SAND2019-10984PE

Smart GaN-Based Inverters for Grid-tied Energy Storage Systems

DOE/OE Peer Review, 09/25/2019

InnoCit

Innovation City, Power and Energy Solutions

DOE SBIR Phase IIB

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

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Acknowledgement

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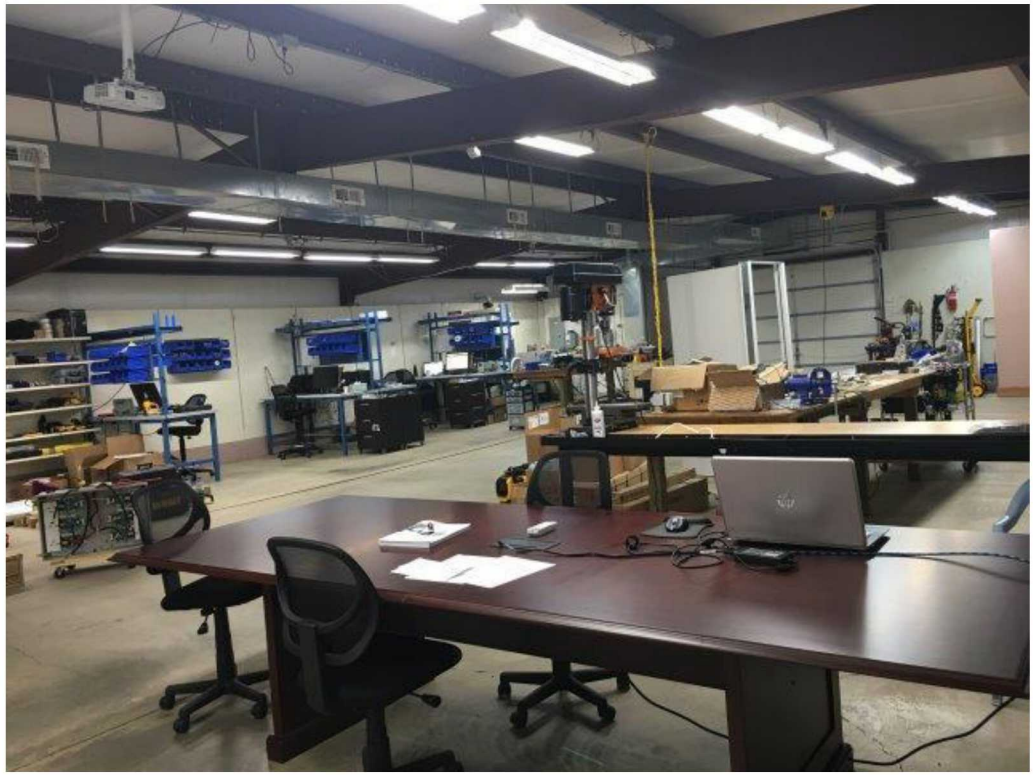
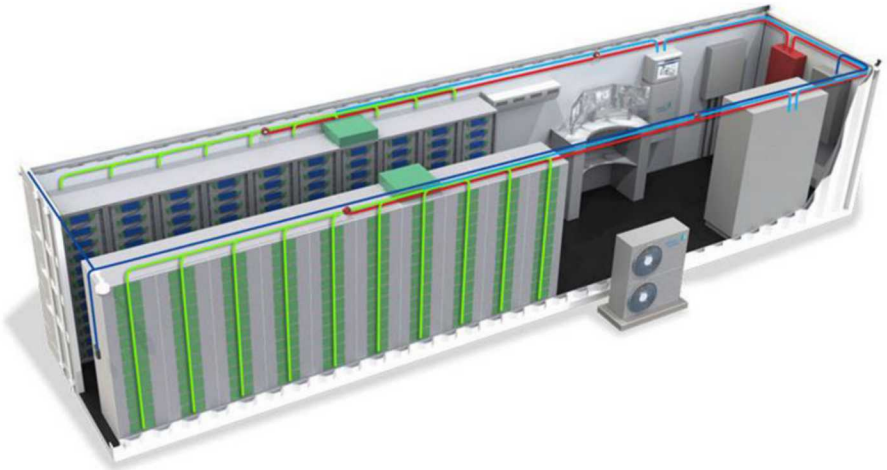
InnoCit

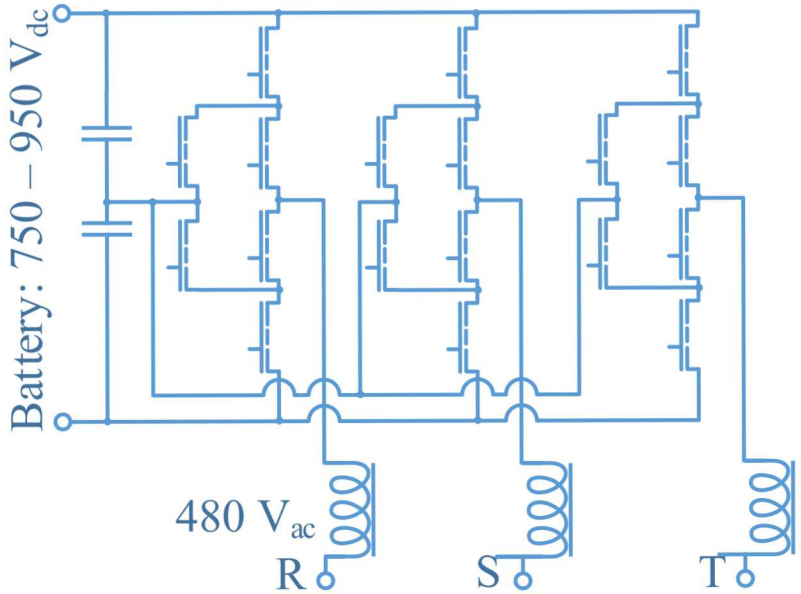
- Founded in 2014
- Tech Transfer Startup
- 4,000 sq. ft. research facility, 10 acre campus, solar farm, based in Missouri
- DOE SBIR Phase I, II, IIB, NSF SBIR Phase I
- Costume manufacturing

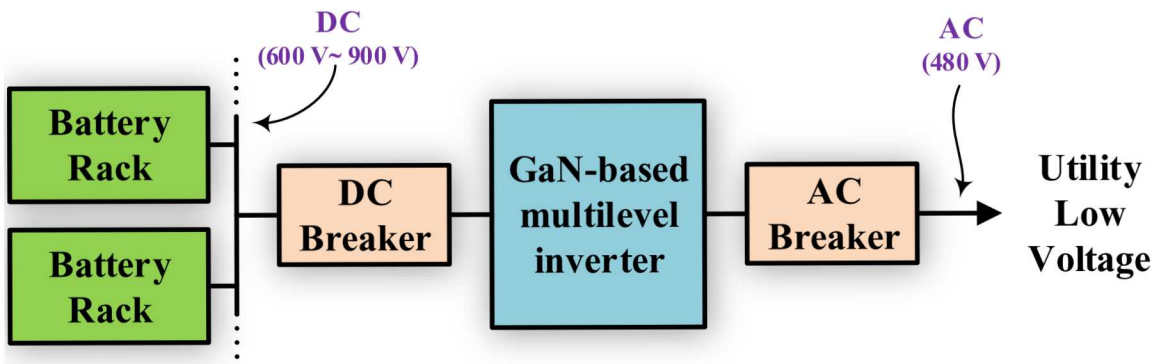


System Specifications

- GaN-based multilevel inverter
- Nominal input voltage: 900V
- Output voltage: 3-phase 480V
- Power rating: 20kW to 200kW



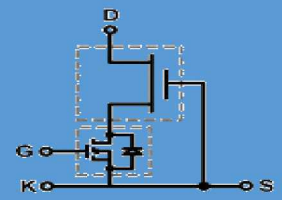
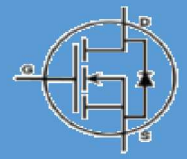
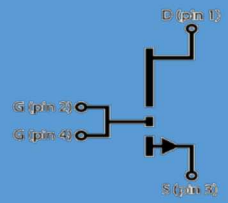




Specific Objectives

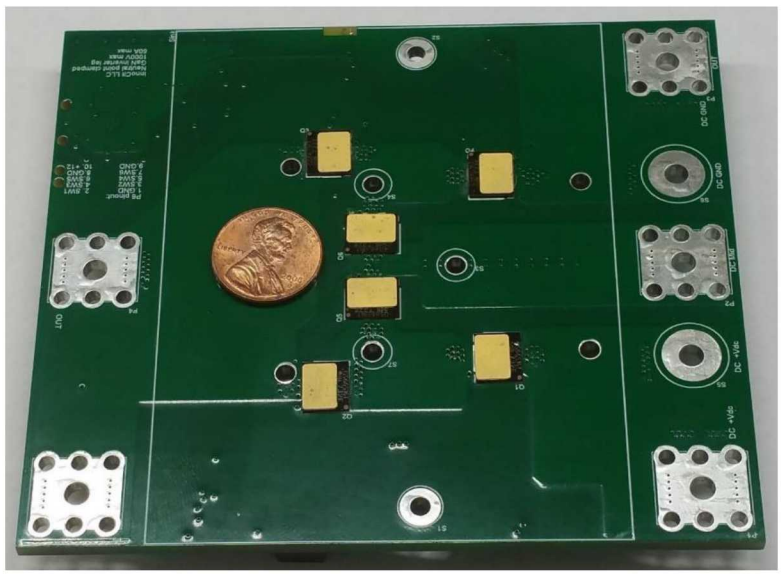
- **Designing 3U rack-chassis-based enclosures for inverter modules**
- **Conduct thermal analysis on the enclosures**
- **Controls and hardware for hot-swap capabilities**
- **Validate final metrics: efficiency of at least 98.6%, weight < 2.2 lb./kW, volume <0.1 ft3/kW, noise <45 dBa**
- **Reliability testing including active bypass and hot-swap features**
- **IEEE 1547, UL 1741, and 1741-SA testing for islanding and fault ride-through**
- **UL certification testing**
- **Remote control and monitoring backbone structure development**

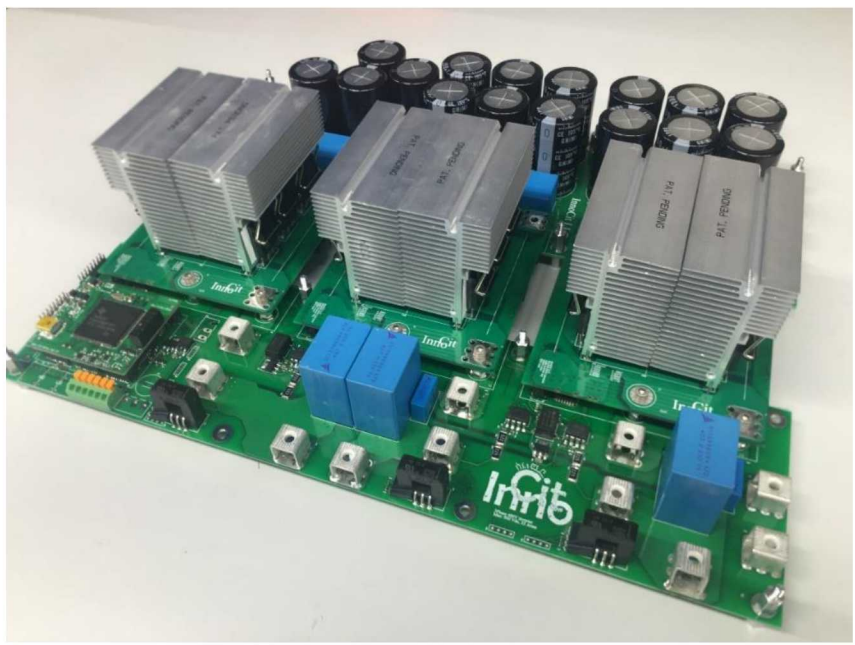
Fast-Paced Technology

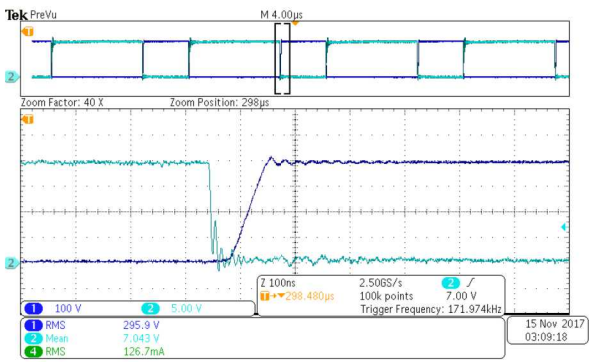
Technology / manufacturer	Transphorm	EPC	GaN systems	GaN systems
				
Switch topology	Cascode: GaN JFET + Si MOSFET	Enhancement mode FET	Enhancement mode FET	Enhancement mode FET
Material	GaN + Si	GaN	GaN	GaN
Part number	TPH3205WS	EPC2034	GS66508T	GS66516T
Voltage	600 V	200 V	650 V	650 V
Current	36 A	31 A	30 A	60 A
Rds-on @ 150˚C	0.10 Ω	0.015 Ω	0.050 Ω	0.025 Ω
CRSS (Reverse transfer)	17.5 pF	5 pF	2 pF	4 pF
Heatsink Plate		no	Yes	Yes

Achievements

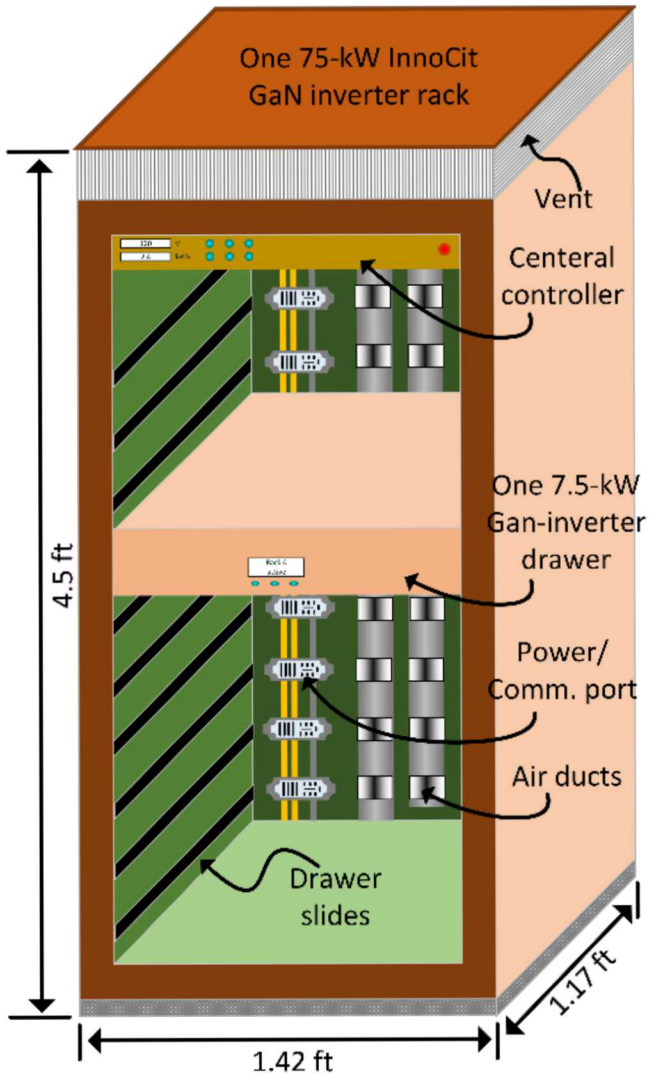
- **First ever floating supply integrated GaN gate driver + switch (commercialized)**
- **First ever modular GaN-based 20-kW inverter (TRL-6)**

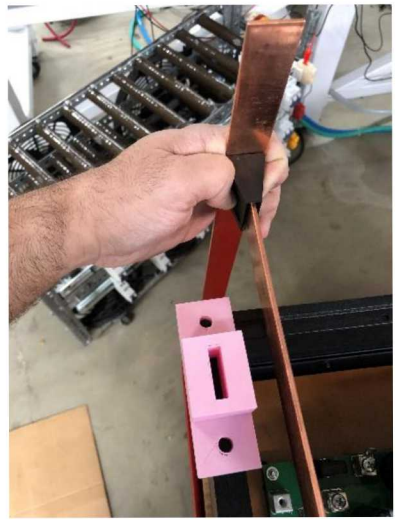




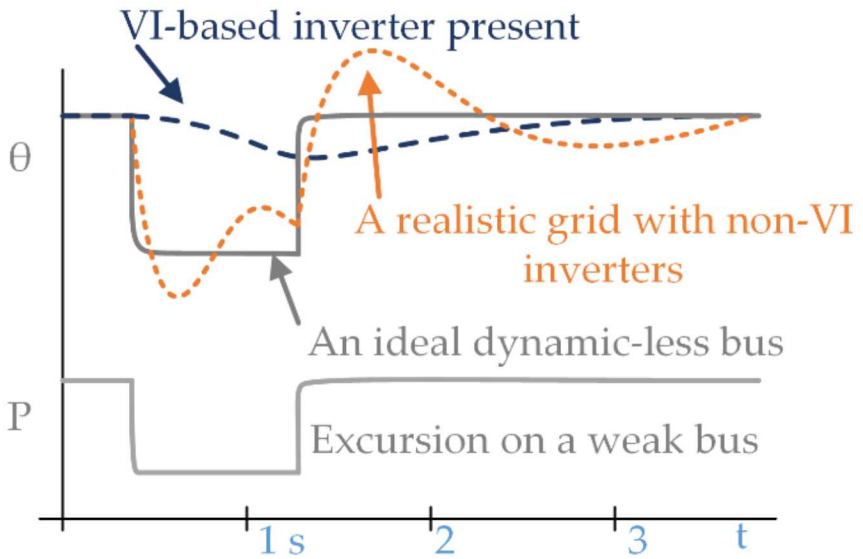


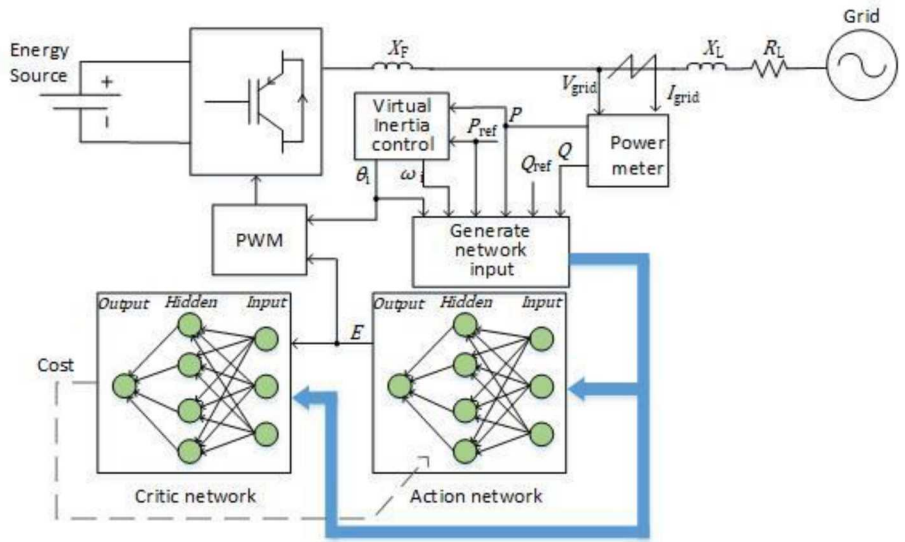
Final System

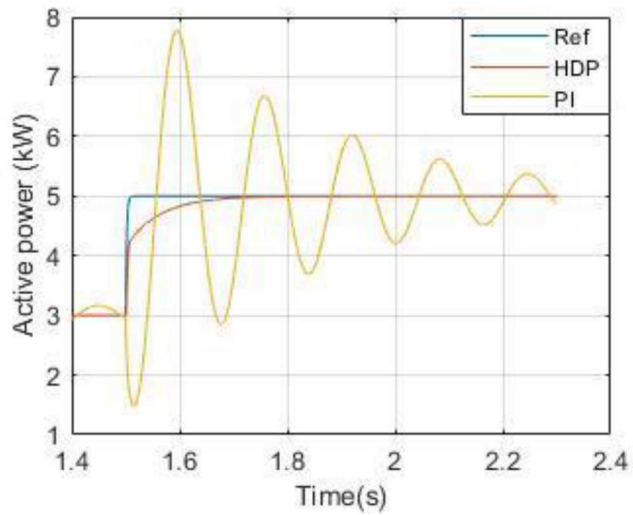




Intelligent Inverter







Commercial Competitiveness

Features\Manufacturer	InnoCit Ganverter (10 units)	Princeton Power BIGI-250	ABB ESSpro-C250	DynaPower MPS-100
Total Power Rating (S)	200-kVA	265-kVA	200-kVA	100-kVA
CEC Efficiency	99%	94.5%	>94%	93.9%
Volume	30-ft^3 (full system + rack)	150-ft^3	41-ft^3	48-ft^3
Weight	540-lbs. (full system + rack)	3500-lbs.	2100-lbs.	1545-lbs.
Current THD	<2%	<5%	<5%	<5%
End-user Price per VA	$0.085/VA	$0.44/VA	$0.58/VA	$0.52/VA

Lessons Learned

- Gate driver design is very critical
- Requires isolated gate drivers and isolated dc-dc power supplies for driving the gate
- When selecting the isolated gate driver and gate power supply, one should ensure that they can withstand the high dv/dt stress due to faster turn ON and OFF times
- With the fast switching of GaN E-HEMTs, any parasitic inductances in the gate switching loop will give rise to ringing which leads to losses and EMI problems - keep the PCB gate-source loop as small as possible
- Best switching performance can be achieved with proper selection of gate resistor

Lessons Learned

- Poor thermal conductivity of GaN semiconductor calls for special attention to thermal design
- GaN E-HEMTs have tiny packaging compared to SiC. Therefore, the heat generated within the device has to be dissipated fast and effectively to keep the junction temperature within allowable limits
- Also, the maximum junction temperature of the GaN E-HEMT selected is low compared to the SiC device
- If using a single heat sink for multiple GaN devices, they have to be aligned flat with the surface of heat sink
- Using thermal grease along with thermal tape will provide the best thermal conductivity

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