Leon Tolbert

- **Chancellor's Professor and Min H. Kao Professor**
  The University of Tennessee
- **Research Interests: grid application of power electronics, microgrids, wide bandgap power electronics, electric vehicles (EVs)**
- **E-mail: tolbert@utk.edu**
- **Webpage: https://potenntial.eecs.utk.edu**

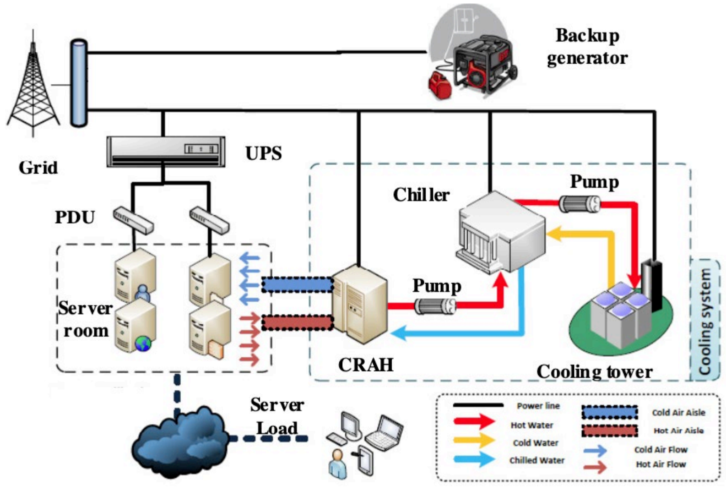
2020-2021 Research Projects

1. Converter-based emulator of data center power distribution system (NSF/DOE)
2. Frequency responsive variable speed drive (VSD) based load control (NSF/DOE)
3. Wide bandgap graduate student traineeship (DOE)
4. Aging effects of providing reactive power on PV inverter semiconductors (DOE/ORNL)
5. Increasing distribution system resiliency using microgrid assets enabled by OpenFMB (DOE/ORNL)
6. Agent-based distributed energy resources for supporting intelligence at the grid edge (ORNL)
7. A smart and flexible microgrid with a low-cost scalable open-source controller (ARPA-E)
8. SiC based modular transformer-less MW-scale power conditioning system and control for FMP (DOE)

Converter-Based Emulator of Data Center Power Distribution System

Project Objectives

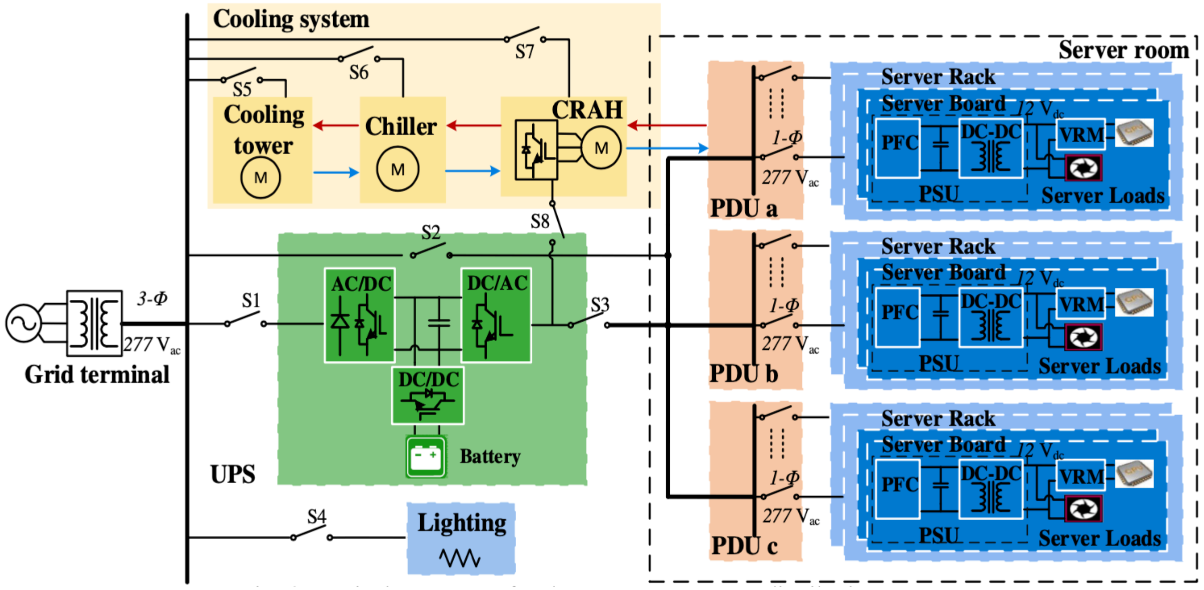
- Develop a converter-based data center power emulator to investigate data centers' load characteristics.
- Develop models that can accurately capture how grid events can affect the dynamic performance of the data center.



Data center schematic

Recent Achievements and Future Work

- Generalized model with a top-level control coordinates different power stages and predicts the data center load characteristics in different operation modes.
- Converter-based data center power emulator is implemented on the CURENT HTB, capable of demonstrating versatile power tests during transient conditions like load variation and voltage sag.
- Reactive power compensation and grid support will be implemented in the data center power emulator



One-line power diagram for data center power

CURENT

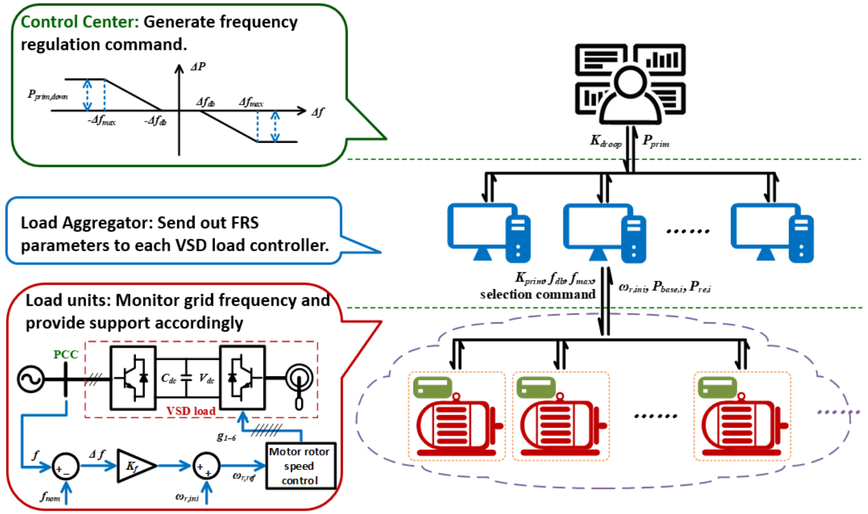
Frequency Responsive VSD-Based Load

Project Objectives

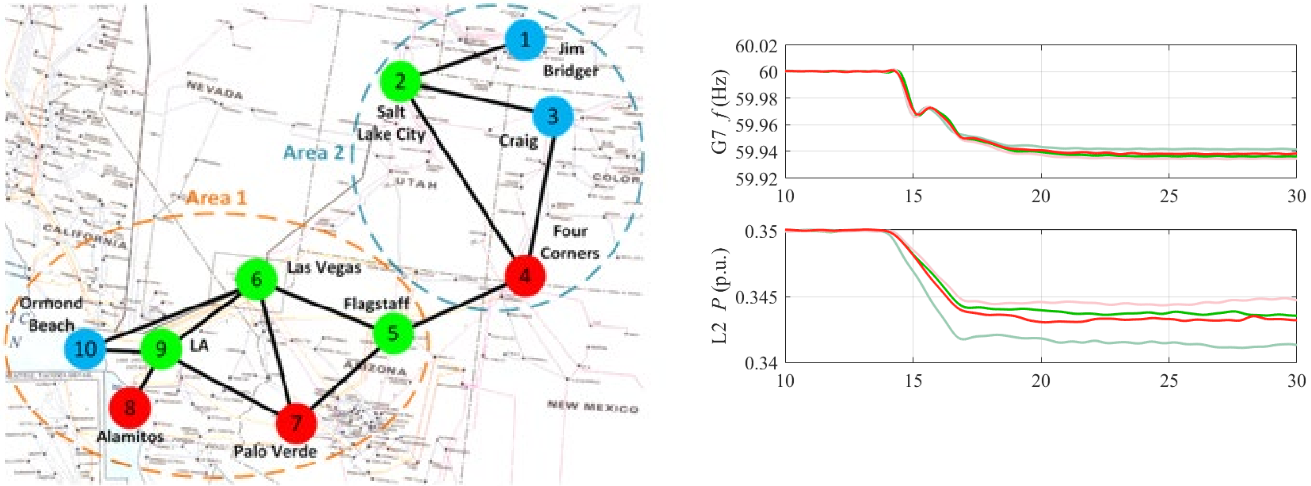
- Propose noncritical VSD loads to provide grid frequency stability support based on hierarchical control architecture.
- Develop VSD load aggregated performance representation model.
- Perform load frequency support analysis in CURENT's HTB.

Recent Achievements

- Hierarchical control includes three levels: (1) system operator, (2) load aggregator, and (3) load units. *f*-*p* droop control can be achieved according to coordination between these layers.
- VSD aggregated model can represent multiple load units in one power emulator
- VSD loads have potential of decreasing rate of change of frequency and mitigating frequency deviation.



Hierarchical control of VSD for frequency regulation



VSD load response to frequency drop in WECC

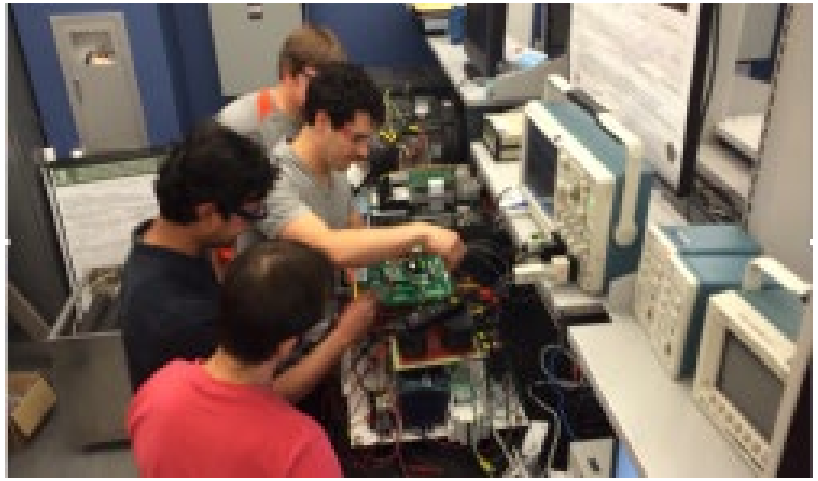
Wide Bandgap Graduate Student Traineeship

Project Objectives

- Industry needs U.S. citizen employees trained with the latest WBG device technology – GaN and SiC
- Develop coursework and hands-on research to train graduate students in the testing, packaging, and application of WBG devices.

Achievements

- 32 U.S. graduate students enrolled to date.
- 20 M.S. degrees, 1 Ph.D. degree thus far.
- Established WBG Graduate Certificate Program.
- Several courses taught with significant WBG content and several new courses:
  - WBG device characterization
  - Power electronics packaging
  - High-frequency magnetics design
  - Converter modeling



Students testing gate drive PCB designs

Traineeship students

CURENT

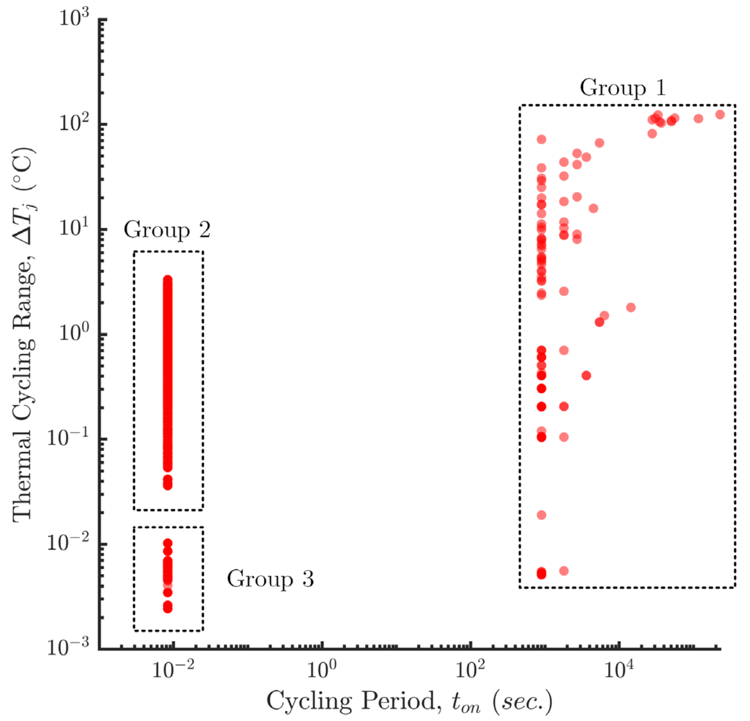
Aging Effects of Providing Reactive Power on PV Inverter Semiconductors

Project Objectives

- Develop an FFT based fatigue simulation for PV inverter semiconductors.
- Proposed simulation increases the time step from 100 μs (as used in conventional Euler method) to 15 minutes, the same as the solar profile data time step.
- Proposed fatigue simulation suitable for long-term evaluation and co-simulation with other quasi-static simulation platforms for power systems

Key Takeaways

- Low frequency thermal cycling (caused by solar angle change, cloud cover, or temporary bird shading) is the leading factor of the PV inverter semiconductor aging.
- The 60-Hz thermal cycling (caused by 60-Hz line currents) only contributes to a minor aging effect.
- PV inverter manufacturers will need to account for the provision of ancillary services, and in particular reactive power support, in the design of future products in order to not negatively impact the lifetime of their products.



Thermal cycling in PV semiconductors

Fatigue Type	t_{on} (s)	Accumulated Fatigue/week
Low Frequency Cycling	> 1/120	0.323%
60-Hz Cycling	1/120	9.01×10^{-6}%
Inverter Idling	1/120	6.46×10^{-19}%

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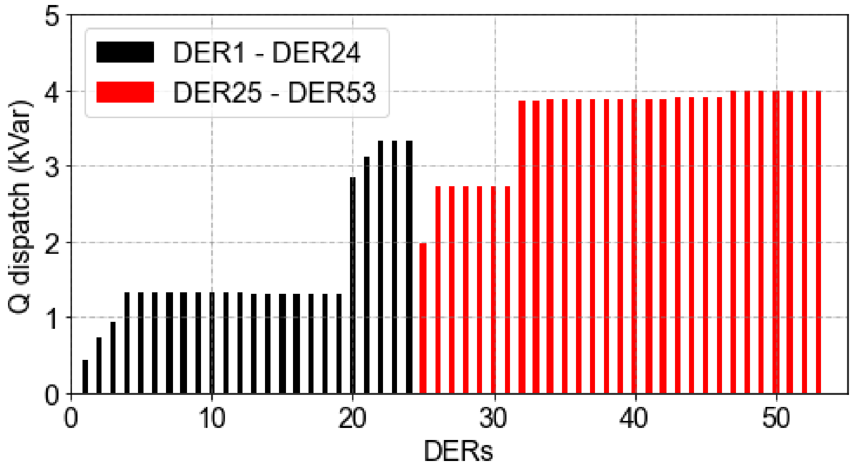
Reactive Power Allocation of PV Inverters for Voltage Support in Power Systems

Project Objectives

- Voltage management by supplying reactive power locally will reduce power losses and transmission congestion.
- Cooperation of utility-owned and non-utility-owned assets can be utilized to achieve higher reliability of the systems.
- The transactive energy approach can be used to increase the engagement of non-utility DERs for the reactive power market.



Location-based reactive power dispatch: proposed modified transactive method

Recent Achievements

- Voltage sensitivity analysis by using perturbation method is performed to obtain the relationship between voltage change at the target location and the amount of reactive power injection.
- Voltage sensitivity is integrated into the transactive DER's supply curve, which represents the cost of DERs to provide reactive power support.
- Location-based methods require less reactive power to support the voltage than the method without considering the DER's location.