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

**DOE OE Peer Review, September 2020**

InnoCit

Innovation City, Power and Energy Solutions

**DOE SBIR Phase IIB**

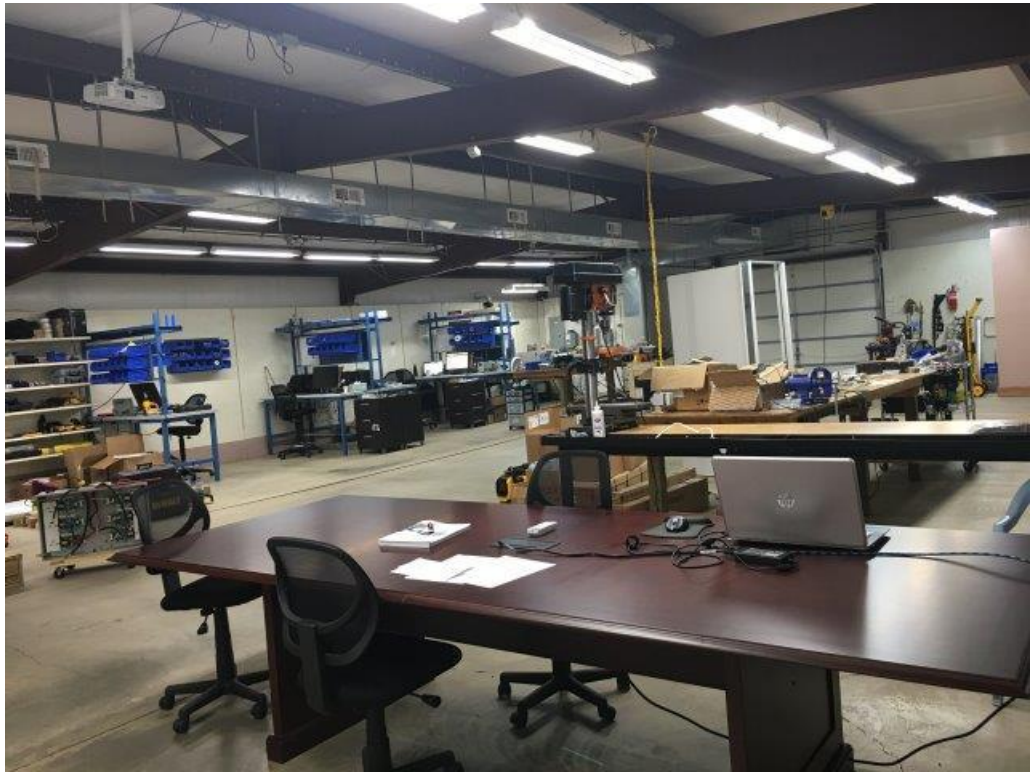
**Year 1 start date: 08/19/2019**

**Year 1 end date: 08/18/2020**

# Acknowledgement

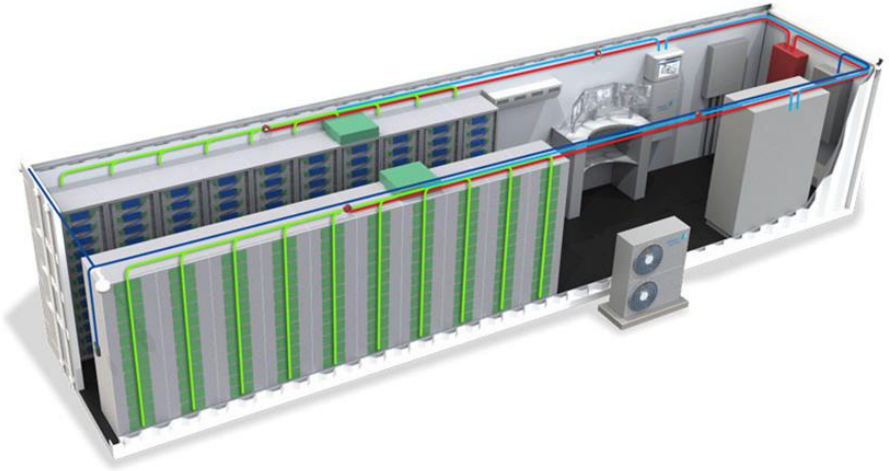
**InnoCit greatly appreciates support of Dr. Imre Gyuk and Dr. Stan Atcitty through DOE SBIR grant DE-SC0013818.**

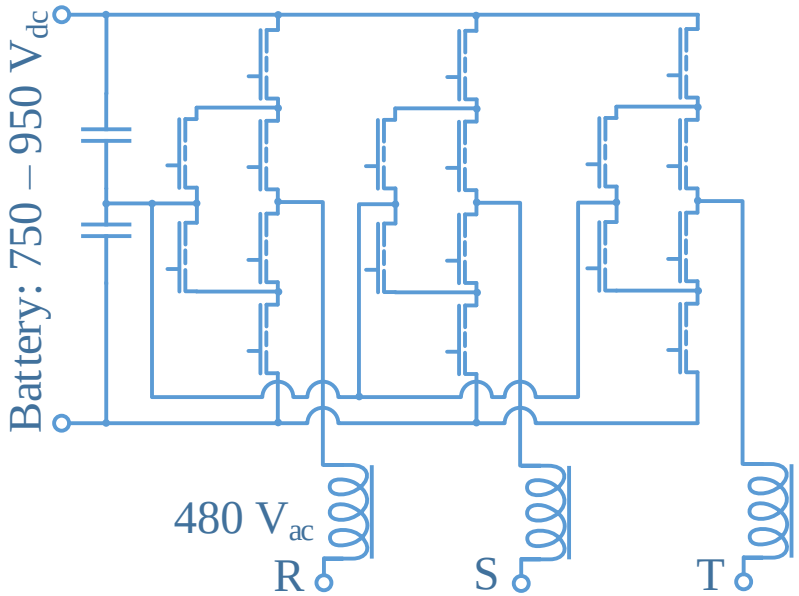
- Founded in 2014
- Tech Transfer Startup
- 4,000 sq. ft. research facility, 10 acre campus, solar farm, based in Missouri
- DOE SBIR Phase I, II, IIB, NSF SBIR Phase I
- Costume manufacturing

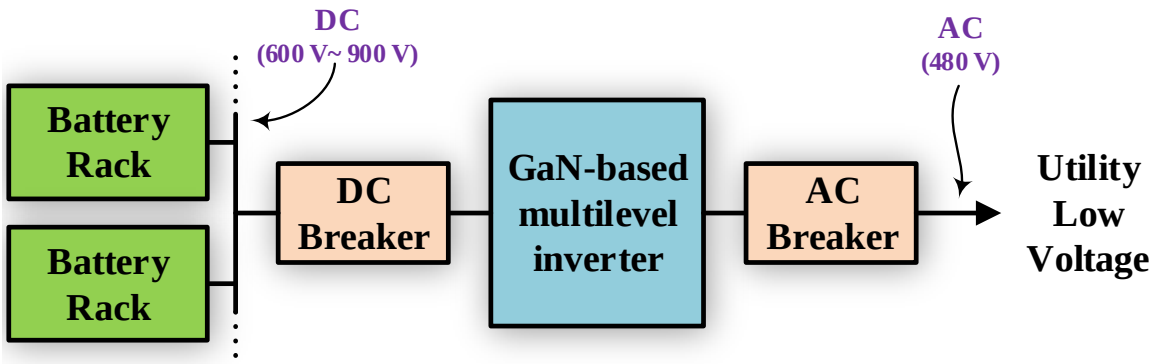


# System Specifications

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



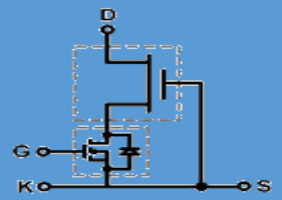
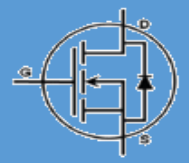
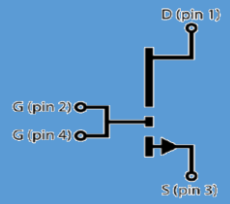
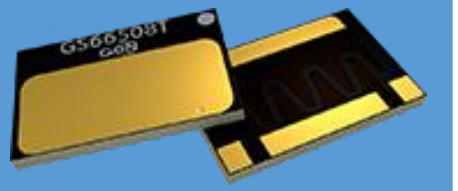


# Specific Objectives

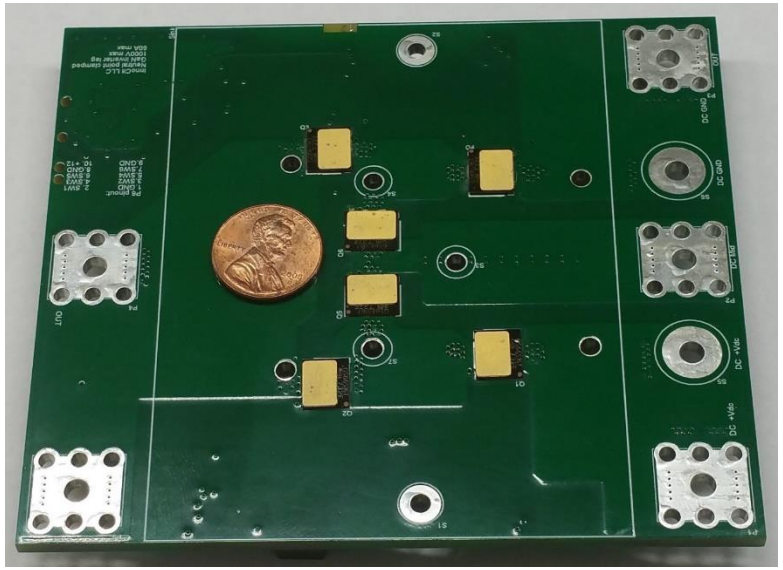
- **Designing 3U rack-chassis-based enclosures for inverter modules**
- **Conduct thermal analysis on the enclosures**
- **Controls and hardware for hot-swap capabilities**
- **Validate final metrics: efficiency of at least 98.6%, weight < 2.2 lb./kW, volume <0.1 ft3/kW, noise <45 dBa**
- **Reliability 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**

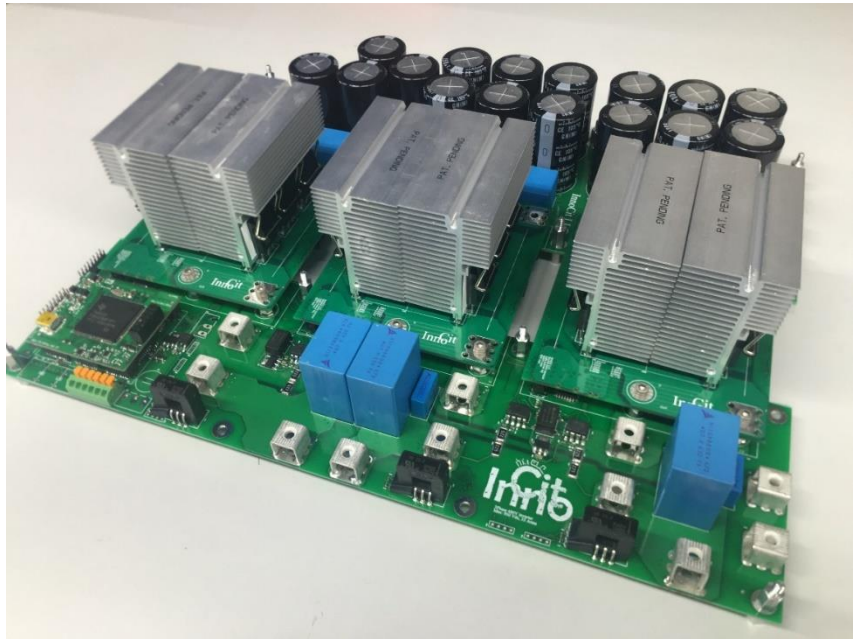
# Fast-Paced Technology

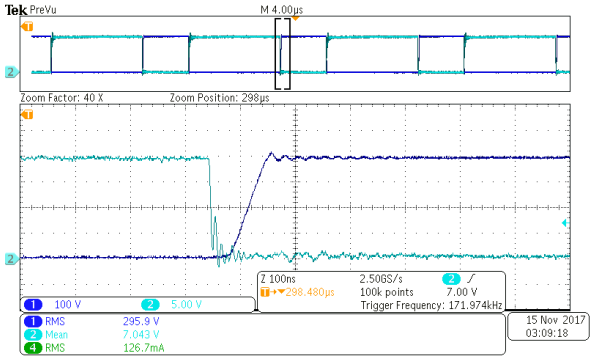
| Technology / manufacturer | Transphorm | EPC | GaN systems | GaN systems |
|---|---|---|---|---|
| |   |   |   |   |
| **Switch topology** | Cascode: GaN JFET + Si MOSFET | Enhancement mode FET | Enhancement mode FET | Enhancement mode FET |
| **Material** | GaN + Si | GaN | GaN | GaN |
| **Part number** | 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)**

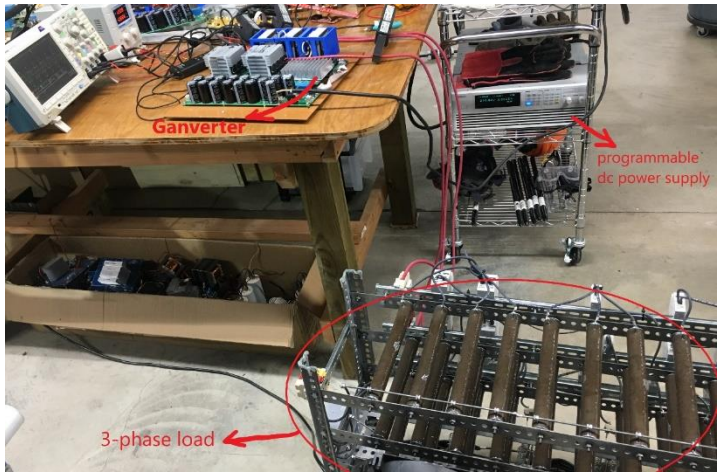


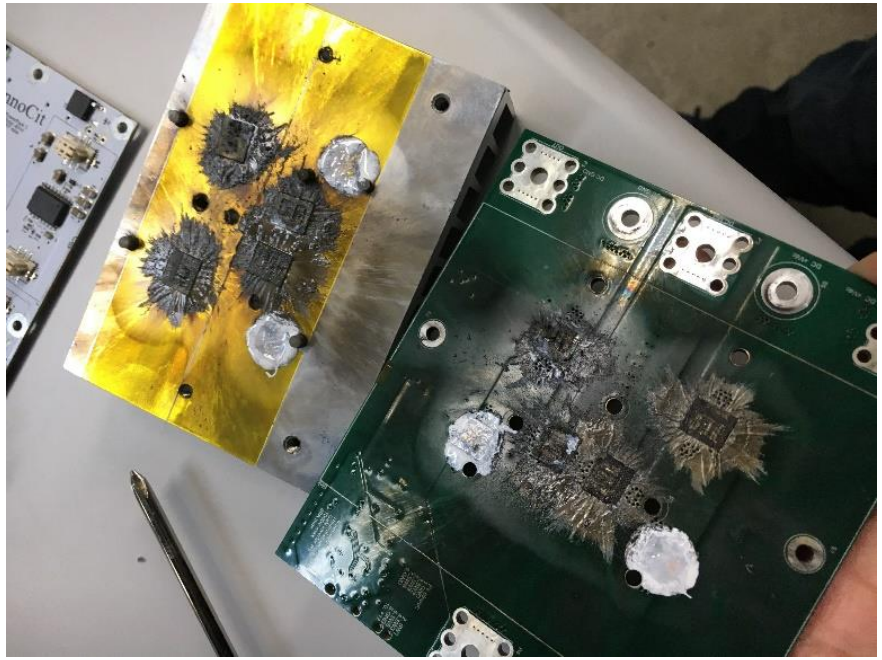


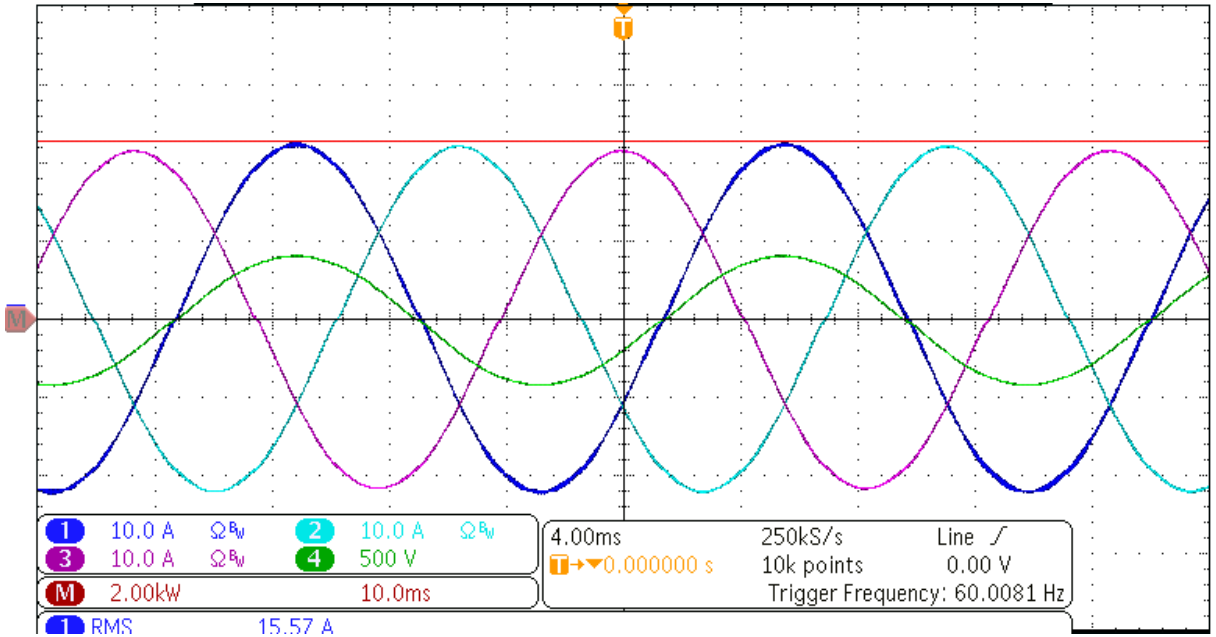


# Switch Reliability

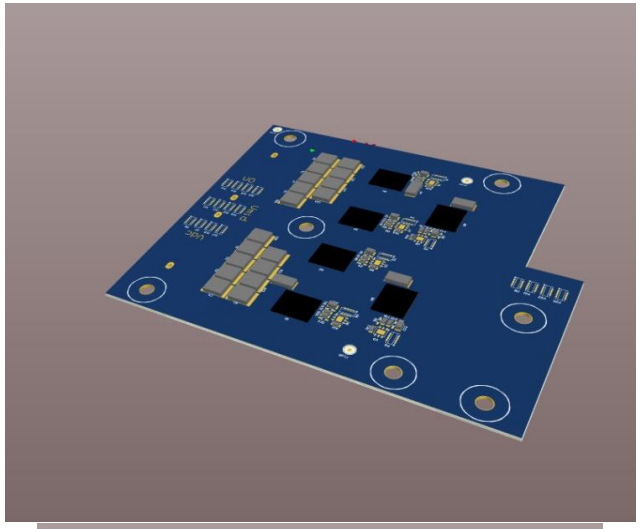
- **Soldering tolerance**

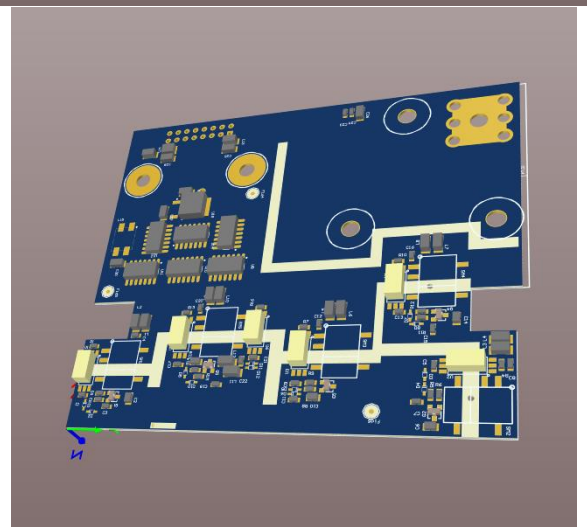


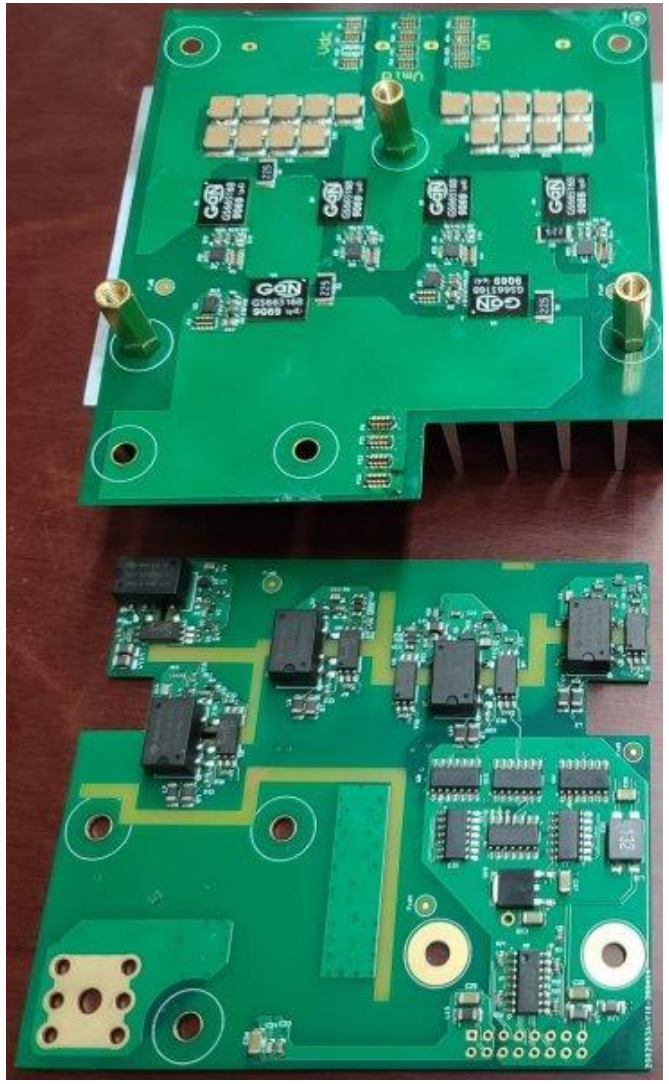



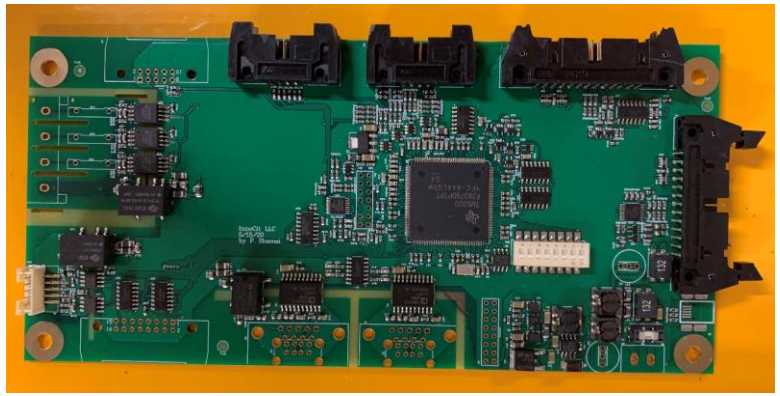


# Bottom-Cooled GaN Switch



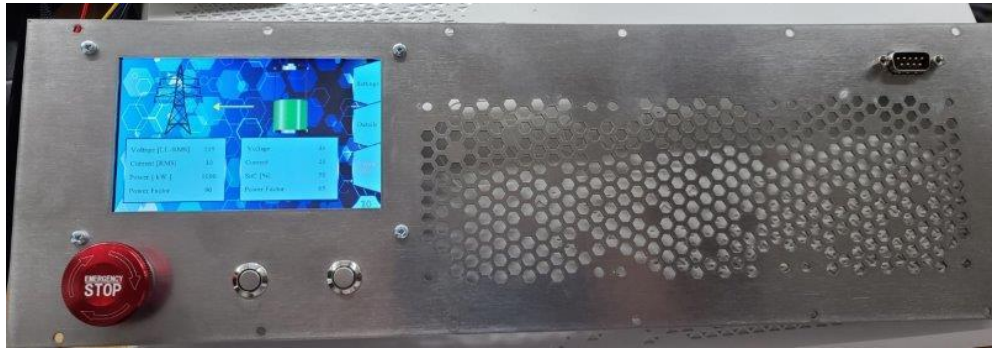




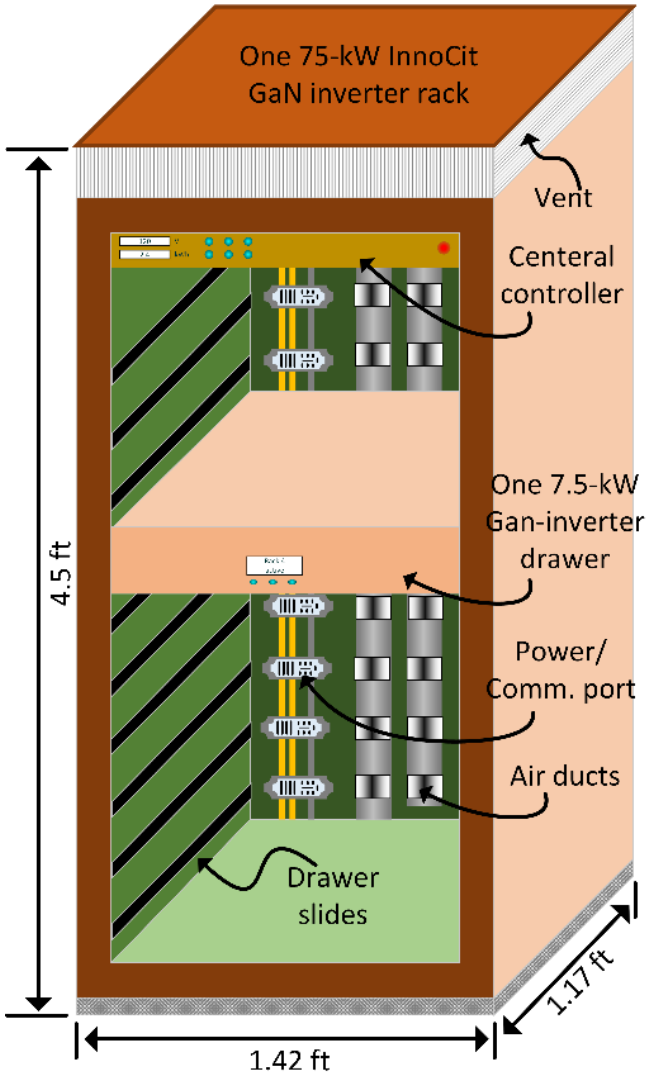


# Final System

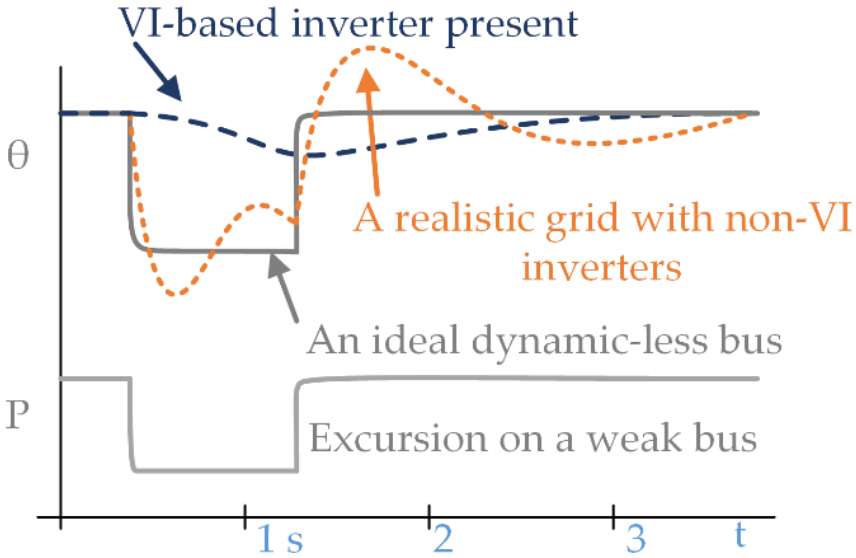
## Interface Panel

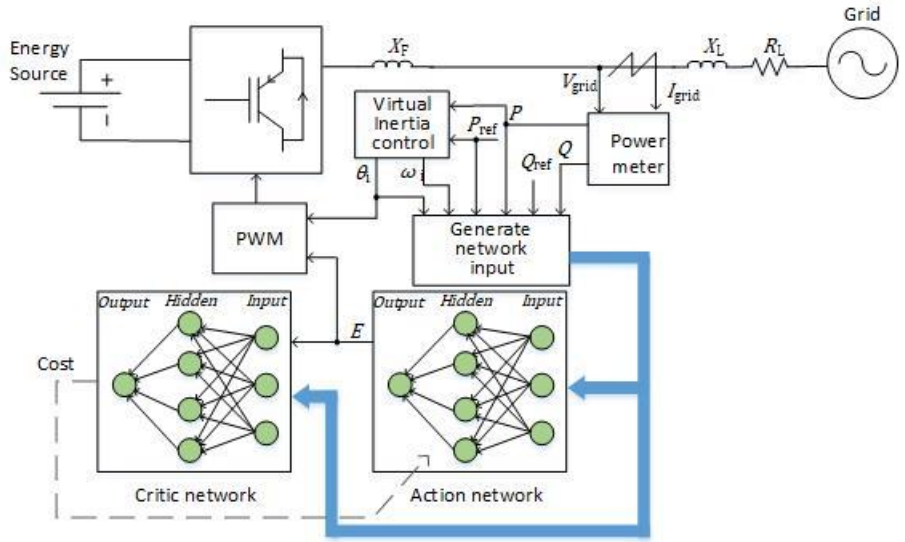


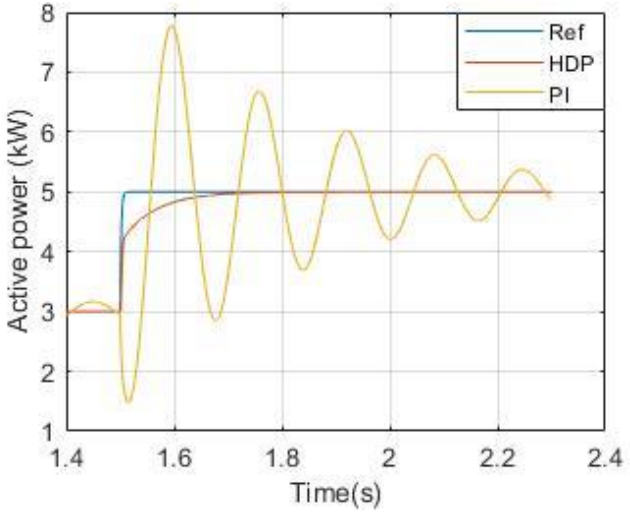
## Planar Inductors

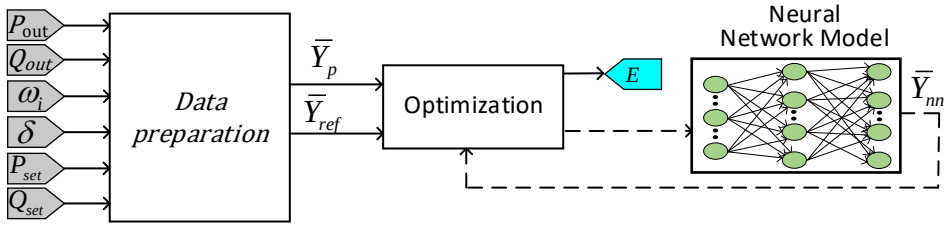


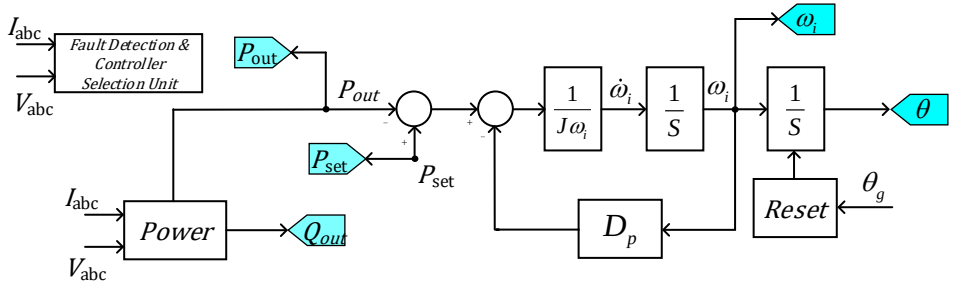
# Intelligent Inverter



# 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

# Contact Information

**Mehdi Ferdowsi**

**InnoCit, LLC**

**President & CEO**

**ferdowsi@innocit.com**