Faculty Research Overview

CURENT Annual Industry Conference

April 29 and May 1, 2024

Knoxville, TN

Fangxing "Fran" Li

- UTK John W. Fisher Professor, CURENT Director, LTB Lead
- Research Interests: resilience, demand response, power system economics, machine learning for power.
- fli6@utk.edu; http://web.eecs.utk.edu/~fli6/

2023-24 Research Projects/Highlights

1. CURENT Large-scale testbed (LTB)
2. Development of Load Flexibility Valuation Methodology & Framework to Input into Planning Tools (**Southern Company**)
3. Networked Microgrids and Solid-State Power Substations Hierarchical Systems Frameworks (**ORNL**)
4. Production Cost Modeling to Assess the Benefit of Geothermal Deployment (**ORNL**)
5. Model-Free Adaptive Control (MFAC) for Autonomous and Resilient Microgrids (**DOD ESTCP**)
6. Adaptive dynamic coordination of damping controllers through deep reinforcement and transfer learning (**NSF**, PI: H. Pulgar)
7. An Equitable, Affordable & Resilient Nationwide Energy System Transition (EARNEST) (**DOE/Stanford**)
8. POSE: Phase I: Toward an Open-Source Ecosystem for Power Systems Research, Education, and Industry Applications (**NSF/Oklahoma State University**)

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CURENT Large-scale Testbed (LTB)

Project Objectives

- To develop a closed-loop platform that includes both dynamic and dispatch/market simulation
- To enable dispatch-dynamic interfaced co-simulation

Recent Achievements

- Created Homepage for CURENT LTB
- Created Linkedin Account for CURENT LTB
- AMS development, benchmark, and release
- AGVis backend improvement with web application

Best Graduate Paper Award, NAPS 2024

Hybrid symbolic-numeric power system modeling and simulation	**ANDES** **Dynamic Modeling and Simulation**	**AGVis** **Energy System Visualization**	Geographical visualization for energy system
Dynamic information interfaced scheduling modeling and simulation	**AMS** **Scheduling Modeling & Sim.**	**DiME** **Multi-terminal Data Streaming**	Data messaging between multiple power system components

LTB Structure

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Model-Free Adaptive Control (MFAC) for Autonomous and Resilient Microgrids (1)

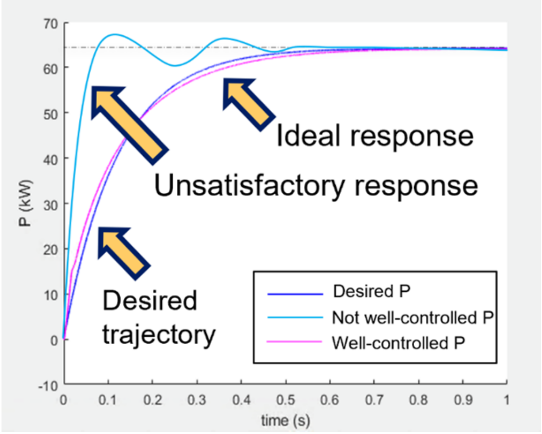
Project Objectives

- Employ domain knowledge and **AI** to achieve autonomous grid-following and grid-forming controls for microgrids
- Achieve higher grid resilience
- Microgrid control under insufficient capacity
- Virtual Inertia Scheduling

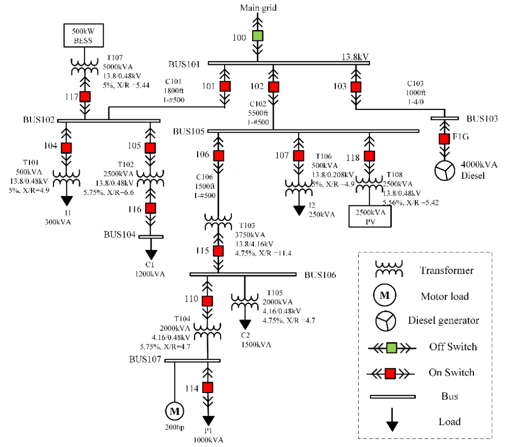
Recent Achievements — Part I:

PQ Control with trajectory tracking capability [1]

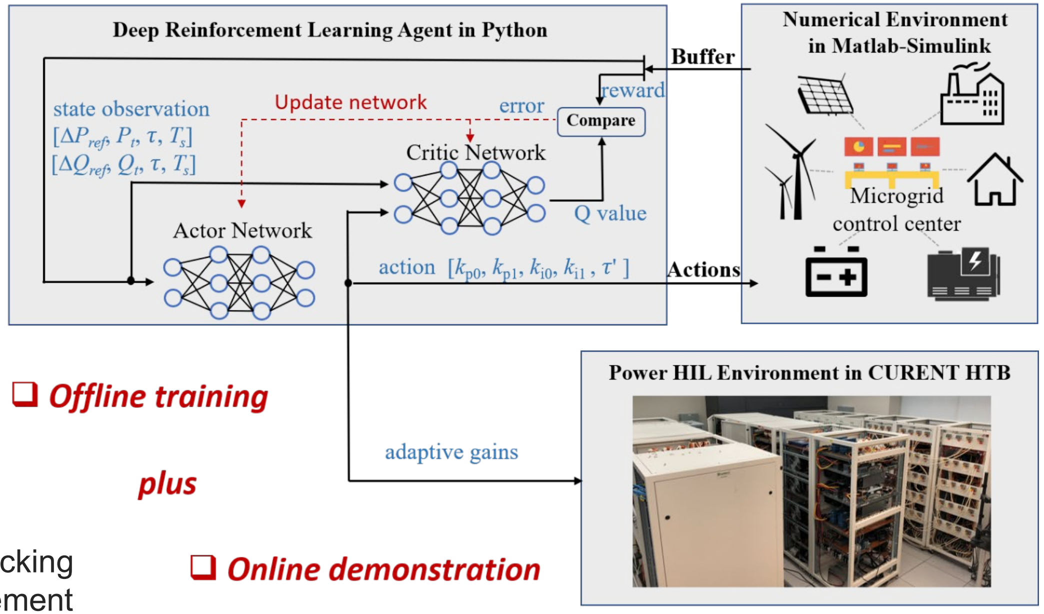
- Developed inverter PQ control for trajectory tracking using physics-informed deep reinforcement learning
- Configurate modified Banshee microgrids in CURENT HTB and validate the controller through power HIL experiment



Power curve tracking the predefined trajectory



Modified Banshee microgrid in HTB

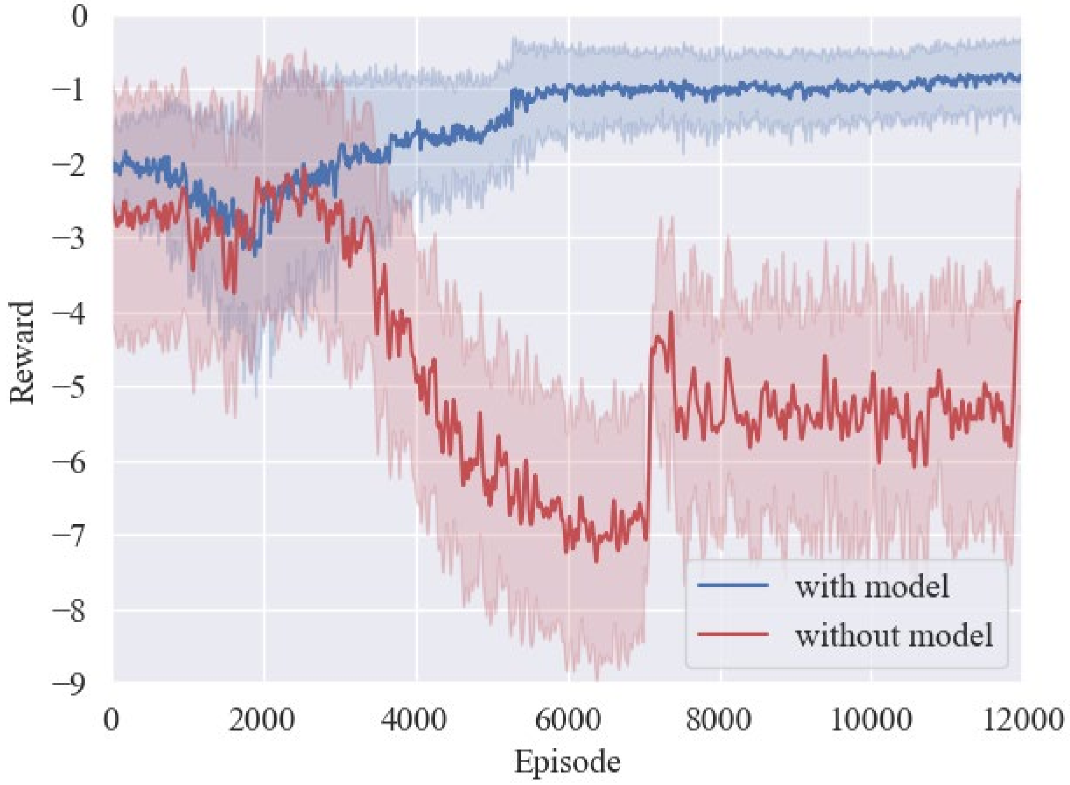


Model-free adaptive PQ control based on physics-informed reinforcement learning and power HIL experiment

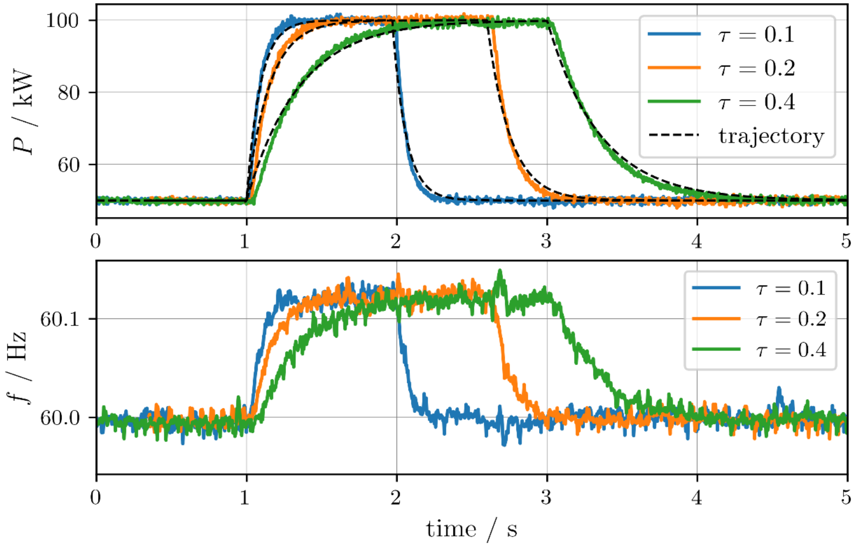
[1] B. She, F. Li*, et.al. “Inverter PQ Control with Trajectory Tracking Capability for Microgrids Based on Physics-informed Reinforcement Learning ", *IEEE Transactions on Smart Grid*, 2024.

Results of PQ control with trajectory tracking

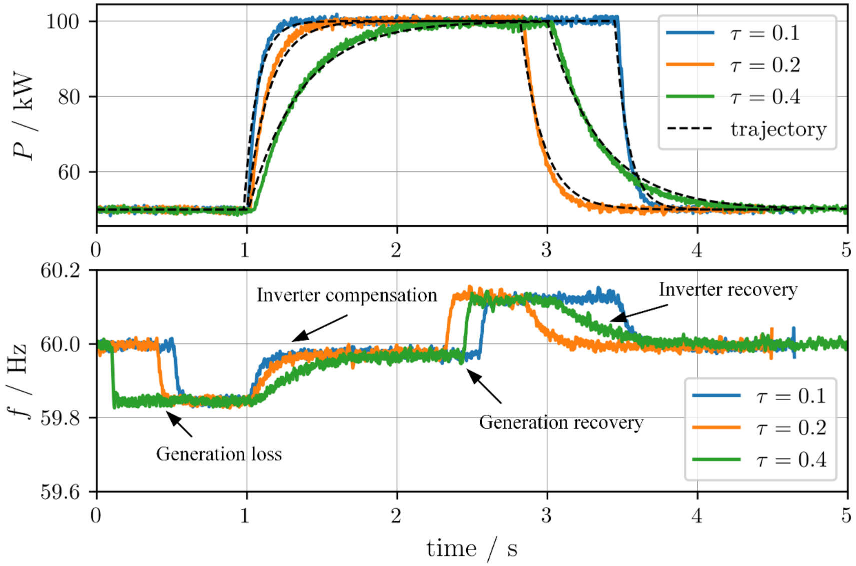
ESTCP



Reward curve with and without model-based analysis



Scheduling reference change



Generation reduction & recovery

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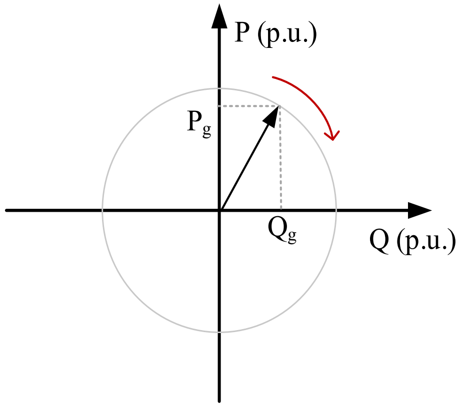
Model-Free Adaptive Control (MFAC) for Autonomous and Resilient Microgrids (2)

Recent Achievements – Part II:

V-f Control considering DER inadequacy [2]

- Developed decentralized and coordinated V-f control under insufficient resource capacity for islanded microgrids
- Mathematically proved the existence of equilibriums and small signal stability



Grid-forming inverter output following the limited DER capacity

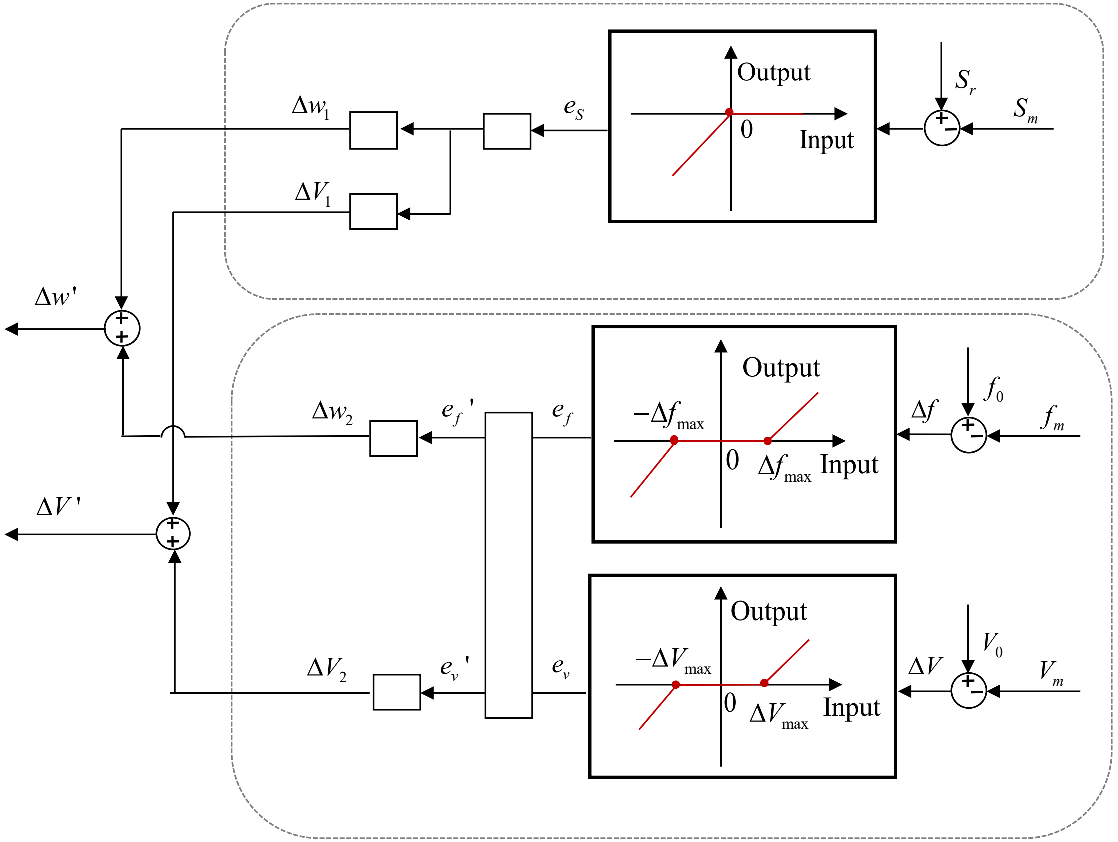
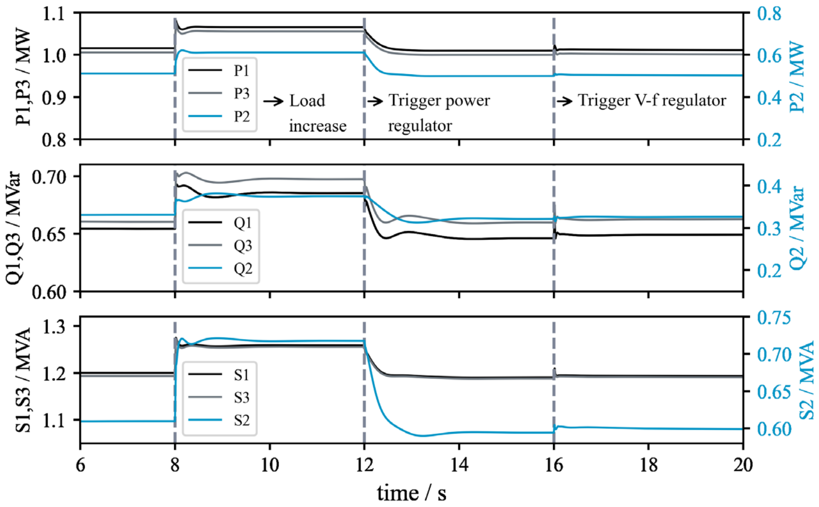


Diagram of the proposed decentralized and coordinated control framework

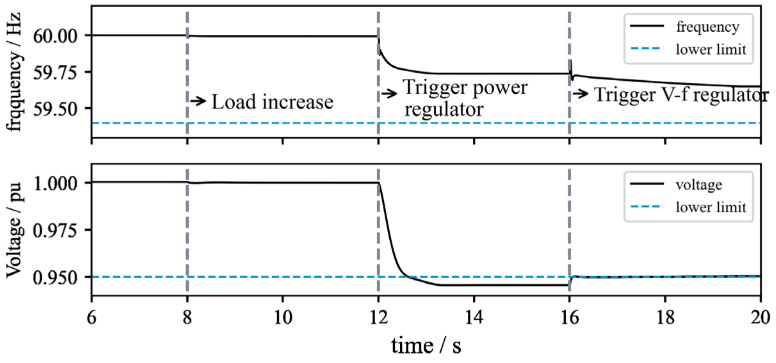
[2] B. She, F. Li*, et.al. "Decentralized and Coordinated V-f Control for Islanded Microgrids Considering DER Adequacy and Demand Control ", *IEEE Transactions on Energy Conversion*, 2023.

Results of V-f control with DER inadequacy

Simulation results: Scenario 1

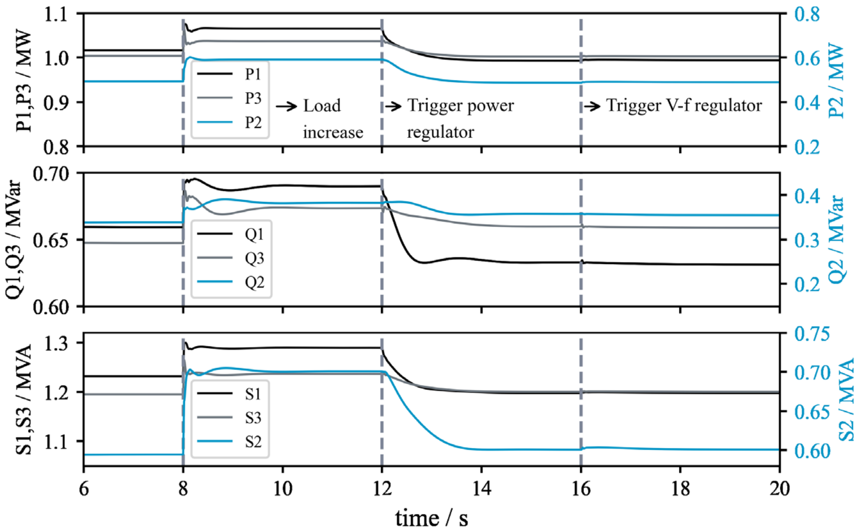


Dynamic inverter output

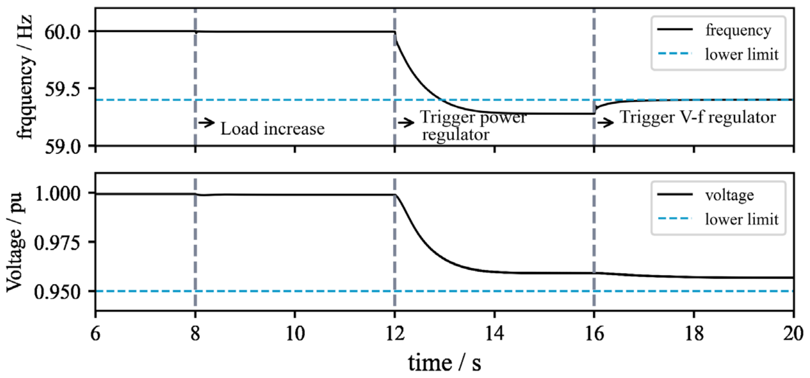


V-f response: increase Q, decrease P

Simulation results: Scenario 2



Dynamic inverter output



V-f response: increase P, decrease Q

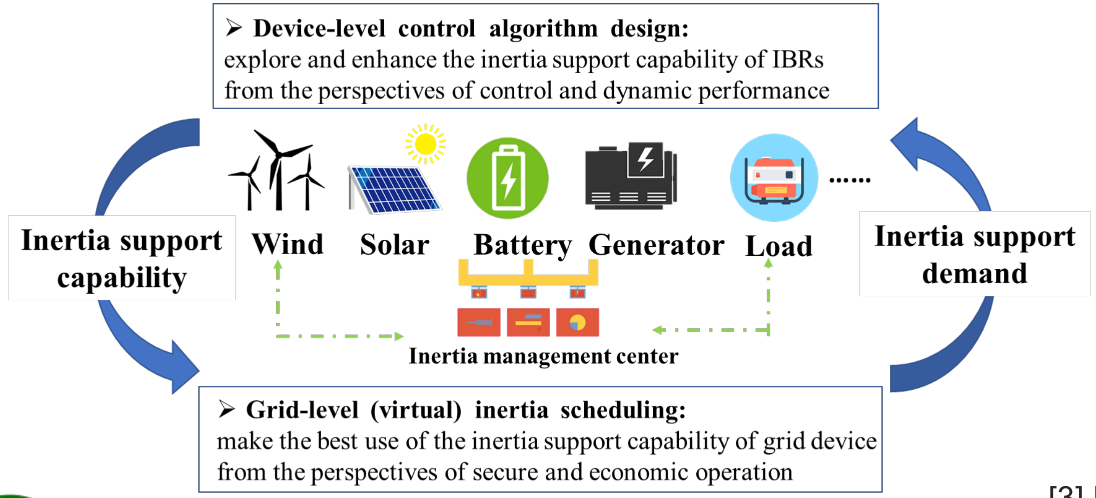
Model-Free Adaptive Control (MFAC) for Autonomous and Resilient Microgrids (3)

ESTCP

Recent Achievements – Part III:

Virtual Inertia Scheduling (VIS) for low inertia grids [3]

- Proposed the concept of VIS, a security-constrained and economy-oriented inertia scheduling and generation dispatch framework for power grids with a large scale of IBRs.
- VIS schedules the power setting points, as well as the control modes and control parameters of IBRs to provide secure and cost-effective inertia support.



➢ Formulation of VIS

Inertia support cost

$$\min_{P,M,D} C_{gen}(P) + C_{aux}(P,M,D)$$

Generation cost

s.t. 1) Standard dispatch constraints

$$2)\begin{cases} M_i^{\min,ibr} \le M_i^{ibr} \le M_i^{\max,ibr}, \forall i \in \{1,\cdots,N_{ibr}\} \\ D_i^{\min,ibr} \le D_i^{ibr} \le D_i^{\max,ibr}, \forall i \in \{1,\cdots,N_{ibr}\} \end{cases}$$

$$3)\begin{cases} -RoCof_{\lim} \le f_0 \dfrac{\Delta P_{e,t}}{M_t} \le RoCof_{\lim}, \ \forall t \in \{1,\cdots,T\} \\ f_{\min} \le f_0 + \Delta f_{nadir,t} \le f_{\max}, \ \forall t \in \{1,\cdots,T\} \end{cases}$$

[3] B. She, F. Li*, et.al. “Virtual Inertia Scheduling for Power Systems with High Penetration of Inverter-based Resources". *IEEE Transaction on Sustainable Energy*, 2024.

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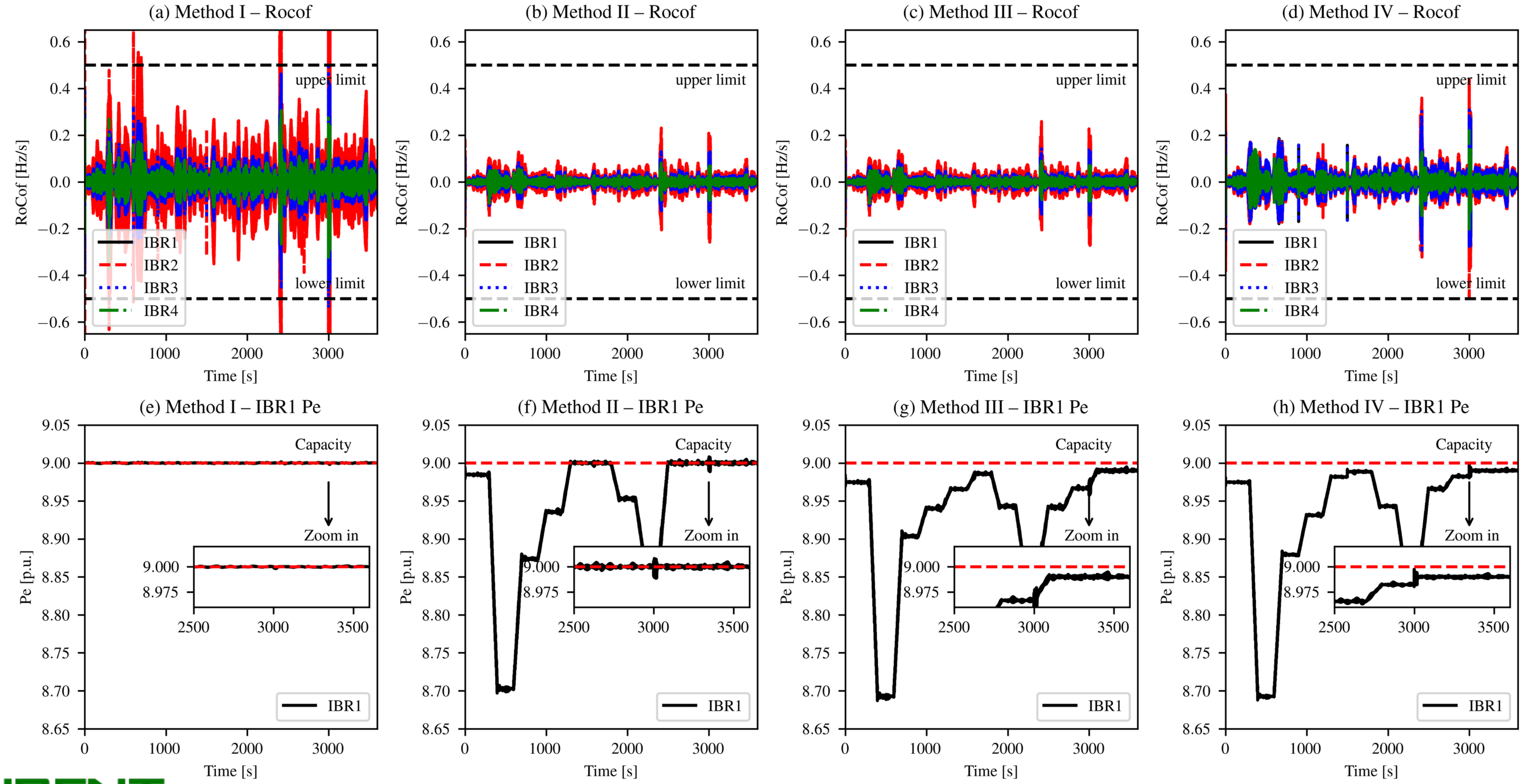
Results of Virtual Inertia Scheduling (VIS)

ESTCP

- **Comparison study of one-hour dispatch + time-domain simulation**



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(I) Constant power; (II) Fixed M & D, no reserve; (III) Fixed M & D, with reserve; (IV) VIS algorithm

Yilu Liu

- UT/ORNL Governor's Chair, CURENT Deputy Director
- Research Interests: grid monitoring and applications, oscillation damping control, Inertia and grid strength, EMP impact, Micro Grid,
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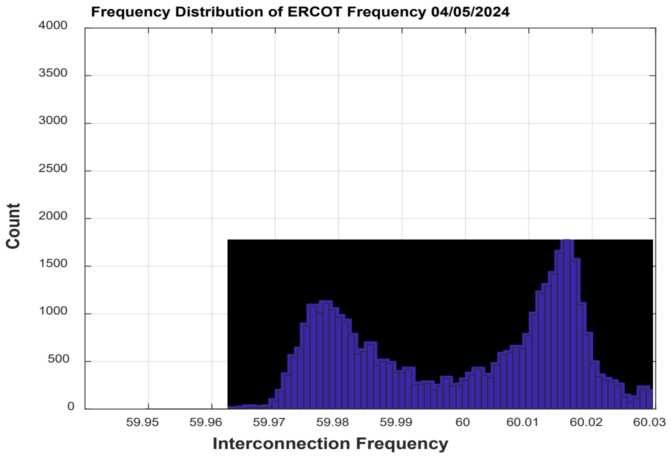
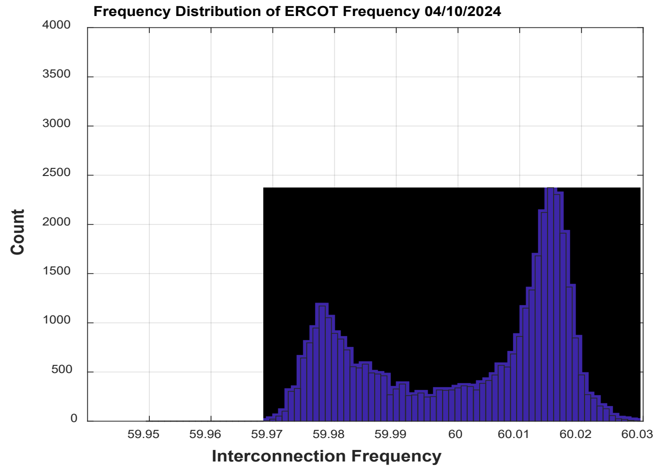
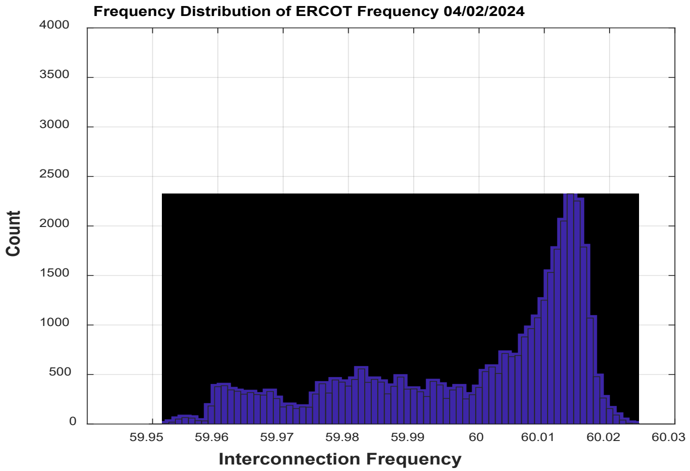
2023-2024 Research Projects

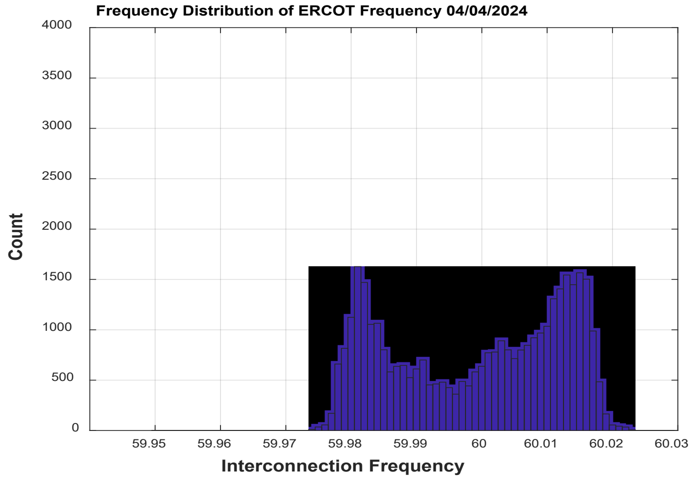
1. Forced oscillation source location tool (EPRI)
2. Forced oscillation source type classification (TVA)
3. EI system inertia trending study (Dominion)
4. Data center models (Dominion)
5. Digital twin for microgrid (Southern Company)
6. Adaptive oscillation damping control and field test (EPRI, NYPA, TERNA, DOE)
7. EMP susceptibility characterization of generation stations (ORNL, TVA, Domimion)
8. Secure timing system using pulsar signal (NSF)
9. BESS probing for inertia estimation in real time (NREL, KIUC, AES, GPTech)
11. Pump storage operation signature-based inertia estimation (WPTO, Dominion, TVA, PG&E)
12. Develop low cost syn-wave monitors for PV systems (ORNL, DiGiCollect).
13. OEDI Distribution state estimation, VW control, and transient data generation (ORNL, DOE SETO)
14. Virtual Operator Assistance – AI based fast real time transient stability prediction tool (ORNL, DOE AGM)
15. FNET/GridEye data transmission, visualization, and real time applications (NERC, AGM)
16. Oscillation and inertia trending (ORNL)
17. Landfill site microgrid development feasibility study (EPB, KUB)
18. Real time grid frequency prediction (Apple)

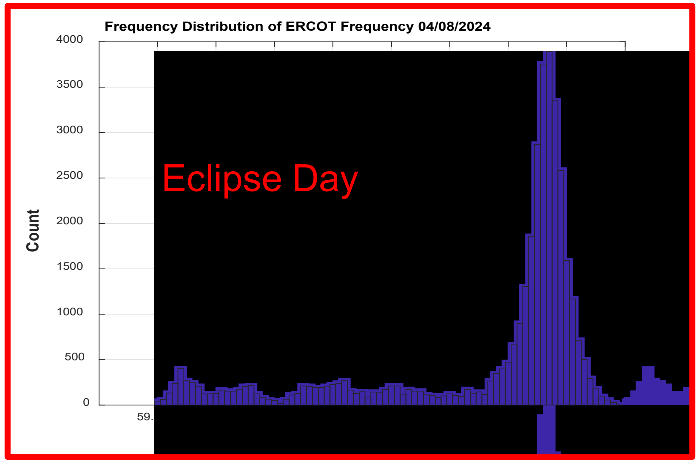
ERCOT Frequency - Eclipse Time 18:00 -19:00 UTC











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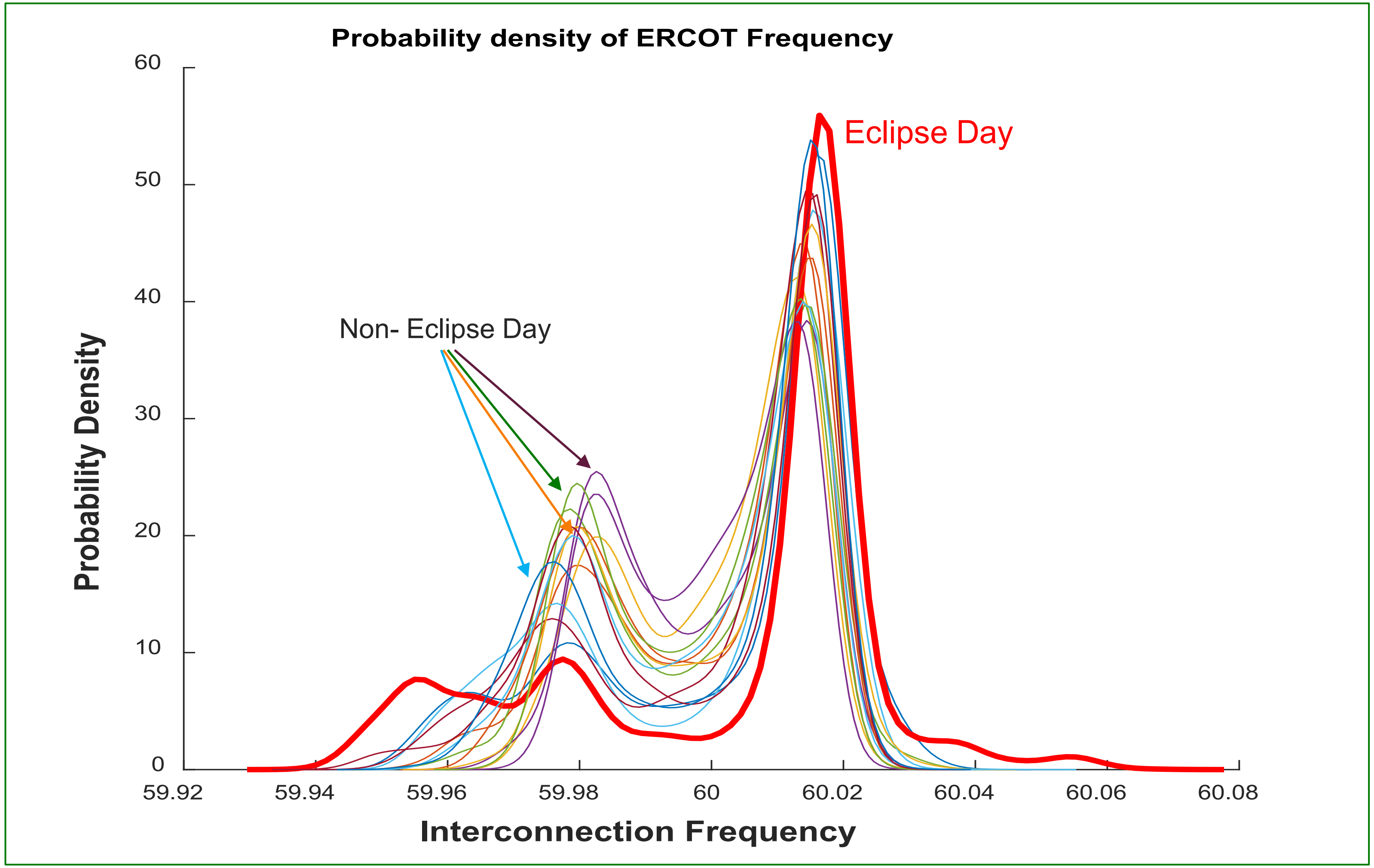
Map Source: https://science.nasa.gov/eclipses/future-eclipses/eclipse-2024/where-when/
Photo Source: Dr. Anil Pahwa

Probability Density of ERCOT (Eclipse hours)



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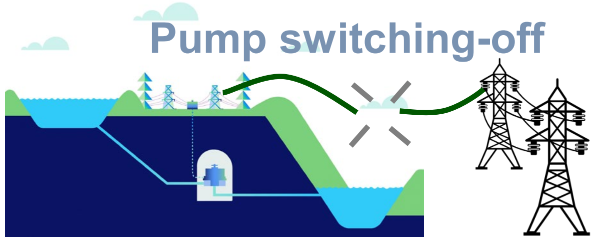
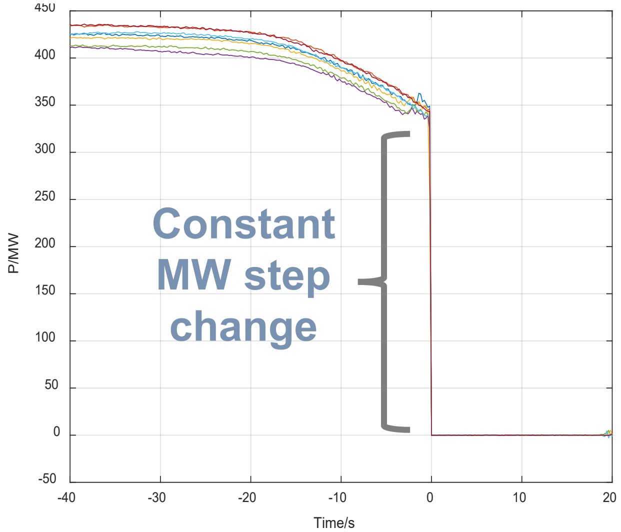
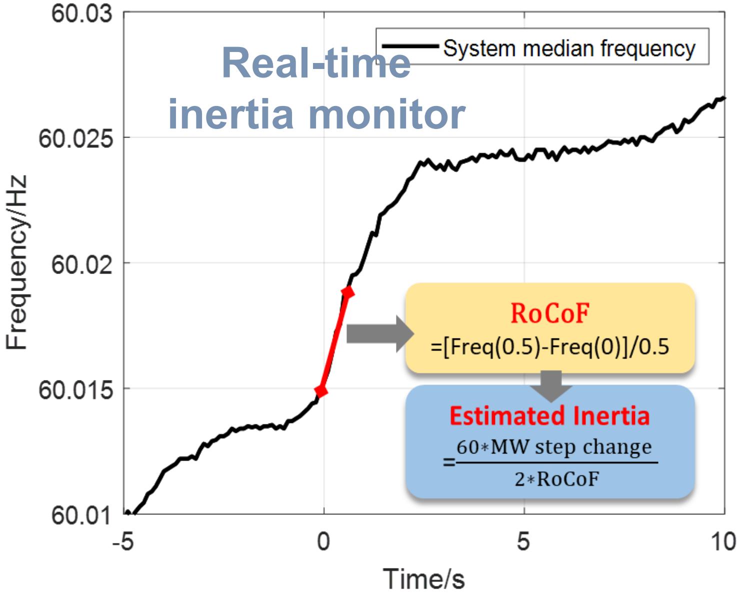
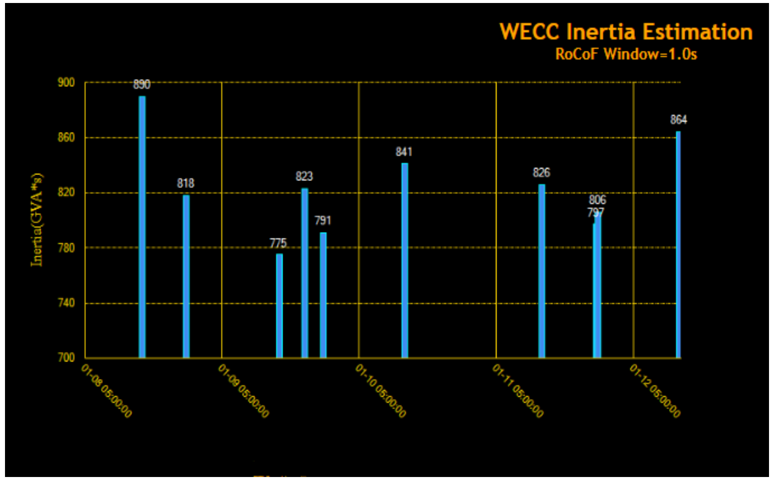
Inertia Monitoring – EI, WECC, KIUC

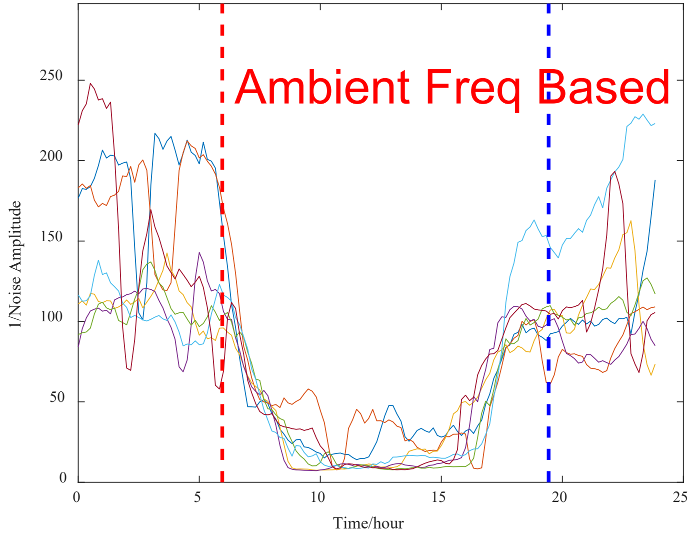


Helms (PG&E)
Bath County (DOM)
Racoon Mt (TVA)

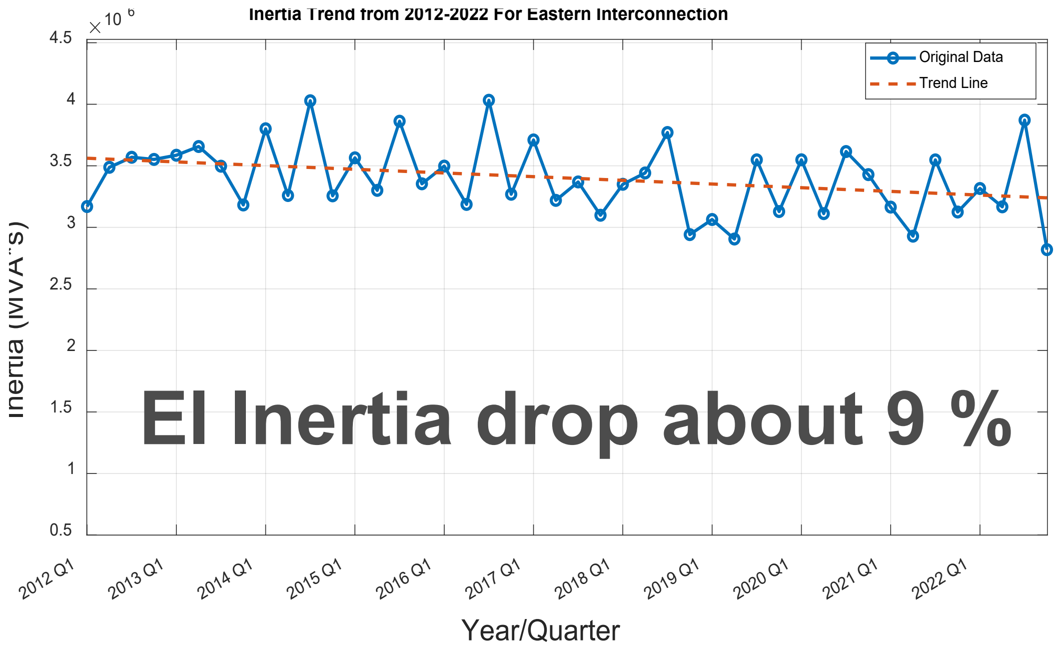


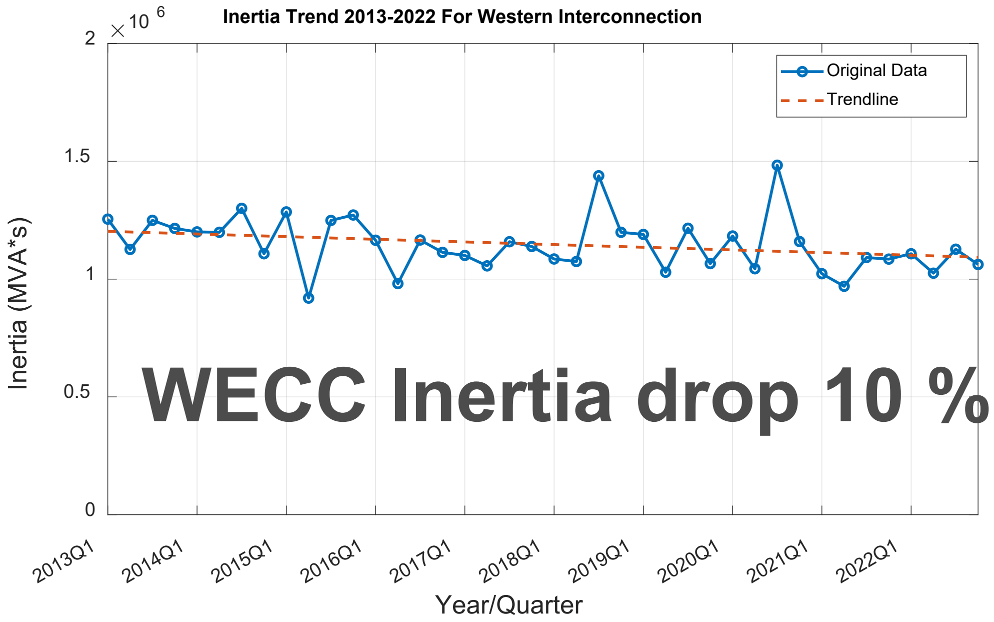


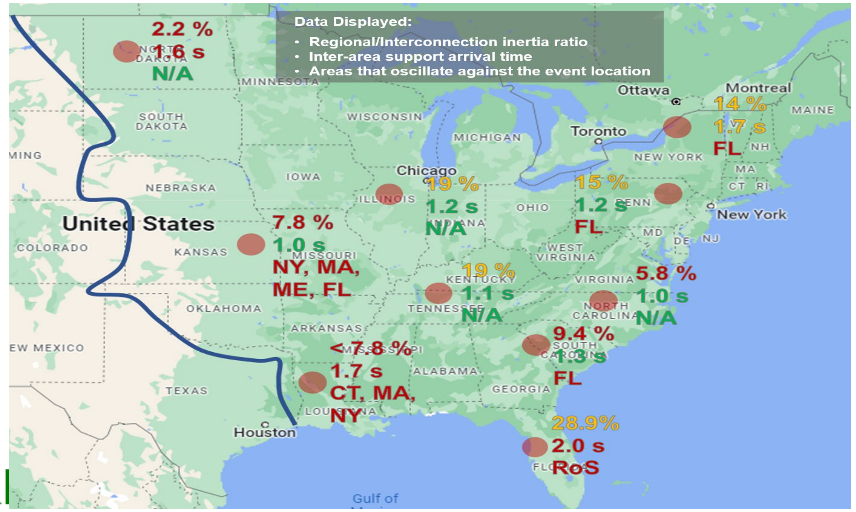


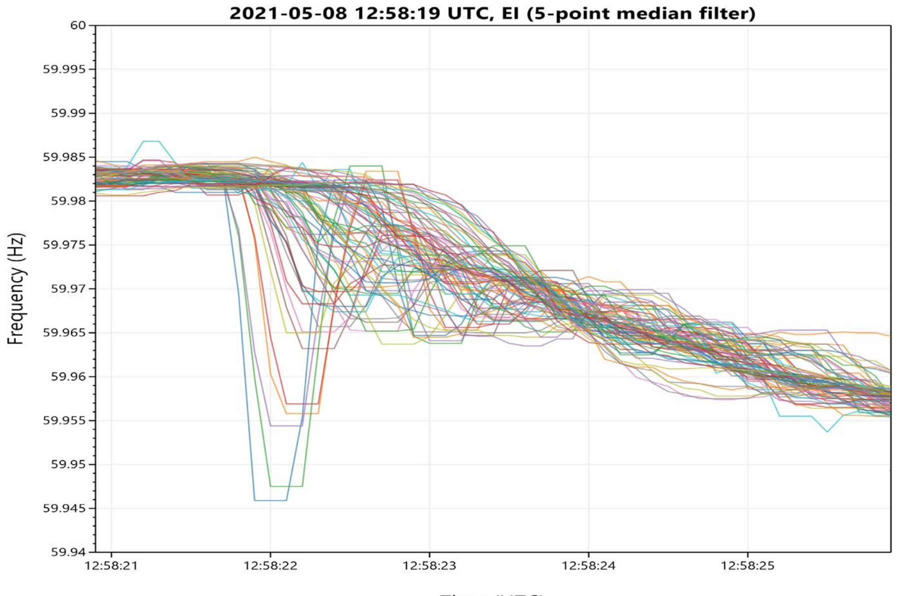


EI, WECC Inertia Trend 2012-2022 (DOM, ORNL)





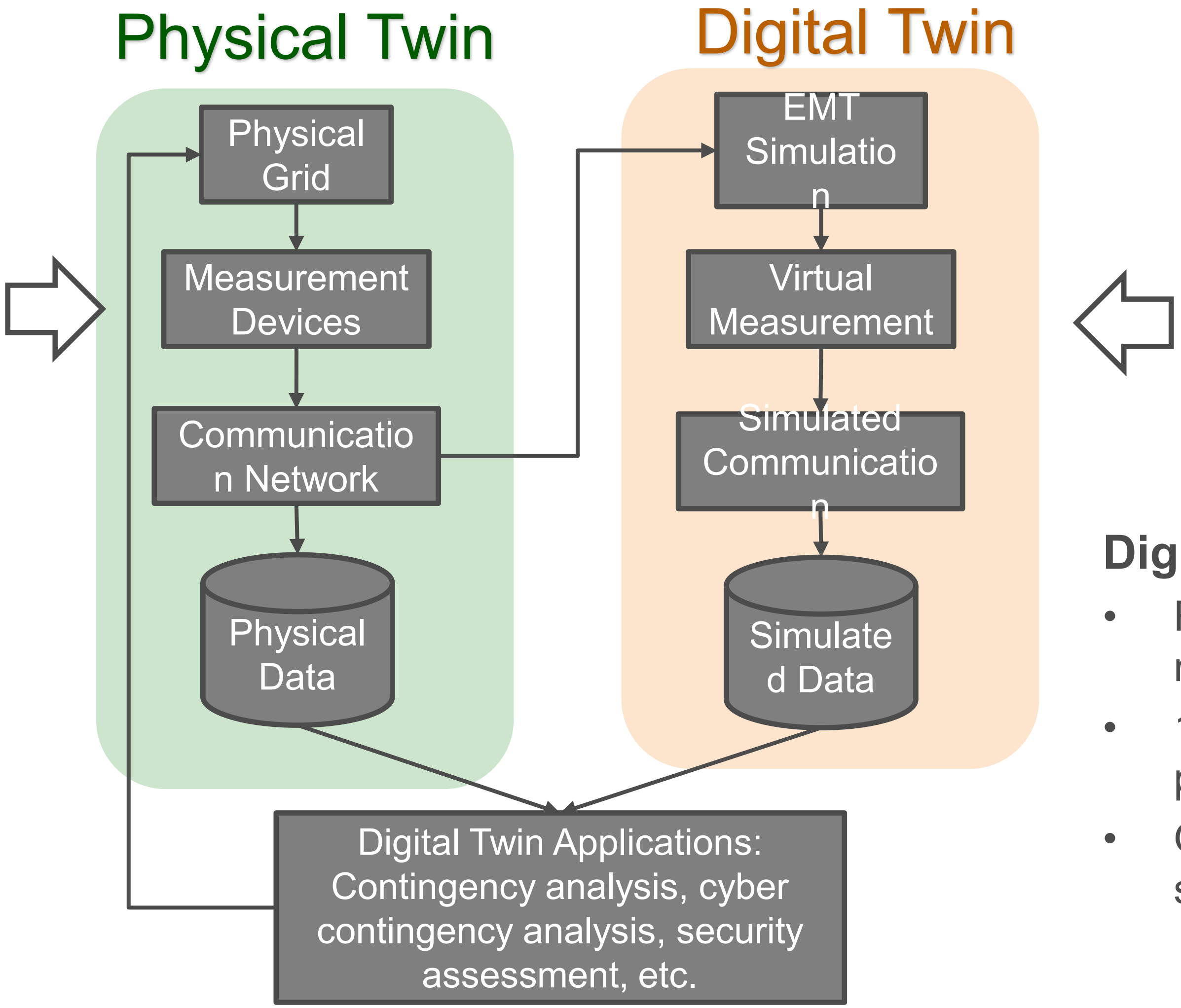




Micro Grid Digital Twin (Southern Company)

Microgrid Components

- Photovoltaic generation
- Battery energy storage
- Diesel Generation
- Residential load



Digital Twin Functionality

- RMS voltage and current measurements
- 14 second measurement period
- Opal-RT real-time simulator

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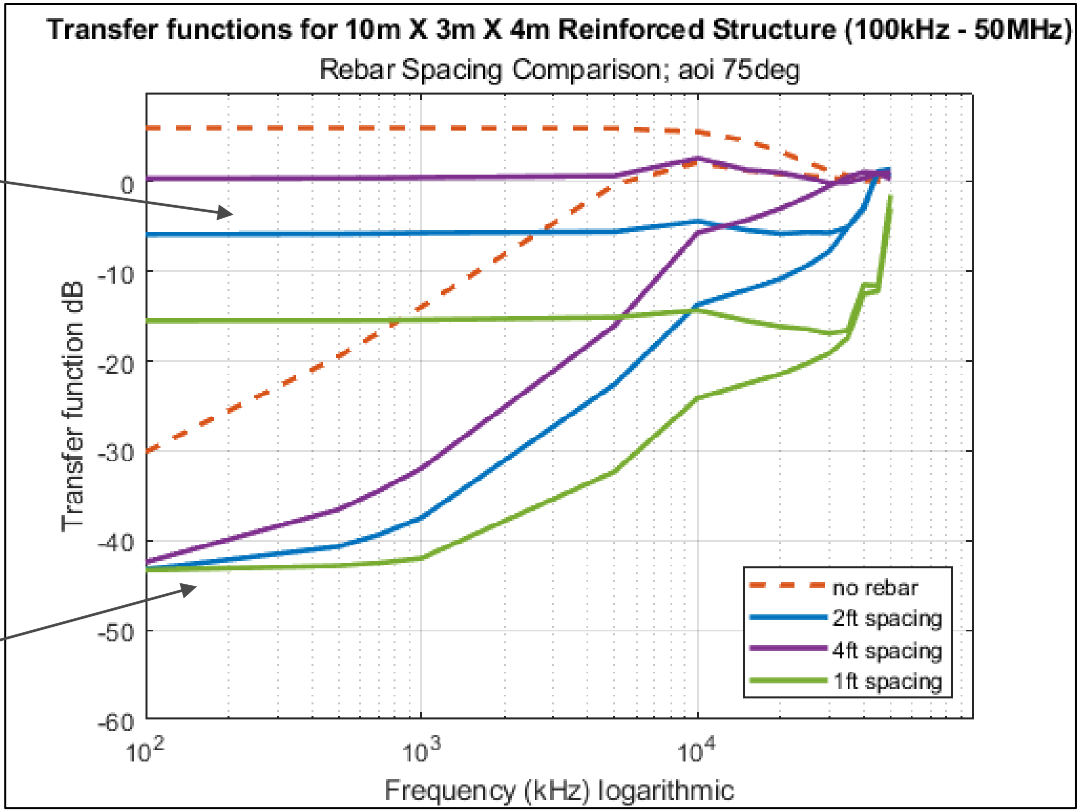
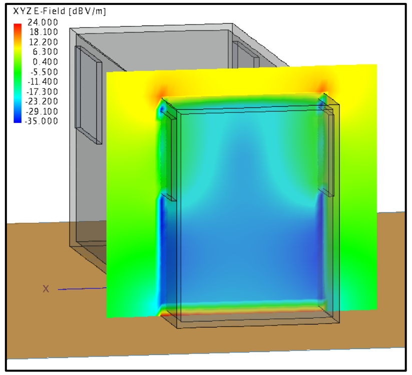
Building EMP Shield Effect (ORNL)

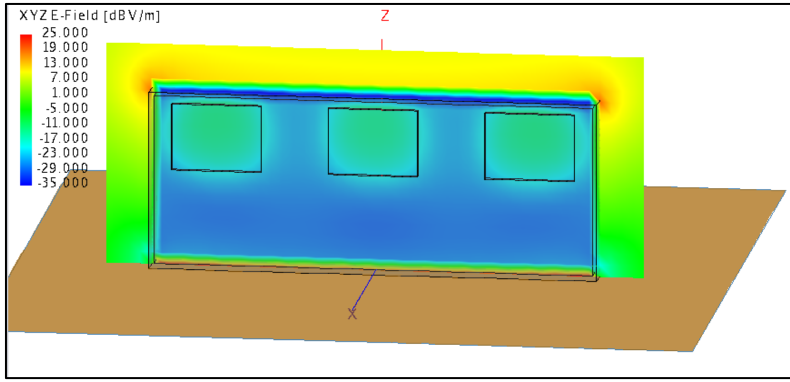
Reinforced Concrete

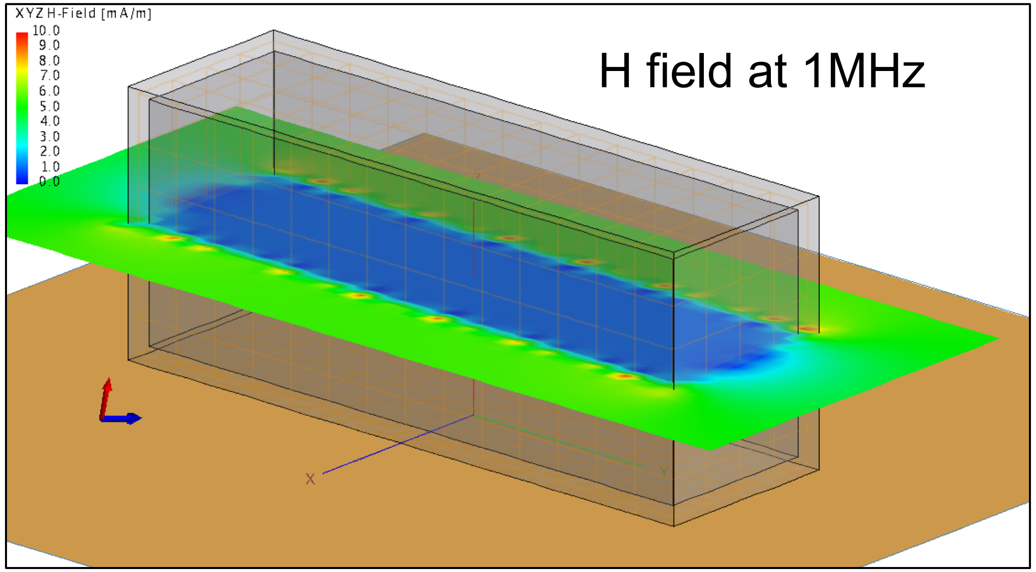
H field



E field







Rebar provides significant H field shielding throughout the frequency range

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Tool Development

- Distribution three phase state estimator
- SPOT- distribution grid sensor placement tool
- Distribution Volt-Watt optimization tool
- Automatic DC to AC power flow conversion tool.
- Forced oscillation source location tool
- PSS/e to PSCAD model conversion tool
- Renewable integration tool – in development
- Regional inertia estimation tool – in development

Hector Pulgar

- **UTK Associate Professor**
- **Research Interests: Power system stability and dynamics, energy storage systems and renewable generation.**
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2023-2024 Research Projects

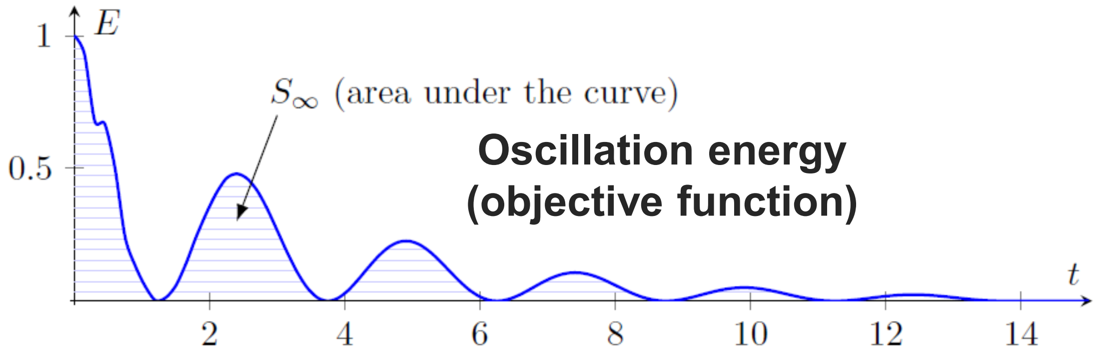
1. Adaptive dynamic coordination of damping controllers: Enhancing oscillation damping through a data-driven approach (funded by NSF)
2. Towards enhanced grid robustness: Augmenting grid regulating capabilities through discrete controls on emerging power technologies (funded by NSF)

Adaptive dynamic coordination of damping controllers: Enhancing oscillation damping through a data-driven approach

Project Objectives

- Adaptability to faults and operating conditions.
- Modal-based and data-driven approaches.
- IBRs are used for damping control only when the system requires them (control commitment determined promptly using activation/deactivation signals based on our data-driven scheme)

IBRs (wind, solar, storage)



Oscillation energy (objective function)

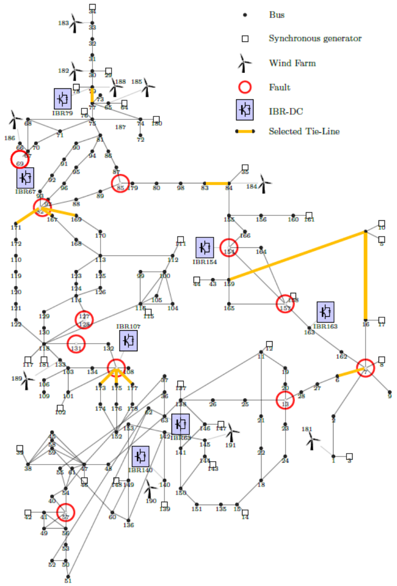


Fig. 4: 179-bus, 30-machine, 7-DC test system.

Results

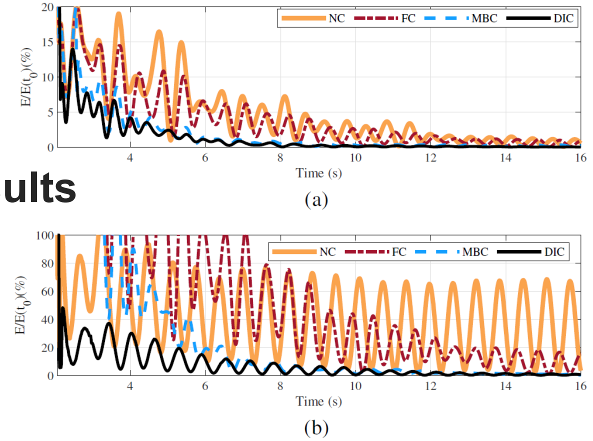
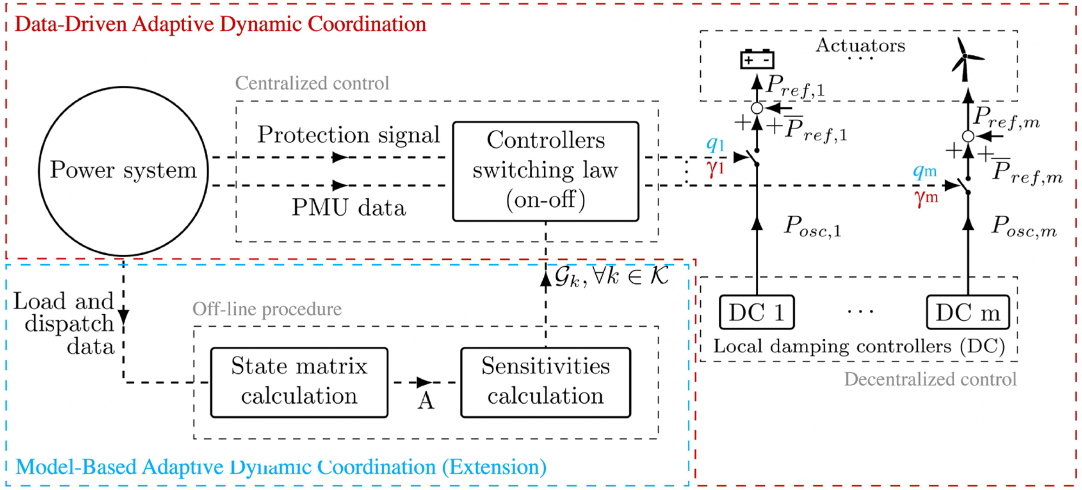
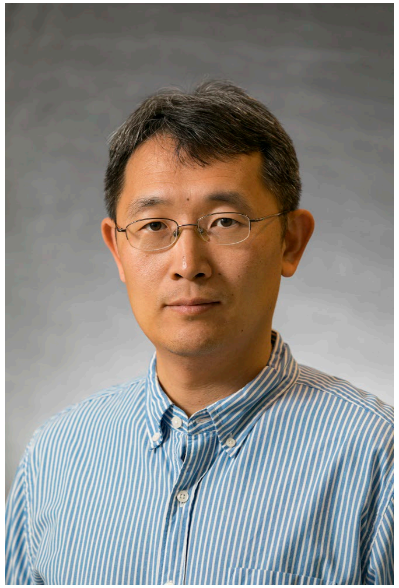


Fig. 10: Comparison between MBC and DIC for short-circuit at bus: (a) 157, and (b) 69.



Control coordination framework



Kai Sun

- **UTK Professor in Power Systems**
- **Research Interests:** Power System Dynamics, Stability and Control; Cascading Outages; Renewable Integration.
- kaisun@utk.edu

2023-2024 Research Projects

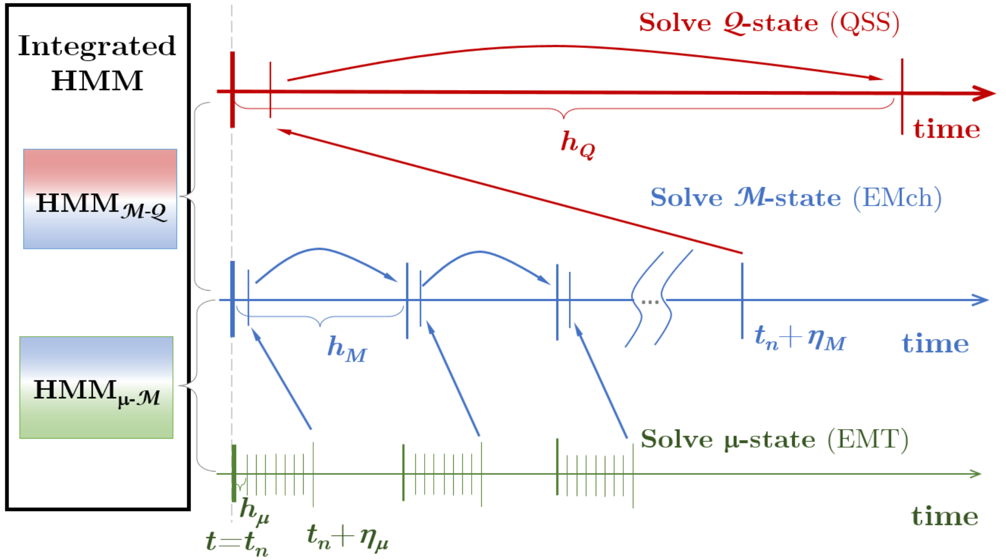
1. A Semi-Analytical, Heterogeneous Multiscale Method for Simulation of Inverter-Dense Power Grids (NSF, ANL)
2. Intelligent Phasor-EMT Partitioning for Hybrid Simulations to Accelerate Large-scale IBR Integration Studies (SETO/NREL, ISO New England, EPRI)
3. Mobility-Energy-Coordinated Platform for Infrastructure Planning to Support AAM Aircraft Operations (NASA/New Mexico State University)

A Semi-Analytical, Heterogeneous Multiscale Method for Simulation of Inverter-Dense Power Grids

Project Objectives:

- Developing a Heterogenous Multiscale Method (HMM) framework for automatic, case-specific model reduction on the fly of each EMT/phasor simulation.
- Developing variable-order variable-step semi-analytical solution (SAS) methods to accelerate EMT/phasor simulations.
- Targeting a 10-100x speedup of EMT simulations on large-scale grid models with 50-100% IBR penetration.

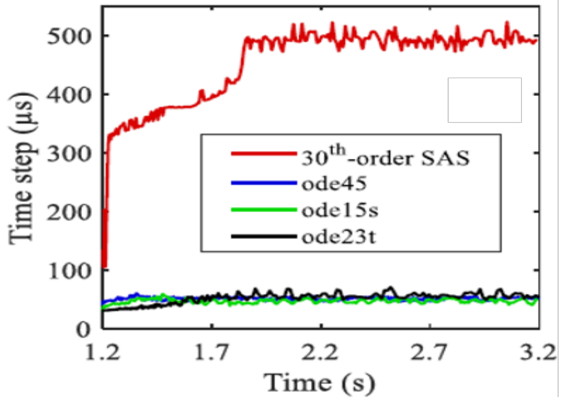
HMM framework for simulating multi-timescale (EMT, electromechanical and quasi-steady-state) grid dynamics

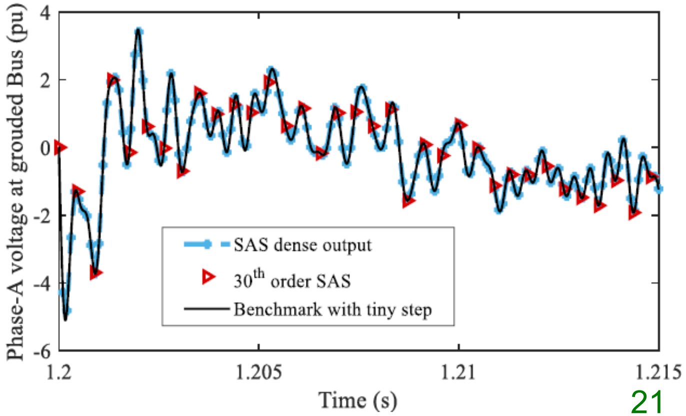


High-order SAS method achieves a 5-20x speedup of accurate EMT simulation by using a 10-100x stepsize.

Comparison of Performance on a 390-Bus System

Approach	PSCAD				SAS
Time step (μs)	5	50	75	100	534
Time cost (s)	425	42.5	28.3	21.5	98
Maximum error (pu)	0.22	2.58	3.36	3.85	7×10^{-4}
Average error ($\times10^{-3}$ pu)	0.41	2.61	2.91	3.3	0.0012





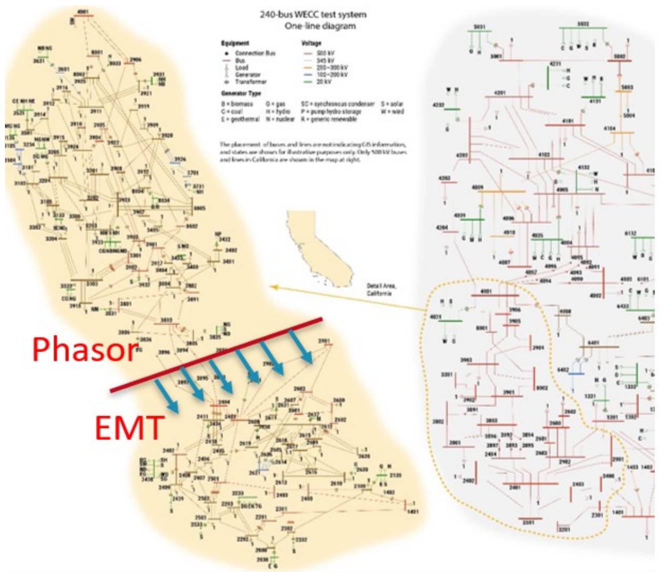
Intelligent Phasor-EMT Partitioning (I-PEP) for Hybrid Simulations to Accelerate Large-scale IBR Integration Studies

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

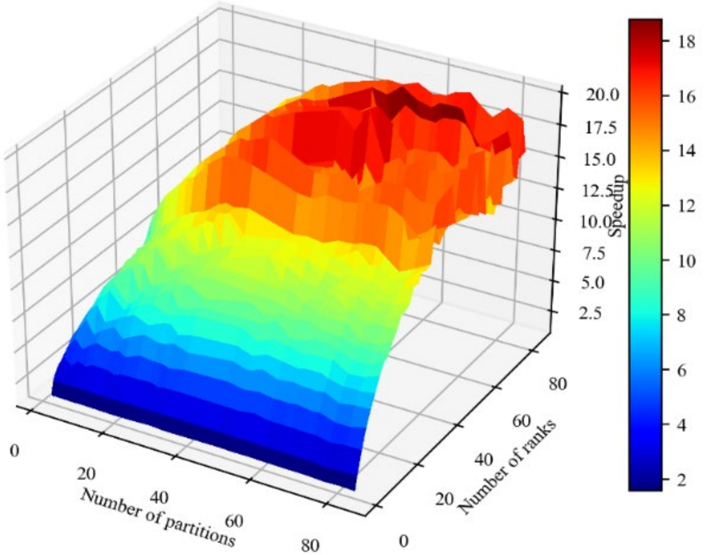
Project Objectives and Achievements:

- Intelligent determination of which portions of the grid to be simulated in EMT models while the rest in phasor models.
- Accelerated NREL's opensource simulator ParaEMT by integrating the SAS method.
- Validation of the method on realistic grid and IBR models.

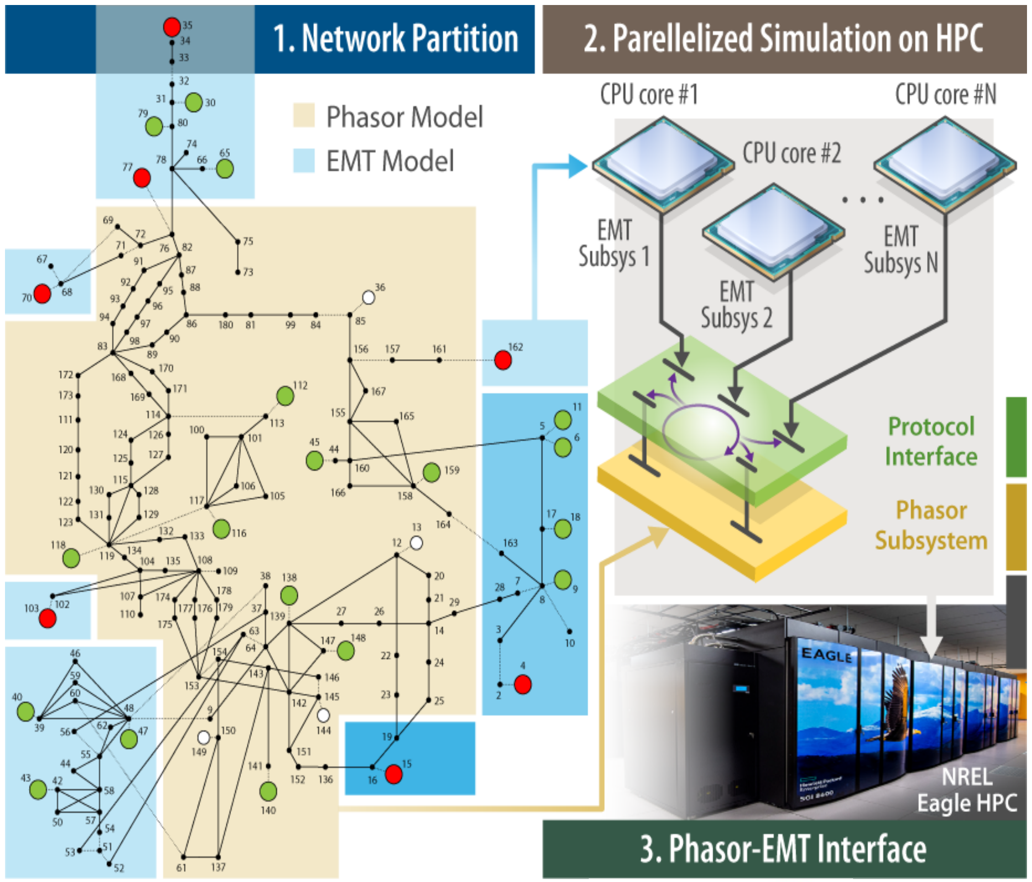
Participation Factor-based Boundary Determination



Speedup by SAS & HPC using 50 µs time step on a 10K-bus EMT model



I-PEP project overview



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NREL
NATIONAL RENEWABLE ENERGY LABORATORY

THE UNIVERSITY OF TENNESSEE KNOXVILLE

EPRI ELECTRIC POWER RESEARCH INSTITUTE

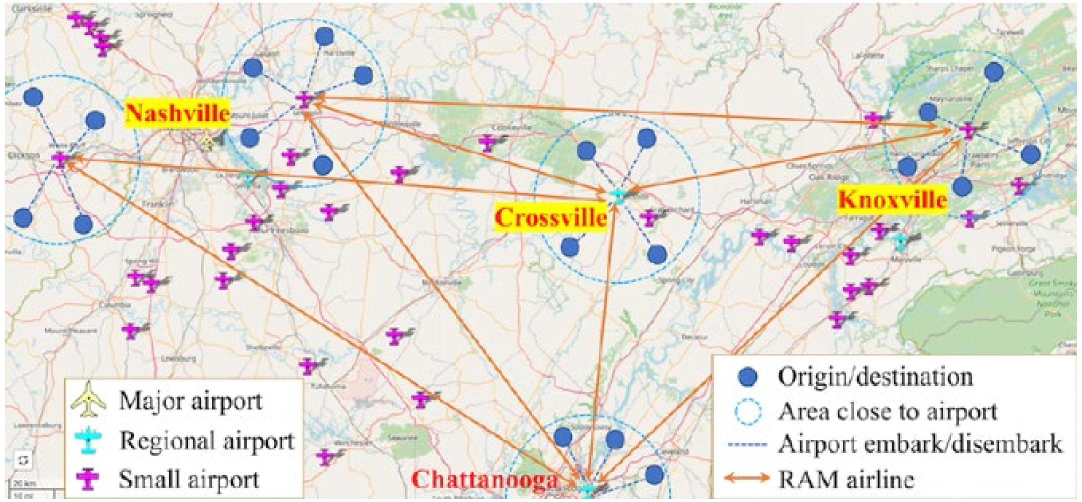
ISO new england

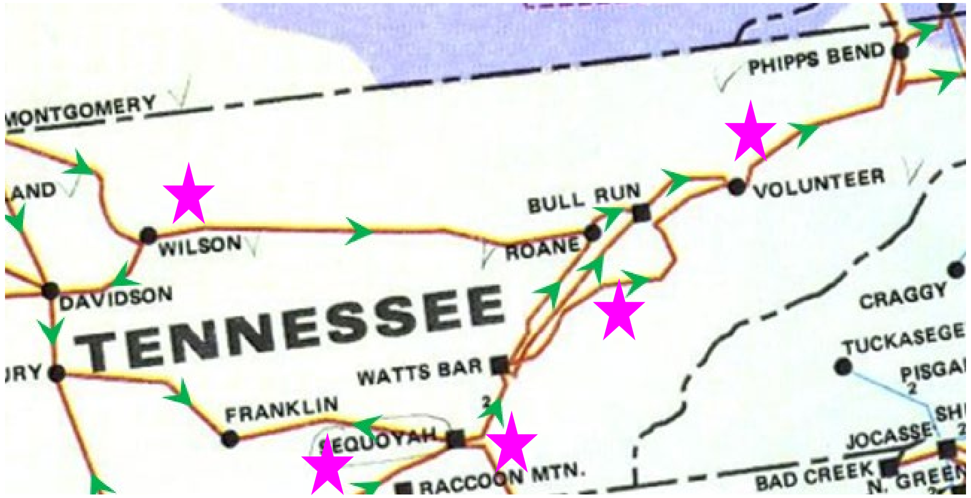
Mobility-Energy-Coordinated Platform for Infrastructure Planning to Support AAM Aircraft Operations

Project Objectives:

- Building power system testbeds to support Advanced Air Mobility (AAM) planning and operation studies.
- Evaluating the impacts of AAM operations on grid reliability and resilience based on power system reliability criteria.
- Accessing electric infrastructure readiness to support AAM aircraft charging.
- Supporting the optimal siting studies on UAM (Urban Air Mobility) and RAM (Regional Air Mobility) portals.

Concept of AAM in Tennessee and candidate locations for RAM portals





CURENT | The University of Tennessee Knoxville | NM State

Kevin Tomsovic

- **UTK Chancellor's Professor and CTI Professor**
- **Research Interests: control, optimization, renewable energy integration, demand response, resilience, cybersecurity.**
- **tomsovic@utk.edu**

2023-24 Research Projects/Highlights

Recently Completed

1. WISP: Watching grid Infrastructure Stealthily through Proxies (**DOE, Raytheon**) (PI: F. Li PI; co-PI: J. Sun)
2. National Transmission Resilience and Reliability (**DOE**) – (PI: F. Li)

Recently awarded and on-going

1. CPS: Medium: Secure Constrained Machine Learning for Critical Infrastructure CPS (**NSF**) (PI: J. Sun, co-PI: H. Qi, H. Lee)
2. A Novel Approach to Mitigating Communication Failures (**NSF**) (co-PIs: S. Djouadi, F. Taousser)

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A New Approach to Control under Network Communication Delays

Project goals and previous accomplishments

- A new mathematical method to estimate the maximum allowed communication delay that does not violate the stability and performance of the power system.
- Manage continuous and discrete dynamics as switching between a continuous-time subsystem (when the communication occurs without any interruption) and a discrete-time subsystem (when the communication fails) by introducing time scales theory.

Recent activities

- A stability criteria has been derived to estimate bounds of the communication loss duration, which guarantees the stability of the system.

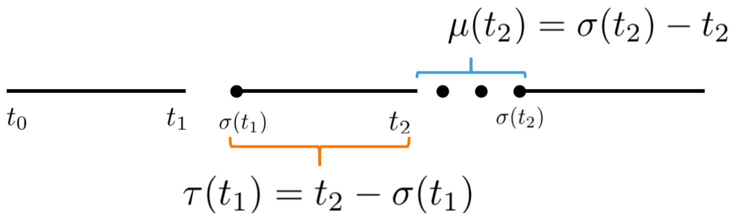
Future works

- Test stability criteria in larger system with considering communication failure.

PIs – Djouadi, Taousser and Tomsovic (PI)

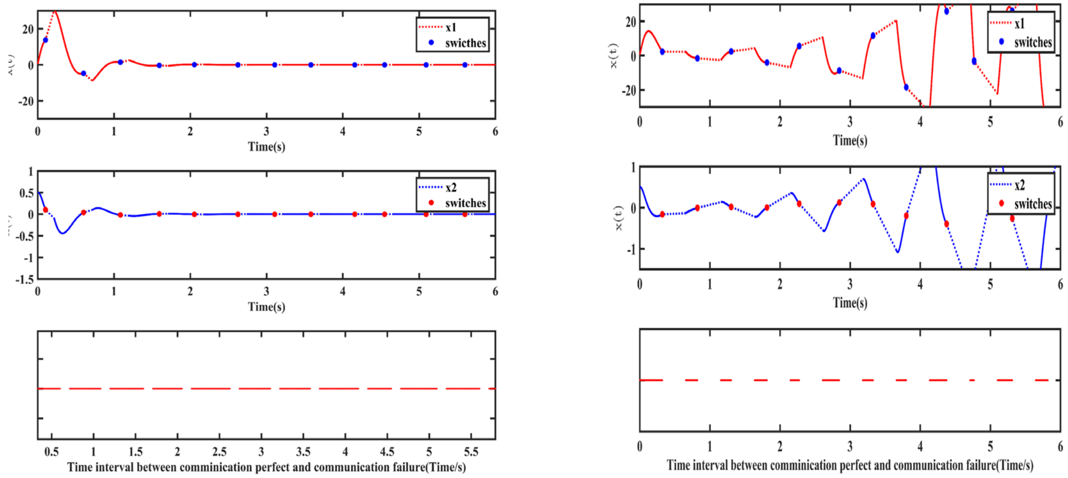
Students: Yichao Wang

Time scales



Switched system

$$x^{\Delta}(t) = \begin{cases} (A+BK)x(t), & t \in \cup_{i=0}^{\infty}[\sigma(t_i), t_{i+1}) \\ \left(\frac{e^{A\mu(t)}-I}{\mu(t)}\right)\left(I + A^{-1}BK\right)x(t), & t \in \cup_{i=0}^{\infty}\{t_{i+1}\} \end{cases}$$



Exploring Physical-Based Constraints in Forecasting: A Defense Mechanism Against Cyberattack

Project goals and previous accomplishments

- Concern with Cyber attacks in machine learning systems
- Physical-based constraints can provide obstacles that makes attacks more difficult.
- Attacker needs to meet the constraints imposed by the physical/topology of system and evade any built-in detection mechanisms in the system.

Recent activities

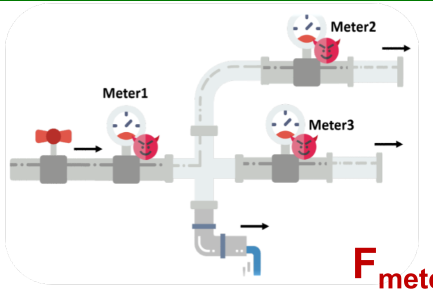
- Proposed a framework to spatially investigate STLF for a defense mechanism (also for traffic systems)
- Applied similarity measures to explore physical-based constraint.
- Outperformed of SAX method, showing more sensitivity to false data injection.

Future works

- Test stability criteria in larger system with considering communication failure.

Pis – Han, Qi, Sun (PI) and Tomsovic

Students: Mojtaba Dezvarei, Farhin Farhad Riya, Ony Hoque, Diyi Liu, Lanmin Liu, Quan Zhou



linear equality/
inequality constraints

$F_{meter1} > F_{meter2} + F_{meter3}$

Water flow measurement

Spatial correlations

- Correlation-based distance: $d_{COR}(X,Y) = \sqrt{2(1 - COR(X,Y))}$
- Periodogram-based distance: $d_p(X,Y) = \sqrt{\sum_{j=1}^{[\frac{N}{2}]}[\rho_x(\omega_j) - \rho_y(\omega_j)]^2}$
- Autocorrelation-based distance: $d_{ACF}(X,Y) = \sqrt{(\hat{\rho}_{X_T} - \hat{\rho}_{Y_T})^T\,\Omega\,(\hat{\rho}_{X_T} - \hat{\rho}_{Y_T})}$
- Symbolic representation SAX: Time series transforming into a string.
- Euclidean-based distance: $d_{EUC}(X,Y) = \sqrt{\sum_{j=0}^{N-1}(x_i - y_i)^2}$

CURENT

Kevin Bai

- **UTK Associate Professor in Power Electronics and Vehicle Electrification**
- **Research Interests: Wide bandgap power electronics, electric vehicle battery chargers, vehicle propulsion systems, battery management systems**
- **kevinbai@utk.edu**

2023-2024 Research Projects

1. "A Smart and Highly Compact Power Electronics Box to Provide Universal Charging Technologies (OBC, Wireless and DCDC)", Magna Powertrain;
2. "Design and Test A 800V/>50kW Three-level Active Neutral Point Clamping Motor Drive Inverter using 650V/60A GaN HEMTs for Electric Vehicles", PowerAmerica;
3. "GaN 800V Module with Double Sided Cooling in a 3L Half Bridge Configuration", Volkswagen Group of America;
4. "Design, Scalability, and Optimization of Combinational Rogowski Coil", Keysight Technologies;
5. "Study grid requirements of installing PEM electrolyzer systems in United States", Robert Bosch;
6. "Scalable Second-life Battery Energy Storage System (Phase 2)", Volkswagen Group of America.

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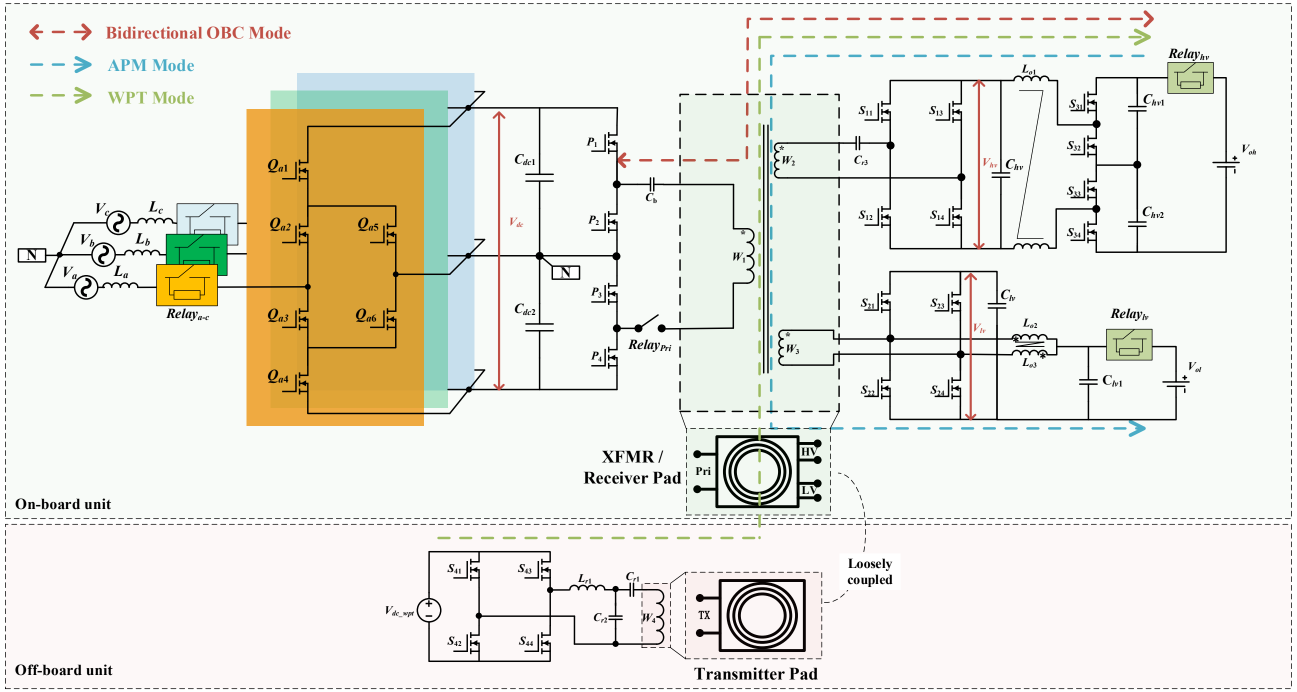
A Smart and Highly Compact Power Electronics Box to Provide Universal Charging Technologies

Project Objectives

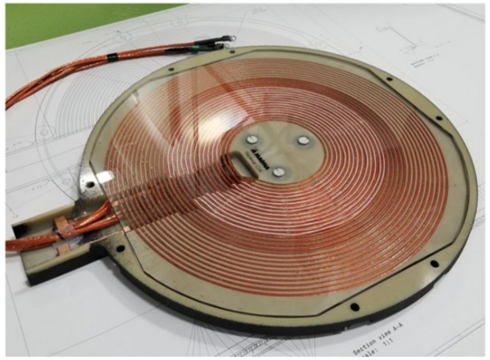
- To integrate DC/DC, OBC and WPT thereby saving the size and cost and offering more charging convenience;
- To provide universal charging for EV drivers;
- To only use GaN devices as a benchmark comparison with Si and SiC.

Recent Achievements

- Finalized the 11kW test of OBC, 6.6kW WPT and V2L modes;
- Developed a novel magnetics coupler;
- Filed two PCTs with Magna through UTRF and published on letter to IEEE Transactions on Industrial Electronics.



The overall Topology



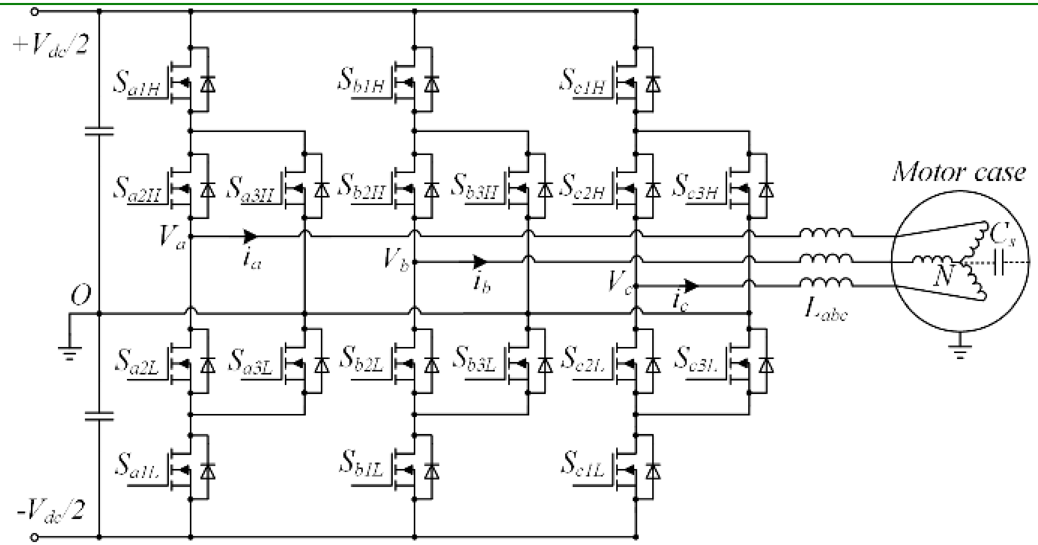
Prototypes

PIs: Kevin Bai, Daniel Costinett

An 800V/>50kW Three-level Active Neutral Point Clamping EV Motor Drive Inverter using GaN HEMTs

Project Objectives

- To explore possibility of using GaN in EV tractions inverters;
- To understand three-level inverter benefits on CM reduction;
- To demonstrate 75kW test to PowerAmerica members.



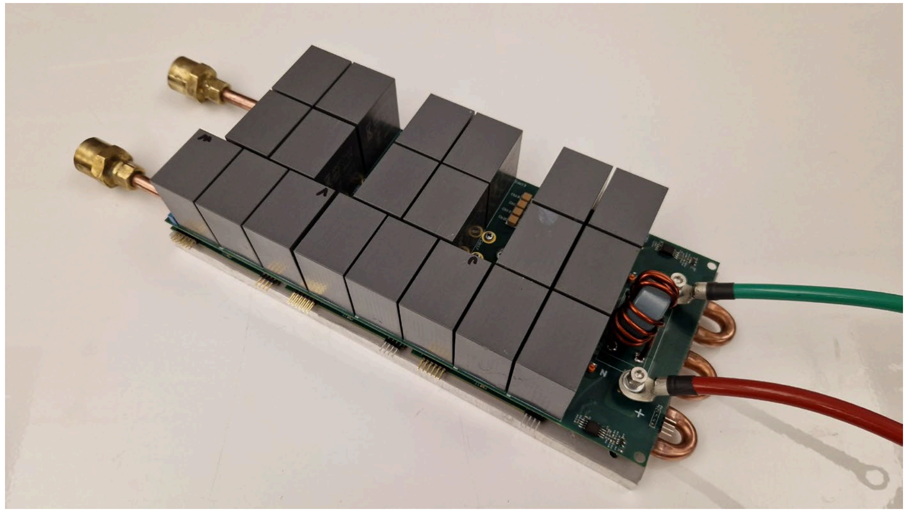
The overall Topology

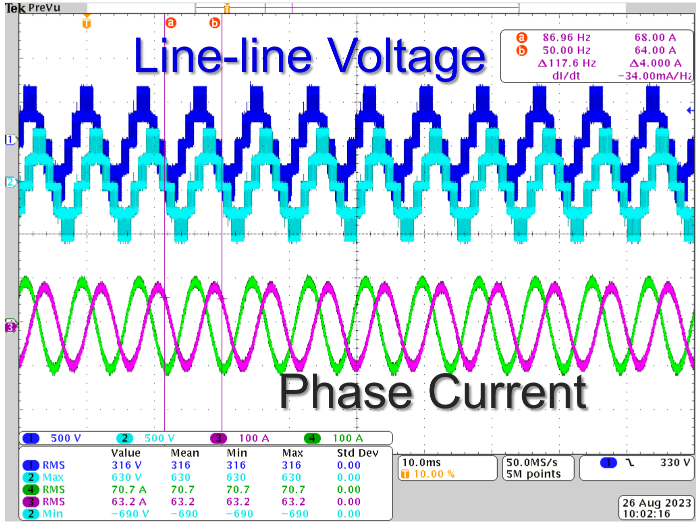
Recent Achievements

- Finalized two versions of prototypes;
- Tested the inverter up to 75kVA on HTB and Mercedes Benz facility.

Mercedes-Benz
Research & Development North America

GaN Systems





CURENT PIs: Kevin Bai, Leon Tolbert and Fred Wang

Prototypes and 800V/75kVA test

Leon Tolbert – The University of Tennessee

- Chancellor's Professor and Min H. Kao Professor, Interim Department Head
  Adjunct Participant at ORNL
- Research Interests: Power electronics for grid and transportation applications, microgrids, energy storage, V2G, wide bandgap power electronics applications
- Email: tolbert@utk.edu

2023-24 Research Projects

1. Asynchronous Hybrid AC/DC Microgrid with Power Conditioning System (DOE)
2. Microgrid Platform Development for Testing Inverter-based Generation Control Parameters (DOD)
3. High Short-Circuit Fault Current Contribution to Enable Legacy Overcurrent Protection for Islanded Microgrids (ORNL)
4. Fault Detection Method by Utilizing Instantaneous Power Theory for Inverter-based Distributed Generation
5. SOC Management for Ultracapacitors for PVSS considering LVRT Operation (UT-ORII)
6. Secondary Use of EV Batteries for Grid Energy Storage (Volkswagen, EPB)
7. Mitigating EMI in GaN-based power electronics packaging
8. A multiscale physics-based magnetics design for high frequency power electronics (ONR)

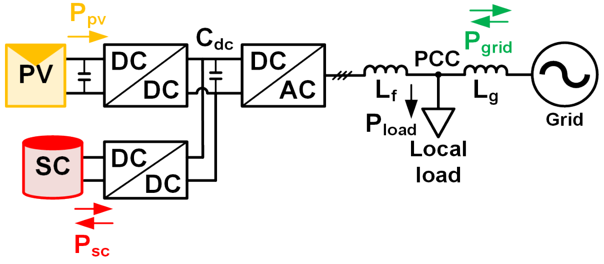
Supercapacitor SOC Management for Grid-Connected PV System Considering LVRT

Project Objectives

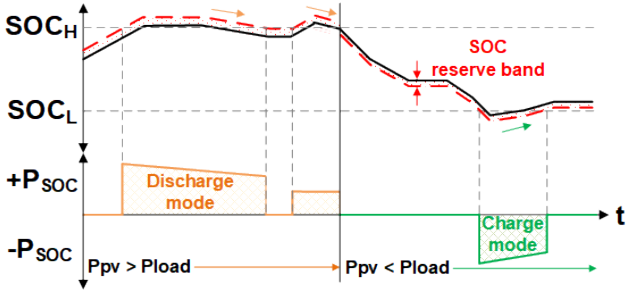
- Provide low-voltage ride-through (LVRT) operation for grid connected PV systems with supercapacitors.
- Proposed SOC management control considers grid conditions by implementing voltage sensitivity factor, PVSS converters' ratings, and supercapacitor rating (voltage, current, temperature) to safely operate and maximize the PVSS capacity while not violating the grid voltage limits.

Key Takeaways

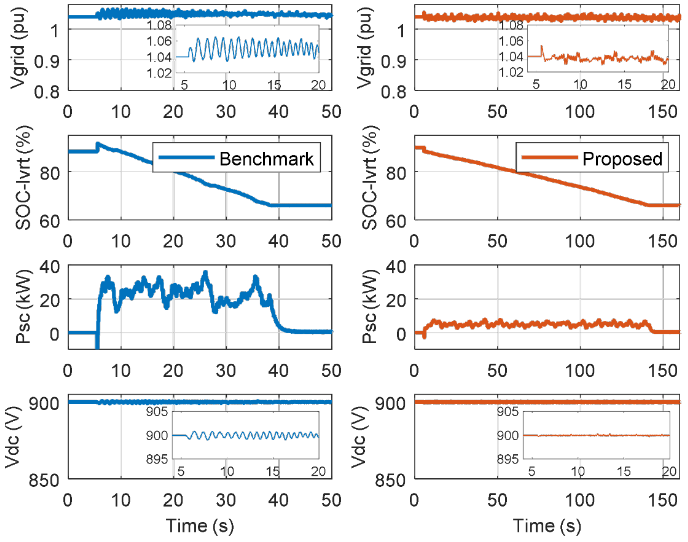
- Supercapacitors avoid the slow response of PV curtailment that reduces the stability of PVSS during grid faults.
- Proposed scheme can provide dynamic SOC reserve levels rather than the fixed reserve margin under different PVSS operating conditions to effectively utilize the SC given its thermal limitations.



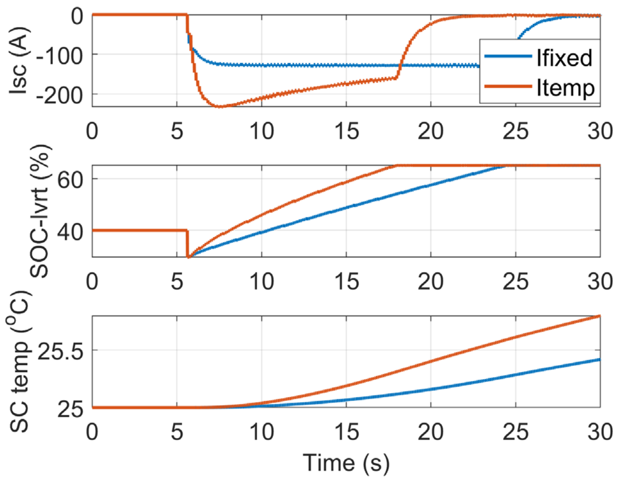
Schematic of a grid-connected photovoltaic with supercapacitor system (PVSS).



SOC reservation concept for LVRT operations



Experimental results of SOC management based on the constant setpoint power (blue) and the proposed method with adjusted power based on grid condition (red).

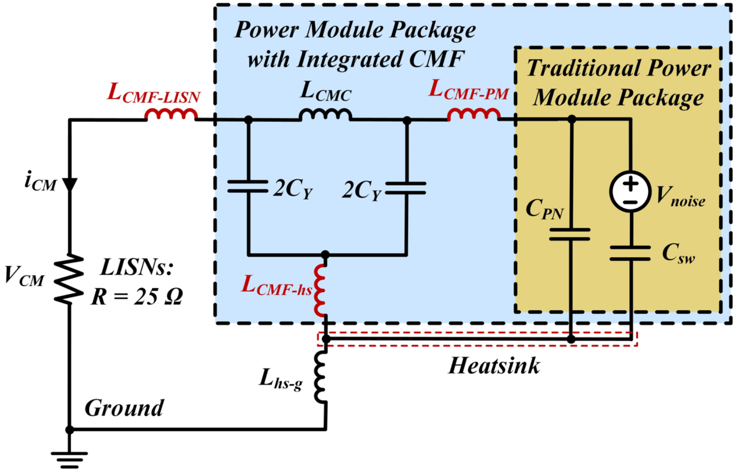


Experimental results of SOC management based on the fixed current (blue) and the current depending on the SC temperature (red).

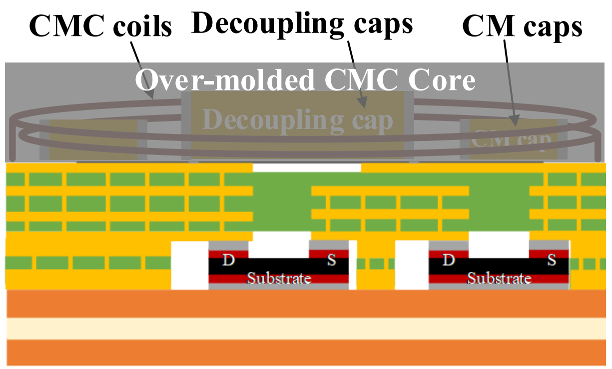
Mitigating EMI in GaN-based power electronics packaging

Project Objectives

- Improve the EMI performance of a GaN-based half-bridge power module by integrating a π-type common-mode filter (CMF) to the package.
- Improve the CMF's magnetic design by over-molding method so as not to decrease the package's power density due to the CMF integration.
- Explore a WBG-package-compatible manufacturing methodology for the over-molded CMF, which could potentially be applied to other WBG packages or circuits.



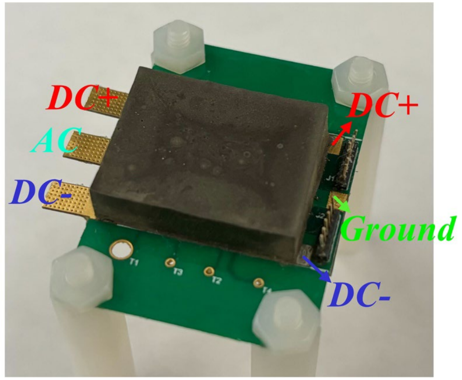
CM equivalent circuits for traditional package and CMF-integrated package



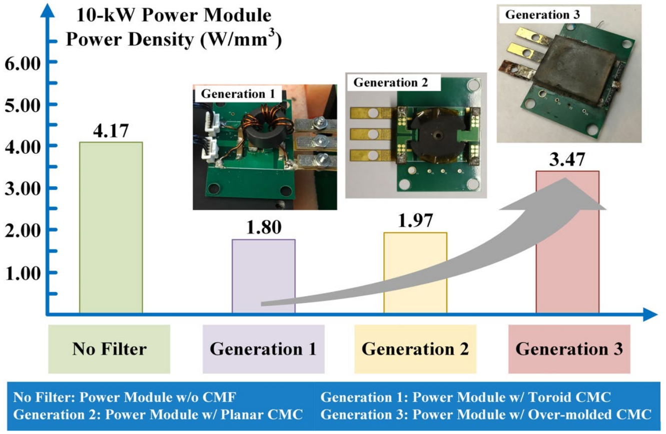
Cut view diagram for the designed GaN power module with over-molded CMF

Key Takeaways

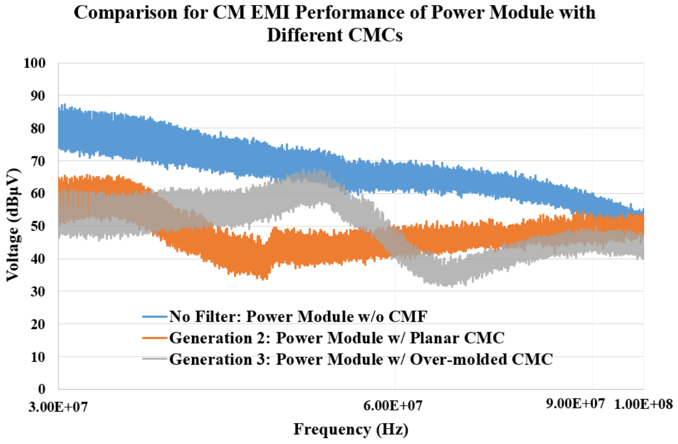
- The over-molded CMF realizes its function of attenuating CM EMI noises in the frequency range of 30 MHz to 100 MHz.
- As the CMF magnetic design improves, the power density increases greatly.



Prototype of GaN-based half-bridge power module with over-molded CMF



Power density comparison for package with different CMC designs



CM EMI noise comparison

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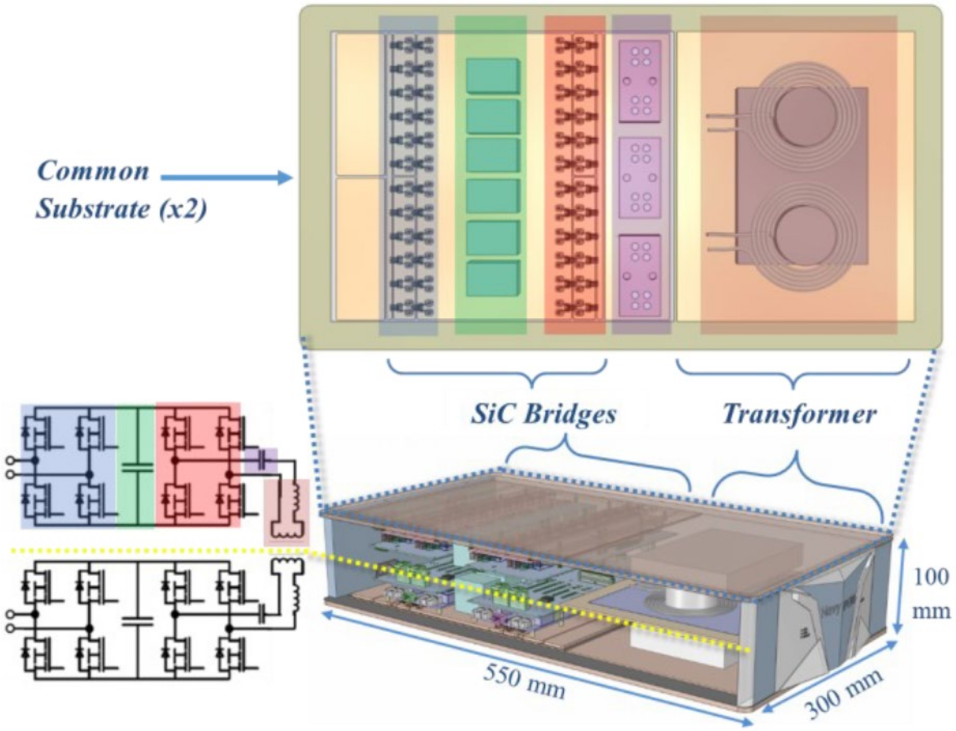
Physics-based magnetics model for high frequency magnetics design

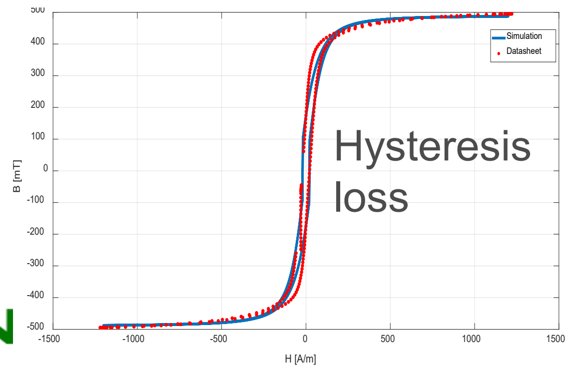
WBG and UWBG semiconductor devices:

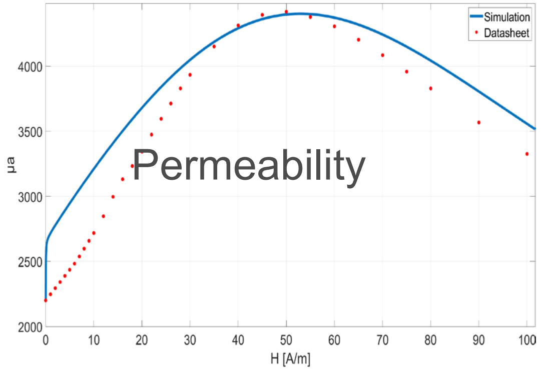
- Higher switching frequency and higher power density
- Potential to drastically reduce passive components size and weight

State-of-the art magnetics need significant improvements:

- Higher saturation for high power applications (up to MW)
- Lower loss for MHz operation
- High-density and low-weight component design techniques







[1] "Design of a High-Density Integrated Power Electronics Building Block (IPEBB) Based on 1.7 KV SiC MOSFETs on a Common Substrate." In *2021 IEEE Applied Power Electronics Conference and Exposition (APEC)*, 1–8, 2021.

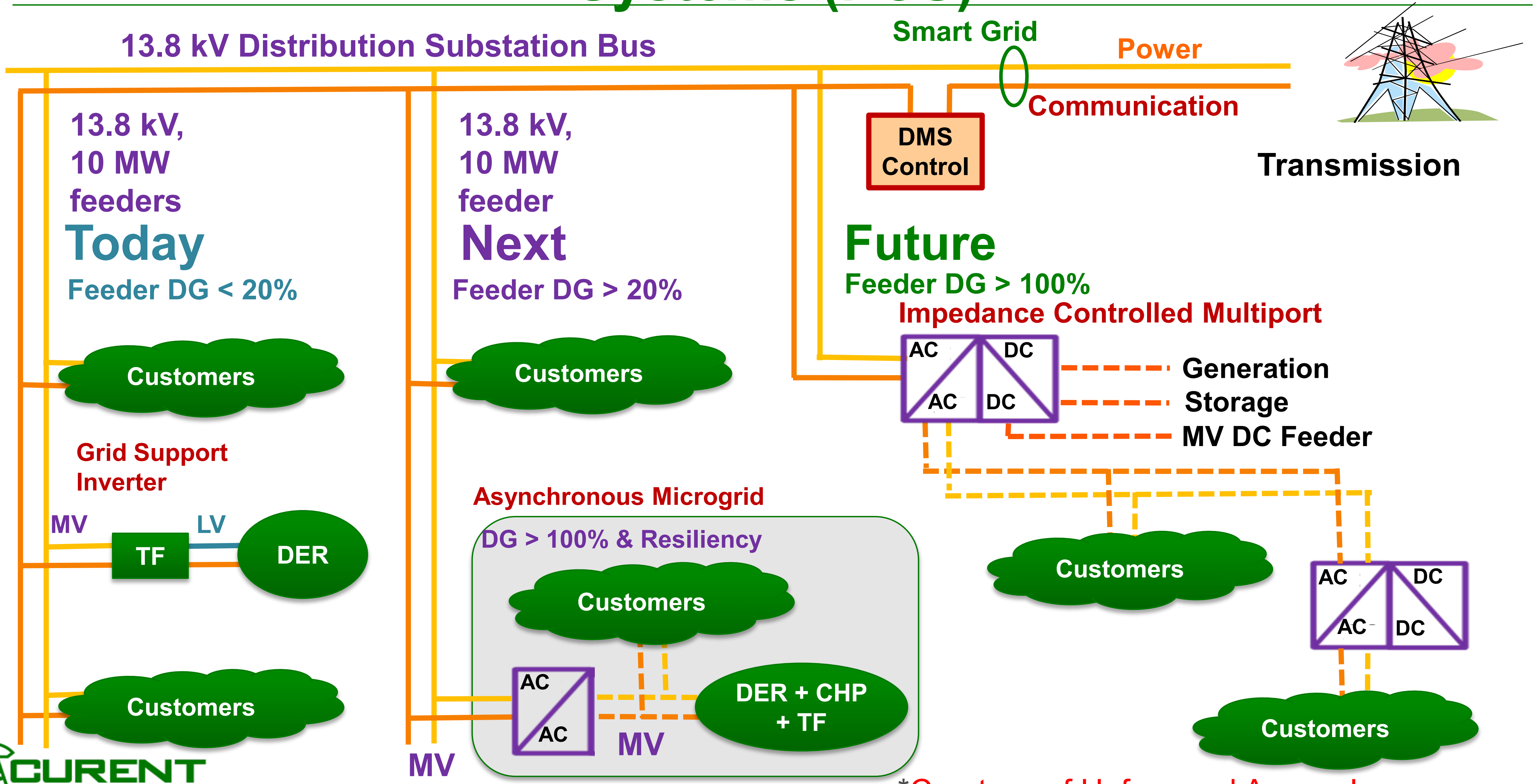
Fred Wang

- **UTK Professor and Condra Chair of Excellence in Power Electronics, ORNL joint faculty**
- **Research Interests: Wide bandgap power electronics, power electronics for grid and transportation applications**
- **fred.wang@utk.edu**

2023-2024 Research Projects

1. SiC based modular transformer-less MW-scale PCS and control for flexible manufacturing plants (DOE AMMTO)
2. Operation and control of large-scale power electronics based power grids (ORNL/DOE OE)
3. Resilient operation of networked community microgrids with high solar penetration (ORNL/DOE SETO)
4. A Low cost hybrid AC/DC scheme for increased transmission capacity (ORNL/DOE OE)
5. Ultra-light tightly-integrated modular aviation-transportation enabling solid-state circuit breaker (ARPA-E)
6. Development of high-density and high-efficiency AC/AC converter using wide bandgap devices (Boeing)
7. Integrated motor drive for fast dynamics application using wide bandgap devices for high power density (ABB)
8. Power electronics based MW universal tester (UTK internal)

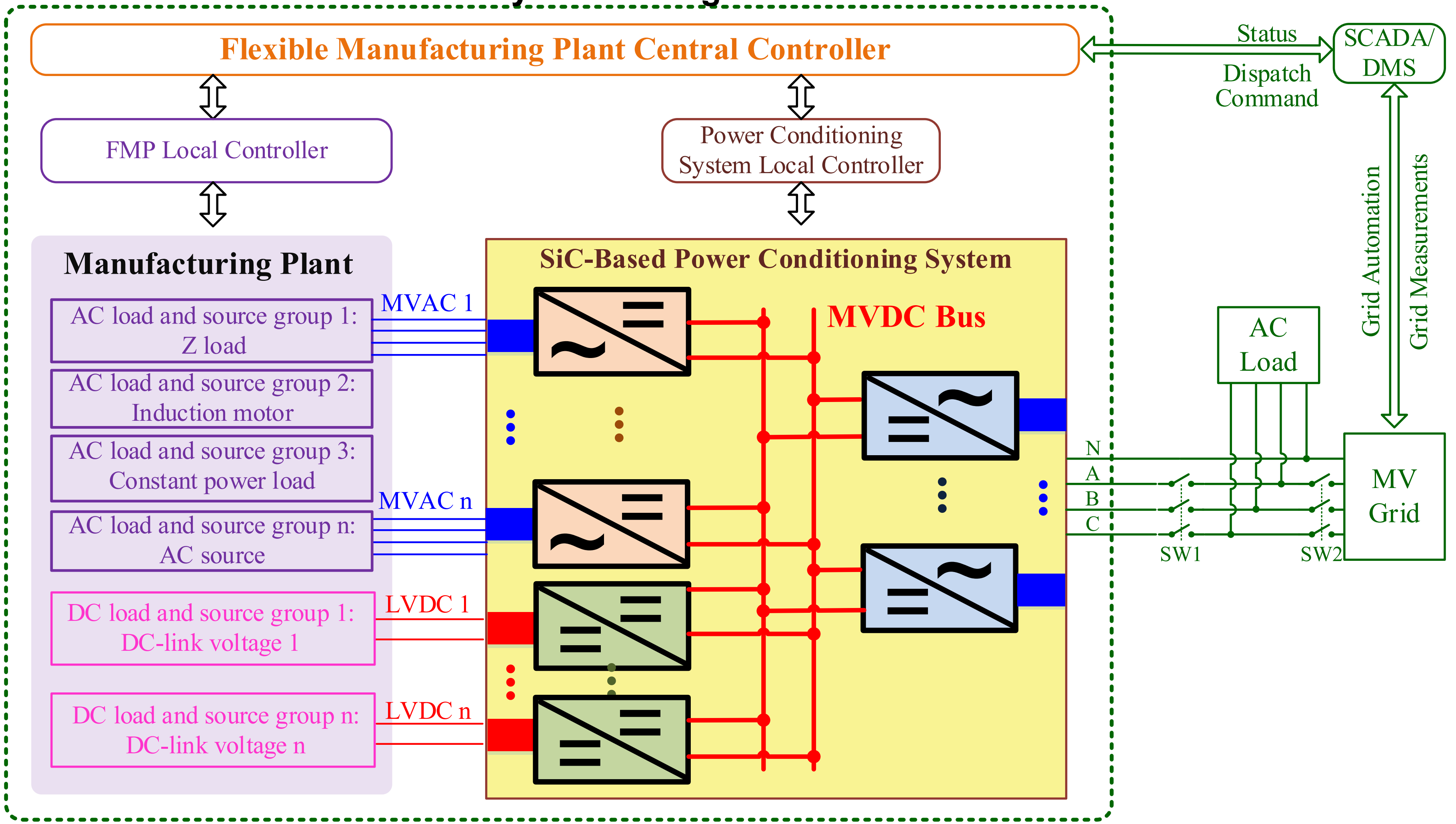
DOE Vision with Medium Voltage Power Conditioning Systems (PCS)

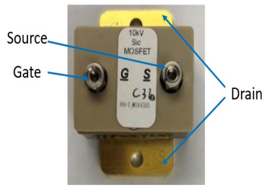


*Courtesy of Hefner and Agarwal

10-kV SiC MOSFET Based Modular Transformer-less MW-Scale Power Conditioning System & Control for Flexible Manufacturing Plant

FMP system configuration

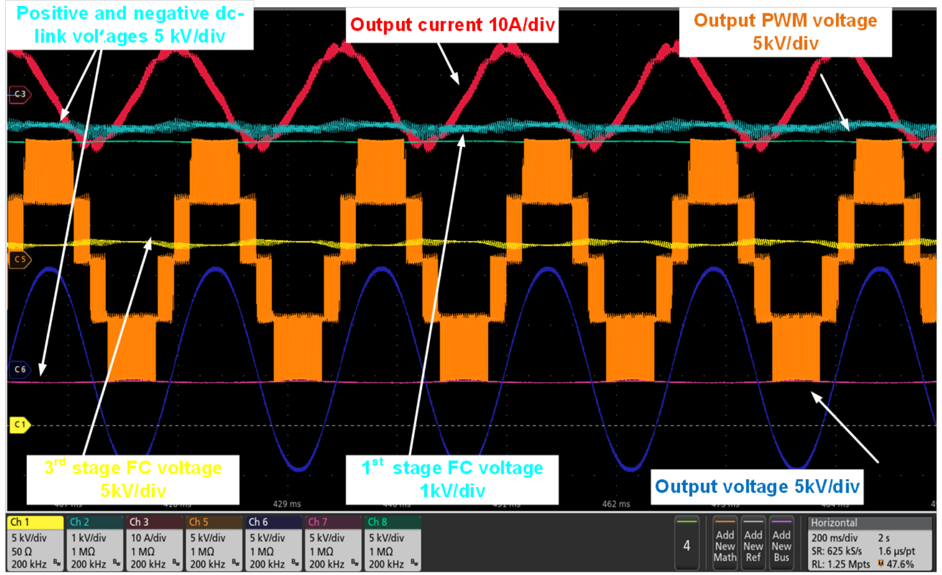




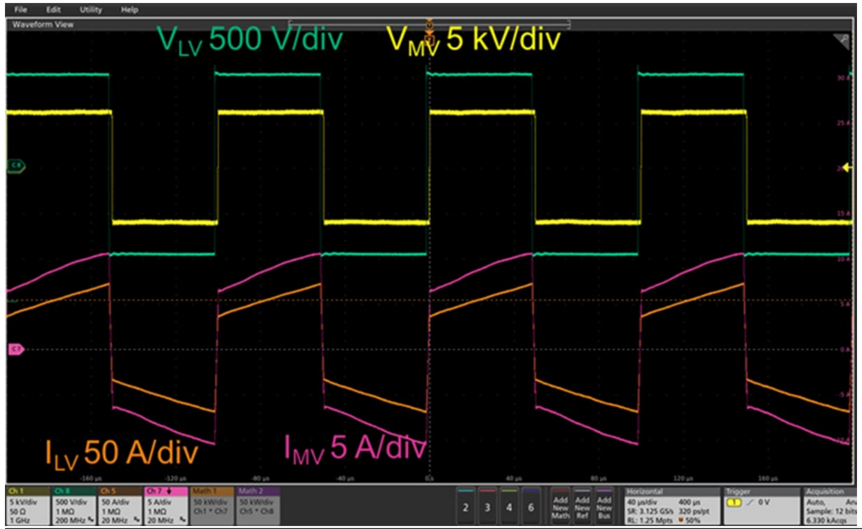
10 kV SiC MOSFET (Discrete)

10 kV SiC MOSFET (Module)

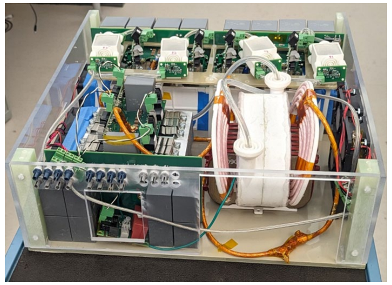
10-kV SiC MOSFET Based Modular Transformer-less MW-Scale Power Conditioning System & Control for Flexible Manufacturing Plant



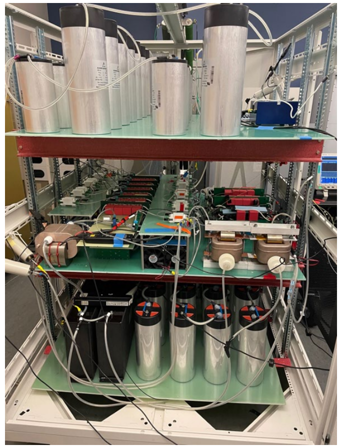
Waveforms at 23 kV DC for 5L DC/AC converter



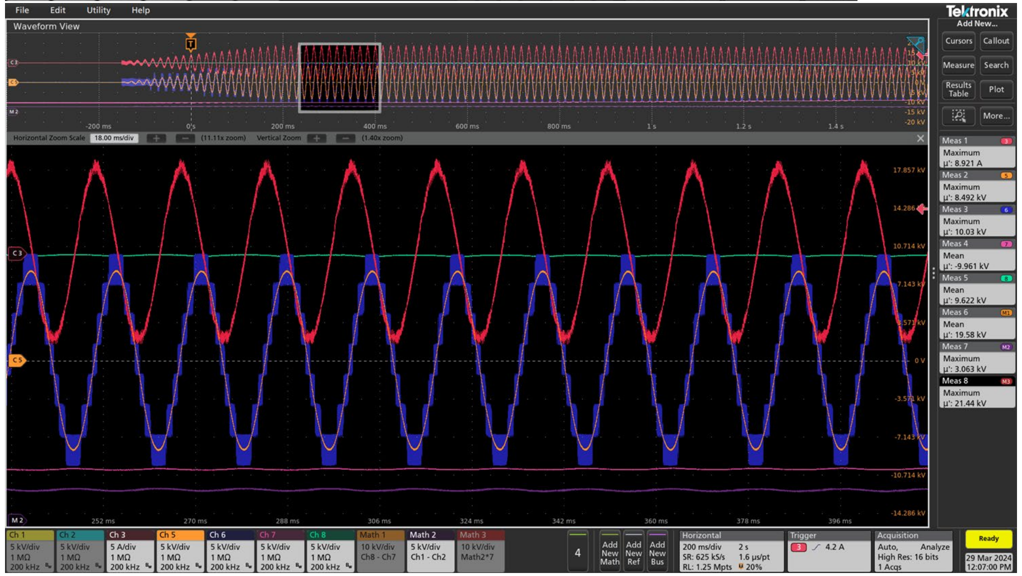
Waveforms at 6.25 kV DC for DC/DC converter



DC/DC converter based on discrete 10 kV SiC MOSFET



DC/AC converter based on 10 kV SiC MOSFET modules

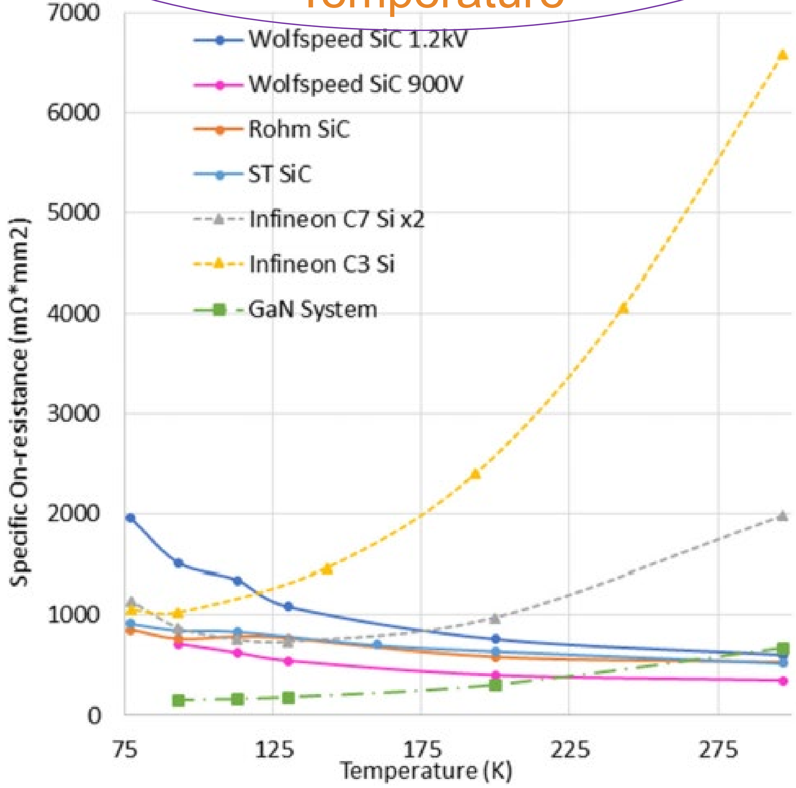


Waveforms at 20 kV DC for 8L DC/AC converter

HTB Testing of the Controller Coordination

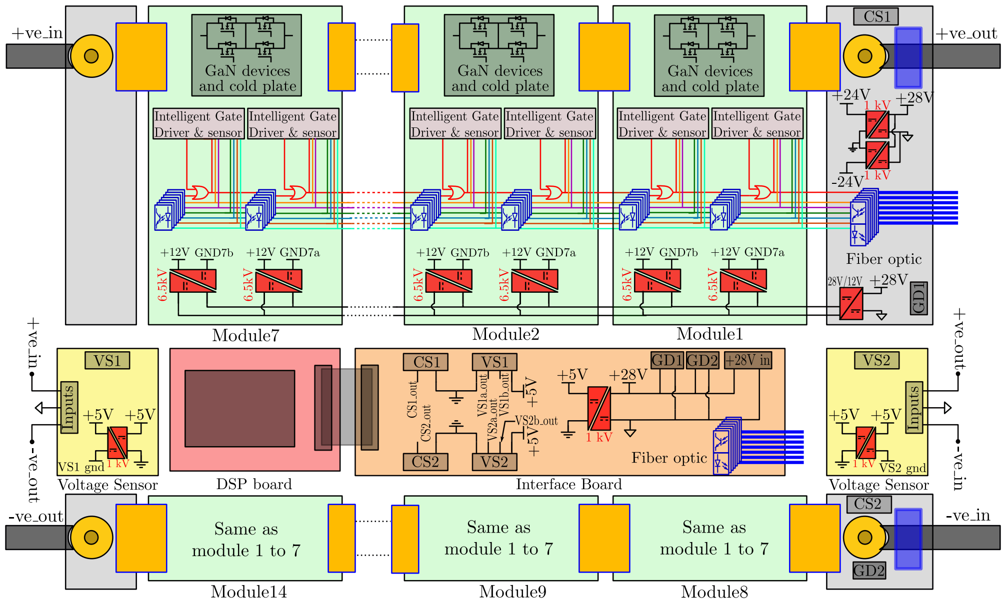
Ultra-Light Tightly-Integrated Modular Aviation-Transportation Enabling Solid-State Circuit Breaker (ULTIMATE SSCB)

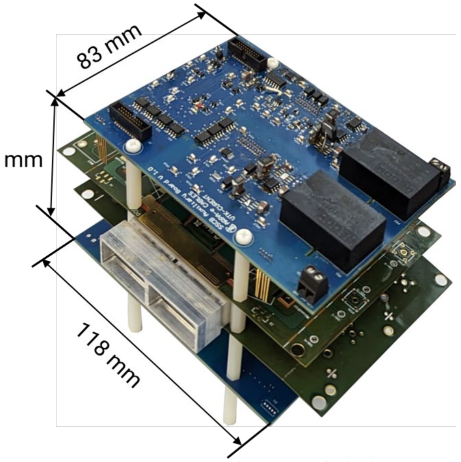
GaN offer large drop in $R_{ds(on)}$ without significant drop in breakdown voltage at Cryogenic Temperature



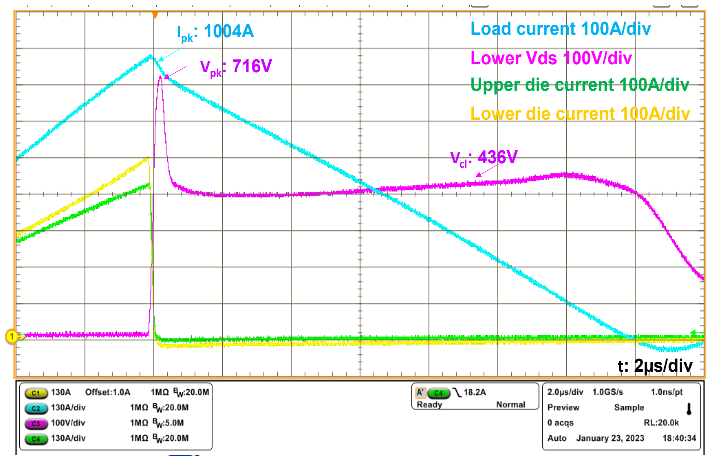
On-state resistance comparison

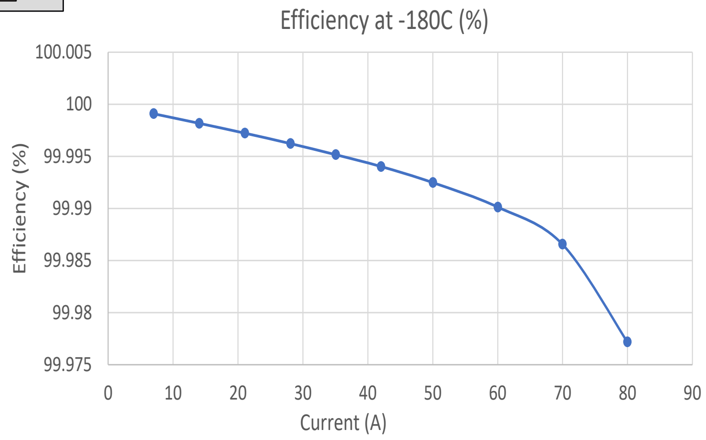
10 kV modular SSCB configuration





Developed 750 V, 100 A SSCB module (456 g, 329 kW/kg density)

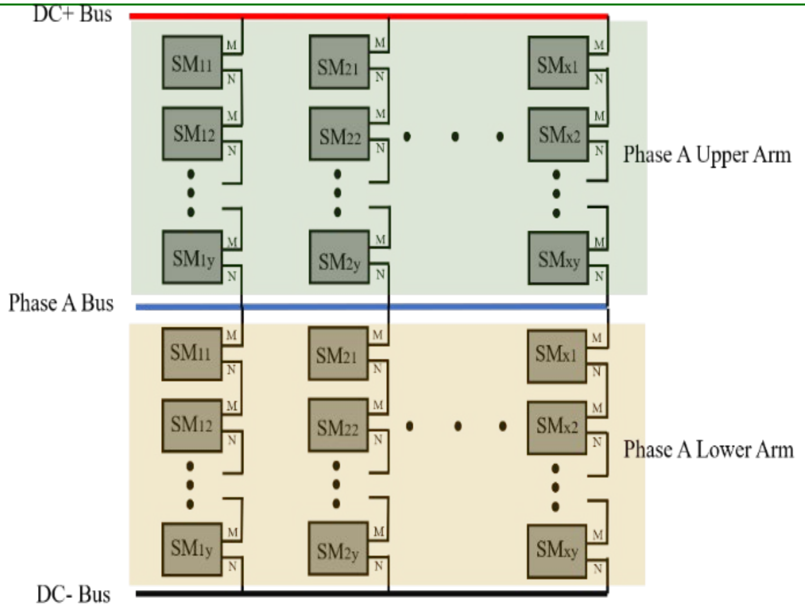




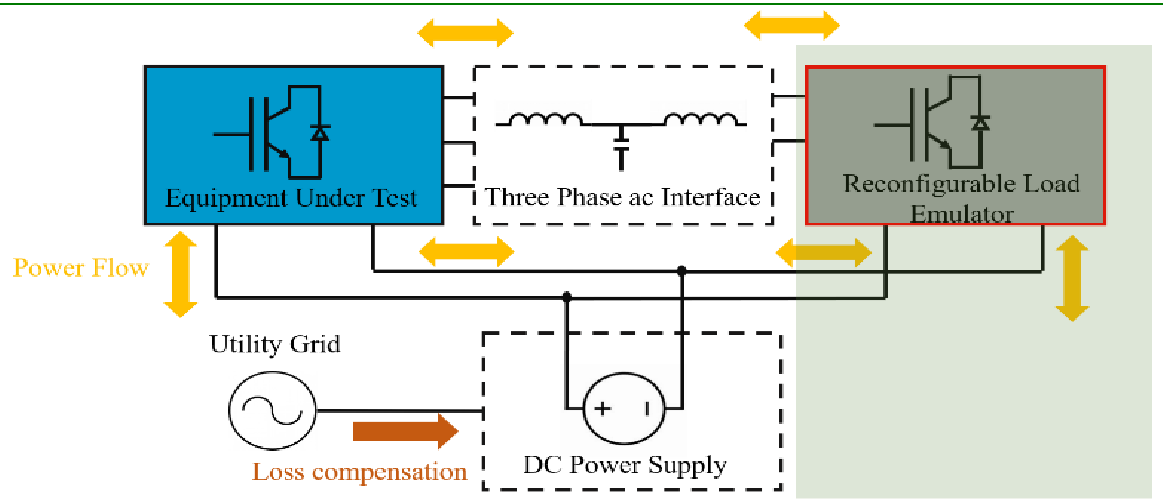
10x current interruption test and efficiency measurement results

CURENT UNIVERSITY OF HOUSTON Rensselaer BOEING

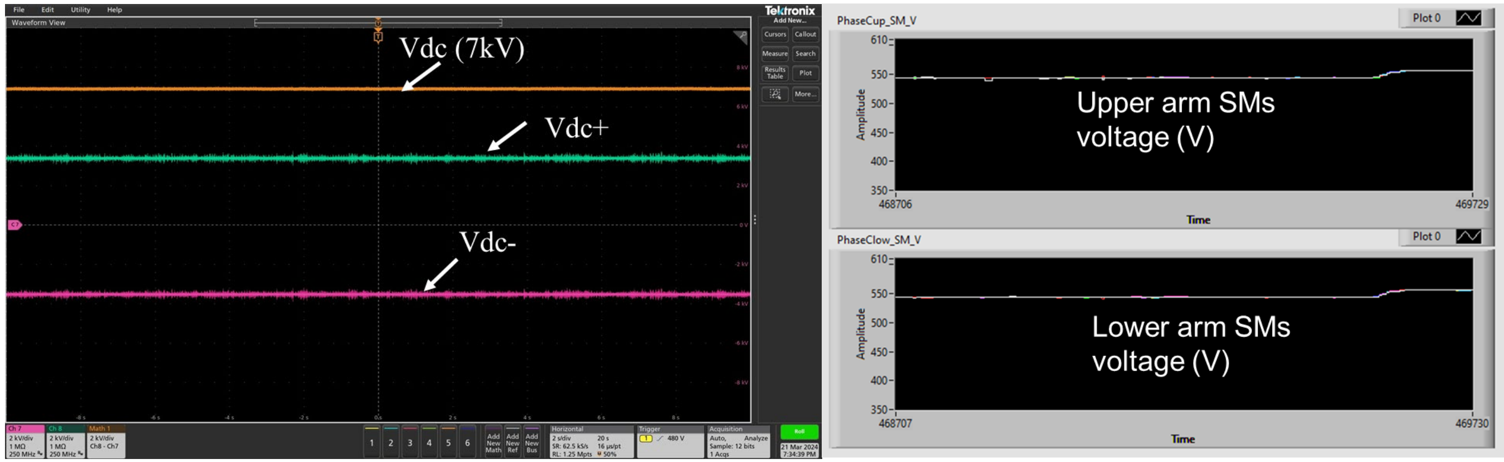
Mega-Watt Power Electronics Based Universal Power Tester



Reconfigurable MMC capable of different voltages (480 V to 13.8 kV) and frequencies (3 to 3000 Hz)

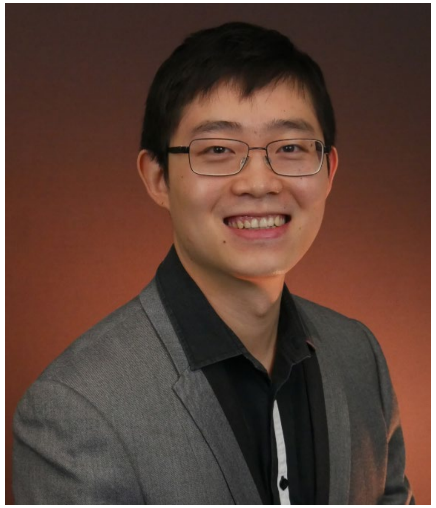


Test set up with universal power tester



DC link voltage

SM voltages



Zheyu Zhang

- **UTK CURENT Alumni**
- **RPI Assistant Professor**
- **Research Interests: Wide bandgap-based power electronics characterization and application for renewable energy, electrified transportation, and space power**
- **zhangz49@rpi.edu**

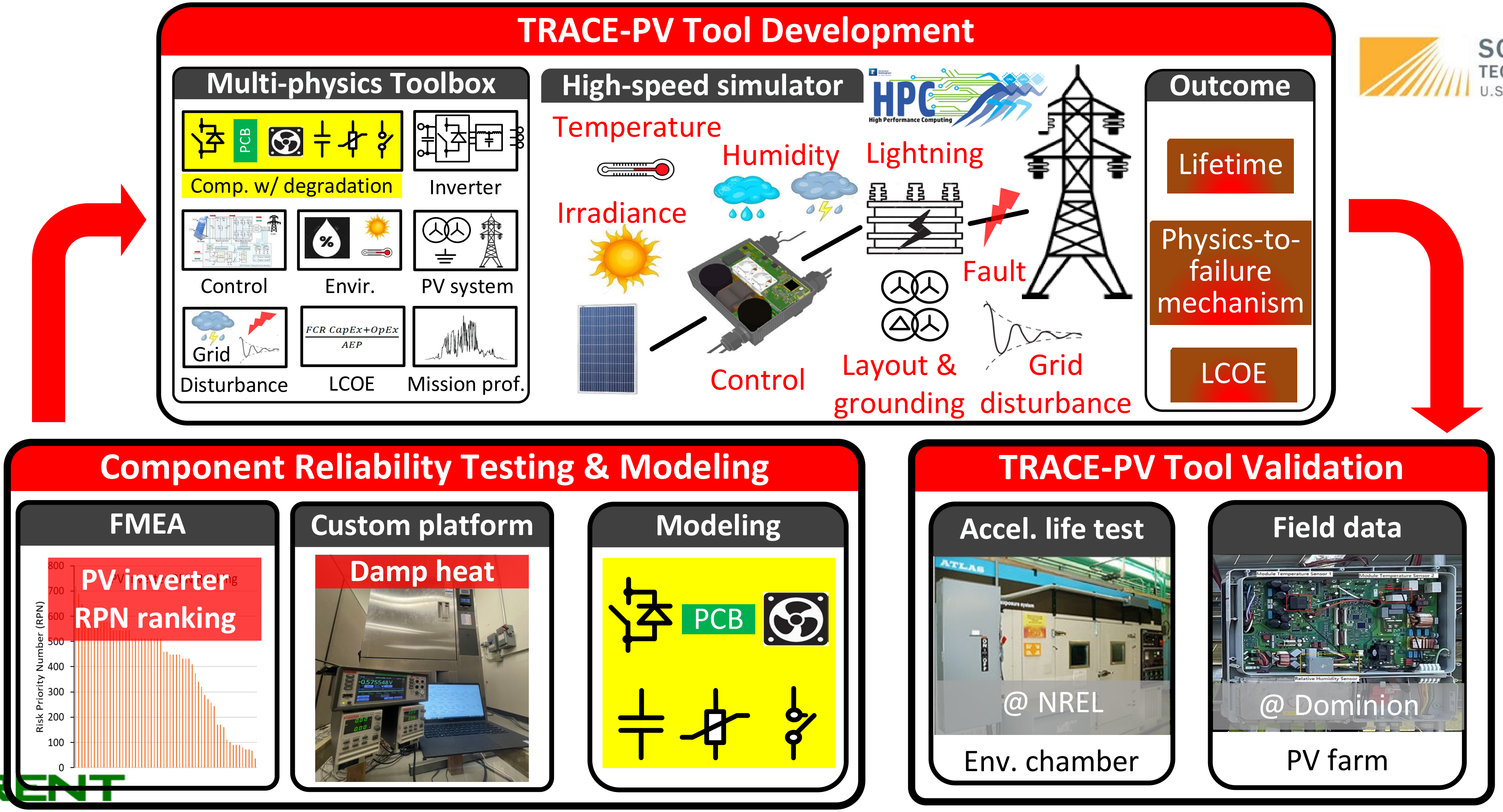
2023-2024 Research Projects

1. Tool for Reliability Assessment of Critical Electronics in PV (TRACE-PV) (DOE EERE SETO)
2. Characterization and Application of Cryogenic Power Semiconductors in Lightweight, Fault-tolerant Systems for Lunar Missions (NASA Early Career Faculty)
3. Ultra-Light Tightly-Integrated Modular Aviation-Transportation Enabling Solid-State Circuit Breaker (UTK/DOE ARPA-E)
4. A UNIVERSAL (Ultrafast, Noise-Immune, Versatile, Efficient, Reliable, Scalable, and Accurate Light-controlled) Switch Module (UTK/DOE ARPA-E)
5. Integrated Three-level GaN Inverter and PMsyn RM Motor for Electric Passenger Vehicles and Medium/heavy Duty Trucks (UTK/DOE EERE VTO)

TRACE-PV: Tool for Reliability Assessment of Critical Electronics in PV

To create an open-source tool for the PV inverter reliability assessment

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy



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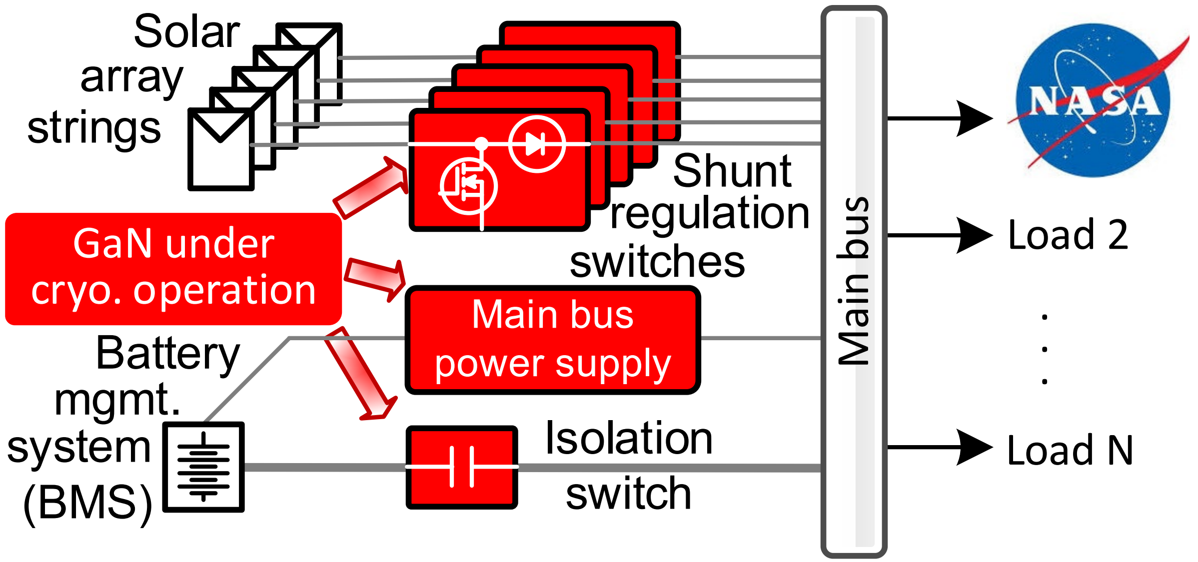
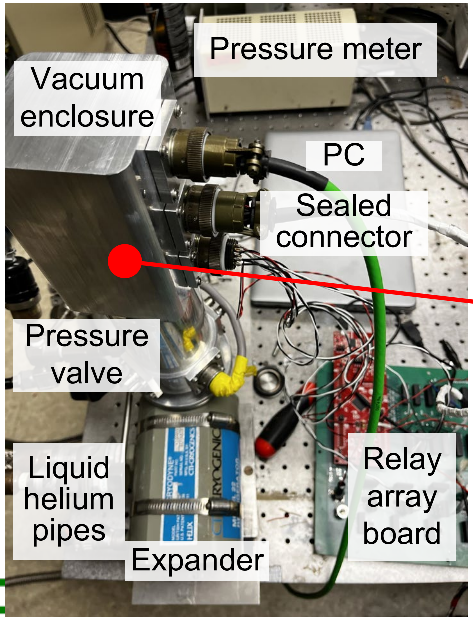
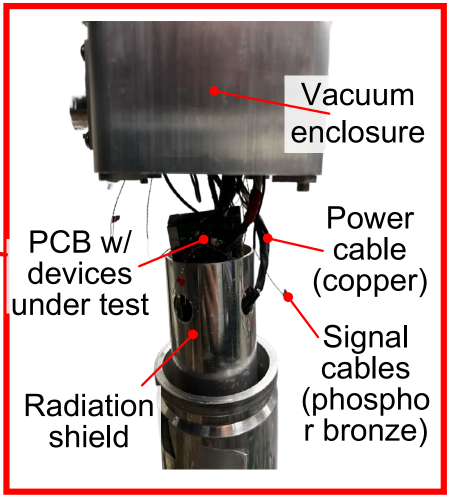
Characterization and Application of Cryogenic Power Semiconductors for Space Power

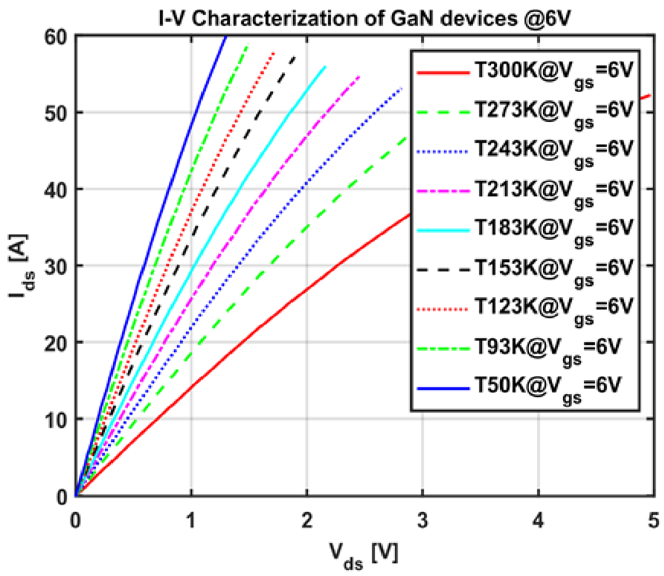
To characterize, model, and apply GaN HEMTs for lunar missions

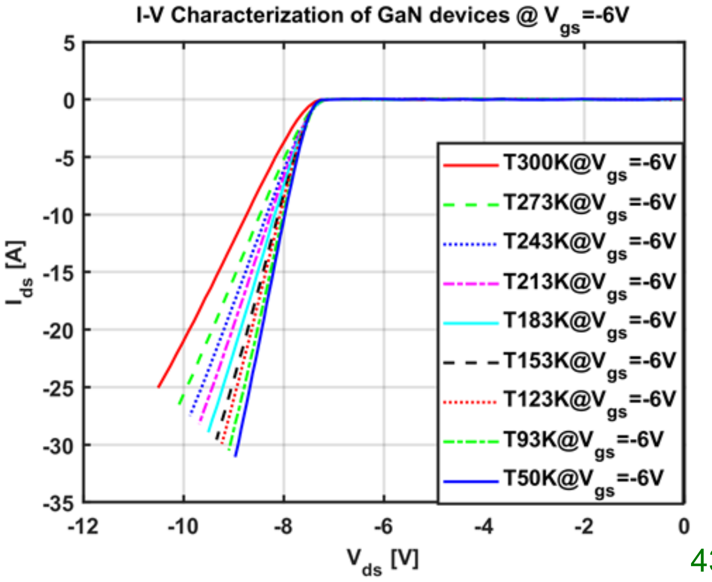
- Wide temperature ranges: 50K to 400K
- Diverse GaN techniques
- Considering statistical variation and key parameters' degradation











Chien-fei Chen

- UTK Research Associate Professor and Director of Energy & Environmental Justice, Institute for a Secure & Sustainable Environment
- Research Interests: Environmental sociology, energy justice, social-technological integration, resilience, community engagement.
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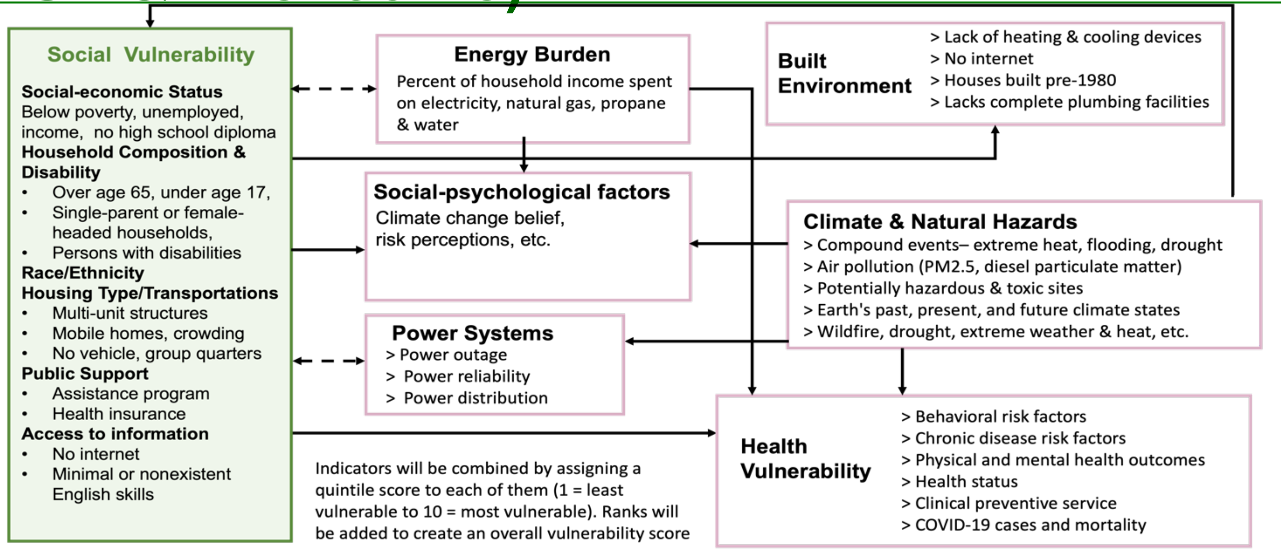
2023-2024 Research Projects

1. “CRISES: Southeast Center for Just, Resilient, and Sustainable Ecosystems (SECURE), NSF, Social Behavioral Economic Science Division (SBE), 2334298.
2. A Community Co-Designed Weatherization and Microgrid Plan for Equitable Energy Security and Environmental Health,” Wellcome Foundation, United Kingdom.
3. “US-Japan Exchange Program for Green Growth Collaboration through Clean Energy Technology (EXCET)”, US. Department of State
4. “Strengthening American Infrastructure (SAI-R): Integrating Cognitive, Social, and Engineering Principles for Large-Scale Planning of Public Charging Infrastructure,” NSF, SBE 2323732
5. “Strengthening American Infrastructure (SAI-R): Community-centered Decision-making Framework for Microgrid Deployment to Enhance Energy Justice and Power System Resilience,” NSF, SBE 2228620;
6. Smart Connected Community (SCC-IRG) Track 1: “Advancing Human-Centered Sociotechnical Research for Enabling Independent Mobility in People with Physical Disabilities,” NSF, CMMI 2124857
7. Building Equity in the Intersections of Climate Change, Built Environment, and Environmental Health: A Community and Social-Technological Integration-Based Research for Solutions,” US EPA (in the process of receiving award $2M).

A Community Co-Designed Weatherization and Microgrid Plan for Equitable Energy Security and Environmental Health (NSF & Wellcome)

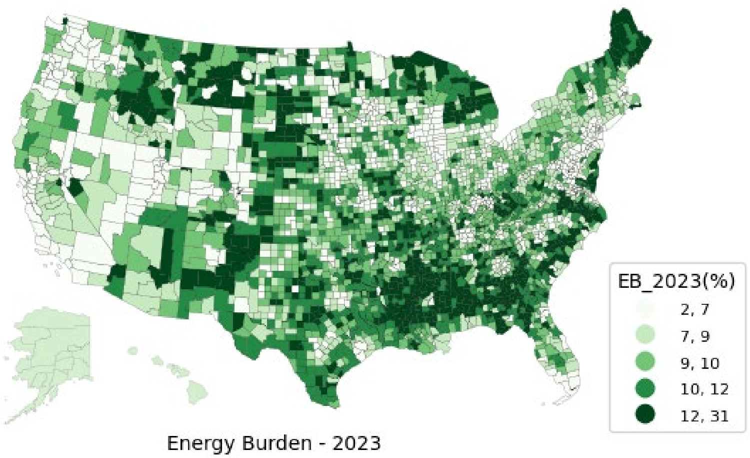
Project Objectives

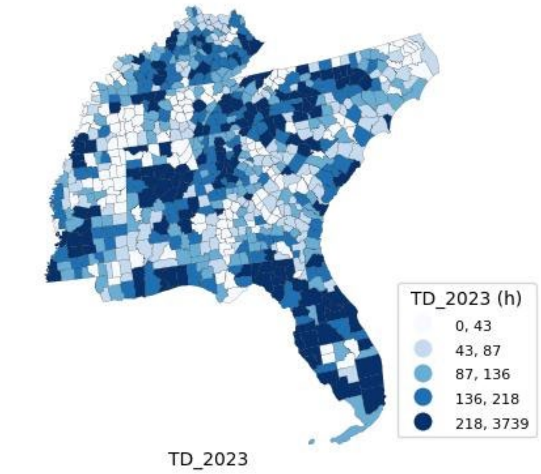
- This project aims to provide climate mitigation solutions, i.e., community microgrids and weatherization with electrification for reducing energy burdens and GHG and improve physical and mental health for underserved communities.
- At micro and macro levels, this project will build a social-technological, equitable tool for analyzing the multidimensionality of concentrated social vulnerability, energy vulnerabilities, climate health, and psychological outcomes of underserved communities.



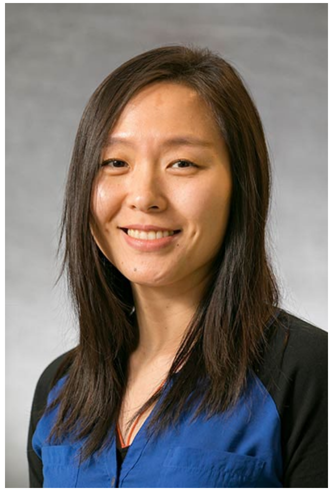
Framework of social, energy, built environment & health

A microgrid in Chattanooga





Analysis of energy burdens & power outage



Stella Sun

- **Professor in EECS UTK**
- **Research Interests: Cyber-Physical Security, Machine Learning Security**
- **jysun@utk.edu**

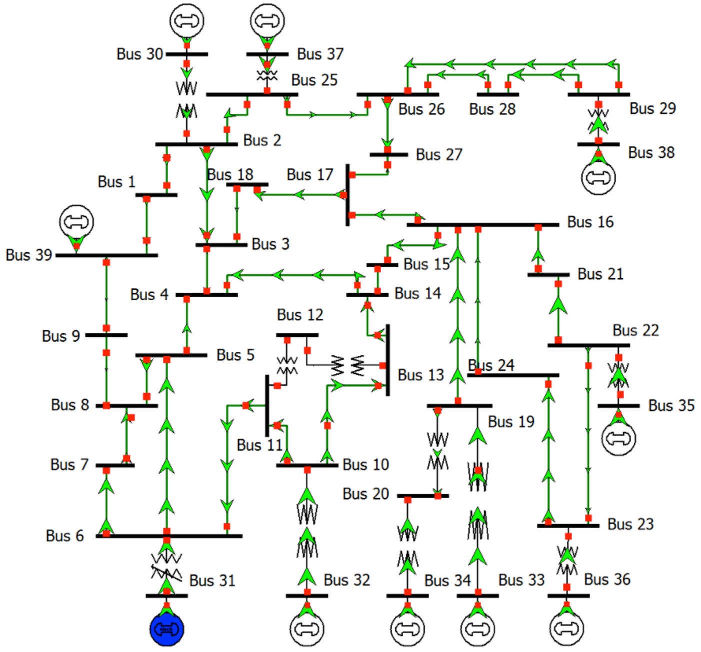
2023-2024 Research Projects

Secure Constrained Machine Learning for Critical Infrastructure CPS (NSF)

Secure Constrained Machine Learning for Critical Infrastructure CPS

Project Objectives

- Develop adversarial machine learning for critical infrastructure cyber-physical systems such as energy, water, and transportation
- Design and develop secure machine learning that mitigates the attacks under physical and topological constraints



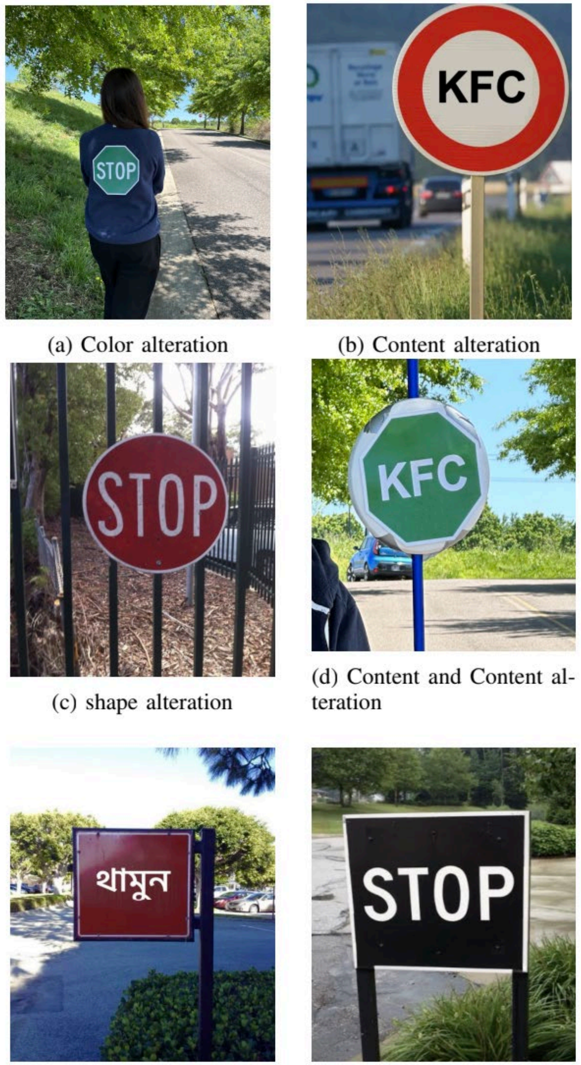
IEEE 39-bus System

Attack	Case	Accu	L_2-Norm	Time (ms)
black-box	10	14.4%	1843.2	131.9
	13	4.3%	4786.72	209.6
	15	28.1%	9079.02	163.3

Adversarial Attack – Power Systems

Method	No False Injection			False Injection	
	No Model	f_1	f_2	f_1	f_2
d_{ECU}	110644.5	110587.1	110675.4	110652.9	110602.3
d_{COR}	0.3204611	0.3183464	0.2687631	0.326226	0.2826415
d_{ACF}	1.247954	1.146977	1.015968	1.149789	1.040784
d_p	0.1336534	0.1309215	0.1109201	0.1273667	0.1091463
d_{SAX}	2.004495	1.735943	1.417392	2.454994	1.002247

Physical Constraints-based Defense



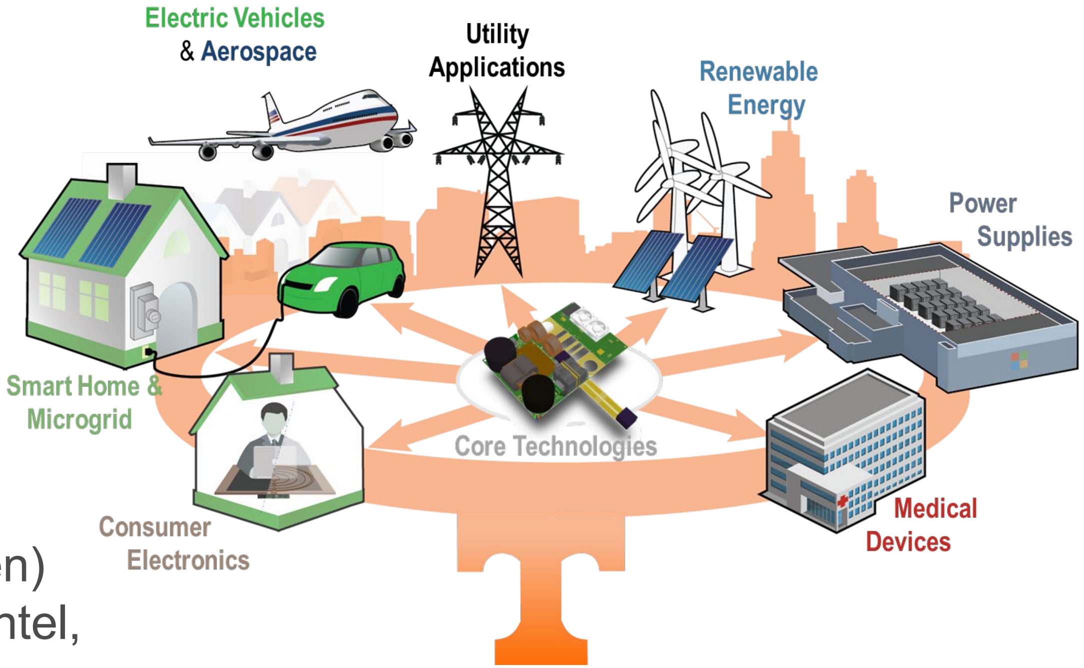
(a) Color alteration (b) Content alteration (c) shape alteration (d) Content and Content alteration (e) Shape and Content alteration (f) Color and Shape alteration

Adversarial Attack - Traffic Sign Recognition

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Daniel Costinett

- **UTK Associate Professor in power electronics**
- **Research Interests: Advanced design and control techniques for power supplies, wireless power transfer, PMIC, medical devices, electric vehicles**
- Daniel.costinett@utk.edu



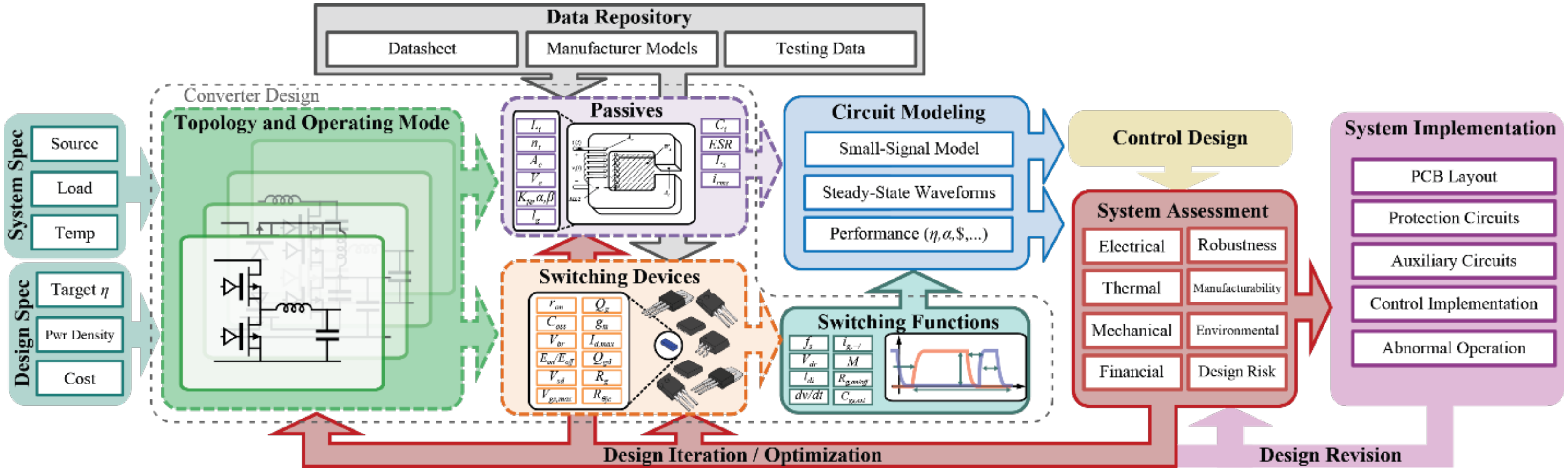
Recent Research Projects

1. Unified Design Framework for Advanced Power Electronics (NSF CAREER)
2. High Frequency 6.6 kW Wireless Charging for EVs (II-VI Foundation)
3. High-Power 120 kW Wireless Charging for EVs (Volkswagen)
4. Multi-Receiver Wireless Power for Consumer Electronics (Intel, Power America)
5. Lightweight wireless power receivers for UAVs (ARL)
6. Integrated High-Current Battery Chargers for Mobile Electronics (Texas Instruments)

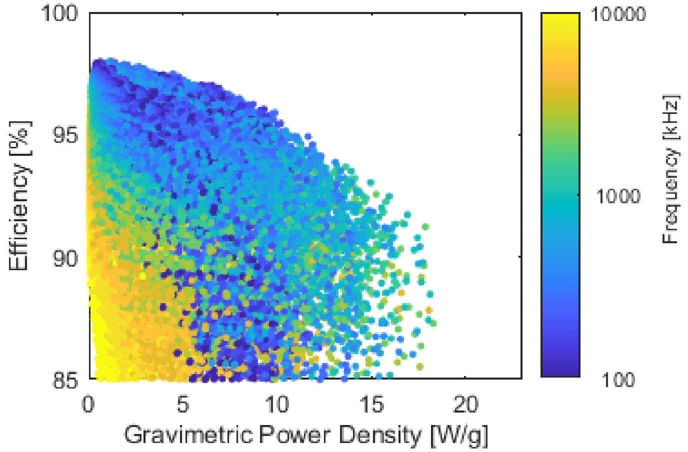
Toolbox for Power Converter Optimization

Project Objectives

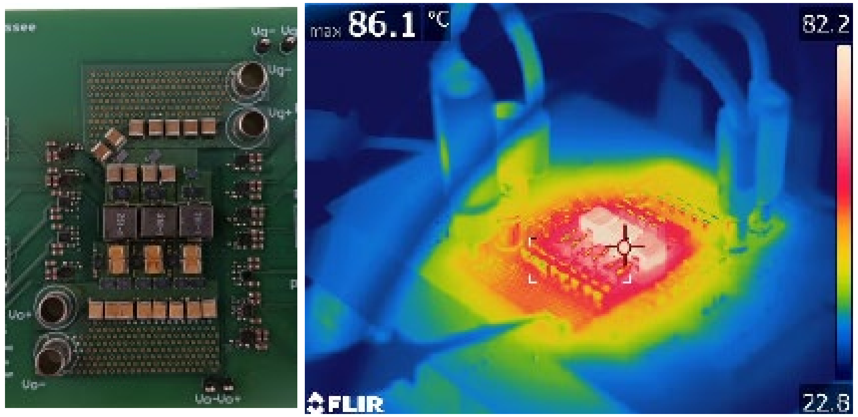
- Develop a general-purpose modeling framework that allows rapid optimization of topology, modulation, and device selection/implementation
- Allow varying levels of model fidelity based on available data
- Uniform comparison of different converter functions and energy storage implementations



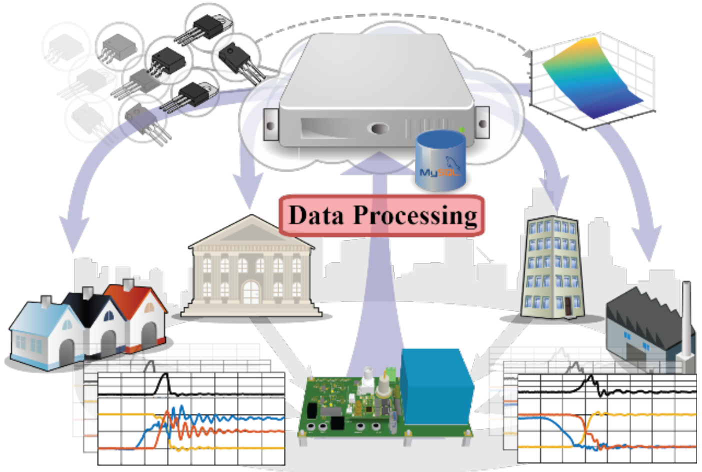
Converter Analysis and Design Paradigm



Optimization Results



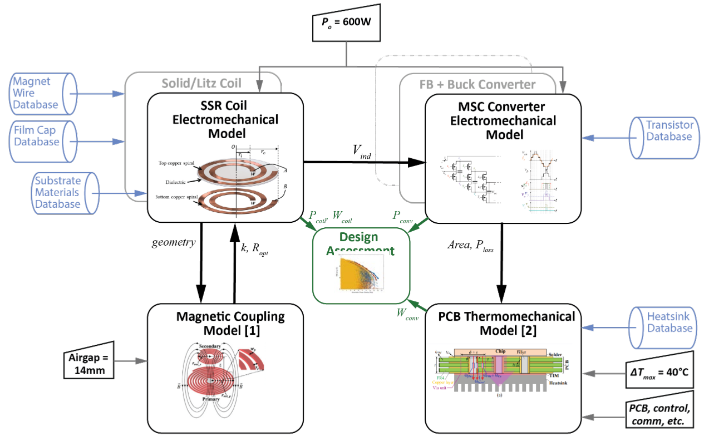
Prototype Converter for 48-1V VRM

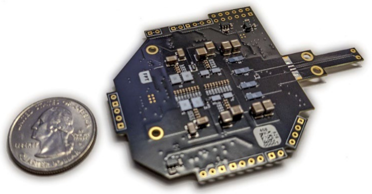


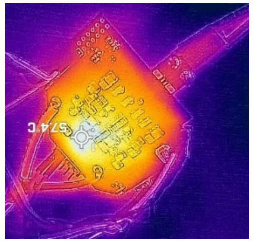
Shared Data Repository

Wireless Power Transfer

Ultralightweight Wireless Chargers for UAVs



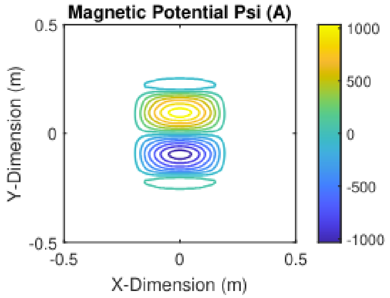


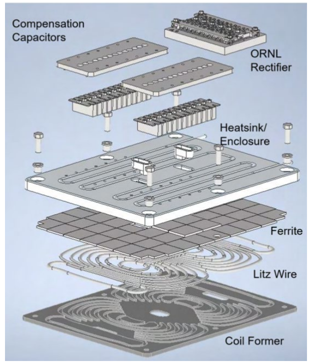


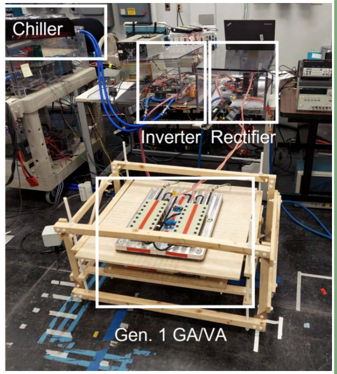
High gravimetric power density wireless receiver design optimization

ARL

High Power Wireless EV Charger



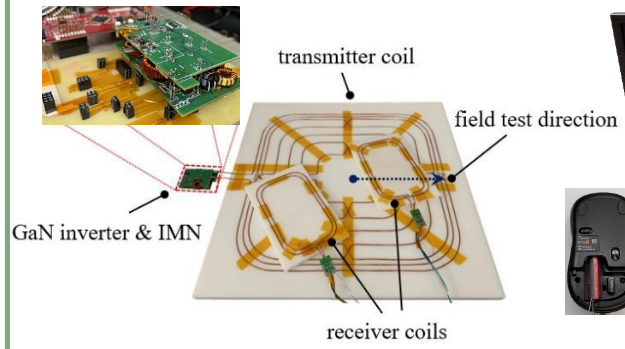




Low stray-field
120kW coil model and prototype

OAK RIDGE National Laboratory

Multi-Receiver Wireless Workstation



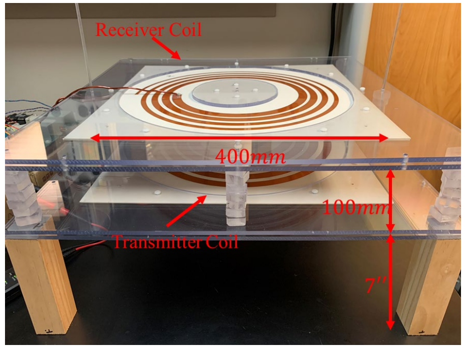
Multi-receiver 100 W workstation with 92% end-to-end efficiency

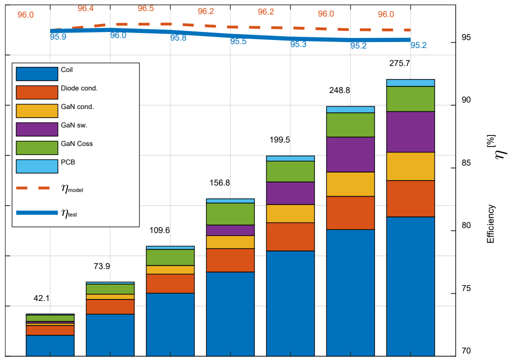
CURENT

intel

POWERAMERICA

High Frequency Wireless EV Charger





Low-profile, self-resonant 3 MHz coils.
95.2% efficiency at 6.6 kW

II-VI Foundation