FREEDM SYSTEMS CENTER

FREEDM Center Highlights

Prof. Iqbal Husain
ABB Distinguished Professor
Center Director

Prof. Srdjan Lukic
Deputy Director

Prof. Mesut Baran
Education Director

Ken Dulaney
Industry Director

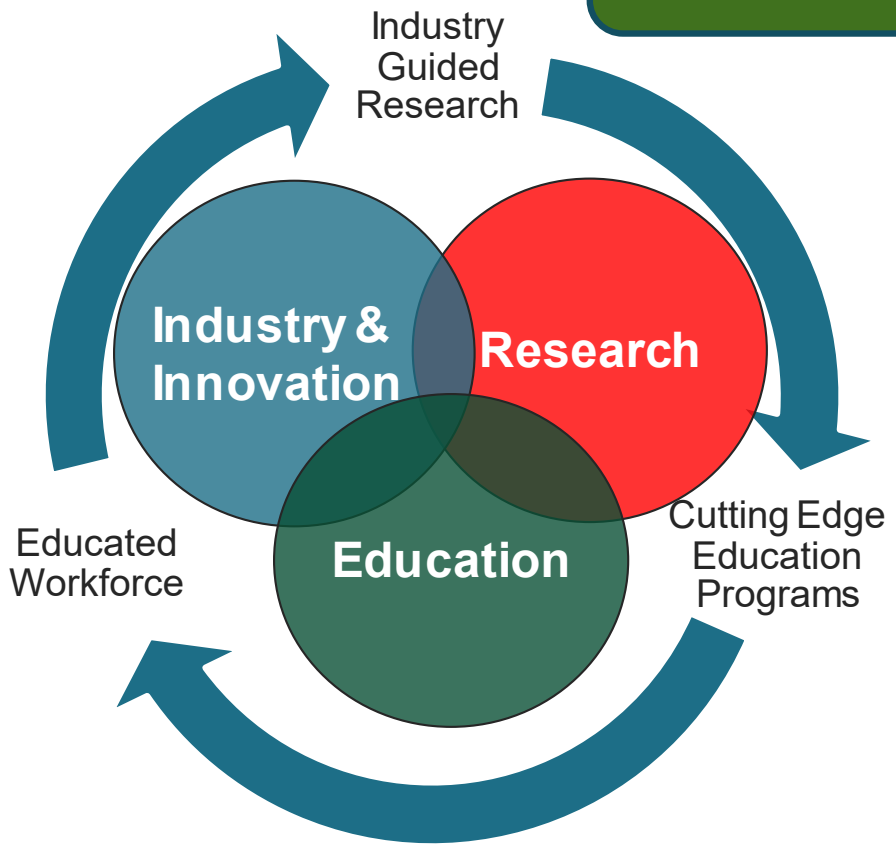
NC STATE UNIVERSITY

Annual Symposium 2024

NSF

Future Renewable Electric Energy Delivery and Management (FREEDM) Center

FREEDM Established in 2008
Graduated from NSF in 2019



FREEDM CENTER

- 300+ GRADUATES SINCE 2008
- $6 MILLION ANNUAL RESEARCH BUDGET
- 100+ PUBLICATIONS EACH YEAR
- 200+ INVENTIONS & PATENTS SINCE 2008

Research Theme: Renewable Energy Integration and Transportation Electrification

FREEDM Growth and Sustainability

- Growth maintained with increase in faculty, graduate and undergraduate students, funded research, industry collaboration, and infrastructure enhancement.
- Several multi-year federally funded projects with Industry collaboration (Renewable Energy, Microgrids, Solid State Transformers Fast EV Chargers, WBG Inverters, Rare-earth free electric machines)
- Engagements with several consortiums
- Participation in key events with faculty/student presentations
- Introducing new courses at both undergraduate and graduate levels

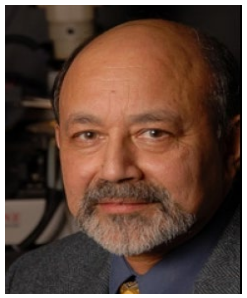
FREEDM SYSTEMS CENTER

Power & Energy Faculty

Power Electronics & Electric Transportation

Dr. Iqbal Husain
Electric Machines
Renewable Energy
Electric Vehicles

Dr. Srdjan Lukic
Wireless
Charging
Motor Drives



Dr. Jayant Baliga
Power
Semiconductor
Devices

Dr. Spyron Pavlidis
WBD Devices

Dr. Subhashish Bhattacharya
Power Electronics
High Power
Converters

Dr. Doug Hopkins
High Performance
Power Electronics &
Packaging

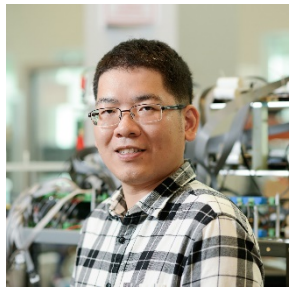
Dr. Wensong Yu
Power
Electronics
High Frequency
Converters

Dr Zeljko Pantic
Power
Electronics,
Wireless Power
Transfer

Smartgrid and Modern Power Systems

Dr. Mesut E Baran
Power Systems
Renewable Energy
Systems

Dr. Aranya Chakrabortty
Power Systems
Stability &
Controls

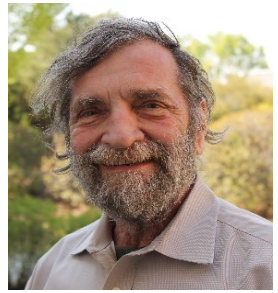


Dr. Wenyuan Tang
Energy Markets
Renewable
Energy

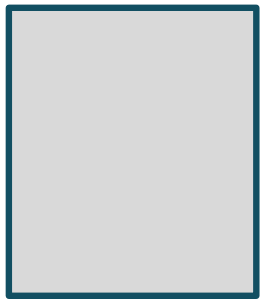
Dr. Alyssa Kody
Power Systems
Optimization and
Controls

Dr. Ning Lu
Power Systems
Smart Grid

John Gadja
Distribution system
protection, generator
interconnections, IBR
settings



Dr. Leonard White
Power Systems
Protection and
Professional Eng.



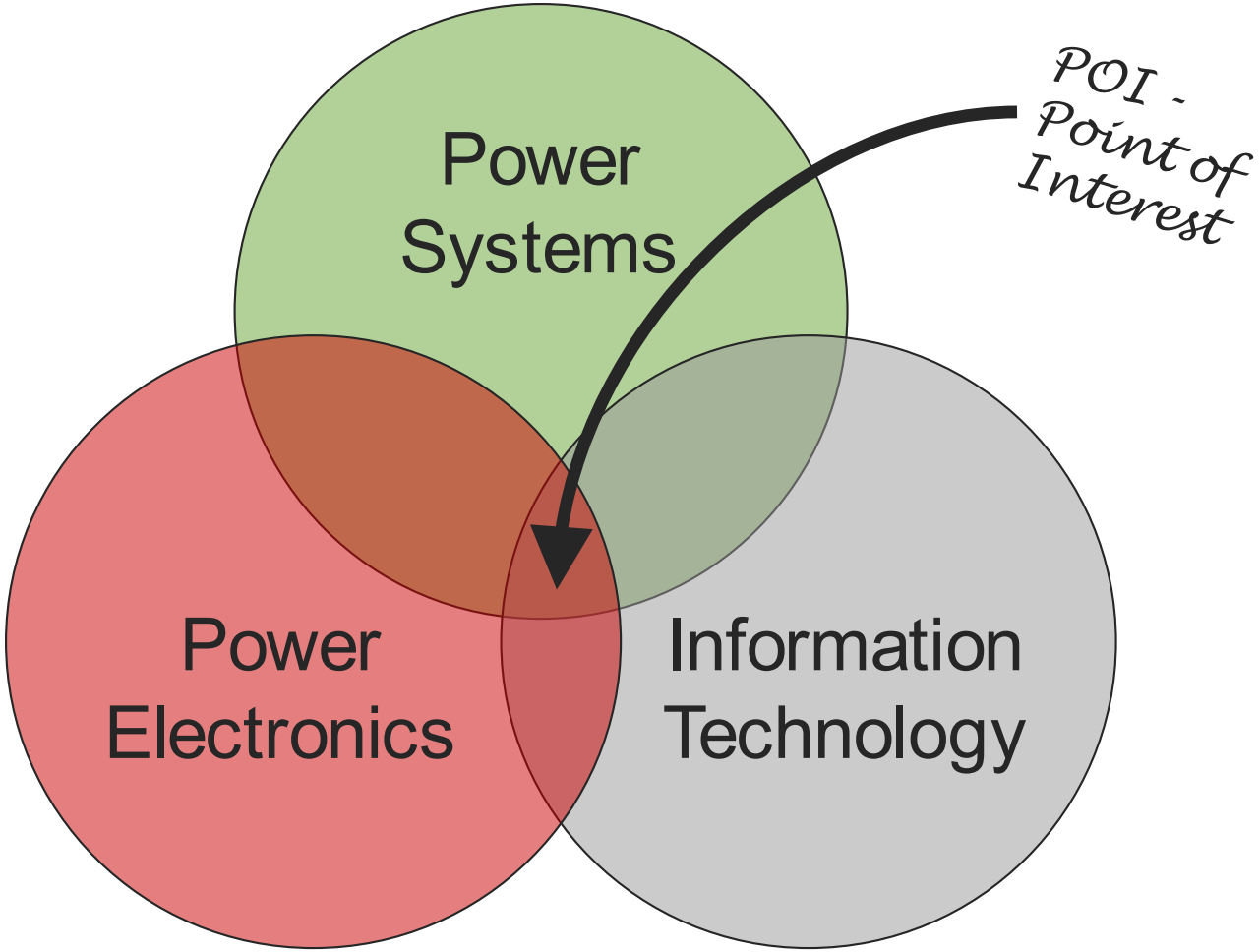
Power Systems,
Power Electronics

FREEDM Additions and Events

Staff Addition to FREEDM Family:

Erik Bishop, Hardware Technician
Bethany Rainwater, Industry & Education Coordinator
Catherine Lema, Administrative Support

What We Do?


Power Systems
Power Electronics
Information Technology
POI - Point of Interest

FREEDM SYSTEMS CENTER

Four Pillars of Research

Wide Bandgap Semiconductors

- Ultra High Efficiency SiC Inverter with Soft/switching dv/dt Filter
- Medium Voltage Motor Drive
- Finite Element Analysis and Fatigue Life Prediction of Power Packages
- Exploring Defect States for High Power Vertical GaN Diodes

Power Systems

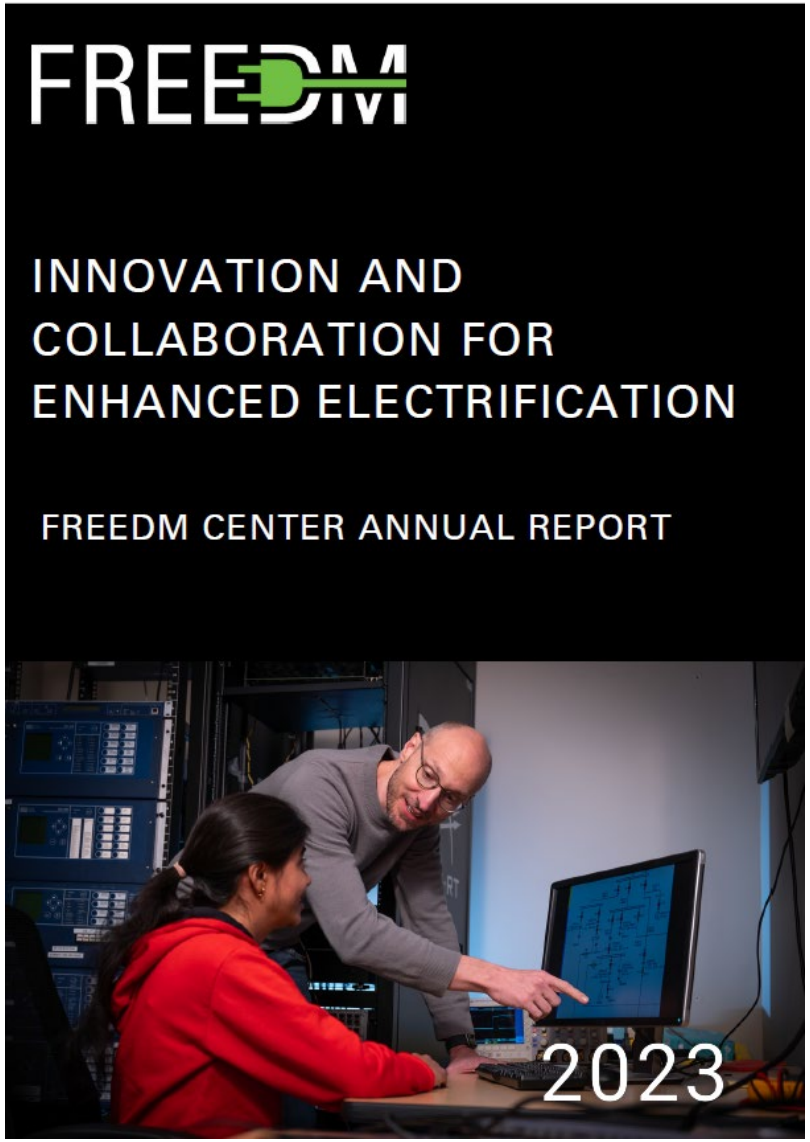
- US DOE Prize winners in Solar Forecasting, Net Load Forecasting, and Hydropower Operations Optimization
- Solar Inverter Demand Response
- Artificial Intelligence-Enabled Tools (ArtIT) for Cyber Hardening of Power Grids
- Professional Science Master's degree in Electric Power Systems Engineering

Transportation

- SiC 98.5% Efficiency Traction drive for Class 8 Electric Trucks
- 1 MW DC Extreme Fast Charger connected at 13.2 kV
- Autonomous Charging of Drones for Delivery in Remote Locations
- Rare-Earth Free Electric Machines and Model-Free Controls for Electric Vehicles

Renewable Energy

- Microgrid Co-design Tool for Optimal Equipment Sizing and Control Coordination
- Solar situational Awareness and Resiliency Services
- Multi-Port Converter for Wave Energy Integration with Energy Storage
- Inverter Controls for Renewable Integration



Annual Report

48 reports on projects by FREEDM faculty and graduate students

FREEDM at Conferences

FREEDM SYSTEMS CENTER

Full

Meta

DUKE ENERGY

ABB

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Associate

FPL

Schneider Electric

EATON

sas

NC Electric Cooperatives
Your Touchstone Energy® Cooperatives

FLEXGEN

Typhoon HIL

HESSE MECHATRONICS

Danfoss

Henkel

DELTA

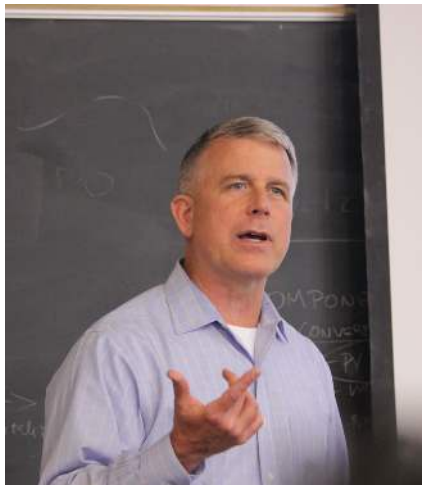
Affiliate

RESILIENT POWER

Industry Member Benefits and Engagement

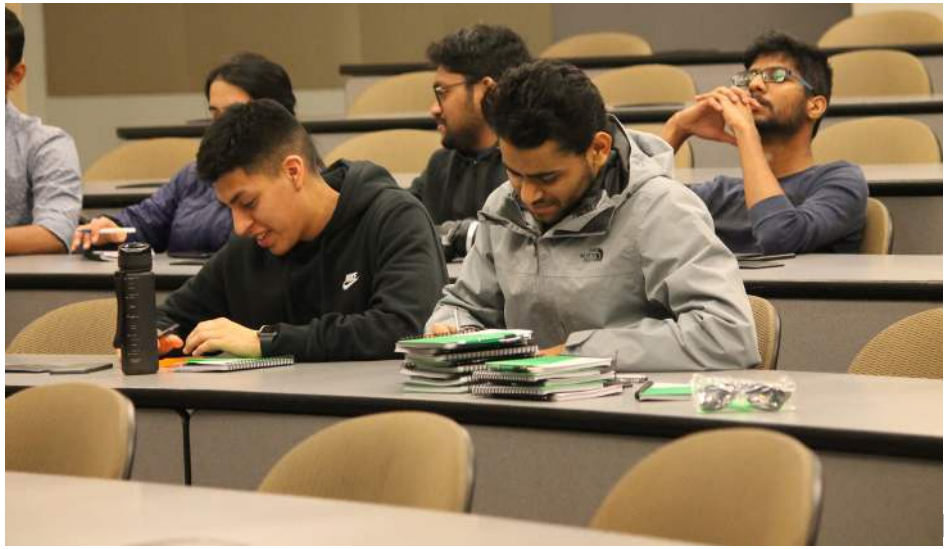
Benefits

- Leverage Research Funds
- Intellectual Property
- Testing Services
- Seminars, Workshops
- Talent Pipeline



Engagement

- Lab Tours for Corporate Executives
- Testing Services
- Research Projects
- Lectures, Seminars
- Site Visits



Partnerships

PowerAmerica

FREEDM Power Electronics and Drives

Research Triangle CleanTech Cluster™

American Public Power Association

Dr. Veliadis, Dr. Husain and Dr. Bhattacharya

CAPER

Center for Advanced Power Engineering Research

Dr. Baran, Dr. Lu, and Dr. Tang

Dr. Husain, Dr. Lukic, and Dr. Awal

AMEC

Atlantic Marine Energy Center

Dr. Bonner, Dr. Husain and Dr. Pantic

Education Programs

- PhD Graduates:

PhD Graduated/ Students	2017	2018	2019	2020	2021	2022	2023 PhD Students
Totals	16	17	13	17	11	14	93

- Master of Science in Electrical Power Systems Engineering (MS-EPSE)
- Master's option available for specialization in Power Electronics and Motor Drives
- CLAWS initiated Master of Science in Wide Bandgap Semiconductors Program
- ECE 492/ ECE 592: Introduction Automotive & Transport Systems. Instructor(s): Jeremy Edmondson, Wenye Wang, Alexander Dean and Iqbal Husain (Fall 2024)
- ECE 792-070 Power System Reliability and Resiliency. Instructor: Alyssa Kody (Fall 2024)
- Unique laboratory capability: 15 kV Class, 1 MW system, PD and EMI testbed, Electric Vehicle Motor Dynamometer, Enhanced Machine Shop (coming)

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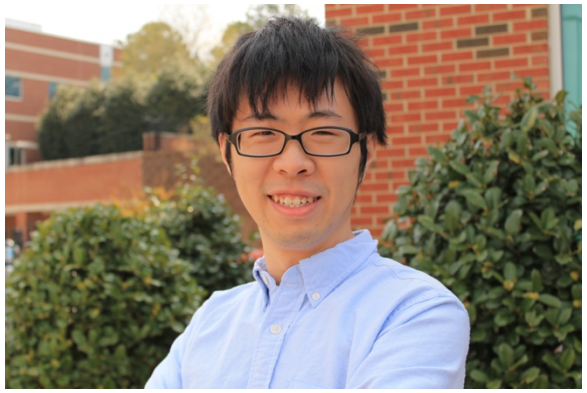
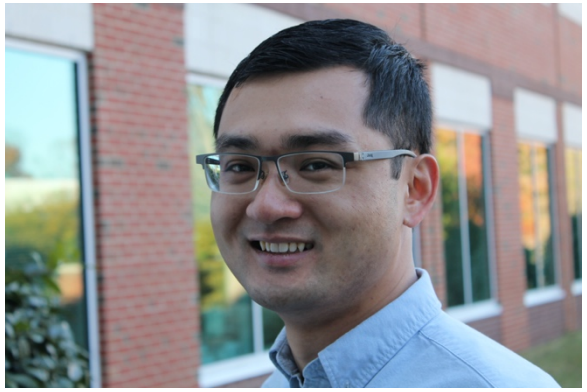
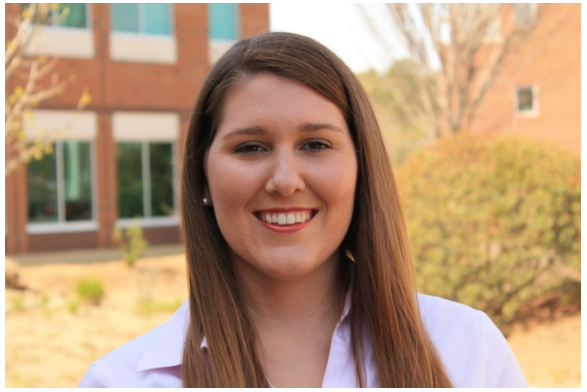
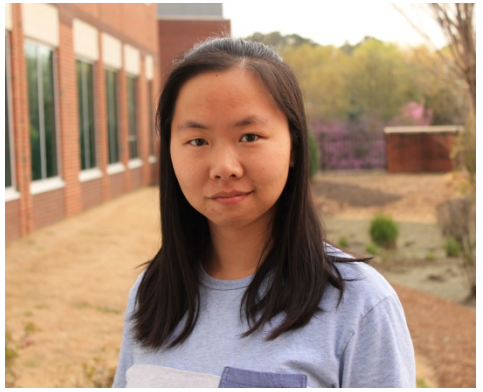
Graduates









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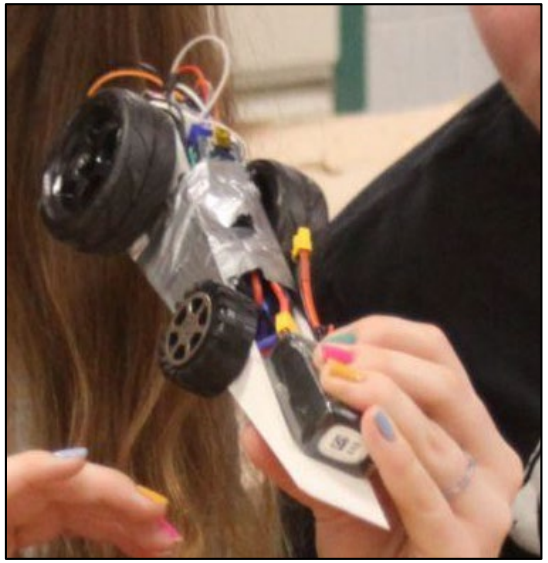
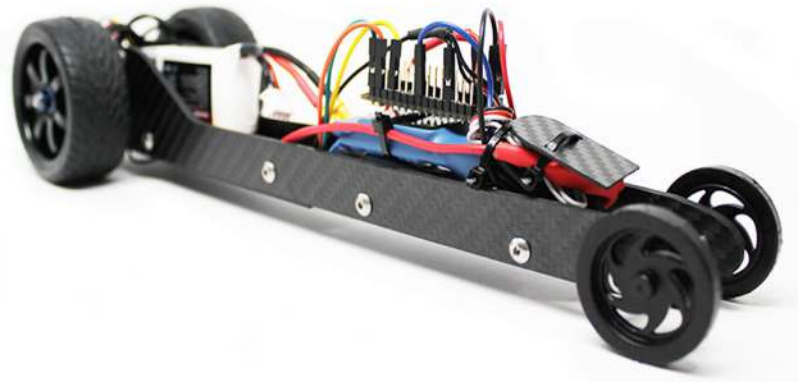
Graduates

Spring and Fall 2023 Graduations

K-12 Engagement





2022-23 STEP Program

- 150 students from grades 6-12 participated in learning, designing, testing, and documenting their experience in electric vehicle modeling
- ~25 students per school.
- Challenged to design a 1/10 scale model electric dragster (e-dragster).
- Erik Schettig, Lecturer of STEM Education, NCSU manages the program

Outreach

Outreach

- Presentations
- Media Events
- Partnership Organizations
- Industry Requests
- Webinars

FREEDM visit by Dr. Arati Prabhakar, Director of White House OSTP

Industry and University Visits

- Interests and visits from Volvo, Caterpillar, Vinfast, Kempower, Trane, Schneider, Siemens Energy
- Lappeenranta University of Technology, Finland; Federation University, Australia; Gachon University, Korea and Karlsruhe Institute of Technology, Germany

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Select Large Awards Since Graduation

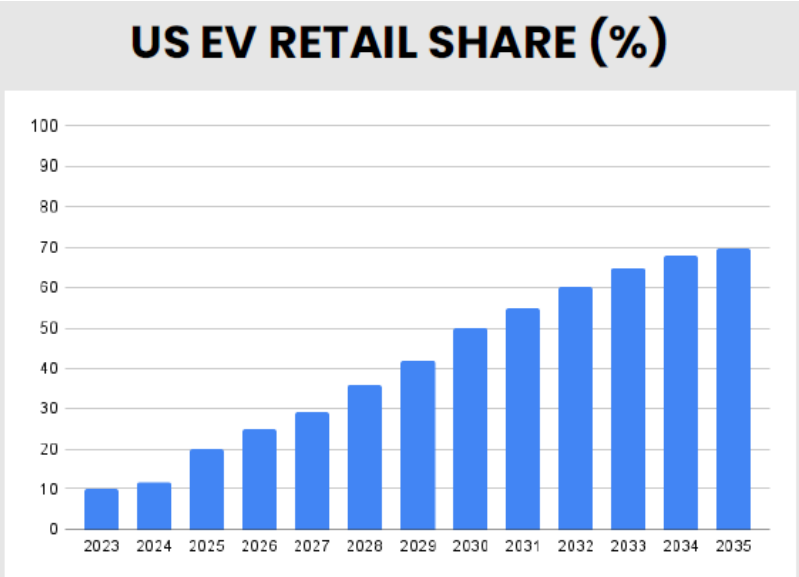
Active

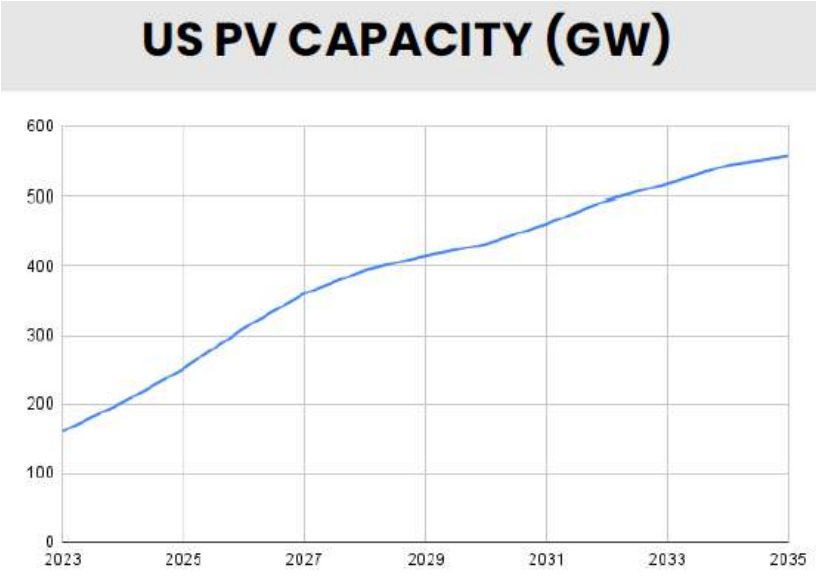
- $4.8 M: Microgrid Control/Co-ordination Co-Design (S. Lukic, I. Husain, A. Chakrabortty, W. Tang)
- $3.9 M: Ultra-low Cost, All-SiC Extreme Fast Charger (S. Lukic, I. Husain, W. Yu)
- $3.1 M: Photovoltaic Analysis and Response Support (W. Tang, N. Lu)
- $1.5 M: Rugged WBG Devices and High Power Density Electric Machines for Electric Vehicles (I. Husain, S. Bhattacharya, V. Veliadis)
- $0.75 M: Universal Interoperability for Grid-Forming Inverters (UNIFI) Consortium (I. Husain, S. Lukic and D. Lubkeman)

Recently Completed

- $2.6 M: Intelligent, Grid-friendly 1MVA Medium Voltage Extreme Fast Charger (S. Lukic, I. Husain, W. Yu)
- $2.1 M: Integrated Microgrid Control Platform (S. Lukic and D. Lubkeman)
- $1.6 M:Solar Inverter Demand Response (N. Lu, W. Tang, M. Baran, S. Lukic, D. Lubkeman)
- $1.4 M: PV Inverters with SiC-based Four Quadrant Power Switch (S. Bhattacharya, J. Baliga, D. Hopkins)

The Future of FREEDM





- Wide bandgap devices with better performances at reduced costs
- Technologies for mass adoption of electric vehicles with managed charging and a more resilient grid
- Robust design tools and novel control methods for transition to a network of microgrids
- Grid forming inverter controls with constraints for massive penetration of renewable energy resources
- Grid planning and forecasting with accurate models may not rely on historic trends.
- With Clean Energy targets for 2035 and 2050 and transportation electrification revolution, extensive research and development essential for many years to come
- Living lab type demonstrations within campus, such as deployment of an extreme fast charge on a 13.2kV feed; BESS with control innovations

Thank You !

Any Questions ?

Iqbal Husain
Email: ihusain2@ncsu.edu

Srdjan Lukic
Email: smlukic@ncsu.edu

Ken Dulaney
Email: ken_dulaney@ncsu.edu