ES technologies
- Technology concept demonstrated through two coupling methods
- Flexible design for a variety of use cases
- Easy to deploy and can be pulled while active
- Supports future system scalability
- Conference paper published: “Inductively Coupled Battery Energy Storage System”, IEEE PES General Meeting 2025

FUTURE DIRECTIONS

- Add voltage gain between the coupled stages
- Increase the switching frequency to improve form factor
- Build two modules to test parallelism
- Demonstrate the implementation in a use-case application (data center)

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