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Power electronics based grid integration technology for energy storage application

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ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

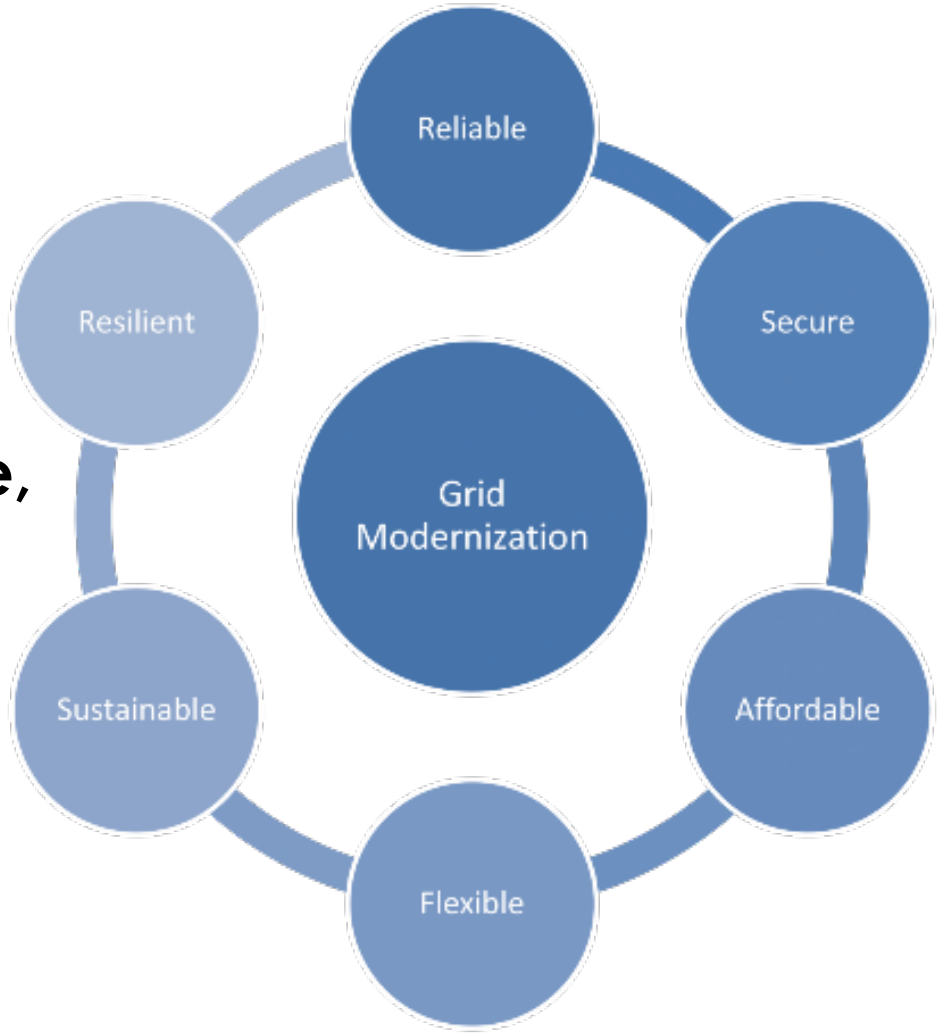
Work Funded under Grid Modernization Laboratory Call

The vision of DOE's Grid Modernization Initiative (GMI) is:

- A future grid that will:

✓ solve the challenges of seamlessly **integrating conventional and renewable sources**, **storage**, and central and distributed generation.

✓ A future grid that will deliver **resilient**, **reliable**, **flexible**, **secure**, **sustainable**, and **affordable** electricity to consumers where they want it, when they want it, how they want it.



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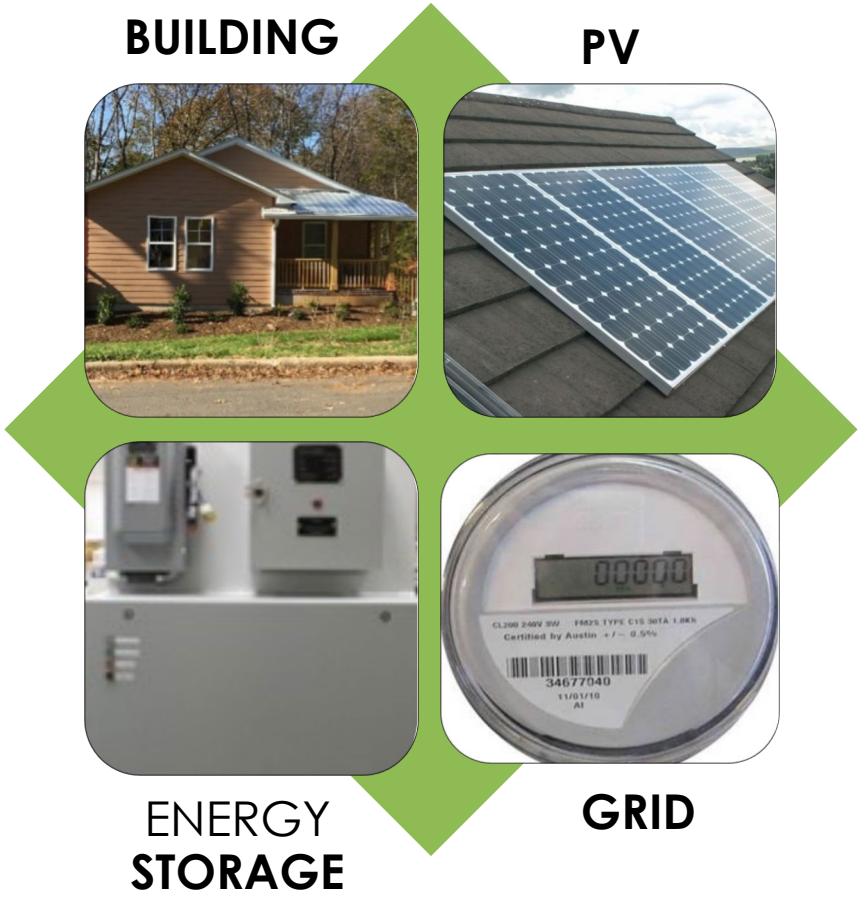
Project Objectives

- **General Project Objectives:**
  - **Broadening the customer base with a low cost energy storage solution.**
  - **Integrated energy system to increase value of storage.**
  - **Overcoming secondary-use energy storage challenges.**
- **Deliverable: Deployment of the system**



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Chatham Habitat for Humanity®

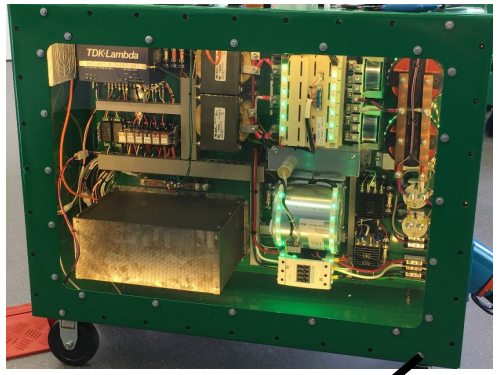
SPIERS NEW TECHNOLOGIES

Overall Approach

3 year Project : Full system completed and under deployment

Year1

Design

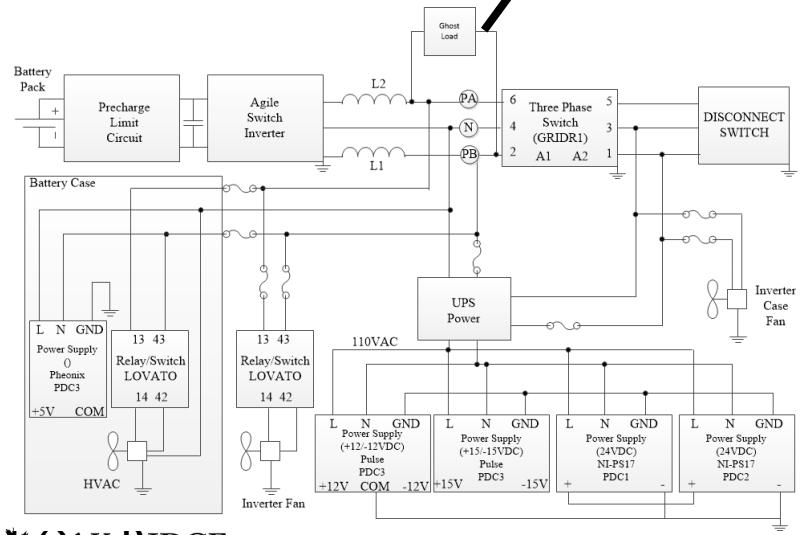


Year 2

Prototype

Year 3:

Full design and deployment



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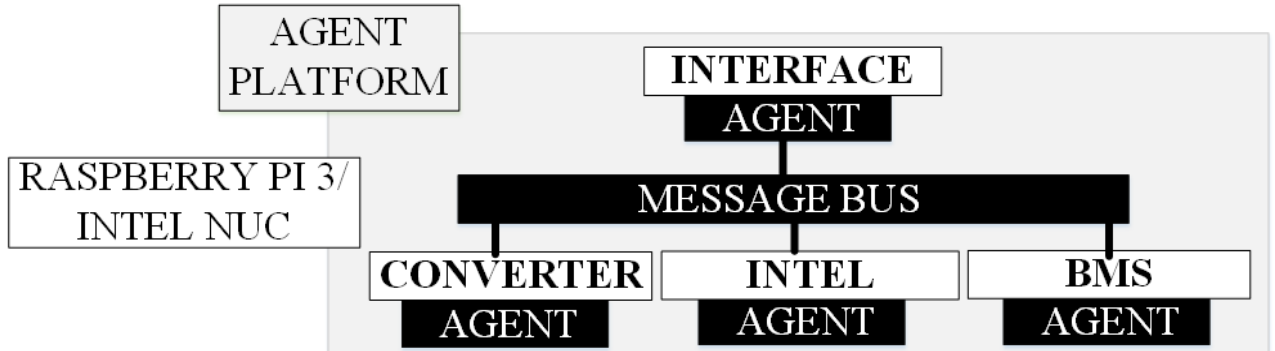
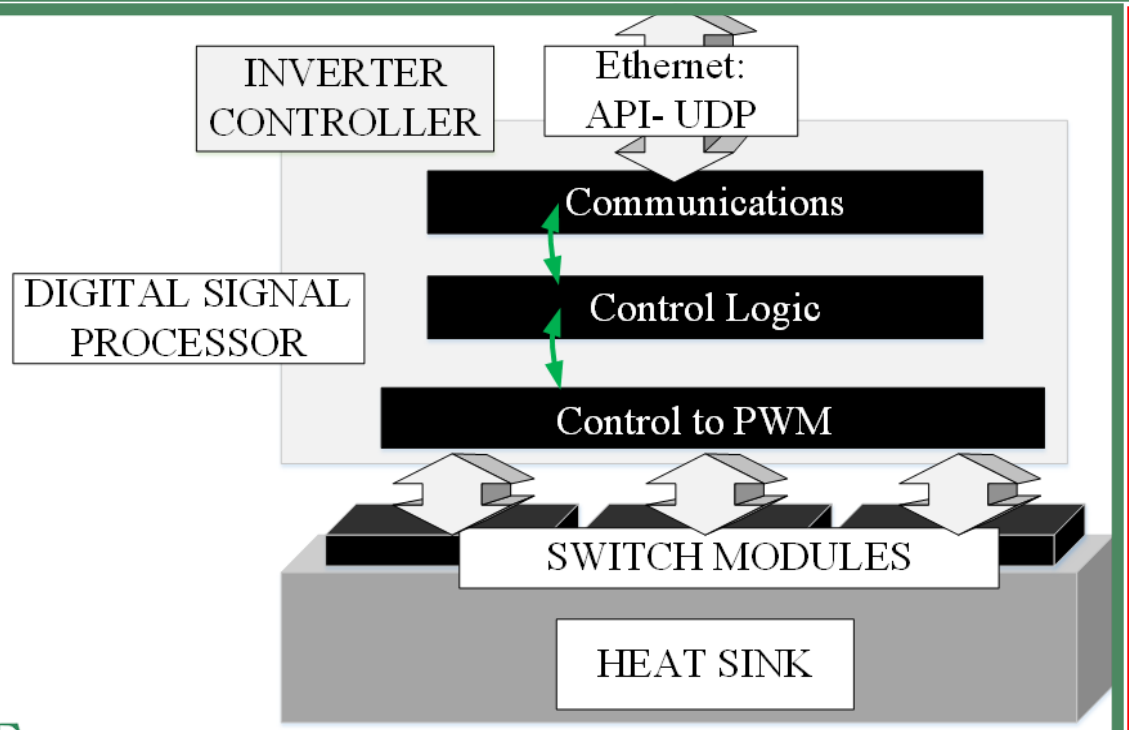
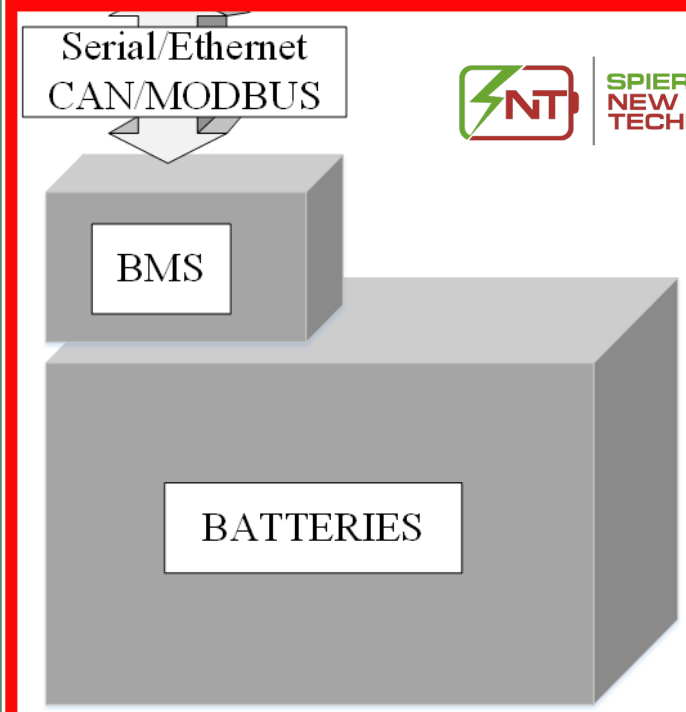
Overall Architecture

Supporting Integration Functionality (ORNL)





Power Conditioning System (ORNL)



Battery System (SNT)

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Specifications

ELECTRICAL		
Power	Inverter	Battery
- **Peak**	12 kW	14 kW
- **Continuous**	10 kW	10 kW
Energy	16 kWh	
AC (Roundtrip) Efficiency	~90%	
Voltage	240 VAC +/- 2%	
Current THD	< 5% THD	
Self-Discharge	< 1% of stored energy over 48 hours	
Response Time	1000 W/s – Ramp from 0 to 100% of rated discharge in < 10s	

GENERAL			
Dimensions	45" W x 65" H x 40" D		
Installed Weight	Inverter:	Battery: 850 Lbs	Total
Ambient Temperature	0°C to 45°C		
Design Life			
Audible Noise	70 dB at 1 meter		
End of Life Disposal	Batteries reclaimed and recycled by Spiers New Technologies		

CODES AND STANDARDS*	
Interconnection	UL1741
Electric Energy Storage	
National Electric Code	NFPA 70

- **Full design specifications developed.**
- **System designed to conform to these standards: pending a third-party verification service.**

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Power Conditioning System (PCS) 2.0

- **Targeted lower cost Digital signal processor equipment and components (compared to previous NI version)**

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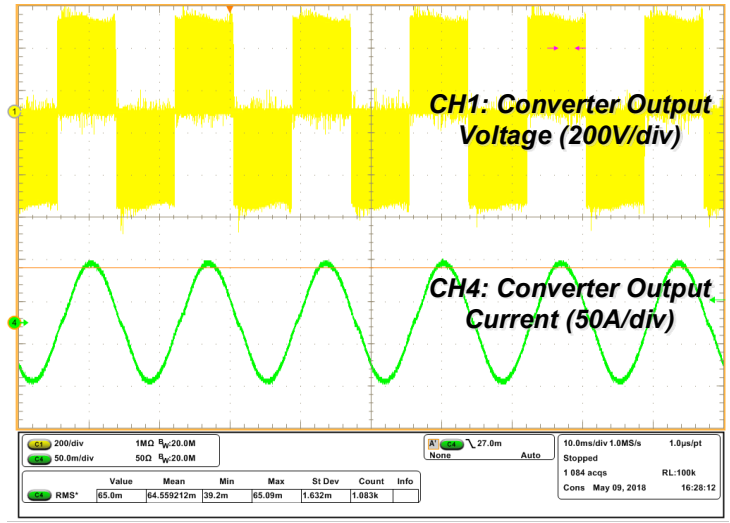
Grid Tied Tests of PCS 2.0

DC Voltage: 440 V Total Power: 11.53 kW



Front control panel of DC power supply (Left) and experimental waveforms captured by the oscilloscope during the continuous open loop operation tests (Right)

- **Grid Emulator and passive load bank were utilized to respectively represent the grid connecting to the house loads**
- **Evaluated the basic functionalities of hardware architecture**
- **Operated continuously in open loop mode to ensure Habitat Generation II thermal design**

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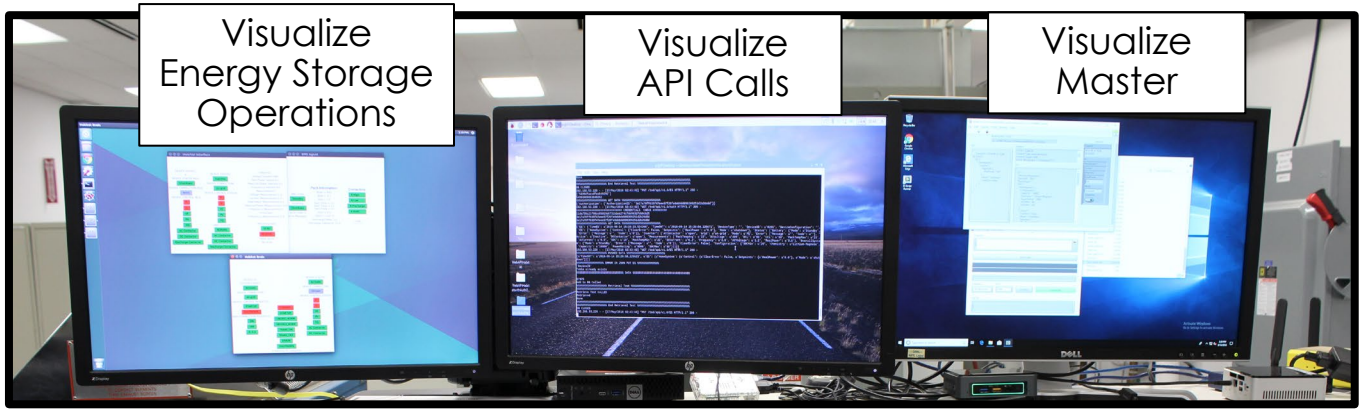
Final Prototype

- **Battery system incorporates self protection and controls**
- **Include contactors with status feedback**
- **Incorporated new Battery Management System (BMS) with multiple communication interfaces.**

Testbed



Software section

RestAPI

POST

GET

COMP

NETWORK SWITCH

COMP

Master Controller and Optimizer

Manual Control

Optimization and Dispatch

Use Case Test/Demos

PNNL/SNL protocols

OE ES program

Hardware section

COMP

Battery and BMS

Energy Storage System

Grid Emulator

GRID

ES System
10 kW

Grid Emulator
100 kW

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Summary of Accomplishments: FY18

- Completed the new version of the hardware interface for the battery system
- Completed the software interface design and development
- The prototype was integrated with two battery units with different BMS systems
- The prototype was tested for bidirectional operation with a grid emulator upto 10 kW.
- Generated a reference design for the BMS systems

FY19 and Future Work

- Complete the deployment process
- Long runs and data collection at site.
- Evaluate achievable economic return
- Develop advance BMS systems with new technologies
  - New semiconductor devices
  - New multi chemistry energy storage systems

Acknowledgment and Collaboration

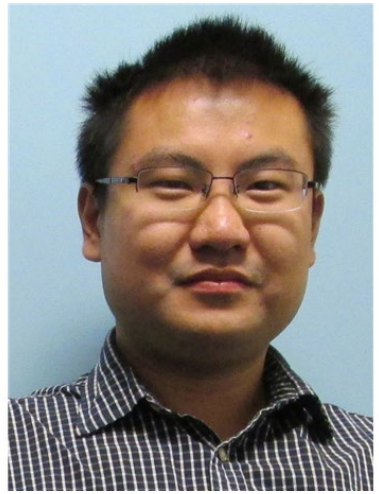
This work is supported by Dr. Imre Gyuk, Manager, Energy Storage Program, Office of Electricity Delivery and Reliability, Department of Energy.

Team

Michael Starke, PhD
System Architect

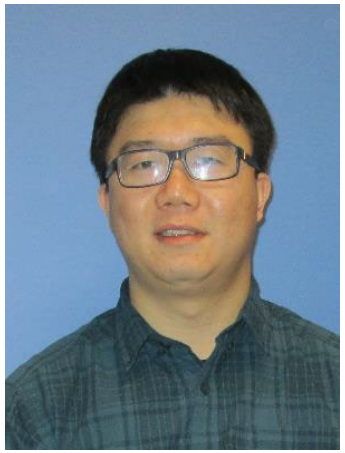
Madhu Chinthavali, PhD
Power Electronics Architecture

Steven Campbell
Mechanical system Integration architect



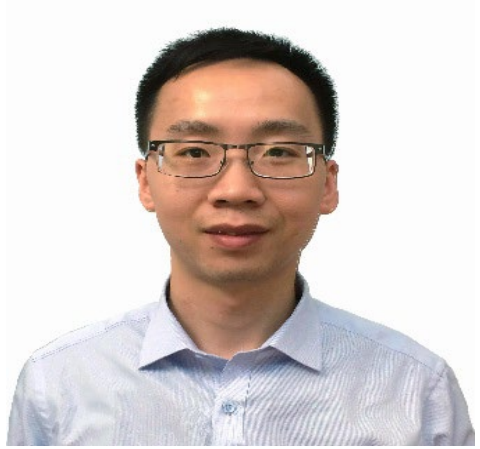
Rong Zeng, PhD
Digital Control

Christian Boone
Mechanical CAD architect



Sheng Zheng, PhD
Power Electronics system Integration

Helia Zandi,
Software Scientist & Engineer



Zhiqiang Wang, PhD
Power Electronics Circuit Simulation and Protection

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