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FORTY-SIXTH ANNUAL REPORT
OF THE
POWER AFFILIATES PROGRAM

University of Illinois at Urbana-Champaign
Department of Electrical and Computer Engineering
306 N. Wright St.
Urbana, IL 61801

PAP-TR- 25-01

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FOREWORD

This report provides a summary of Power Affiliates Program (PAP) activities in the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign for the calendar year 2025. Information listed below is intended to be a progress report to the affiliate companies. The PAP is the foundation of the industrial liaison effort in the power and energy systems area. Current affiliates associated with the PAP are:

City Water, Light & Power, Springfield, IL
Continental Automotive
G&W Electric
MidAmerican Energy Company
PowerWorld Corporation
S&C Electric Company
Sargent & Lundy Engineers

2025 was an active year for the PAP and the highlights are covered in this report. We acknowledge the valuable interaction of the Affiliates and are most thankful to these companies for their continued support.

Arijit Banerjee, Director
Alejandro Domínguez-García, Co-director
Subhonmesh Bose
Ulas Coskun
George Gross
Kiruba S. Haran
Philip Krein
Olga Mironenko
Jonathon Schuh
Andrew Stillwell
Richard Zhang
Kevin Toomey
Jeremy Sykes

1. INTRODUCTION AND SUMMARY

The Power Affiliates Program was initiated in January 1979 as part of a major effort to strengthen the power and energy systems area. The original objectives were to:

- Maintain stimulating, meaningful and high quality undergraduate and graduate programs in electric power engineering.
- Increase university-industrial interaction at all levels of education and research in electric power engineering.

These objectives are as valid today as they were in 1979. The multi-faceted activities in 2025 under the PAP umbrella clearly were in support of these objectives.

Throughout the past 46 years, the PAP has maintained a stable financial base during times of rapid change in the power industry and provided seed money for research. This led to additional funding by other sources and has made it possible for students to be exposed to industrial problems and participate in technical and professional meetings.

This annual report is organized as follows. The financial statement for the 2025 calendar year is given in Section 2. Section 3 describes how the Power Program fits into the departmental structure. There is no official degree or option associated with the Power Program, but there is a significant level of specialization, which is possible through a set of courses developed and offered by the faculty group who constitute the Power and Energy Systems Area. Section 4 gives a brief description of the courses for specializing in electric power and tabulates the enrollment figures for the most recent offerings. Included in this section is a historical record of the number of graduates who have taken three or more of these courses. Section 5 lists the activities of both the students and the faculty members during the 2024 calendar year. Section 6 gives information about the graduate students in the power area. In addition to personal data and interests, each student has written a brief abstract of his or her research work. Laboratories and other facilities of the power area are discussed in Section 7. The report concludes with a directories in Sections 8 and 9 and with the 2024 publications list in Section 10.

2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 2024 was prepared from a detailed University statement as of December 31, 2024.

Income carried over from the 2023 calendar year	$127,376.71
Total income during Calendar Year 2024 *	$ 26,200
Total available income during calendar year 2024	$ 153,476.71

Expenditure	**Expenditure Amount**
Personnel	$ 3,997.15
Supplies	$ 2,432.23
Services	$ 6,798.30
Transportation/Travel	$ 1,357.82
Total expenditures	$ 14,585.50

Summary

Amount of funds available during calendar year 2024	$ 153,476.71
Amount of expenses during calendar year 2024	$ 14,585.50
Balance as of December 31, 2024	$ 138,891.21

* This does not include funds that were received in 2024 but not posted on the university accounting system until 2024.

3. THE POWER PROGRAM WITHIN THE DEPARTMENT

Electrical engineering undergraduate students are required to complete 128 hours of course work for a BSEE degree. Detailed descriptions of the undergraduate program and suggested curriculum in Power are on the Department web site. The MEng is a technical degree requiring a minimum of 32 credit hours and includes a professional development requirement. MSEE students are required to complete a minimum of 32 credit hours including a graduate thesis. All PhD students must qualify through a research paper and presentation and complete course and thesis requirements. A detailed description of the graduate programs is given on the Department web site.

The Electrical and Computer Engineering Department is subdivided into eight distinct technical areas as follows:

Biological Imaging, Bioengineering, and Acoustics
Circuits
Communications and Control
Computer Engineering
Electromagnetics, Optics and Remote Sensing
Microelectronics and Nanotechnology
Power and Energy Systems
Signal Processing and Data Science

While the Department does not have official degree-granting options in these areas, in practice, the eight areas serve as the appropriate grouping of faculty activities and interest. In terms of size, the Power and Energy Systems area represents about 9% of the total active faculty and about 14% of the total student enrollment. The faculty committee in each group has the responsibility for administering courses and research in that group within the Department. The Power and Energy Systems Area Committee and associated faculty for the 2024 – 2025 year together with their fields of interest are:

A. Banerjee	Electromechanical energy conversion systems, power electronics, electrical machines and drives, electric propulsion systems, renewable energy, robotic actuators
S. Bose	Algorithm and market design for power systems, renewable integration, smart transportation, networked dynamical systems
A. Domínguez-García	Power and energy systems, microgrids, grid data analytics, reliability analysis, cyberinfrastructures, decision science
G. Gross (Emeritus)	Large-scale system analysis and computing, energy economics, effective bio-fuel applications for electricity, electricity planning and analysis
K. Haran	Autonomous vehicular technology, UAVs, electric transportation, electrical machines and drive systems, power and energy systems
P. T. Krein (Emeritus)	Electric machinery and electromechanics, power and energy systems, power electronics, energy efficient buildings, transportation electrification

A. Stillwell	Power electronics, alternative and renewable energy systems, transportation electrification, wide bandgap power devices, design optimization
R. Zhang	Control theory, electric power systems, power electronics, data science

In addition to this committee, the area has two teaching professors that help with instruction and consulting on research projects. These are:

J. Schuh	Came to us with a PhD in Theoretical and Applied Mechanics (at UIUC) and is a Teaching Assistant Professor in the ECE department. He teaches courses in power engineering and senior design. His goal as an educator is to instill knowledge of fundamental behavior to allow his students to solve a range of problems outside those covered in class.
O. Mironenko	Came to us with a PhD in ECE from the University of Delaware and is a Teaching Assistant Professor in the ECE department. She teaches courses in power engineering, including renewables and electric vehicles. Her goal as an educator includes demonstrating to students the applicability of gained knowledge to address real-world challenges, as well as well as to benefit the student's future career goals.

Two of the primary responsibilities of the Power and Energy Systems Area Committee are to improve, keep current, and staff the courses assigned to the Power and Energy Systems Area. In 2024 those courses were:

ECE 217	Solar Car
ECE 330	Power Circuits and Electromechanics
ECE 333	Green Electric Energy
ECE 398 GG	Electric Vehicles (EVs)
ECE 431	Electric Machinery
ECE 432	Advanced Electric Machinery
ECE 464	Power Electronics
ECE 469	Power Electronics Laboratory
ECE 476	Power System Analysis
ECE 530	Analysis Techniques for Large-Scale Electrical Systems
ECE 554	Dynamic System Reliability
ECE 568	Modeling and Control of Electromechanical Systems
ECE 573	Power Systems Operations and Control
ECE 576	Power System Dynamics and Stability
ECE 590 I	Seminar: Power Systems
ECE 598 AB	Power-Electronic Converter and Control for Electric Machines: Theory and Practice
ECE 598 KSH	Electrical Machine Design
ECE 598 SB1	Electricity Markets

The four-hundred level courses are advanced undergraduate or beginning graduate courses, while the five-hundred level courses are graduate. The Power and Energy Systems Area Committee periodically evaluates each course outline for possible revision for future offerings. A brief description of each of these courses, together with the enrollment of the past year, is included in the next section. In addition, the Power Faculty supervises numerous student projects performed in ECE 445. This is the capstone design course for our seniors.

4. COURSES AND ENROLLMENT

As one of seven major areas in Electrical and Computer Engineering, the Power and Energy Systems Area is responsible for the development and offering of a considerable number of courses. Current courses assigned to the power area are described briefly below. Total enrollment for courses offered in the 2024 – 2025 academic year is also given for each course.

ECE 217: Solar Car

The course objective is to show students that a multidisciplinary understanding is essential to create a complex system. UIUC's own Solar Car "Argo" will be the example. The course will cover high-level aspects of the design, construction, analysis, and economics of solar-powered electric vehicles. Topics will bridge a variety of engineering disciplines integrated with business to present a cohesive overview highlighting complexities of solar-powered vehicles. Students are expected to gain hands-on experience working with the Solar Car Team to build the next solar car. In-class presentations will provide a platform to individuals to convey ideas and contributions to a broad set of multidisciplinary audience. In place of a text are Instructor Notes and *Solar Car Wiki*. References are *Solar Car Primer*, by E. F. Thacher and *The Leading Edge: Aerodynamic Design of Ultra-streamlined Land Vehicles*, by G. Tamai, 1999. The total enrollment for the academic year 2024 – 2025 was 32.

ECE 330: Power Circuits and Electromechanics

The goal of this three-hour course is to provide an introduction to three-phase circuits, transformers, and electromechanical systems with an emphasis on analysis and some design insight. The course starts with a review of phasors followed by three-phase power circuits, mutual inductance, magnetic circuits and transformers. Electromechanical systems are analyzed using energy-balance concepts. Introduction to synchronous, induction, dc and small machines is given. The required text is *Power Circuits and Electromechanics*, by M. A. Pai. The total enrollment for the academic year 2024 – 2025 was 320.

ECE 333: Green Electric Energy

A course on the challenges of meeting future energy needs using renewable resources; this is a three-hour technical elective for engineering introductory-level undergraduate students with a background in electric circuits. The course explores the technical, economic, environmental and policy aspects of renewable and alternative energy systems to provide a comprehensive picture of their role in meeting society's electricity needs. The upsurge in the worldwide demand for oil-based resources, the restructuring of the electricity industry, advances in engineering technology and the increasing interest in environmental protection are presenting unparalleled challenges to the electric power industry. The role of new energy-resource technologies, the application of power electronics, the use of demand-side management, and the effects of market forces in addressing these challenges are discussed. The course covers the basics of energy production from renewable sources, the relevant thermodynamics background, the structure and nature of the interconnected electric power system and the critical need for environmentally sensitive solutions. In addition, the economic and regulatory policy aspects of electricity and electricity markets are treated. The course has the following texts: *Renewable and Efficient Electric Power Systems*, 2nd Edition, by G. M. Masters, 2013. The total enrollment for academic year 2024 – 2025 was 148.

ECE 398GG: Electric Vehicles (EVs)

Electric vehicles (EVs) have the potential to drastically reduce the global CO2 footprint to effectively address climate change issues. Massive EV adoption requires the establishment of an EV charging infrastructure (EVCI) to supply the energy needs of EV owners/users. This three-hour course examines technical, economic, environmental and policy aspects of EVs and the required EVCI. A basic physics discussion of rolling vehicles serves to determine the power and energy requirements and their implications for energy storage and transfer. The course covers the EV architectures and configurations, as well as the detailed description of the deployment of motors and generators, drives for traction applications, batteries and their management and the EV-grid nexus. The description of the various technologies and approaches deployed in EV design and operations is augmented by a detailed examination of the energy efficiency and environmental benefits of EVs. The application of power electronics to EV charging is accompanied by a detailed examination of the EVCI and its interactions with existing infrastructures. Throughout the course, there is a strong focus on the efficient utilization of energy in an environmentally sensitive manner to emphasize the significant role of EVs and EVCI in the energy transition. Copies of the slides used in the lectures will be downloadable from the course website. The total enrollment for academic year 2023 – 2024 was 29.

ECE 431: Electric Machinery

This four-hour course contains a laboratory one-credit hour component, which is an elective in a list of fourteen from which students select two. The fifteen experiments typically include power measurement, power-factor correction, transformer characteristics, three-phase transformer connections, induction motor tests, induction motor torque-speed characteristics, synchronous machine tests, synchronous-machine power characteristics, digital simulation of machine dynamics, motor control, and a written, plus oral project presentation on power and energy system topics. This class includes an offsite trip to a corporate manufacturing facility to see the use of electric machinery in large scale industrial design. The required text is *Electric Machinery,* by Fitzgerald, Kingsley, and Umans, 2013. The total enrollment for academic year 2024 – 2025 was 46.

ECE 432: Advanced Electric Machinery

This three-hour course contains advanced theory and analysis of rotating and linear machines and drives. It includes power electronic drives for dc and ac motors. The analysis uses *d-q* transformations and related techniques. Emphasis is placed on time-scale modeling of electromechanical devices and on their function in drives. The required text was *Analysis of Electric Machinery and Drive Systems*, by P. C. Krause, O. Wasynczuk, S. D. Sudhoff, and S. D. Pekarek, IEEE Press, 2025. This class was not offered in the 2024 – 2025 academic year.

ECE 464: Power Electronics

This three-hour course is a comprehensive treatment of switching power-conversion systems and the devices used to build them. Concepts of switch control are developed from general switching functions. Phase control, pulse-width modulation, and phase modulation are studied for applications in all types of converters. Converter topologies are introduced along with design concepts for power filters and interfaces. Devices such as diodes, thyristors, bipolar transistors, field effect transistors, capacitors, and magnetic components are examined in the context of high-power switching applications. The required text is *Elements of Power Electronics*, 2^{nd} Edition, 2014, by P. T. Krein. The total enrollment for academic year 2024 – 2025 was 109.

ECE 469: Power Electronics Laboratory

This two-hour course, designed to accompany ECE 464, is a laboratory study of circuits and devices used for switching power converters, solid-state motor drives, and power controllers, including dc-dc, ac-dc, and dc-ac converters and applications. It includes high-power measurements for silicon-controlled rectifiers, diodes, capacitors, power transistors and magnetic component. The total enrollment for the academic year 2024 – 2025 was 72.

ECE 476: Power System Analysis

This three-hour course is the first of two courses on power system analysis. Topics included are transmission-line parameter calculations, equivalent circuits, network analysis, load flow, fault analysis, symmetrical components, unsymmetrical fault analysis, and introduction to economic dispatch. The course is designed to be a stand-alone introduction to the fundamentals of power system analysis and provide the basis for all subsequent courses in the power system analysis. The required text is *Power System Analysis & Design*, 7^{th} Edition, 2022, by J. D. Glover, T. J. Overbye, M. S. Sarma and A. B. Birchfield. The total enrollment for academic year 2024 – 2025 was 52.

GRADUATE COURSES:

ECE 530: Analysis Techniques for Large-Scale Electrical Systems

This is a four-hour course in modeling power systems in steady-state and dynamic regimes. It includes analysis and simulation techniques for power and power electronics systems as well as computational issues in power systems and power electronics. Topics covered are advanced power flow, sparsity techniques, power-flow control, least-squares and estimation-applications averaging techniques for power electronics systems, numerical integration of differential equations and Krylov subspace applications. This class was not offered in the 2024 – 2025 academic year.

ECE 554: Dynamic System Reliability

This four-hour course offers subjects in new and developing areas of knowledge in electrical and computer engineering intended to augment the existing curriculum. Topics include basic reliability concepts, uncertainty modeling, reliability analysis, system design, fault detection, diagnosis, and applications. Text is *Large Scale System Analysis Under Uncertainty* by Alejandro D. Dominguez-Garcia, 2022. This class was not offered in the 2024 – 2025 academic year.

ECE 568: Modeling and Control of Electromechanical Systems

This four-hour course addresses issues of electrical drives in a modern control and circuit framework. Dynamic models of electric machines are presented. There is special emphasis on field-oriented control methods for ac motors. Power electronics systems for high-performance drives are studied. Nonlinear system methods such as periodic transformations, averaging, geometric control, and feedback linearization are presented. Special topics covered include electrostatic micromachines and permanent magnet machines. The recommended texts are *Control of Electrical Drives*, 3rd edition, 2001, by W. Leonard and *Analysis of Electric Machines*, 2025 by P. Krause, O. Wasynczuk, S. D. Sudhoff, and S. D. Pekarek. The total enrollment for academic year 2024 – 2025 was 28.

ECE 573: Power Systems Operations and Control

This four-hour course provides an overview of power system operations and control with major emphasis on security and economics. The role of EMS (energy management system) and principal EMS functions are discussed in depth. Major topics include: optimal power flows; economic dispatch problems; role of reactive power; resource scheduling and commitment; state estimation; observability; bad data identification/detection, analysis and processing; electricity restructuring; competitive electricity markets; market design; congestion management; and ancillary services. The two suggested texts are *Power Generation, Operation and Control*, 2nd edition, by Wood and Wollenberg, and *State Estimation* *in Electric Power Systems: A Generalized Approach* by A. Monticelli, Kluwer Academic Publishers, Boston, 1999. This class was not offered in the 2024 – 2025 academic year.

ECE 576: Power Systems Dynamics and Stability

This four-hour course includes the dynamic representation of interconnected power systems—electrical plus mechanical, linearized dynamic models of multi-machine systems, methods of coherency identification, order reduction by singular perturbation, time-scale decomposition and aggregation techniques, dynamic equivalents, direct methods of stability analysis and power system stabilizer design. The required text is *Power Systems Dynamics and Stability* by P. W. Sauer and M. A. Pai, 1997. The total enrollment for academic year 2024 – 2025 was 5.

ECE 590 I Seminar: Power Systems

This course is a graduate seminar on advanced topics of current interest. Both faculty and students participate by presenting either current research results or topics of interest in journal publications. Guest speakers from industry and other universities are also scheduled periodically throughout the semester. Approximately 60 students participated in this course for both semesters.

ECE 598 KSH: Electrical Machine Design

Technologies like advanced materials, manufacturing processes and power electronics can open up the design space for new electrical machine solutions aimed at emerging applications in the transportation, energy, and industrial sectors. To take full advantage of these developments, engineers need to be well versed in the multidisciplinary design process for electrical machines, with a good understanding of complex trade-offs that span multiple disciplines. They must also be comfortable with both analytical and numerical tools and know when to apply these to obtain the best results. The course attempts to prepare electrical and mechanical engineers for this opportunity by focusing on practical design considerations. It builds on fundamentals covered in ECE 330 and 431 and takes students through the design of a variety of electromechanical devices. Fundamental principles of energy conversion applicable to all types of electric machinery are first reviewed. Basic design rules, analytical formulae and the use of numerical design tools are then introduced, and experience is gained through a hands-on design project. This class was not offered in the 2024 – 2025 academic year.

ECE 598 AB: Power-Electronic Converter and Control for Electric Machines: Theory and Practice

This course introduces modeling, analysis, and design of electromechanical energy-conversion systems from a simultaneous perspective of power electronics, electromechanics, and control. We will take a hands-on approach. Theories are discussed in lectures and implemented in real-world laboratory setups. Three-phase power-electronic converters specifically designed for machine drives are introduced.

Dynamic models of different types of electrical machines are developed using generalized machine theory. Finally, different control architectures and their impact on the dynamic performance of the drive are discussed. "Real-world" examples from many existing and emerging applications including electric vehicles, renewable energy systems, and high-power and high-performance industrial drives are used to show the need for interdisciplinary understanding from a system perspective. The required text is *Control of Electrical Drives*, 3rd edition, 2001 by W. Leonhard. References include *Vector Control and Dynamics of AC Drives* by D. W. Novotny and T. A. Lipo, *High-Power Converters and AC Drives,* by B. Wu and M. Narimani, 1996. *Control of Electric Machine Drive Systems* by S. Sul, *Power Electronics and Motor Drives: Advances and Trends* by B. K. Bose, 2011 and various IEEE papers. Prerequisites: ECE 464 (Power Electronics) and ECE 431 (Electric Machinery). ECE 486 is preferred. This class was not offered in the 2024 – 2025 academic year.

ECE 598 SB1: Mathematical Foundations of Electricity Markets

Power system operation is linked to the operation of electricity markets. In this course, we study the modeling and analysis of competitive electricity markets that facilitate the balance of demand and supply of electricity across a power network. We leverage tools from optimization theory, microeconomics, and game theory to investigate the rationale behind current market designs, how they operate, and analyze the outcomes, given the strategic behavior of the market participants. The course illustrates the complex interaction of mechanism design with the physics of the underlying grid, a feature that distinguishes electricity markets from traditional marketplaces. While the bulk of the course focuses on wholesale electricity markets in the US, we conclude with current debates on the creation of retail markets to harness the flexibility of demand side resources. This class was not offered in the 2024 – 2025 academic year.

NUMBER OF ELECTRIC POWER AND ENERGY SYSTEM AREA GRADUATES IN RECENT YEARS

Annual Average of Power Area Graduates

1950-1970

B.S.E.E.	-	25
M.S.E.E.	-	3

1970-1980

B.S.E.E.	-	44
M.S.E.E.	-	7

1980-1990

B.S.E.E.	-	32
M.S.E.E.	-	5
Ph.D.	-	2

1990-1995

B.S.E.E.	-	40
M.S.E.E	-	6
Ph.D.	-	2

1995-2000

B.S.E.E.	-	35
M.S.E.E.	-	9
Ph.D.	-	3

2000-2005

B.S.E.E.	-	40
M.S.E.E.	-	8
Ph.D.	-	3

2005-2010

B.S.E.E.	-	50
M.S.E.E.	-	10
Ph.D.	-	5

2010-2015

B.S.E.E.	-	60
M.S.E.E.	-	12
Ph.D.	-	6

2015-2020

B.S.E.E.	-	50
M.S.E.E.	-	10
Ph.D.	-	5

2020-2023

B.S.E.E.	-	75
M.S.E.E.	-	25
Ph.D.	-	11

2024-2025

B.S.E.E.	-	56
M.S.E.E	-	5
Ph.D.	-	3

5. ACTIVITIES

Faculty and students in the Power and Energy Systems Area participated in a considerable number of special activities during the academic year 2024 – 2025. The major events are listed below:

JUNE 2024

- Philip Krein participated in the IEEE Transportation Electrification Council Administrative Committee Meeting, attending also as a presentor, author, and the instructor of a tutorial (ITEC) in Chicago, IL.
- Kiruba S. Haran presented at the IEEE Transportation Electrification Conference (ITEC) in Chicago, IL.
- George Gross directed, and presented lectures at, the 2024 edition of the *Transmission Business School* in Chicago, IL.
- Alejandro Domínguez-García presented research at the European Control Conference held in Stockholm, Sweden.
- Olga Mironenko presented research at the American Society for Engineering Education (ASEE) held in Portland, OR.
- Andrew Stillwell presented research at the IEEE Workshop on Control and Modeling for Power Electronics (COMPEL), held in Lahore Pakistan. Graduate students Aria Delmar presented at IEEE Workshop on Control and Modeling for Power Electronics, held in Lahore Pakistan.
- Graduate student Soumil Chaubil, Andrew Freeman, and Nicole Stokowski attended and/or presented research at the IEEE Transport Electrification Conference & Expo (ITEC), held in Chicago.

JULY 2024

- Kiruba S. Haran presented research at the IEEE Transportation Electrification Conference (ITEC) held in Chicago, IL.
- George Gross organized, and participated in the instruction at, the University of Salerno Summer School on Smart Grids in Fisciano, Italy.
- Philip Krein attended and was a judge at the IEEE Future Energy Challenge student competition and event, held in Austin, TX.
- Olga Mironenko attended the Narrative Engineer Workshop as part of the UIUC team that was held at Emory/Georgia Tech, GA.
- Richard Zhang presented research at the International Symposium on Mathematical Programming (ISMP) held in Montreal, Canada.
- Graduate student Hong-Ming Chui presented research at the International Symposium Mathematical Programming Summit in Montreal, Canada.

- Graduate student Iven Guclu presented research at Federal Energy Regulatory Commission, ERC Increasing Real-Time and Day-Ahead Market and Planning Efficiency Through Improved Software Conference in Washington D.C.

- Graduate student Boya Hou presented research at the Fourth Symposium on Machine Learning and Dynamical Systems at Fields Institute in Toronto, Canada.

SEPTEMBER 2024

- Philip Krein participates in our joint educational institute in China, the Zhejiang University/University of Illinois Urbana-Champaign Institute. Prior to October 2024, he led the joint research center between the two universities. In September 2024, he traveled to the Institute to participate in freshmen welcoming events and to manage research interactions.

- Kiruba S. Haran attended his induction ceremony into the National Academy of Engineering, (NAE) in Washington D.C. Philip Krein also attended (NAE), including attendance and participation at Section 6 meetings and events.

- Kiruba S. Haran taught a short course and presented research at the Applied Superconductivity Conference (ASC) in Salt Lake City, UT. Graduate students, Joshua Feldman and Jianqiao Xiao also presented research at this event.

- Graduate student Jianqiao Xiao competed in the Perfect Pitch Competition at the National Science Foundation Engineering Research Centers (NSF ERC) Biennial Meeting held in Washington, D.C.

OCTOBER 2024

- Richard Zhang gave invited talks at UCLA and USC in early October and then visited faculty at Caltech, Los Angeles, CA.

- Jonathon Schuh presented research at the Society of Rheology in Austin, TX.

- Philip Krein and Andrew Stillwell attended the IEEE Energy Conversion Congress and meetings of the IEEE Power Electronics Society, in Tempe, AZ. Also attending were Graduate students Arjit Bali, Anubhav Bose, and Brian Wolhaupter, some of whom presented research.

- Richard Zhang gave an invited lecture at the University of Washington (UW) and then presented a paper at the Institute for the Operations Research and the Management Sciences (INFORMS) Annual Meeting that was held in Seattle, WA.

- Olga Mironenko attended and helped recruit prospective graduate students at the Society of Women Engineers Conference in Chicago, IL.

- Graduate student Boya Hou presented at the Cornell Young Researcher's Workshop in Ithaca, NY. Hou also presented at the Modeling, Estimation, and Control Conference (MECC) held in Chicago, IL.

NOVEMBER 2024

- Philip Krein participated in the IEEE Foundational Annual meeting as a board member elect at the IEEE headquarters in Piscataway, NJ.

- In collaboration with the Coordinated Science Laboratory, Philip Krein presented and moderated the Compute-Energy-Nexus Workshop, on campus, Urbana, IL.

- Jonathon Schuh presented research at the American Physical Society, Division of Fluid Dynamics in Salt Lake City, UT.

- Graduate student Anjana Samarakoon attended the Center for Power Optimization of Electro-Thermal Systems, (POETS) Annual Meeting.

- Graduate student, Parag Bajaj presented research at the Annual Conference of the IEEE Industrial Electronics Society in Chicago, IL.

DECEMBER 2024

- Subhonmesh Bose presented research at the PSERC IAB Meeting in Phoenix, AZ.

- Alejandro Domínguez-García presented research at the Conference on Decision and Control in Milan Italy.

- Graduate students, Temitope Amuda, Iven Guclu, and Boya Hou presented research at the PSERC IAB Meeting in Tempe, AZ.

- Graduate student Joshua Feldman presented research at the American Society for Gravitational and Space Research, held in San Juan, PR.

JANUARY 2025

- Kiruba S. Haran attended the NSF's Center for Power Optimization of Electro-Thermal Systems (POETS) Annual Meeting in Fayetteville, Arkansas.

- Olga Mironenko attended the Kern Entrepreneurial Engineering Network, or KEEN Conference, in order to develop techniques for teaching and facilitating entrepreneurship in engineering students. KEEN was held in Austin, TX.

- Graduate students Grant McKechnie and TG Roberts presented research at the Universal Interoperability for Grid Forming Inverters (UNIFI) Consortium held in Tempe, AZ.

FEBRUARY 2025

- Airjit Banerjee was invited to perform a lecture at the University of Wisconsin at Madison.

- Philip Krein participated in IEEE Foundation Board meetings at the IEE Board series in Bellevue, WA.

- Alejandro Domínguez-García attended and had a leadership role in the Power Systems Engineering Research Center (PSERC) Executive Committee (EC) Retreat in Chicago, IL.

- Kiruba S. Haran participated in the Commercial Superconductivity Summit (CSS), in Kissimmee, FL. Attending workshops and as a guest on roundtable discussions on applications of HTS technologies with which he was involved.

MARCH 2025

- Philip Krein attended the IEEE Applied Power Electronics Conference (APEC), IEEE Power Electronics Society (PELS), and IEEE Transportation Electrification Council meetings in Atlanta, GA. Graduate students Aria Delmar, Andrew Freeman, Anuj Maheshwari, and Nicole Stokowski also presented research APEC in Atlanta Georgia.

- Richard Zhang was invited to lecture at Stanford University ISL Colloquium, in San Francisco, CA. He also gave a lecture neaby at the corporate headquarters of Meta Platforms, formerly Facebook in Menlo Park, CA.

- Kiruba S. Haran visited United Technologies (UTC) Aerospace Systems - Collins Aerospace in Rockford, IL leading ECE 431 on a field trip.

- Alejandro Domínguez-García was invited to speak at a seminar at Washington University in St. Louis, MO.

- Arjit Banerjee attended the Department of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) Energy Innovation Summit (The Summit) in Washington, DC.

- Graduate student Andrew Freeman attended the Department of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) Energy Innovation Summit (The Summit) in Washington, DC.

APRIL 2025

- Philip Krein, was host emeritus to the Power and Energy Conference at Illinois (PECI) in Urbana, IL. He provided a keynote address and met with invited speakers and students.

- Graduate students organized the annual Power and Energy Conference of Illinois (PECI). Andrew Freeman and Grant McKechnie were co-directors of the conference, PECI 2025. Academics from prestigious research institutions were invited to speak. Likewise graduate students from other universities came to town to participate. Graduate students Nina Ayar and Anjana Samarakoon also presented their research at the event.

- Graduate student Muhammad Talal Khalid presented research at the IEEE Energy and Policy Forum in Washington, D.C.

MAY 2025

- Philip Krein traveled to Zhejiang University in China May through June 2025 to carry out duties related to the Zhejiang University/University of Illinois Urbana-Champaign Institute and to participate in graduation ceremonies.

- Graduate student Yaokun Shi presented research at the International Society for Magnetic Resonance in Medicine (ISMRM) in Honolulu, HI.

- Graduate students: Nina Ayar presented at the student run annual conference Power and Energy Conference of Illinois, Urbana, IL.

- Graduate student Anjana Samarakoon presented at the International Electric Machines and Drives Conference (IEMDC) in Houston, TX.

GUEST SPEAKERS

During the 2024–25 year, the power area group hosted the following people, from academia and industry:

- Ben Kroposki, Director of Power Systems Engineering at National Renewable Energy Laboratory "Integrating Massive Amounts of Wind and Solar in Electric Grids," September.
- Laurent Massoulie, Scientific Director of the Paris Inria Centre and Professor at Applied Maths Center of Ecole Polytechnique. Inria Paris, DIENS PSL University, "Graph Alignment: Informational and Computational Limits," September.
- Matt Hannan, Director of Platform Engineering, and Jonathan Wojtalik, Electrical Engineering Manager in New Product Development at Milwaukee Tool, November.
- Wen-Mei Hwu, Senior Research Director, NVIDIA, chaired and moderated several sessions at the Compute-Energy-Nexus conference held on campus, November.
- William Schaumann, Senior Associate at Burns & McDonnell, was a panelist at the Compute-Energy-Nexus conference held on campus, November.
- Chris Gladwin, CEO and Founder of Ocient, Joe Jablonski, Co-founder of Ocient chaired sessions and were panelists at the Compute-Energy-Nexus conference held on campus, November.
- Christopher Zhang, Manager at ComEd, Exelon, invited to meet with students and faculty, and given tour of facility, November.
- Xuan Wei, visiting scholar, Zhejiang University/University of Illinois Institute (ZJUI), "Capacitive Power Transfer," April.
- Simona Sabatino, visiting graduate student, University of Salerno, Italy "Advanced Li-ion Battery Management System," April.
- Samantha Coday, MIT "Monolithic Bidirectional GaN enabling wide-range and ultra-dense capacitor-based power conversion," April (PECI).
- Brian Johnson, University of Texas Austin, "Imagining Energy Conversion Systems as Circuits," April (PECI).
- Jinia Roy, University of Wisconsin Madison "Evolution of Marx Generator for pulsed power: Challenges and opportunities with WBG devices," April (PECI).
- Xin Zan, University of Maryland, "Switched-Mode Power Amplifiers from 3 to 300 MHz: Design and Exploration," April (PECI).
- Jessica Boles, UC Berkeley, "Piezoelectric-based Power Electronics: Converters, Components, and Miniaturization," April (PECI).
- David Perreault, MIT, "Advances in High-Frequency Power Conversion for Industrial Applications," April (PECI).

- Patrick Chapman, former faculty, CEO of Stormentum Division Head, Superconducting Magnet Division at Brookhaven National Lab, “From Strings to Cells: The Evolution of Power Electronics for Home Energy Systems,” April.

- David Perreault, MIT, “Architectures and Topologies for High-Frequency, High-Density Power Conversion,” May.

LOCAL LECTURES

During the academic year 2024 – 2025, the power faculty and students presented the following seminars to our local audiences:

- Philip Krein, “Building ubiquitous EV charging infrastructure,” Rantoul, IL, October 2024.

- George Gross “Energy Supply and Demand in Electric Vehicles,” November 2024.

- Philip Krein, “Wind energy update,” Savoy, IL, November 2024.

- Philip Krein, Andrew Stillwell, and Alejandro Domínguez-García presented and were panelists at Compute Energy Nexus, Urbana, IL, November 2024.

- Arijit Banerjee, Saturday Engineering for Everyone: “From Motion to Music - The Power of Electromechanical Energy Conversion,” February 2025.

- William H. Vavrik “Control and Modeling of Power Converters for Datacenter Power Delivery,” April 2025.

- Victoria, Jeziorczak, “Design and Implementation of a PV Grid-Tied Inverter,” April 2025.

- Andrew J. Freeman, “Design Considerations of Auxiliary Circuits in a Multilevel Converter for Aerospace Deicing,” April 2025.

- Omkar N. Kulkarni, “Driving on Sunlight: Technical Insights into Illini Solar Car’s Electrical Architecture,” April 2025.

- Alejandro Domínguez-García, “From Nikola Tesla to TESLA: How the Electric Grid Became the Most Complex System Ever Engineered,” May 2025.

6. STUDENT PROJECTS

This section of the report contains information on the graduate students whose major research efforts were supervised by faculty in the Power and Energy Systems Area. While not all of these students received financial aid from the Power Affiliates Program in terms of Research Assistantships, they were all associated with the program through the active involvement of their respective advisors. Those students supported by the Power Affiliates Program received maximum one-half time Research Assistantships for 11 months. The results of each student's work will be made available to all affiliate companies in the form of technical reports upon request. The following students were associated with the Power and Energy Systems Area and their work is described in the following pages:

Amuda, Temitope Victor (Ph.D.)
Appiah, Listowell (Ph.D.)
Armstrong, Sebastian
Ayar, Nina V (M.S.)
Bajaj, Parag (M.S.)
Bali, Arjit (Ph.D.)
Billings, Ryan (Ph.D.)
Bose, Anubhav (Ph.D.)
Butts, Dennis Chen
Chaubal, Soumil (M.S.)
Chiu, Hong-Ming (Ph.D.)
Delmar, Aria (Ph.D.)
Feldman, Joshua Michael (Ph.D.)
Freeman, Andrew (M.S.)
Guclu, Arda (Ph.D.)
Guzel, Iven (Ph.D.)
Harmjanz, Fernando (Ph.D.)
Horvath, Ryan Matthew (M.S.)
Hou, Chun Ying (Ph.D.)
Jeziorczak, Victoria (M.S.)
Karakaya, Furkan (Ph.D.)
Khalid, Muhammad Talal (Ph.D.)
Layek, Kunal (Post Ph.D)
Maheshwari, Anuj (Ph.D.)
Mazumdar, Debojyoti (M.S.)
McKechnie, Grant (Ph.D.)
Ngo, Trang An Ha (M.S.)
Qi, Matthew (M.S.)
Roberts, T.G. (Ph.D.)
Rodgers, Aidan Finn (M.S.)
Rousan, Tamer Mohammad (Ph.D.)
Samarakoon, Anjana Jayasanka (Ph.D.)
Shi, Yaokun (M.S.)
Silk, Eric (Ph.D.)
Stoens, Michael J. (M.S.)
Stokowski, Nicole M. (M.S.)
Vavrik, William (M.S.)
Wang, Yijin (Ph.D.)
Witharamalage, Mudith (Ph.D.)
Wolhaupter, Brian Andrew (M.S.)

Temitope Victor Amuda

B.S.:	November 2017, University of Lagos, Nigeria
Status:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Microgrid Control and Operations, Numerical Analysis

A Data-Driven Voltage Regulation
Framework for Power Distribution Systems

Temitope Amuda with Advisor Prof. Alejandro Domínguez-García

Supported by the Department of Energy

ABSTRACT

We consider the problem of voltage regulation in power distribution networks with inverter-based resources (IBRs) whose reactive power output can be controlled. The problem is formulated as a stochastic optimization program, which is solved online using a modified version of the projected stochastic gradient descent (PSGD) algorithm. The proposed PSGD-based algorithm leverages the sensitivities of changes in bus voltage magnitudes to changes in the reactive power setpoints of the IBRs. We propose a method for learning such sensitivities online using a recursive least squares estimator. To ensure the proper operation of the estimator, the sequence of incremental changes in IBR reactive power setpoints must remain persistently exciting. This requirement is guaranteed by design through a mechanism that is built into the voltage regulator. We demonstrate that the estimator and the regulator are amenable to a distributed implementation. We showcase the eff

Nina Ayar

B.S.: May 2021, University of Illinois Urbana-Champaign

Status: Working towards M.S. at University of Illinois Urbana-Champaign

Professional Interests: Electric Machines, Sustainable Transportation, Biomedical Devices

Design of a Compact Permanent Magnet Vernier Machine for Portable Medical Applications

Nina Ayar with Advisor Prof. Kiruba S. Haran

Supported by Grainger CEME

ABSTRACT

The demand for small high-torque machines is steadily increasing due to the growing need for precise, low-cost motors capable of operating in tight spaces, especially in applications such as robotics, automation, and medical devices. Permanent magnet vernier machines (PMVM) are a promising topology, delivering high torque at low speeds and having fairly small torque ripple.

This research focuses on the design optimization and development of a small-scale PMVM that can deliver high torque and enable the precise spatial encoding in a portable MRI system. Previous iterations of the MRI device utilized stepper motors to drive the magnetic arrays necessary for imaging. However, the large form factor of the stepper motors rendered the system bulky and difficult to maneuver, motivating this research direction. PMVMs achieve high torque at low speeds without additional mechanical components due to the vernier effect—a magnetic gearing phenomenon that enhances torque production by leveraging the interaction between the magnetic field harmonics in the air gap.

Finite element analysis of the proposed design shows a machine capable of meeting the system requirements, achieving an average torque of 2.0 Nm and dimensioned 50 x 50 x 80 mm3, sufficient to overcome the pull forces between the magnetic arrays.

Parag Bajaj

B.S.:	May 2021, University of Illinois at Urbana-Champaign
Status:	Working towards M.S. at University of Illinois at Urbana Champaign
Professional Interests:	Electrical Machines, Electrical Transportation

Effects of Rotor Geometry on Equivalent-Circuit Parameters of Variable-Pole Induction Machines."

Parag Bajaj with Soumil Chaubal, Anuj Maheshwari,
Advising Prof. Arijit Banerjee

Supported by Grainger CEME

ABSTRACT

Induction machines (IM) serve as a viable alternative to permanent magnet-based solutions for electric vehicle (EV) drivetrain applications, owing to their cost-effectiveness and reliability. The EV drive profile requires high torque to accelerate at low speeds and low torque to cruise at high speeds. A fixed pole IM sacrifices performance at partial loads and high speeds to meet the high torque requirement at low speeds. A variable-pole IM utilizes the pole count of the machine as an additional degree of freedom. The torque-speed curve of the IM is dependent on the machine's equivalent circuit parameters and is dominated by the leakage parameters of the rotor. These circuit parameters are determined by the slot geometry, bar dimensions of the squirrel cage, and vary with the pole count of the machine. This paper develops an analytical method to determine equivalent circuit parameters from the machine geometry and explores the effect of varying pole counts.

Arjit Bali

B.S.:	May 2018, Rose-Hulman Institute of Technology, Terre Haute IN
M.S.:	December 2023, University of Illinois Urbana-Champaign
Status:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests	Electric Machines and Drives, Power Electronics, Control, Electric Vehicles

Active-Filter Inverter Architecture for Electric Aviation Applications

Arjit Bali with Advisers, Prof. Kiruba S. Haran and Andrew Stillwell*

Supported by POETS (Power Optimization of Electro-Thermal Systems)

Abstract

Electric aviation demands lightweight, high-efficiency electro-mechanical energy conversion systems, but the bulky passive components typically required for filtering often limit power density. Slotless Permanent Magnet Synchronous Machines (PMSMs), particularly when cryogenically cooled with liquid nitrogen, achieve high power density through reduced iron losses and improved thermal conductivity. This architecture's main challenge lies in the extremely low per-phase inductance, which increases susceptibility to current ripple and harmonic distortion. To address this, we propose an active filter motor drive architecture. A primary low-frequency two-level Voltage Source Inverter (VSI) using IGBTs delivers the fundamental current, benefiting from reduced conduction losses at cryogenic temperatures. A secondary Flying Capacitor Multilevel (FCML) inverter using high-speed GaN devices acts as an active filter, injecting high-frequency ripple currents to cancel harmonics introduced by the VSI. This functional decoupling enhances waveform quality, reduces passive filtering requirements, and supports modular integration. The system is validated in PLECS simulations, and a Field-Oriented Control (FOC) scheme is developed to suppress circulating currents between stages.

*This research was a collaboration with student Arjit Bali, above.

Anubhav Bose

B.S.:	May 2021, University of Mumbai, Mumbai India
M.S.:	May 2023, University of Illinois Urbana-Champaign
Status:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Transportation Electrification, Electric Machines & Drives, Energy Storage Systems

A Generalized Multilevel Inverter & Slotless Permanent Magnet Motor-Drive Co-Design Framework

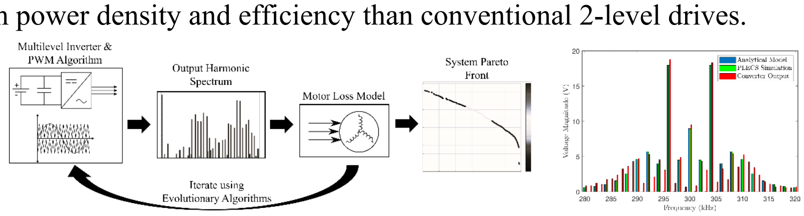
Anubhav Bose with Advisor Prof. Kiruba S. Haran*

Supported by the NSF Center for Power Optimization of Electro-Thermal Systems (POETS)

Abstract

Slotless machines have been shown to have exceptional power density and suitability for aerospace propulsion applications. However, their low synchronous inductance places specific considerations on the power electronic drive specifications and design. Motor drives with exceptionally high switching frequencies, or bulky AC line filters have been usually proposed as solutions to the very high level of AC current ripple caused due to the low motor inductance. Both solutions compromise heavily on overall system weight and losses and thus mitigate the advantages of the slotless motor topology in the first place.

Multi-level interleaved converters have been frequently proposed as an alternative in academic literature, but so far, they have not been specifically optimized for this application. This research proposes an analytical motor-drive codesign framework to maximize system-level power density and efficiency for this class of multi-level motor drives. Inverter output spectrum estimation is coupled with motor loss analysis to iteratively arrive at the optimal drive design. The proposed co-design and optimization framework shows that multi-level motor-drives can achieve significantly higher system power density and efficiency than conventional 2-level drives.



Left: Multilevel Motor-Drive Co-Design Flow; Right: Output Harmonic Results Compared between Simulation and Experiments

*This research was a collaboration with student Arjit Bali, above.

Soumil Chaubal

B.S.:	May 2021, Indian Institute of Technology, Bombay
M.S.:	May 2025, at University of Illinois Urbana-Champaign
Professional Interests:	Dynamic and Stability of Power Systems, Microgrid Modeling and Simulation, Real-time Simulation, Cyber Security of Microgrids

Continuously-Variable-Pole Induction Machine Drive for Electric Vehicles

With Advisor Prof. Arijit Banerjee

Supported Grainger CEME

ABSTRACT

This paper presents an operational methodology for continuous pole sharing in variable pole induction motors (VPIMs) to minimize machine and drive power loss. An optimization problem is formulated to determine torque sharing among poles, revealing that combining two-pole and six-pole components yields minimum losses and enhances magnetic material utilization for a typical machine, particularly at intermediate torque-speed operating points. A modulation method that incorporates common-mode voltage injection is introduced to maximize dc bus utilization. A proposed control architecture enables one pole to operate under vector control and the other under scalar control, thereby reducing parameter dependence for synchronization and reference generation. The proposed approach supports dynamic loss minimization using the dc bus current and by varying the scalar-controlled pole magnitude. Experimental results conducted on a toroidally wound 36-slot machine validate the effectiveness of the proposed approach.

Hong Ming-Chiu

B.S.: May 2020, National Yang Ming Chiao Tung University

Status: Working towards Ph.D. at University of Illinois Urbana-Champaign

Professional Interests: Machine Learning and Optimization

Well-conditioned Primal-Dual Interior-point Method for Accurate Low-rank Semidefinite Programming

with Advisor Prof. Richard Zhang

Supported by NSF Career and ONR Award

ABSTRACT

We describe how the low-rank structure in an SDP can be exploited to reduce the per-iteration cost of a convex primal-dual interior-point method down to $O(n^3)$ time and $O(n^2)$ memory, even at very high accuracies. A traditional difficulty is the dense Newton subproblem at each iteration, which becomes progressively ill-conditioned as progress is made towards the solution. Preconditioners have been proposed to improve conditioning, but these can be expensive to set up, and fundamentally become ineffective at high accuracies, as the preconditioner itself becomes increasingly ill-conditioned. Instead, we present a well-conditioned reformulation of the Newton subproblem that is cheap to set up, and whose condition number is guaranteed to remain bounded over all iterations of the interior-point method. In theory, applying an inner iterative method to the reformulation reduces the per-iteration cost of the outer interior-point method to $O(n^3)$ time and $O(n^2)$ memory. We also present a well-conditioned preconditioner that theoretically increases the outer per-iteration cost to $O(n^3r^3)$ time and $O(n^2r^2)$ memory, where r is an upper-bound on the solution rank, but in practice greatly improves the convergence of the inner iterations.

Aria Delmar

B.S.:	May 2021, Florida State University
M.S.:	August 2023, University of Illinois Urbana-Champaign
Status:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Power Electronics, Power Electronics Control, Renewable Energy

Control and Modeling of Current-Sourced, Hybrid Switched-Capacitor Converters with Dynamic Loads.

Aria Delmar with Advisor Asst. Prof. Andrew Stillwell*

Supported by the UIUC ECE Department and Grainger Foundation

ABSTRACT

Modern processor loads place stringent power delivery demands on power density, efficiency, and dynamic performance. Previous work presented a current sourced hybrid switched capacitor with all magnetics located at the input. This design is well-suited to a system-in-package (SiP) implementation, where high-quality input magnetics can be connected externally. This paper develops a control model for the current-sourced converter, with an emphasis on characterizing the converter's ability to respond to a dynamic load. The reduced order model shows converter operation maintains the benefits of a current type buck converter, but the switched-capacitor sizing has a significant impact on the control bandwidth. Sizing equations for the converter are derived and shown to match well with simulated results.

*This research was a collaboration with students Andrew Freeman and Nicole Stokowski, below.

Joshua Michael Feldman

B.S.:	May 2019, University of Illinois Urbana-Champaign
M.S.:	December 2021, University of Illinois Urbana-Champaign
Status	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Electric Aviation, Cryogenics, Superconductivity, Heat Transfer

Study of Flow-Boiling Liquid Nitrogen for Use in Cryogenic Motor Cooling

Joshua Feldman with Advisors Prof. Kiruba S. Haran

Supported by NASA

ABSTRACT

Cryogenic cooling of motors can increase specific power and power density by reducing the winding resistivity or enable superconducting windings. Proper thermal modelling of cryogenic motors requires experimentally verified correlations for predicting convective heat transfer coefficient (HTC) of the cryogenic fluid. For flow-boiling fluids, some correlations exist but can have widely varying predictions. Furthermore, no correlations exist for tubes which are partially heated or coiled. Here we present results from an experiment to measure the HTC of flow-boiling nitrogen in a straight, uniformly heated tube. The results will serve to improve the accuracy of flow-boiling correlations for liquid nitrogen. The results will also serve as a baseline for future experiments measuring the HTC of flow-boiling nitrogen in partially heated and coiled tubes. It is our hope that these results will improve thermal modelling accuracy of cryogenic motors.

Andrew Freeman

B.S.: May 2023, Purdue University

Status: Working towards Ph.D. at University of Illinois Urbana-Champaign

Professional Interests: Power Electronics, Electrification, Renewable Energy

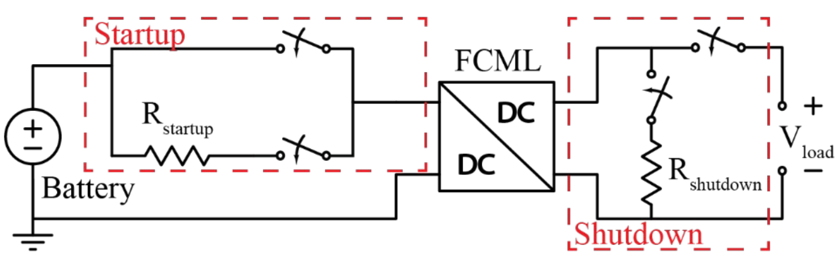
DC-DC Converter for Electric Aircraft Wing Deicing

Andrew Freeman with Advisor Prof. Andrew Stillwell and Prof. Nenad Miljkovic *

Supported ARPA-E Department of Energy

ABSTRACT

The buildup of ice on aircraft poses a significant challenge for the aviation sector. It directly contributes to fatal accidents, compromising air travel safety and necessitating costly, inefficient, and occasionally ineffective de-icing methods before and during flights. Adjacent to the development of an electro-thermal pulse dc-dc power converter for rapid and effective deicing, this work focuses on auxiliary startup and shutdown, which are necessary for rapid and repeatable deicing. These circuits ensure flying capacitor balancing and low switch stress by limiting capacitor slew rate during on/off transitions. Design considerations include minimizing throughput losses and ensuring safe transitions between operating converters. Verification of the mechanisms is performed via simulation compared to results of physical testing. Furthermore, state observation methods, including voltage and current sensing, are being implemented to ensure stable control of the converter in unstable supply or loading conditions.



*This research was a collaboration with students Aria Delmar, above and Nicole Stokowski, below.

Arda Güçlü

B.S.: May 2021, Bilkent University, Ankara, Turkey

Status: Working towards Ph.D. at University of Illinois Urbana-Champaign

Professional Interests: Electricity Markets, Control Theory

Tangential Randomization in Linear Bandits (TRAiL): Guaranteed Inference and Regret Bounds

Arda Güçlü with Advisor Prof. Subhonmesh Bose

Supported by National Science Foundation

ABSTRACT

Adaptive control tackles the question of control in an unknown environment. While a number of algorithms already exist in this space, our work deals with an under-explored algorithmic framework called forced exploration. We provide theoretical guarantees for the performance of our proposed algorithm called TRAiL (Tangential Randomization in Linear Bandits). The project sheds light into how inference about the environment interplays with control performance of an algorithm in adaptive control problems.

Iven Guzel

B.S.:	June 2019, Middle East Technical University, Ankara, Turkey
M.S.:	July 2022, Middle East Technical University, Ankara, Turkey
Status:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Optimization Methods Applied to Power Systems and the Smart Grid

Power System State Estimation by Phase Synchronization and Eigenvectors

Iven Guzel with Advisor Prof. Richard Y. Zhang

Supported by the National Science Foundation and C3.ai

ABSTRACT

To estimate accurate voltage phasors from inaccurate voltage magnitude and complex power measurements, the standard approach is to iteratively refine a good initial guess using the Gauss–Newton method. But the nonconvexity of the estimation makes the Gauss–Newton method sensitive to its initial guess, so human intervention is needed to detect convergence to plausible but ultimately spurious estimates. This paper makes a novel connection between the angle estimation subproblem and phase synchronization to yield two key benefits: (1) an exceptionally high quality initial guess over the angles, known as a *spectral initialization*; (2) a correctness guarantee for the estimated angles, known as a *global optimality certificate*. These are formulated as sparse eigenvalue-eigenvector problems, which we efficiently compute in time comparable to a few Gauss—Newton iterations. Our experiments on the complete set of Polish, PEGASE, and RTE models show, where voltage magnitudes are already reasonably accurate, that spectral initialization provides an almost-perfect single-shot estimation of n angles from $2n$ moderately noisy bus power measurements (i.e. n pairs of PQ measurements), whose correctness becomes guaranteed after a single Gauss–Newton iteration. For less accurate voltage magnitudes, the performance of the method degrades gracefully; even with moderate voltage magnitude errors, the estimated voltage angles remain surprisingly accurate.

Boya Hou

B.S.: March 2019, Zhejiang University

M.S.: December 2019, University of Illinois Urbana-Champaign

Ph.D.: December 2025, University of Illinois Urbana-Champaign

Professional Interests: Machine Learning, Optimization, and Control Theory

Nonparametric Sparse Learning of Dynamical Systems.

Boya Hou with Advisor Assoc. Prof. Subhonmesh Bose

Supported by ITI and NSF

ABSTRACT

Building an accurate, expressive representation of the underlying dynamics of model-based learning is a critical challenge, especially for high-dimensional continuous-state tasks. I focus on Markovian dynamical systems and propose to embed the transition kernel into Reproducing Kernel Hilbert Spaces (RKHS). Inspired by embeddings of conditional probability distributions into RKHS, known as conditional mean embeddings (CMEs), I represented the transition dynamics of discrete-time Markov processes through CME operators and designed a data-driven algorithm to learn the system dynamics. When interacting with RKHS, descriptions of dynamics often incur prohibitive data storage requirements. I explore techniques to reduce redundancy in datasets, which yield simpler system representations with lower data storage requirements. I present a method to learn *compressed* representations of nonlinear dynamics from both i.i.d samples and correlated processes with sample complexity guarantees, with reinforced learning of continuous state and action space, power system transient stability analysis, and uncertainty propagation through unknown nonlinear system dynamics.

In many applications, it is desirable to study *continuous-time* system models. In this vein, I adopt a similar framework to study the infinitesimal generators of diffusion processes, where the infinitesimal generators encapsulate the transition dynamics. I embed the generators into RKHS and establish theoretical properties of such embedded generators, including their domain and the continuity of their associated operator family. I also develop a representation of embedded generators in terms of covariance-type operators to allow for application of the discrete-time sample complexity analysis methodology to continuous-time settings. Building upon this representation, I propose an entirely data-driven algorithm with sample complexity guarantees for learning embeddings of generators. To address these challenges, I present the first work on compressed decentralized operator learning with detailed theoretical analysis.

Victoria E. Jeziorczak

B.S.: May 2023, Northern Illinois University

M.S.: May 2025, University of Illinois at Urbana-Champaign

Professional Interests: Power and Controls, Power Electronics, Mechanical Engineering

Interfacing Solar Panels to the ECEB Grid: An Inverter and Filter Overview

Victora E. Jeziorczak with Advisor Prof. Arijit Banerjee

Supported Teaching Assistanceship

ABSTRACT

Grid-tied inverters inject harmonics into the grid when using high-frequency PWM, reducing the grid's energy quality. Therefore, a filter is required between the power inverter and the utility grid to ensure quality energy that abides by IEEE standards for grid integration. A 4kW, 400V grid-tied inverter and LCL filter design is proposed to interface an array of solar panels to the utility grid. The solar panel array mentioned is located on the roof of the University of Illinois Urbana-Champaign's Department of Electrical and Computer Engineering building. A theoretical overview of the two-level, three-phase power inverter and its filter, along with their corresponding designs, is discussed.

Furkan Karakaya

B.S.:	2017, ECE – Middle East Technical University, Ankara, Turkey
M.S.:	2021, ECE – Middle East Technical University, Ankara, Turkey
Ph.D.:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Power Electronics and Renewable Energy

Condition-monitoring tool development for SiC MOSFETs

Furkan Karakaya with Advisor Assoc. Prof. Arijit Banerjee

Supported by the Office of Naval Research MVDC Risk Reduction Program

ABSTRACT

Silicon Carbide (SiC) MOSFETs are being widely adopted in the industry as a viable substitute for conventional power transistors, due to their superior figure-of-merit and compact, efficient power conversion. However, the relatively novel manufacturing technology of these devices raises further questions regarding long-term reliability, as SiC devices have been known to suffer from degradation over time, manifesting in an increased on-state impedance or a spike in gate leakage current. In order to identify the remaining useful lifetime of a SiC MOSFET, measuring the on-state impedance periodically is essential, though the operating voltage and current levels in kilovolts and kiloamperes presents a challenge, due to the impedance values typically falling in the range of several dozen milliohms.

Our recent design successfully addresses this challenge and enables reliable on-state impedance characterization, even during an active converter operation, with an estimated error of less than 5%. The key idea behind the proposed design involves injecting a sinusoidal current in the MHz range, with the resultant voltage being filtered out by custom-engineered analog circuitry. Then, necessary calculations are performed by the circuit, enabling on-state resistance and package inductance to be accurately estimated in the milliohm and nanohenry ranges, respectively.

Muhammad Talal Khalid

B.S.:	N.E.D. University of Engineering and Technology, Pakistan
M.S.:	University of Technology Sydney, Australia
Status:	Working towards M.S. at University of Illinois Urbana-Champaign
Professional Interests:	Electric Vehicle Charging Infrastructure, Electricity Rates, Electric Transportation Planning and Policy

A Contextual Engineering approach to electric utility decision-making.

Talal Khalid with Advisor Prof. Kiruba S. Haran

Supported by ECE Indirect Cost Recovery

ABSTRACT

The transition to electric transportation relies heavily on the sustainable deployment of associated charging infrastructure. Utility transportation electrification programs and policy design typically follow a deductive approach, however, this check-list method of program design often neglects contextual needs and community predispositions that are crucial in determining their local appropriateness. Understanding the community-specific interactions between stakeholders is critical to analyze their decisions, choices, and reactions to utility programs and policies related to technological advancements. To integrate community context into utility decision-making, a Contextual Engineering (CE) framework was developed for contextual decision-making that recognizes stakeholder motivations, local knowledge, decision-maker biases, partiality of perspectives, unique societal conditions, and community power dynamics. This study contends that using community-particular criteria in conjunction with mathematical and scientific decision-making models will significantly improve the effectiveness and community acceptance of utility transportation electrification programs and policies. We then implemented the process in Paducah, KY. Contextual data, informed by the contextual appropriacy guidelines, were collected by examining the existing literature and conducting stakeholder interviews and on-ground ethnographic observations in Paducah. An in-depth thematic analysis on these data was performed to identify the contextual evaluation criteria against which the different policy options to advance EVFCFs will be evaluated by the community members. Insights from this analysis were then integrated into a "Fuzzy Analytical Hierarchy Process" to rank various policy options.

Anuj Maheshwari

B.S.:	May 2019, Indian Institute of Technology (IIT), Kharagpur, India
M.S.:	December 2022, University of Illinois Urbana-Champaign
Status:	Working towards Ph.D. at University of Illinois Urbana-Champaign
Professional Interests:	Design and Control of Power Electronics, DC-DC Converters

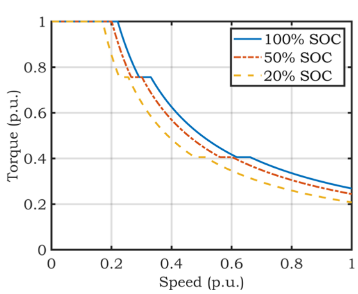
Dual-Use of Onboard Chargers to Achieve Controllable DC Bus Voltage for Electric Vehicles

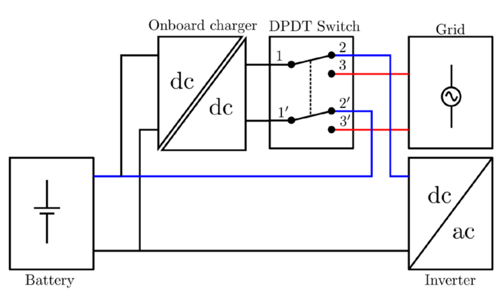
Anuj Maeshwari with Advisor Prof. Arijit Banerjee

Supported by Grainger CEME

ABSTRACT

Traction applications require a highly efficient and power-dense drive-train while delivering a rated torque-speed envelope. When a battery is directly connected to the traction inverter dc link, the torque-speed envelope shrinks as the battery discharges, as shown in Fig. 1. Consequently, a dc-dc converter is needed to meet the torque-speed requirement. We are working on an alternate architecture using an onboard charger to boost the dc-link voltage, as shown in Fig. 2. The onboard charger is reconfigured into a partial power processing converter to control the dc-link voltage using a double pole double throw (DPDT) switch. The proposed architecture not only removes the need for a separate dc-dc converter, increasing the power density of the drive train, but also enhances the efficiency as the converter only processes part of the power consumed in the motor. The project has been funded starting June 2024 by the Advanced Research Project Agency – Energy (APRA-E) through the prestigious APRA-E Open competition in 2018.





Grant McKechnie

B.S.: December 2024, University of Illinois Urbana-Champaign

Status: Working towards Ph.D. at University of Illinois Urbana-Champaign

Professional Interests: Power electronics and power systems

Hardware in the Loop Testing of Three Phase and Single Phase GFM Inverter-based Systems

Grant McKechnie with Advisor Prof. Alejandro Domínguez-García

Supported by Department of Energy

ABSTRACT

Single-phase grid-forming (GFM) inverters play an important role in residential renewable energy systems, but modeling their dynamics remains difficult due to fundamental differences from three-phase counterparts. Traditional control methods, effective in balanced three-phase systems, cannot be directly applied due to the asymmetry of the system. We present a high-order modeling framework for single-phase GFM inverters, designed for integration into the BANSHEE radial test feeder. The proposed model employs a Second Order Generalized Integrator (SOGI) to convert single-phase voltage and current measurements into the DQ reference frame, which decouples active and reactive power control similar to three-phase strategies. Additionally, we investigated synchronization dynamics for single-phase GFM inverters connected to stiff grids and power reference tracking. Simulation results validate the model's ability to replicate power reference tracking, stability under load changes, and grid synchronization.The project has been funded starting June 2024 by the Advanced Project Research Agency – Energy (APRA-E) through the prestigious APRA-E Open competition in 2018.

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Design, Analysis, and Controller Hardware-in-the Loop (C-HIL) Testing of Hybrid Control Systems for Networked Microgrids

T.G. Roberts with Advisor Prof. Alejandro Domínguez-García

Supported by Department of Energy

ABSTRACT

The goal of this research is to develop a suite of controls for a radial three-feeder microgrid, and test them in a real-time controller hardware-in-the loop (C-HIL) setting. This microgrid comprises synchronous generators on feeders 1 and 3 as well as a grid forming (GFM) inverter and grid following (GFL) inverter on feeder 2. The structure of the microgrid and our developed controls allow the microgrid to run in grid connected mode, as well as in fully islanded mode, networked mode, partially islanded mode, and backfed mode. The controls developed include secondary frequency and voltage control, tie-line power control, re-synchronization control, as well as discrete controls that facilitate mode changes. We have mathematically presented the controllers for each mode, and discussed how they interact to modify the reference setpoints for each resource. This work combines detailed models of the generating resources and microgrid elements with real time hardware. Previous work has focused on individual elements of this work, such as microgrid islanding/reconnection in the C-HIL space, or networking microgrid control formulation, however to our knowledge no work has combined elements as we have here. The result is a comprehensive look at a heterogeneous-generation microgrid that is able to change topologies on command, and recover from unintentional disturbances.

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Partial Discharge Investigation of Electric Machine Winding due to Thermo-Mechanical Stresses for Electric Aircraft Propulsion

Anjana J. Samarakoon with Advisor Kiruba S. Haran

Supported by NSF and POETS

ABSTRACT

The power density requirements and mission profile of electric aircraft propulsion motors result in significant stress on the motor winding's insulation. Traditional motor winding insulation design methods do not account for the thermomechanical stresses placed on motor windings in electric aircraft propulsion motor applications. This paper presents the results of initial experiments that aim to develop models and methodologies for designing high-reliability aircraft propulsion motors accounting for mechanical stress on the insulation. Twenty motorrette samples were manufactured and aged with thermal cycles. Partial discharge inception voltage (PDIV) was recorded as the samples were aged. Data is reported for PDIV as a function of thermal profile and the number of cycles experienced by the insulation. The experiments use both representative motorrettes and representative thermal environments for an urban air mobility electric motor application. Experimental results are discussed by relating hot spot temperature, PDIV degradation and cycle count. The results of these experiments will serve as an initial data set to aid in developing motor winding aging models relevant to aircraft applications and, eventually, a combined motor and insulation system design methodology for high-reliability aircraft propulsion motors.

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Towards Miniaturization of MRI Devices: Roadmap, Challenges, and Progress

Yaokun Shi with Advisor Prof. Kiruba S. Haran

Supported by Grainger CEME

ABSTRACT

Portable, low-field MRI technology has developed in recent years due to increased flexibility and reduced cost compared to traditional MRI, further leading to the adoption of point-of-care MRI devices for head and prostate imaging. A semi-open imaging volume is sometimes preferred by patients, reducing the form factor of an MRI device and improving patient comfort. Recent work has demonstrated the possibility of removing gradient coils and using an inhomogeneous base magnetic field to encode spatial information. This work proposes a more extreme encoding strategy involving rotating permanent magnet arrays, utilizing inhomogeneity in the base magnetic field to our advantage while providing a semi-open, single-sided geometry for various use cases.

The magnet arrays, combined with excitation at different center frequencies, produce volumetric signal generation that can be back-projected to form the final image. The field maps are acquired through FEA analysis, and a prototype with an in-house RF coil is constructed and tested. Simulated and empirical data acquisition and image reconstruction proved the feasibility of this approach, and optimizations on signal acquisition and image quality are under investigation. Nevertheless, the imaging capability of this novel portable MRI prototype opens up new possibilities for miniature MRI devices to be used for rapid scans in point-of-care scenarios.

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Secure Distributed Control Algorithms for Microgrids

Eric Silk with Advisor Prof. Alejandro Domínguez-García

Supported by Department of Energy's CyDERMS project

ABSTRACT

As distributed energy resources (DERs) continue to see increased utilization in the modern grid, the use of distributed controls becomes increasingly necessary for their operation. We use a promising family of algorithms known as consensus algorithms that rely heavily on Ratio Consensus (RC) and Min-Max Consensus (MMC).

The goal of this project is to develop a software framework for the control of microgrids using these consensus algorithms, while maintaining their security and reliability in spite of errors and malicious activities. My contributions thus far have been the application of modern software design principles to produce a generic, platform-agnostic implementation in C++ as well as a Python based implementation for rapid prototyping and research uses. Current targets are principally Raspberry Pi single board computers (SBC's) with the intent to communicate to hardware-in-the-loop (HIL) power systems simulators and real-world systems. To achieve the stated goals, we have successfully developed, implemented, and tested an algorithm for online error-checking that requires intermittent information from a small subset of devices in the network.

Future work will include investigating the effect of communication graph structure on error detection, convergence properties, extensions and generalization of the error checking scheme, and security studies involving red- and blue-teaming exercises.

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Risk-Sensitive Energy Procurement under Uncertain Wind

Michael J. Stoens with Advisor Prof. Kiruba S. Haran

Supported by the Grainger CEME

ABSTRACT

With the rapid adoption of electrification, power density, reliability, and fault tolerance of electric drive systems are becoming increasingly important. The U.S. Department of Energy has established future targets for power density in power electronics, electric motors, and electric tractive drive systems. To meet these targets, research is focusing on higher power, lighter weight systems.

One promising approach to improving motor power density is the use of slotless permanent magnet synchronous machines (PMSMs). This architecture reduces the iron content in the machine by eliminating stator teeth. However, removing the stator teeth significantly lowers the per-phase inductance. Traditional voltage source inverters (VSIs) rely on motor inductance to filter output current, making them less suitable for low-inductance machines.

A potential alternative is the Current Source Inverter (CSI). CSIs utilize a DC link inductor to maintain constant input current, which is then sinusoidally commutated to the load. This eliminates the inverter's dependence on motor inductance for current filtering, making CSIs a strong candidate for driving slotless PMSMs. This work investigates the implementation of a CSI using modern semiconductor devices and advanced control techniques for driving slotless PMSMs. The goal is to evaluate its feasibility, performance, and potential advantages over conventional drive systems in high-power-density applications."

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An 8-level Flying Capacitor Multilevel Converter for Electric Aircraft Pulse Deicing

Nicole Stokowski with Advisor Asst. Prof. Andrew Stillwell*

Supported by ARPA-E

ABSTRACT

Commercial and small personal aircraft use a variety of methods to remove and/or prevent ice buildup on plane wings. Recent research into "pulsed-defrosting" techniques on small passenger aircraft has gained traction, which calls for controlled power systems that can provide the necessary energy to remove accumulated ice. This work looks at the design of a 3 kW, 8-level flying capacitor multilevel (FCML) converter, with over 99% efficiency, that can be used as a controlled energy buffer between the aircraft battery and the deicing mechanism. The prototype developed in this work lends itself to an extremely lightweight design (15 kW/kg), with no heat-sink due to good thermal performance. Additional work is done to prove the reliability of the prototype through environmental testing.

*This research was a collaboration with students Aria Delmar and Andrew Freeman, above.

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Modeling and dynamic control of a novel converter for data-center power delivery

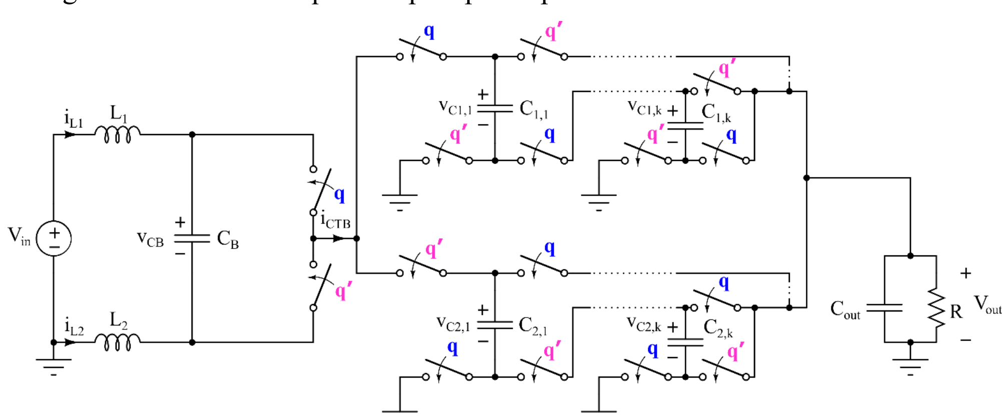
William H. Vavrik with Advisor Prof. Andrew Stillwell

Supported by UIUC ECE Department and Grainger Fund

ABSTRACT

Modern processor loads place stringent power delivery demands on power density, efficiency, and dynamic performance. In previous work, a current-sourced hybrid switched-capacitor converter design was presented so all converter magnetics are at the input. However, to be able to regulate these loads, and respond to dynamic situations, a mathematical model of the converter needs to be developed to properly design the controller to close the loop on this design.

This work has derived the model and simulated results that have been published at the IEEE conference: Control and Modeling of Power Electronics (COMPEL) 2024 in Lahore, Pakistan in June of last year. The closed loop dynamics of this converter are under investigation and hardware results are pending. A PID controller with near-optimal performance has been proposed and high-speed sensing is being used to accomplish fast dynamic performance. Simulated results are shown in Figure 2 which shows quick step response performance.



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Stackelberg Game Between Firm and Policymaker

Yijin Wang with Advisor Prof. Subhonmesh Bose

Supported by Grainger Foundation and National Science Foundation

ABSTRACT

Adoption of products which have environmental impacts, such as electric vehicles (EVs) and solar panels, are often spurred by government rebates. We seek to analyze a Stackelberg game between a firm selling a product and a policymaker who seeks to encourage adoption of the product through rebates. In such a game, the leader, which is the policymaker, decides on their rebate policy first, followed by the determination of the pricing strategy of the follower, which is the firm. Such analysis may be helpful in the decisions of solar/EV companies and policymakers as the urgency of adopting carbon-free technologies rises.

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A Comparison of the Electrical Endurance of Plasma Sprayed Aluminum Oxide to Existing Insulation Materials.

Brian Wolhaupter with Advisor Prof. Kiruba S. Haran

Supported by Grainger CEME

ABSTRACT

Increasing demand for high power density electric machines has exposed the limitations of conventional polymer insulation. The low thermal conductivity and low resistance to high temperatures combine to accelerate the degradation of the insulation. Ceramics have the potential to replace polymer insulation in certain applications, and they have slowly been incorporated into the potting materials and even strand insulation. However, the slot liners have not seen as much advancement due to the challenges associated with producing the thin ceramic structures and then bonding them into stator cores. This presentation introduces the possibility of using plasma sprayed ceramic coatings to overcome these challenges and presents the results of a study on the long-term electrical behavior of plasma sprayed ceramic coatings when compared to conventional polymer slot liner materials.

7. LABORATORY FACILITIES

The Power Area has assembled some of the nation's finest facilities for experimental and computer-based research and teaching. Both undergraduate and graduate students can take advantage of these facilities.

The **Grainger Power Engineering Software Laboratory** Located in rooms 4038 (workstations 1 – 5) & 4068 (workstations 1 – 5) Electrical and Computer Engineering Building. The Software Laboratory has nine advanced personal computers. All stations are connected to the campus network and Internet.

A major objective of the laboratory is to develop an extensive library of commercial software and large-scale databases for power area applications. Some of the commercial software packages currently in use include:

- **Mathematica / Wolfram** (advanced symbolic mathematics, fully integrated technical computing) Mathcad / PTC (Industry standard for engineering calculations)
- **MATLAB / MathWorks** (MATrix LAB, technical computing)
- **Simulink** (Matlab package, graphical simulation, model-based design, dynamic and embedded)
- **SimElectronics** (Simulink Toolbox, Model and simulate electronic and electromechanical systems)
- **SimPowerSystems** (Simulink Toolbox, Modeling and simulating electric power systems)
- **xPC Target** (Simulink, Rapid control prototyping and hardware-in-the-loop)
- **PLECS** (Simulink, fast simulation of electrical and power electronic circuits)
- **acslX(treme) / Aegis** (general-purpose simulation environment)
- **LabVIEW** (Visual programming language, lab bench dynamometer control program)
- **PSS/E / Siemens PTI** (Power System Simulator for Engineering, electrical transmission)
- **RISKSYM / Henwood** (package for energy market analysis)
- **PowerWorld** (Power systems analysis, power market analysis, locational marginal price analysis)
- **Power System Tool Box** (PST Version 2.0)
- **ANSYS / Ansoft** (FEA finite element analysis modeling)
- **Maxwell** (ANSYS, EM Field Simulation for High-Performance Electromechanical Design)
- **RMxprt** (ANSYS, Design Software for Electric Machines)
- **Simplorer** (ANSYS, simulation of electrical, electromechanical, electromagnetic, power, thermal)
- **Flux / Magsoft** (Electromagnetic and Thermal Physics Simulation)
- **Eagle / CadSoft** (Schematic capture and PCB design)

- **SAM / NREL** (System Advisor Model, PV Photovoltaic system cost estimation)
- **Altera Quartus & DSP Builder** (FPGA software & Digital Signal Processing tool)
- **SPEED / STAR-CCM+ / CD-adapco / Siemens** (design and analysis of electric machines)

The **Grainger Electrical Machinery Laboratory** is located in 4024 ECEB. This facility is primarily for undergraduate teaching and is used for ECE 431 (Electric Machinery), ECE 469 (Power Electronics), many ECE 445 (Senior Design) groups, and student groups and projects, including Engineering Open House (EOH), Future Energy Challenge (FEC), Solar Decathlon (Solar House), Wide Impact Developmental Engineering (WIDE), Society of Women Engineers (SWE), Formula Electric Car, and Fuel Cell Electric Car. With many power and energy teaching labs cutting back on hardware and machines, or going totally software and virtual because of fiscal restraints, the Grainger lab has been able to maintain and increase our large inventory of test machines and equipment. Ten self-contained machinery workstations are available. Each has an integral horsepower machine set with a servo-based dynamometer. The lab benches are equipped with digital watt meters, oscilloscopes, signal generators, power supplies, and speed / torque displays. The equipment is suitable for the study of induction, synchronous, and DC machines. Small portable machine sets are used to introduce stepper motors and brushless DC machines. Transformers, resistor boxes, capacitor boxes, SCR, and power FET units are provided to support a full range of experiments in all aspects of power and power electronics. The facility has a dedicated three-phase supply 120/208 Vac (225 kVA) and 240 Vdc (+/- 120 Vdc) 80 A supply.

The **Advanced Power Applications Labs** is located in 4020 and 4026 ECEB. These research labs have motor test benches with precision dynamometers. The benches can access 208 Vac 3-phase, 480 Vac 3-phase, and 240 Vdc. These labs serve as a research facility for all hardware aspects of power electronics, machines, and power systems. Additional equipment is available for the study of harmonic effects, high-performance switching converters, and digitally controlled converters/drives. Computers are available throughout the laboratory for automation of experiments using LabVIEW and Matlab/ Simulink/Real-Time Toolbox. This fourth-floor lab has direct access to the roof to allow for solar panel and weather station placement.

The **Power and Energy Computer Research Lab** Located in 4076 ECEB. This laboratory provides the user with a controller hardware-in-the-loop (C-HIL) testbed. The C-HIL testbed is used to achieve: (1) high-fidelity modeling and real-time simulation of an electric power grid, (2) the synthesis of coordination and control algorithms on several controller hardware platforms, and (3) the testing and validation of the resulting coordination and control technologies. The electric power grid is modeled using the Typhoon HIL Platform, and the Arduino Due, Raspberry Pi, and National Instruments cRIO controller hardware platforms are employed in the testbed. The hardware used in this testbed includes:

A set of Arduino Due microcontrollers, each coupled with a W5100 Ethernet shield and XBee module

- Eight Typhoon HIL 402 unit
- Four Typhoon HIL 603 units
- A National Instruments cRIO 9068 with NI PS-15 power supply
- Two 24 Port Gigabit Switches

This comes with a set of software packages installed on two advanced personal computers as listed below:

- Arduino IDE Software
- LabVIEW
- Typhoon HIL testing software
- MATLAB

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10. SELECTED PUBLICATIONS

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