Contract #: DE-SC0011963 Program Manager: Dr. Imre Gyuk Technical Point of Contact: Dr. Stan Atcitty

SAND2015-7685C

Highly Efficient, High Power Density GaN-based DC-DC Converters for Grid-Tied Energy Storage Applications

APEI

Department of Energy Phase II SBIR

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SBIR Program Goals and Timeline

Design and develop a high efficiency (>98%) power dense (>10 kw/L) bidirectional GaN based DC-DC converter for energy storage applications

Phase I → Phase II → Phase III

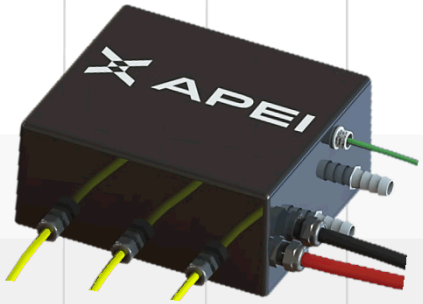
2014 2015 2016 2017 2018 2019

Developed a general hardware platform capable of using GaN, SiC, and SI

Evaluate the benefits of GaN and begin Ph. II design

Start Program

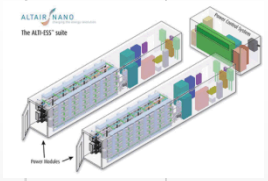
Key Deliverables: GaN DC-DC converter demonstrator (>99% efficient at 3 kW)



Design, build and test a >50 kW DC-DC for use in ESS

Key Deliverables: >50 kW DC-DC Converter

Interface converter between battery storage and Grid-tied inverter



Fully qualify DC-DC converter for use in commercial applications

APEI, Inc. will work with its partners to transition this DC-DC converter technology to a commercial product

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Program Target Applications

- Residential and light commercial (<10 kw)
  - Renewable energy storage and interface converter
  - Hybrid Electric/Electric vehicle
- Industrial (10 kW to MW scale)
  - Renewable energy storage and interface converter
  - Uninterruptible power supplies
  - Hybrid Electric/Electric heavy vehicle (locomotives, heavy machinery)

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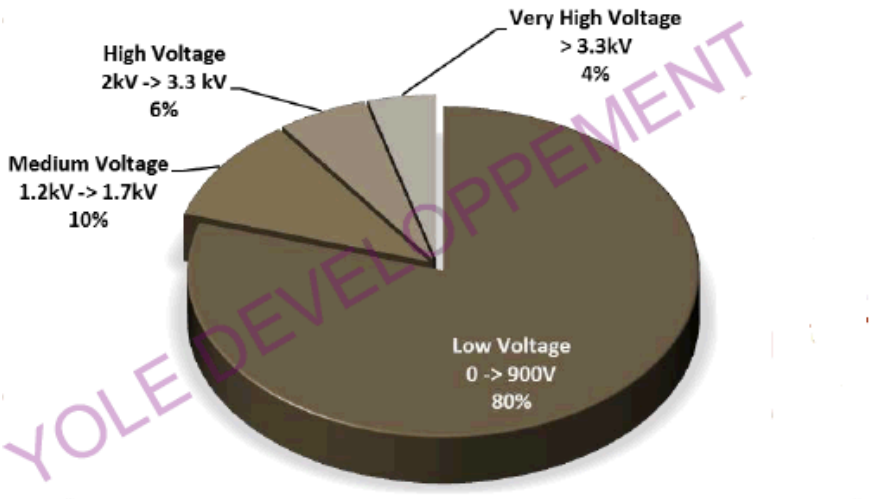
Power Electronics and Energy Storage Markets

Power Electronics Market

- **< 900 V** – GaN set to grow greatly in this area. GaN has the potential to offer higher performance and lower cost.
- **> 1.2 kV** – Currently, ideal Area for SiC; GaN research being done to penetrate this market



Power electronics market split by voltage range

Source: Yole Développement

Energy Storage Market

- The global energy storage market is expected to grow to $400 B by 2020 [1]

[1]. http://climatecrocks.com/2013/07/20/more-on-energy-storage-breakthrough-batteries/

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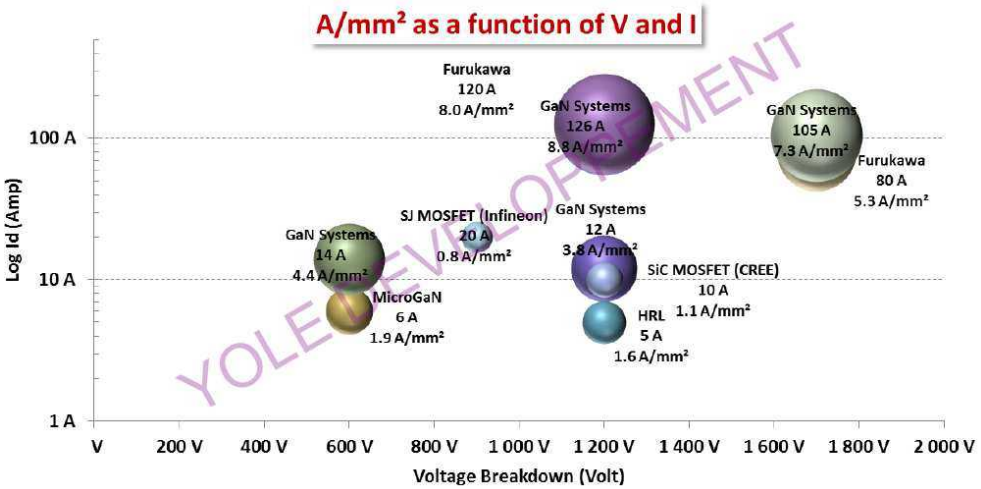
Advantages of GaN



- Extremely fast switching which enables:
  - Smaller/less expensive filtering elements
  - Lower switching loss increases efficiency and reduces cooling requirements
- Cascode arrangement enables:
  - Simple drive requirements (Si MOSFET front end)
  - Usable anti-parallel diode
- GaN on Si enables lower cost than SiC

"Power GaN: Market & Technology Analysis," Yole Developpment.

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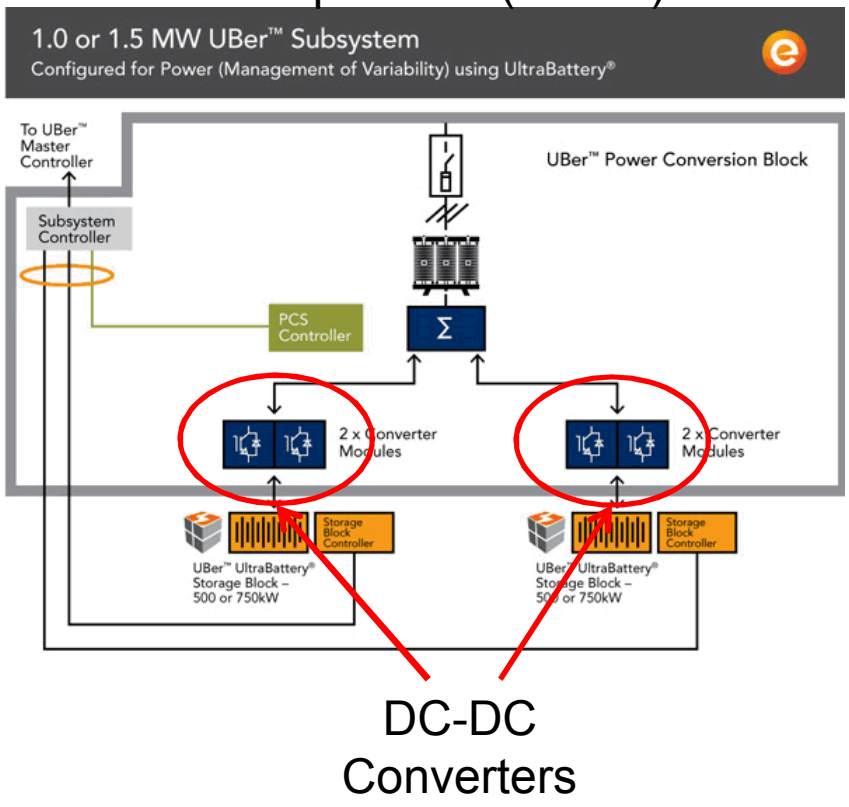
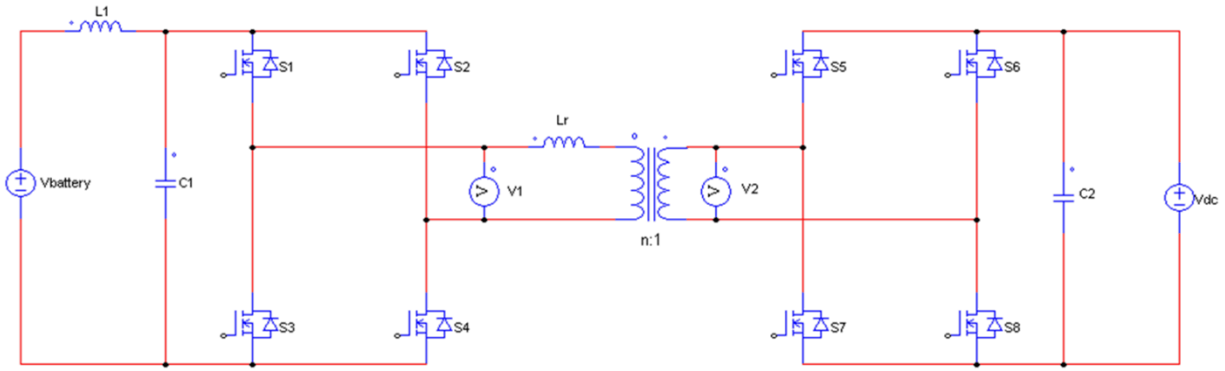
Need for High Efficiency DC-DC Converters in Energy Storage Systems

- High efficiency DC-DC converters provide critical functionality in energy storage systems
  - They provide galvanic isolation (safety)
  - They are inherently capable of providing circuit breaker functionality
  - They interface the inverter to the batteries
  - They control the charging/discharging of batteries
- **High efficiency is critical and can significantly decrease wasted energy, operational cost, and payback period**

Example ESS (Ecoult)



Technical Approach



- Dual Active Bridge (DAB) topology
  - Power bidirectional
  - Soft switching topology decreases switching loss
  - High frequency isolation transformer enables galvanic isolation in a small volume
  - Scalable from 100's of watts to MWs

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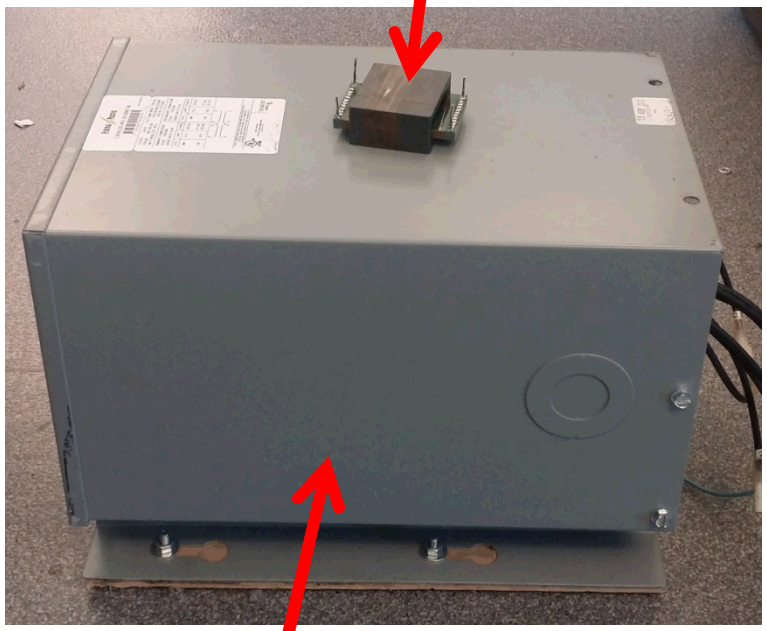
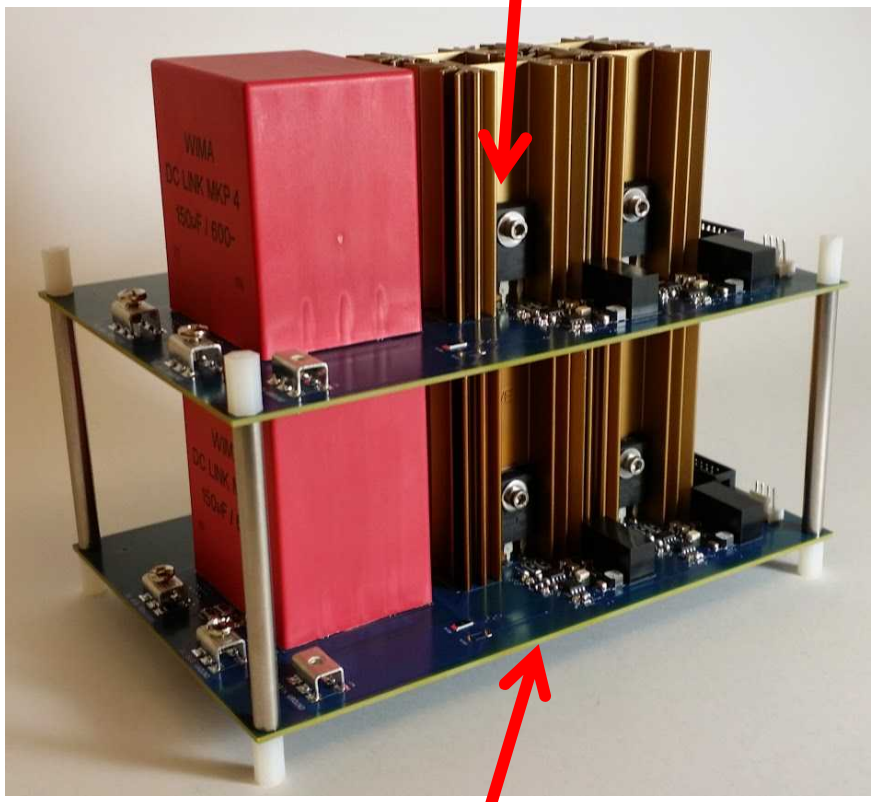
Hardware Prototype

100 kHz Ferrite Transformer
8 kW – 328 grams



60 Hz Si-Steel Transformer
7.5 kVA – 150 lbs

Primary Side Full Bridge



Secondary Side Full Bridge

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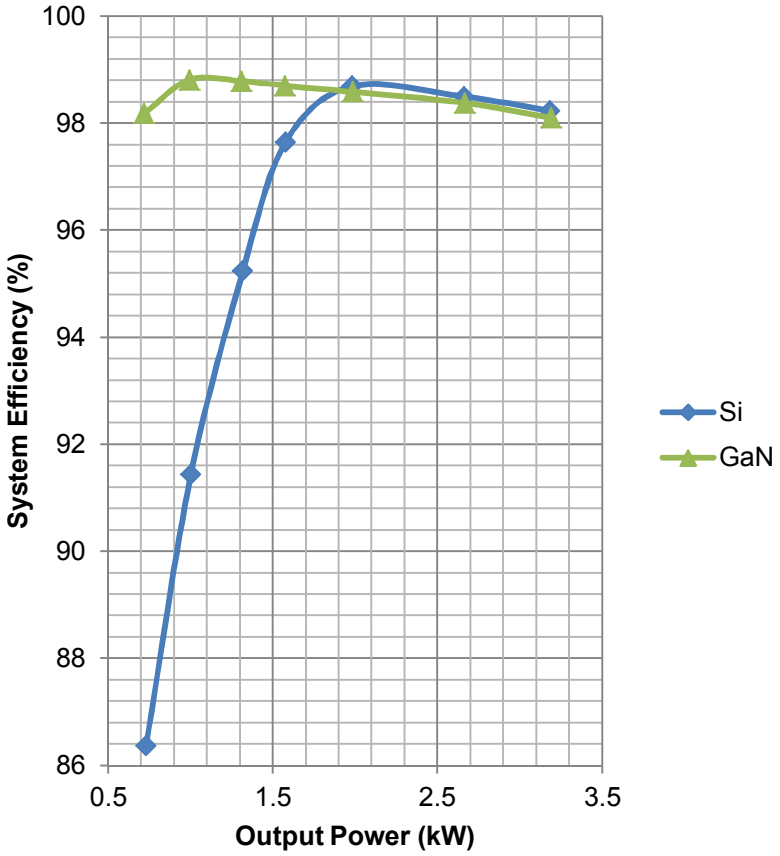
Phase I Results

- GaN proved to be superior to state of the art super junction Si FETs
- Improved weighted efficiency (CEC efficiency) by 2.7% (95.66% for Si and 98.37% for GaN)
- GaN can further dominate by lowering conduction loss via power module



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Phase II Plans

- Develop a custom power module around GaN capable of >250 A and >600 V
- Use the developed module to create a scalable 50 kW power processing unit for energy storage units (series/parallel capability for use in higher voltage/higher power applications)
  - >50 kHz operation to enable small magnetic components
  - >98% efficiency to reduce cooling requirements
- Explore advanced magnetic based control strategies to improve system efficiency at light loads

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Summary

- High efficiency bidirectional DC-DC converters are critical for current and future energy storage systems
- GaN transistor technology can greatly improve efficiency compared to Si technology
- The DC-DC converter demonstrator deliverable for Phase I exceeded all initial targets
- GaN power modules required to achieve higher power levels are being developed in this effort
- A high power (>50 kw) converter is being developed in the Phase II utilizing a custom GaN power module to enable higher efficiency energy storage units

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Questions?

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