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

Annual Symposium 2024
Future Renewable Electric Energy Delivery and Management (FREEDM) Center

FREEDM Established in 2008
Graduated from NSF in 2019

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
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. Mesut E Baran
  Power Systems
  Renewable Energy Systems

- Dr. Aranya Chakrabortty
  Power Systems
  Stability & Controls

- Dr. Wenyuan Tang
  Energy Markets
  Renewable Energy

- 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

- 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.

Smartgrid and Modern Power Systems

- Dr. Alyssa Kody
  Power Systems Optimization and Controls

- Dr. Zeljko Pantic
  Power Electronics
  Wireless Power Transfer

- Power Systems, Power Electronics
Staff Addition to FREEDM Family:

Erik Bishop, Hardware Technician
Bethany Rainwater, Industry & Education Coordinator
Catherine Lema, Administrative Support
What We Do?

- Power Systems
- Information Technology
- Power Electronics

POI - Point of Interest
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

**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

**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

**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

APEC 2024
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

Dr. Bonner, Dr. Husain, and Dr. Pantic

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

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

Dr. Veliadis, Dr. Husain and Dr. Bhattacharyya

Dr. Bonner, Dr. Husain and Dr. Pantic
Education Programs

• PhD Graduates:

<table>
<thead>
<tr>
<th>PhD Graduated/Students</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023 PhD Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td>16</td>
<td>17</td>
<td>13</td>
<td>17</td>
<td>11</td>
<td>14</td>
<td>93</td>
</tr>
</tbody>
</table>

• 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)
Graduates
Graduates

Spring and Fall 2023 Graduations
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

- 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
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)
• 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