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TWENTY-NINTH ANNUAL REPORT
OF THE
POWER AFFILIATES PROGRAM

University of Illinois at Urbana-Champaign
Department of Electrical and Computer Engineering
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PAP-TR 08-1

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FOREWORD

This report provides a summary of the activities of the Power Affiliates Program (PAP) in the Department of Electrical and Computer engineering at the University of Illinois at Urbana-Champaign for the calendar year 2007. The information is intended to be a progress report to the affiliate companies listed below. The PAP is the foundation of the industrial liaison effort in the power and energy systems area. The active affiliates associated with the PAP are:

Advanced Analogic Technologies, Inc.
Ameren
Bitrode Corporation
BP America
Citadel Investment Group
City Water, Light & Power, Springfield, IL
Electrical Manufacturing & Coil Winding Association, Inc.
Exelon
MidAmerican Energy Company
Patrick Engineering
PowerWorld Corporation
S&C Electric Company
Sargent & Lundy Engineers

2007 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.

Pete Sauer, Director
Patrick Chapman
Kevin Colravy
Alejandro Domínguez-García
George Gross
Phil Krein
Tom Overbye
M. A. Pai

1. INTRODUCTION AND SUMMARY

The Power Affiliates Program (PAP) 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 much valid today as they were in 1979. The multi-faceted activities in 2007 under the PAP umbrella clearly were in support of these objectives.

Throughout the past twenty-nine years, the Power Affiliates Program has maintained a stable financial base during times of rapid change in the power industry. This base provided the seed money for research, which led to additional funding by other sources. This base has also made it possible for students to be exposed to industrial problems and to participate in technical and professional meetings. With the cyclical nature of funding by government agencies, the Power Affiliates Program is a critically important source of support.

This annual report is organized as follows. The financial statement for the 2007 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 in this area through a set of courses developed and offered by the group of faculty 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 2007 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 directory in Section 8 and the list of 2007 publications is given in Section 9.

2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 2007 was prepared from a detailed University statement as of December 31, 2007.

Income carried over from the calendar year 2006	$ 5,393
Total income during calendar year 2007 *	61,500
Total available income during calendar year 2007	$66,893

Expenditure	**Expenditure Amount**
Personnel and Services	$40,581
Materials/Supplies/Equipment	6,522
Transportation/Travel	3,026
Total expenditures	$50,129

Summary

Amount of funds available during calendar year 2007	$66,893
Amount of expenses during calendar year 2007	50,129
Balance as of December 31, 2007	$16,764

* This does not include funds that were received in 2007, but not posted on the university accounting system until 2008.

3. THE POWER PROGRAM WITHIN THE DEPARTMENT

Electrical engineering undergraduate students are required to complete 128 hours of course work for a B.S.E.E. degree. Detailed descriptions of the undergraduate program and suggested curriculum in Power are given in [1]. All M.S.E.E. students are required to complete a minimum of 32 credit hours (old system was 8 units) including a graduate thesis. All Ph.D. students must qualify through a written examination and complete course and thesis requirements. A detailed description of the graduate program is given in [2].

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

Bioengineering, Acoustics and Magnetic Res. Engineering
Circuits and Signal Processing
Communications and Control
Computer Engineering
Electromagnetics, Optics and Remote Sensing
Microelectronics and Quantum Electronics
Power and Energy Systems

While the Department does not have official degree-granting options in each of these areas, in practice, the seven areas serve as the appropriate grouping of the faculty activities and interest. In terms of size, the Power and Energy Systems area represents about 7% of the total active faculty and about 10% of the total student enrollment. The faculty committee in each area has the responsibility for administering courses and research in that area within the Department.

The Power and Energy Systems Area Committee and associated faculty for the 2007 - 2008 academic year together with their fields of interest are:

P. Chapman	(machines, power electronics, circuits)
A. Domínguez-García	(reliability theory and analysis)
G. Gross	(power system economics, planning and operations; reliability; electric regulatory policy; industry restructuring; market design)
P. T. Krein	(power electronics, machines, electrostatics)
T. J. Overbye	(operations, visualization and restructuring of power systems)
M. A. Pai	(dynamics, stability and computational methods in power systems
P. W. Sauer	(modeling and simulation of machines and power systems)

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 2007-2008 those courses were

ECE 307	Techniques for Engineering Decisions
ECE 398RES	Renewable Energy Systems
ECE 430	Power Circuits and Electromechanics
ECE 431	Electric Machinery
ECE 432	Advanced Electric Machinery
ECE 464	Power Electronics
ECE 469	Power Electronics Laboratory
ECE 476	Power System Analysis
ECE 477	Power System Operation & Control
ENG 491FEC	Future Energy Challenge
ECE 530	Analysis Techniques for Large-Scale Electrical Systems
ECE 568	Modeling and Control of Electromechanical Systems
ECE 573	Power Systems Control
ECE 576	Power System Dynamics and Stability
ECE 588	Electricity Resource Planning
ECE 590I	Seminar in Special Topics: Power Systems
ECE 598PE	Power Electronic Drives and Systems
ECE 598PH	Hybrid Systems Analysis of Power System Dynamics
ECE 598TO	Issues in Competitive Electricity Markets
ECE 598PLC	Advanced Topics in Power Electronics

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. The current courses assigned to the power area are described briefly below. The total enrollment for courses offered in the academic year 2007-2008 is also given for each course.

ECE 307 Techniques for Engineering Decisions

This course is concerned with modeling of decisions and analysis of models to develop a systematic approach to making decisions. The focus is on the development of techniques for solving typical problems faced in making engineering decisions in industry and government. Topics include resource allocation, logistics, scheduling, sequential decision-making and explicit consideration of uncertainty in decisions. Extensive use of case studies gets students involved in real world decisions. The course has two required texts: Operations Research: Principles and Practice, A. Ravindran, D. T. Phillips and S. S. Solberg and Making Hard Decisions: An Introduction to Decision Analysis, R. T. Clemen. The total enrollment for the academic year 2007-2008 was 15.

ECE 398RES Renewable Energy Systems

A new course on the challenges of meeting the future energy needs using renewable resources taught by Prof. P. Chapman and Prof. G. Gross. A three-hour technical elective for engineering undergraduate students with a background in electric circuits at an introductory level. 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 world-wide demand for oil-based resources, the restructuring of the electricity industry, the 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 total enrollment for the academic year 2007-2008 was 39.

ECE 430 Power Circuits and Electromechanics

ECE 430 is a course in power circuits and electromechanics. It is a new course after the restructuring of the undergraduate curriculum. 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 was Power Circuits and Electromechanics by M.A. Pai. The total enrollment for the academic year 2007-2008 was 190.

ECE 431 Electric Machinery

This four-hour course contains a laboratory one credit hour component, which is an elective in a list of 14 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. The required text was Electric Machinery, by Fitzgerald, Kingsley, and Umans. The total enrollment for the academic year 2007-2008 was 31.

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 the time scale modeling of electromechanical devices and on their function in drives. The required text was Analysis of Electric Machinery, by P.C. Krause and O. Wasynczuk, IEEE Press. The total enrollment for the academic year 2007-2008 was 9.

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 was Elements of Power Electronics by P. T. Krein. The total enrollment for the academic year 2007-2008 was 31.

ECE 469 Power Electronics Laboratory

This two-hour course 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 components. The course is designed to accompany ECE 364. A lab manual by P. Krein is used for the course. The total enrollment for the academic year 2007-2008 was 19.

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 was <u>Power System Analysis & Design</u>, by Glover and Sarma. The total enrollment for the academic year 2007-2008 was 32.

ECE 477 Power System Operation & Control

This three-hour course is the second of two courses on power system analysis. Topics included are economic operation of power systems, optimal load flow concepts, automatic generation control, state estimation, classical transient stability, modeling for dynamic and transient stability, and d-c transmission. The recommended text is <u>Power Generation, Operation and Control</u>, 2nd edition, by Wood and Wollenberg. This class was not offered in the 2007-2008 academic year.

ENG 491FEC Future Energy Challenge

This three-hour course is a special topics course focusing on the Future Energy Challenge (FEC) student team competition. This competition is an international event sponsored by IEEE, the U.S. Department of Energy, the U.S. Department of Defense, and other sponsors. Schools compete in two topic areas: a fuel-cell power processing topic and a motor system topic. Illinois is one of just 7 schools selected, based on our proposal, to be part of the motor topic competition. The final events are in May after graduation. This class was not offered in the 2007-2008 academic year.

Graduate Courses:

ECE 530 Analysis Techniques for Large-Scale Electrical Systems

This is a newly developed graduate course in the modeling of power systems in the steady state and dynamic regimes. It includes the analysis and simulation techniques for power and power electronic 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 electronic systems, numerical integration of differential equations and Krylov subspace applications. The course uses the notes of George Gross in lieu of a text. The total enrollment for the academic year 2007-2008 was 11.

ECE 568 Advanced Modeling and Control of Electromechanical Systems

This 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 electronic 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 required texts were Control of Electrical Drives, 2nd edition by W. Leonard and Analysis of Electric Machines, 2nd edition by P. Krause, O. Wasynczuk and S. Sudhoff. This class was not offered in the 2007-2008 academic year.

ECE 573 Power Systems Control

The course provides an overview of power system operations and control with major emphasis on security and economics. The role of the EMS (energy management system) and the principal EMS functions are discussed in depth. The 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. The total enrollment for the academic year 2007-2008 was 13.

ECE 576 Power Systems Dynamics and Stability

The course includes the dynamic representation of interconnected power systems - electrical plus mechanical, linearized dynamic models of multimachine 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 was Power Systems Dynamics and Stability by P. W. Sauer and M. A. Pai. This class was not offered in the 2007-2008 academic year.

ECE 588 Electricity Resource Planning

This course provides coverage of the basic techniques in electricity resource planning including methodologies for reliability evaluation and assessment, production costing, marginal costing, supply-side and demand-side planning and integrated resource planning. Throughout the course, probabilistic approaches are emphasized. In place of a text, notes specifically prepared by George Gross are used. This class was not offered in the 2007-2008 academic year.

ECE 590I Seminar in Special Topics: 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 36 students participated in this course for both semesters.

ECE 598PE Power Electronic Devices and Systems

This advanced course in power electronics considers the unique devices and models used for switching energy conversion systems. Emerging nonlinear approaches to operation and control are discussed. Design issues for fast dynamic converters are presented. The goal of the course is to provide students with a rich background in the broad issues of high-performance power electronics at the graduate level. Specific topics include magnetic device design, power semiconductor device models, interfaces and gate drives, small-signal and large-signal converter control models. Averaging methods are presented for power converters. Concepts and methods of geometric control are addressed. The required text is Elements of Power Electronics by P.T. Krein. This class was not offered in the 2007-2008 academic year.

ECE 598PH Hybrid Systems Analysis of Power System Dynamics

The purpose of the course is to present a new approach to the analysis of large scale complex networks, such as power systems, by viewing them as interconnections of dynamic devices, discrete devices and algebraic constraints. Such hybrid systems can display very interesting forms of behavior. Trajectory sensitivity analysis used as a tool for security monitoring, stability analysis and model verification. Aspects of hybrid system control are presented. This class was not offered in the 2007-2008 academic year.

ECE 598TO Issues in Competitive Electricity Markets

This course provides an introduction to competitive electricity markets. The course covers topics including market structures and paradigms, transmission services, transmission congestion management, allocation of real power losses, optimal bidding strategies, and market power analysis. This class was not offered in the 2007-2008 academic year.

ECE 598PLC Advanced Topics in Power Electronics

This course extends the topics of the undergraduate power electronics course. The goal is provide the students with a theoretical basis for advanced research in power electronics. Device and converter modeling are studied in detail. Analog and digital pulse width modulation methods are explored. Averaging and nonlinear control theory relevant to power electronics is studied. The course includes a large-team design project that requires the students to draw from current literature. The total enrollment for the academic year 2007-2008 was 13.

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

Annual Average 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

1980-1995

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

2005-2006

B.S.E.E. - 41
M.S.E.E. - 10
Ph.D. - 2

2006-2007

B.S.E.E. - 47
M.S.E.E. - 7
Ph.D. - 10

2007-2008

B.S.E.E. - 43
M.S.E.E. - 7
Ph.D. - 7

5. ACTIVITIES

The faculty and students in the Power and Energy Systems Area participated in a considerable number of special activities during the calendar year 2007. The major events are listed below:

January

- Hawaiian International Conference on System Science, Waikoloa, HI
  - Pete Sauer chaired a mini-track
  - Tom Overbye presented a paper
- Tom Overbye met with the Tennessee Valley Authority to discuss power system visualization, Chattanooga, TN
- George Gross invited speaker at the Univesity of Texas at Arlington on "Transmission Investment In The Competitive Environment"
- Pete Sauer participated in an NSF panel review, Washington, D.C.
- Pete Sauer participated in an NAE search executive workshop, Washington, D.C.

February

- Pete Sauer participated in the PSERC Executive Committee Retreat, Washington, D.C.
- Pete Sauer attended the NAE Gordon and Grainger Prize Ceremonies, Washington, D.C.
- Philip Krein participated in the EPRI/PSMA Workshop on Energy Efficiency, Chaired the International Future Energy Challenge Workshop and attended the IEEE Applied Power Conference, Anaheim, CA
- George Gross invited speaker at IGPA, UIUC on "Global Energy Trends", Urbana, IL
- Patrick Chapman:
  - Attended the 2007 IEEE Power Electronics Society Conference (PESC) as a technical program committee reviewer
  - Attended the Applied Power and Energy Conference (APEC) as publications chair, with graduate students Wayne Weaver and Alexis Kwasinski, Anaheim, CA

March

- Pete Sauer arranged a visit, by UIUC faculty and students, to PJM to discuss research on cyber security, Philadelphia, PA
- Pete Sauer and George Gross visited ITC about PSERC membership, Ann Arbor, MI
- George Gross:
  - invited speaker at the ECE Alumni Association Spring Board Meeting on "Global Energy Trends: The Supply/Demand And The Technology Dimensions", Urbana, IL
  - invited plenary speaker at the 3CIIEE, The Third International Congress of Electrical and Electronic Engineering, Bogota, Colombia

- Tom Overbye hosted project workshop with graduate students Steven Judd, Joseph Tate and Matt Davis, as part of the tasks of the project management plan with Tennessee Valley Authority (TVA), Chattanooga, TN
- Patrick Chapman attended the Office of Naval Research (ONR) Logistics Workshop, Quantico, VA
- Philip Krein attended the IEEE Nominations and Appointments Committee meeting, Panama City, Panama
- Philip Krein invited speaker on "Power Electronics and the Next Electrical Energy Revolution," IEEE Southeastern Michigan Section, IEEE Distinguished Lecture, Dearborn, MI
- Philip Krein accompanied students on the ECE 431 class field trip to Siemens, Chicago, IL

April

- Philip Krein and Patrick Chapman attended a meeting for an engineering research center at the National Science Foundation (NSF), Arlington, VA
- Philip Krein invited speaker on "Electric Power Visions: next generation resources, storage, and delivery," the Boeing Company, IEEE Distinguished Lecture, Seattle, WA
- Philip Krein accompanied students on the ECE 431 class field trip to Delphi Corporation, Kokomo, IN

May

- Philip Krein and graduate student Timothy O'Connell made presentations and attended the IEEE International Electric Machines and Drives Conference, Antalya, Turkey
- Philip Krein and Patrick Chapman attended and presented papers at the IEEE Electric Ship Technologies Symposium, Arlington, VA
- George Gross and Pete Sauer attended the Electric Power Conference and Exhibition, Chicago, IL
- Pete Sauer, George Gross and Tom Overbye hosted the PSERC IAB meeting, Urbana, IL
- Jonathan Kimball attended the collaboration meeting with Texas A&M, Houston, TX
- Ali Davoudi, graduate student, attended and presented a paper at the 2007 IEEE International Symposium on Circuits and Systems (ISCS), New Orleans, LA

June

- Tom Overbye and graduate student Matt Davis attended the 2007 International Workshop on Electric Power Control Centers (EPCC), Ullensvang, Norway

- Philip Krein, Patrick Chapman, Jonathan Kimball and graduate students Grant Pitel, Alexis Kwasinski, Nicholas Benavides, Liyan Qu and Ali Davoudi attended and presented papers at the IEEE Power Electronics Specialists Conference (PESC), Orlando, FL

- Pete Sauer met with OSI to request software for the ITI/TCIP Project, Minneapolis, MN

- Pete Sauer participated in the Northwest National Laboratory-DOE/CERTS Project Review meeting, Richland, WA

- George Gross, Pete Sauer and Tom Overbye attended the 2007 IEEE Power Engineering Society (PES) General Meeting, Tampa, FL

July

- Philip Krein and Patrick Chapman attended the proposal preparation meeting with Grainger CEME collaborators at Illinois, Georgia Tech and Purdue, Atlanta, GA

- Philip Krein visited the Google platform group and Tesla Motors, San Jose, CA

- Patrick Chapman attended and presented a paper at the 2007 Summer Computer Simulation Conference (SCSC07), San Diego, CA

- George Gross met with the Greek government's electricity regulatory agency, Athens, Greece

- Pete Sauer, George Gross and Tom Overbye attended the Power Systems Engineering Research Center (PSERC) Summer Planning Workshop, Sedona, AZ

- George Gross invited speaker at the Farm Vision 2010 – Young/Innovative Farmer Seminar , on Energy Perspectives, Urbana, IL

August

- Philip Krein attended the IEEE Nominations and Appointments Committee Meeting, Jackson, WY

- Patrick Chapman attended the USDA Panel Meeting, Washington, D.C.

- George Gross met with the Brazilian government's energy regulatory commission, Brasilia, Brazil

- Philip Krein chaired the final events of the International Future Energy Challenge, Dallas, TX

- Pete Sauer, George Gross, Tom Overbye and graduate students Matias Negrete and Brian Raczkowski attended and presented papers at the International Institute for Research and Education in Power Systems Dynamics (IREP) Conference, Charleston, SC

September

- George Gross participated in a site visit for a National Science and Engineering Research Council Review Meeting of the Canadian Wind Energy Strategic Network, Toronto, Canada

- Pete Sauer:
  - participated in the Energy Information Security Program Advisors Research Meeting, Chantilly, VA
  - presented a report at the Section 6 National Academy of Engineering Meeting, Washington, D.C.
  - chaired the NAE Gordon Prize Committee Meeting, Washington, D.C.

- Philip Krein:
  - attended the IEEE Nominations and Appointments Committee Meeting, Salt lake City, UT
  - invited to make a presentation at the Energy and Refining Symposium at UIC, Chicago, IL
  - attend the Administrative Committee Meeting of the IEEE Power Electronics Society (PES), New Orleans, LA
  - invited plenary speaker on "Battery Management for Maximum Performance in Plug-In Electric and Hybrid Vehicles," at the IEEE Vehicle Power Propulsion Conference, Dallas, TX
  - invited speaker on "Power Electronics and the Next Electrical Energy Revolution,", IEEE Distinguished Lecture, Chicago AIChE Symposium, Chicago, IL

- Philip Krein, Patrick Chapman and graduate student Ali Davoudi attended and presented papers at the IEEE Vehicular Propulsion Power Workshop, Arlington, TX

- Patrick Chapman attended the IDOT TRP Kickoff Meeting on Wind Powered Electrical Systems in Highway Rest Areas, Weigh Stations and Team Section Buildings, Springfield, IL

- Tom Overbye and graduate students Joseph Tate and Matt Davis attended and presented papers at the 2007 North American Power symposium, Las Cruces, NM

- Shanshan Liu, graduate student, attended and presented a paper at the 7th WSEAS International conference on Simulation, Modeling and Optimization, Beijing, China

October

- Pete Sauer and graduate student Timothy O'Connell attended and presented a paper at the Electrical manufacturing and Coil Winding Association, Inc. Conference and Expo, Nashville, TN

- Tom Overbye:
  - visited American Electric Power to discuss research, Columbus, OH
  - visited First Energy to discuss research, Akron, OH
  - invited to give a talk at Stanford University's Global Climate and Energy Project Workshop, Stanford, CA
  - made presentation at PowerWorld Client Conference, New Orleans, LA

- Patrick Chapman invited speaker on "Experiences of a Professor with the SBIR Program and an Alternative-Energy Startup," enhancing linkages between Universities and Small Businesses in EPSCoR jurisdictions at the USDA EPSCOR Conference, Portland, ME

- George Gross invited speaker at the Prisms of Globalization Seminar Series entitled "The Limits and Opportunities of Technology" on Global Energy Issues, Center for Global Studies, UIUC, Urbana, IL

- Pablo Ruiz, graduate student, attended and presented a paper at the INFORMS 2007, Seattle, WA

November

- George Gross invited speaker at the Earnst & Young Strategic Growth Forum Cleantech Symposium, Palm Springs, CA

- Philip Krein
    - Invited keynote speaker on "Digital Control Generations – Digital Controls for Power Electronics through the Third Generation," at the IEEE Power Electronics and Drives Systems Conference, Bangkok, Thailand
    - attended the IEEE Technical Activities Board Meeting, Boston, MA
    - invited speaker on "Battery Management for Maximum Performance in Plug-In Electric and Hybrid Vehicles", Massachusetts Institute of Technology, Cambridge, MA

- Pete Sauer:
    - attended the National Science Foundation Workshop, Washington, D.C.
    - attended the ECE Advisory Board Meeting at Purdue University, West Lafayette, IN
    - visited the Department of Energy and National Science Foundation to discuss TCIP, Washington, D.C.

December

- Patrick Chapman:
    - Attended the Office of Naval Research (ONR) and University of Texas-Austin project kickoff meeting, Austin, TX
    - Attended Sargent and Lundy Collaborative and Developmental Meeting, Chicago, IL

- Pete Sauer, George Gross, Tom Overbye, and Alejandro Dominguez-Garcia participated in the PSERC IAB Meeting, Washington, D.C.

During the 2007 calendar year, the power area group hosted the following guest speakers:

- Charles Debries and Chris Thornton, Texas Instruments, Warrenville, IL "TurboTrans Enhancement Of The Dynamic Performance Of DC/DC Converters", February
- Ari Zachas, Georgia Institute of Technology, Atlanta, GA, "PM Generator Characteristics For Oscillatory Engine Based Portable Power System", March
- Dr. Said Ahmed-Zaid, Boise State University, Boise, ID, "Theory And Analysis Of Series-Connected Induction Machines", March
- Dr. Ted K.A. Brekken, Oregon State University, Corvallis, OR, "Control Of A Doubly-Fed Induction Wind Generator Under Unbalanced Grid Voltage Conditions", April
- Neal Balu, Wisconsin Public Service Corporation, Green Bay, WI, "Overview Of FERC Order No. 890", April
- Brian Garden and Dane Barhoover, Bibb and Associates, Inc., Lenexa, KS, "Components Of Competitive Electricity Markets", September
- Jason T. Stauth, University of California at Berkeley, Berkeley, CA, "Pulse-Density Modulation For RF Transmitter Applications", October
- Hsiao-Dong Chiang, Cornell University, Ithaca, NY, "On-Line Voltage And Dynamic Security Assessment And Control: Theory, Nonlinear Computations, Practical Installations And Future Directions", October
- Bei Bou, The University of Texas at Arlington, Arlington, TX, "Investigation Of A Probability Characterization Of Power System Blackouts", October
- Jianhui Wang, Argonne National Laboratory, Argonne, IL, "Electricity Market Simulation And Hydro Power Modeling At Argonne National Laboratory", November
- Nicholas Josefik, U.S. Army Engineer Research and Development Center – Construction Engineering Research laboratory (ERDC-CERL), Champaign, IL, "Hydrogen Fuel Cell For Emergency Backup Power At New Mexico National Guard", December

During the 2007 calendar year, the power faculty and students presented the following seminars to our local audiences:

- Xin Geng, "Design And Analysis Of Pulse Width Modulation Techniques For Spectrum Shaping", January
- Jonathan Kimball, "Time-Scale Modeling Of Switching Power Converters", January
- Philip Krein, "Discussion Of The Grainger Center For Electric Machinery And Electromechanics Collaborative Network: An Overview Of Machines And Energy On A National Scale", February
- Nicholas Benavides, "A Survey Of Radioisotope Batteries", February
- Pablo Ruiz, "Post-Contingency Voltage And Reactive Power Approximations Using Sensitivities", February
- Wayne Weaver, "Geometric And Game Theoretic Control Of Energy Assets In Small-Scale Power Systems", March
- Alexis Kwasinski, "Highly-Reliable And Flexible Microgrid With Multiple-Input DC-DC Converters", April

- Timothy O'Connell, "The Schwarz-Christoffel Method Applied To Electric Machine Slot Shape Optimization", April
- Matias Negrete-Pincetic, "Assessment Of The 2006 Illinois Electricity Auction", April
- Abhishek Banerjee, "Behavioral Analysis Of Various IGBT Structures Under Hard And Soft Over-Current Turn-Off", September
- Pablo Ruiz, "Post-Contingency Voltage And Reactive Power Estimation And Large Error Detection", September
- Charles Davis and Joseph Tate, "Wide Area Phasor Data Visualization", September
- Hector Pulgar, "On A Necessary Condition For Power System Collapse", October
- Rajesh Nelli, "Day-Ahead Unit Commitment With Demand Response In Energy And Capacity Reserves Electricity Markets", October
- Angel Aquino-Lugo, "Distributed Intelligent Agents For Distribution Network Restoration", October
- Linda Monge-Guerrero, "Data-Driven Power System Analysis", October
- Matias Negrete-Pincetic, "Auction Design For The Acquisition Of Future Electricity Supply", November
- Anupama Kowli, "Load Modeling For Long Term Planning Studies", November

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. The following students were associated with the Power and Energy Systems Area and their work is described in the following pages:

- Amrhein, Marco (Ph.D.)
- Aquino-Lugo, Angel (Ph.D.)
- Banerjee, Abhishek (M.S.)
- Bazzi, Ali (Ph.D.)
- Beltran, Hector (Ph.D.)
- Benavides, Nicholas (Ph.D.)
- Bollman, Andrew (M.S.)
- Byoun, Jaesoo (Ph.D.)
- Chen, Yongxiang (M.S.)
- Davis, Charles M. (Ph.D.)
- Davoudi, Ali (Ph.D.)
- Dhople, Sairaj (M.S.)
- Esram, Trishan (Ph.D.)
- Friedl, Andrew (M.S.)
- Geng, Xin (Ph.D.)
- Guille, Christophe (M.S.)
- Güler, Teoman (Ph.D.)
- Johnson, Melanie (M.S.)
- Judd, Steven (M.S.)
- Kowli, Anupama (M.S.)
- Kroeze, Ryan (M.S.(
- Kuai, Yingying (Ph.D.)
- Kwasinski, Alexis (Ph.D.)
- Liu, Shanshan (Ph.D.)
- Maisonneuve, Nicolas (M.S.)
- Monge-Guerrero, Linda (Ph.D.)
- Nee, Brett (Ph.D.)
- Negrete, Matias (Ph.D.)
- Nelli, Rajesh (M.S.)
- Niu, Penglin (Ph.D.)
- O'Connell, Timothy (Ph.D.)
- Pitel, Grant (Ph.D.)
- Pulgar, Hector (Ph.D.)
- Qu, Liyan (Ph.D.)
- Raczkowski, Brian (Ph.D.)
- Revelo, Renata (M.S.)
- Rogers, Katherine (M.S.)
- Ruiz, Pablo (Ph.D.)
- Safavinejad, Sean (M.S.)
- Sander, Jonathan (M.S.)
- Sayyah, Arash (M.S.)
- Shenoy, Pradeep (M.S.)
- Sithimolada, Viboon (Ph.D.)
- Tate, Zeb (Ph.D.)
- Wang, Gui (Ph.D.)
- Weaver, Wayne (Ph.D.)
- Wiczkowski, Piotr (M.S.)
- Xiong, Leilei (M.S.)
- Yeu, Rodney (Ph.D.)

Marco Amrhein

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B.S.:	December 2000, Zurich University of Applied Sciences, Winterthur, Switzerland
M.S.:	November 2003, University of Illinois at Urbana-Champaign
Ph.D.:	May 2007, University of Illinois at Urbana-Champaign

Magnetic Equivalent Circuits Applied to Induction Machine Design

Marco Amrhein with advisor Philip T. Krein

Supported by the Power Affiliates Program and Grainger CEME

ABSTRACT

New developments in power electronics technology, materials, and changing application requirements are driving advances in electric machines. But special-purpose induction machines have not enjoyed the same attention in inverter-fed applications as permanent-magnet and switched-reluctance machines. Induction machines are often not considered, particularly in the traction and aerospace community, due to their low power density and low efficiency. Because induction machines need to satisfy the standards of the National Electrical Manufacturers Association, performance capabilities are limited. Computer-aided design (CAD) tools for special-purpose machines that overcome these limitations are not available.

Magnetic equivalent circuits (MEC) provide an excellent foundation for electrical machine design work. They are flexible in terms of size and accuracy, have moderate computational complexity, are easily parameterized, and can be extended readily to three–dimensional (3-D) analysis. But despite the successful use of MEC as a modeling tool, a generalized three-dimensional (3-D) formulation useable for a comprehensive computer-aided design (CAD) tool has not yet emerged.

This project provides the framework of a 3-D MEC modeling approach intended for design. Theory, reluctance network generation, and modeling of motion are discussed. A new force calculation approach based on the Maxwell Stress Tensor method is presented. The solution of the complete, nonlinear network equations in combination with mechanical and electrical differential equations is discussed. An induction machine model is introduced that features a variable reluctance element mesh. Results for a 500 W induction machine designed for the Future Energy Challenge competition are compared to measurements, analytical models, and commercial finite element analysis (FEA) models. This machine has design flaws; it saturates the stator and rotor teeth during nominal load, a fact not discovered by the design software (analytical-based) and the associated FEA package. However, the 3-D MEC model estimates a limited torque capability due to a smaller air-gap flux. The model is about an order of magnitude smaller in complexity and size than the FEA model. All the presented results indicate that MEC, corrected for local saturation, is a promising option for a design tool.

Angel Aquino-Lugo

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M.S.	May 2006, University of Puerto Rico, Mayagüez, Puerto Rico
Status:	Working towards Ph.D. at UIUC

Distributed Intelligent Agents for Power System Restoration and Control

Angel A. Aquino-Lugo with advisor T.J. Overbye
Supported by NSF TCIP Project and a University of Puerto Rico Fellowship

ABSTRACT

Typically the electricity power network is divided into two basic levels: the transmission network and the distribution network. The transmission network usually operates at higher voltage levels, while the distribution system usually operates at lower voltage levels. Another important difference is that the distribution networks are usually radial and also have many points of connection that are normally open.

Under normal circumstances, the power systems are operated and coordinated in a centralized way. Every time that the power network fails because of a disturbance or some reconfiguration is needed, the central control center determines which system elements to switch and which control actions to implement. In this research, we are investigating the concept of delegating these functions to agents distributed throughout a distribution network. These agents would be in charge of the system switching response in case of a system failure and determining the control actions needed to minimize the distribution network power losses in a decentralized approach. Each agent would interact and communicate which other agents in the system to exchange information of the system as well as coordinating control actions in the power distribution network. Our work will also explore which control algorithms are adequate to be implemented with these agents, as well as, the communication requirements needed to make the functionality of these distributed agents a reality.

Abhishek Banerjee

Date of Birth:	August, 30th 1984
Place of Birth:	Siliguri (West Bengal), India
B.S:	June 2006, Kettering University, Flint, Michigan, United States
M.S:	December 2007, University of Illinois at Urbana-Champaign, Urbana, United States

Behavioral Analysis of Insulated Gate Bipolar Transistors during Hard and Soft Turn-off

Abhishek Banerjee with advisor Philip Krein

Hard and soft turn-off behavior of insulated gate bipolar transistors is examined. Insulated gate bipolar transistors are used as switching devices in power converters for machine drives. Faults during operation of converters occurring due to reasons such as loss of control, device parasitics and load-side malfunctions might necessitate shut down of the devices to protect them from destruction. Hard turn-off entails a direct shut-down when a fault is detected, whereas soft turn-off involves a relatively slower shut-down to prevent overvoltage stress and consequent breakdown of the device. For short-circuit conditions, soft turn-off helps reduce overvoltage. However, for overcurrent situations, several factors are evaluated to determine whether soft turn-off should be used: the amount of parasitic inductance, the turn-off overvoltage, and the capability of the power device to handle higher current for brief intervals. Also, soft turn-off uses excess pulse energy due to longer turn-off time. This excess energy leads to increased losses and potential to hurt the device. Thus, the trade-off is to maximize overvoltage reduction for the least increase in pulse area. Through simulations and hardware tests, it is shown that soft turn-off for short-circuit current is necessary but for overcurrent conditions, is application based.

Ali Bazzi

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Place of Birth:	Bint Jbeil, Lebanon
B.S.:	June 2006, American University of Beirut, Lebanon
M.S.:	July 2007, American University of Beirut, Lebanon
Status:	Working towards Ph.D. in Electrical Engineering at UIUC
Professional Interests:	Power electronics, motor control, nonlinear control and estimation, renewable energy.

Induction Motor Power Loss Minimization Using Ripple Correlation Control

Ali Bazzi with Prof. Philip T. Krein

Supported through a Small Business Technology Transfer project grant through the National Science Foundation

ABSTRACT

The project investigates applying ripple correlation control (RCC) optimization technique, to power loss minimization in induction motors. Induction motors are oversized in many industrial applications in which they operate under low-efficiency conditions. Operating at a constant output power, the power loss minimization resembles input power minimization. As part of the project, input power has been proved to have a convex relation with the rotor flux in simulation, hardware, and frequency analyses, which is basic in the application of RCC to this optimization problem. The project has been successfully simulated and it is being built in hardware. The preliminary results show convergence to the optimal rotor flux value that minimizes the input power. Other studies are being held in parallel with the implementation such as RCC sensitivity to induction motor parameters and errors in measurements.

Héctor Beltrán Mora

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Professional Interests:	Renewable Energies and Power Systems Planning.

Integrating Renewable Energy Sources to Power Systems

Héctor Beltrán with advisor Thomas Overbye

Renewable energy effectively uses natural resources such as sunlight, wind, rain, tides and geothermal heat, which are naturally replenished. Renewable energy technologies range from solar power, wind power, hydroelectricity/micro hydro, biomass and biofuels for transportation. In 2006, about 18 percent of global final energy consumption came from renewables, with 13% coming from traditional biomass, like wood-burning. Hydropower was the next largest renewable source, providing 3%, followed by hot water/heating which contributed 1.3%. Modern technologies, such as geothermal, wind, solar, and ocean energy together provided some 0.8% of final energy consumption. The technical potential for their use is very large, exceeding all other readily available sources.

We are looking for specific niches where renewable energy is the best option available to provide electricity in isolated areas. It will be analyzed the potential, the performance and possible hybrid combinations of renewable energy with conventional technologies such as natural gas or diesel as backup. The cost of providing energy from this mechanism will be compared with the prices of electricity from the grid and we will study the possible economical and environmental benefits.

Nicholas D. Benavides

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Nicholas D. Benavides received the B.S. in electrical engineering at the University of Missouri - Rolla in 2003, and the M.S. and Ph.D. in electrical engineering at University of Illinois at Urbana-Champaign in 2004 and 2007, respectively. He received the Grainger Outstanding Power Engineering Student Award in 2003, 2005, and 2007.

Dr. Benavides was with SmartSpark Energy Systems, Inc. (Champaign, IL) from 2005 through 2007 where he worked on power conversion systems for portable energy harvesting and fuel cell applications. Presently he is with Converteam Naval Systems, Inc. (Pittsburgh, PA) in research and development. His current work focuses on high-power applications including medium-voltage motor drives for naval propulsion systems. His research interests include power electronics, electric machines, and alternative energy conversion.

Optimization of Power Converters in Portable Energy Sources

Nicholas Benavides with advisor P.L. Chapman

ABSTRACT

Portable electronic devices have grown in number and complexity. Powering these devices with lightweight sources is a major research focus. Advanced technology energy sources such as fuel cells and combustion-based microturbines seek to supplant chemical batteries due to their theoretically high energy density. These sources typically do not have directly useful output, and are most efficient when used at a constant power level. This requires complex power conversion and secondary energy storage to meet changing load demand. Our work focuses on optimizing the tradeoff between mission length and optimal converter efficiency. A short mission time can use a light-weight, inefficient converter by adding a small amount of fuel. Conversely on a long mission, the fuel is the most significant mass in the system, and any drop in efficiency has a larger effect on the net mass. As the mission lengths approach 1000 hrs, the maximum possible efficiency is desired, even if the optimum results in a heavier converter.

Andrew Bollman

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B.S.:	December 2007, University of Illinois at Urbana-Champaign
Status:	Working towards M.S. at UIUC
Professional Interests:	Power Electronics, Distributed Generation, Renewable Energy

Distributed Generation in Micro-grids

Andrew Bollman with advisor P. T. Krein

ABSTRACT

Distributed generation research is focused on addressing the technological, environmental and economic issues that power systems will face in the future. Distributed generation places small generators close to the load decreasing losses from the typical miles of transmission lines that now exist. Putting smaller generation plants close to the loads will allow the use of both the electricity created for power and the waste heat produced for steam or hot water, increasing the total system efficiency. This dual ability is a trait shared by fuel cells, micro-turbines, or ultra-low emission internal combustion engines. The use of low-emission sources for combined heat processes as well as the inclusion of renewable energy sources will result in lower emissions and a more environmentally friendly generating network.

Distributed energy sources will require intelligent and autonomous controls to take advantage of their full potential. These controls will detect anomalies in the grid and disconnect from the main grid, 'islanding' themselves and providing more reliable and higher-quality power to the loads. The resulting 'micro-grid' will then seamlessly reconnect when the grid has stabilized decreasing the possibility of total failure on the entire system. Furthermore, energy sources such as wind and solar are intermittent and will require controls to ensure they are operating with maximum effectiveness. Solving these issues will create a power system that addresses the concerns of increasing fuel costs, an aging infrastructure and the increase in loads that require high power quality.

The concept of an islanded micro-grid can be extended further to include applications where the grid in not serviceable or non-existent. An area that has experienced a large natural disaster would benefit from the capability to move smaller generation sets into the area that could provide reliable energy to critical loads. The capability would assist in the recovery of the area as well as enable the provision of critical services to the people and emergency responders in the area.

Jaesoo Byoun

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Place of Birth:	Seoul, South Korea
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Ph.D.:	May 2007, University of Illinois at Urbana-Champaign
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Analysis and System-On-Chip Implementation of Digitally Controlled Multi-Port DC-DC Converters

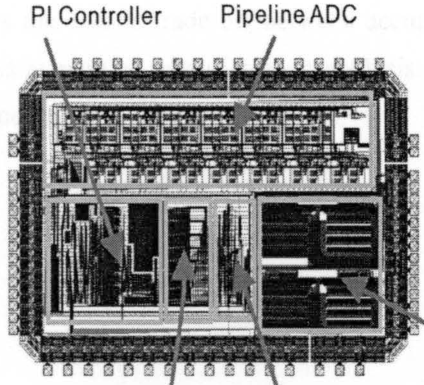
Jaesoo Byoun with advisor Prof. Patrick Chapman

Supported by Grainger Endowments

ABSTRACT

A proposed power management architecture that uses digital phase control to maximize the advantages of digital control in the low-voltage power electronics field. The implemented architecture consists of 7-bit Pipelined ADC, PI digital controller, Digital Phase Controller, Digital PWM and CMOS Power Device. The implemented architecture design is submitted for fabrication to MOSIS.

The proposed architecture is to stabilize the feedback loop without a current sensor from full load to no load conditions by using digital phase controller. The architecture also has multi-input multi-output functionality and sets not only the sequence of on-and-off of the dc-dc converters but also the device itching command signal.



Yongxiang Chen

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B.S.:	August 2005, University of Illinois at Urbana-Champaign
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Professional Interests:	Power Electronics and Energy Conversion

Dynamic Modeling of Multiple-Input Power Converters

Yongxiang Chen with advisor P. L. Chapman

ABSTRACT

Multiple input power converters are used to supply energy to systems that have multiple energy sources. For example, a solar vehicle that is powered by a solar panel and a battery can use a two-input dc-dc converter, which can be controlled to provides maximum power point tracking of the solar panel and steady output power to the motor simultaneously. An example of a two-input dc-dc converter is shown.

The design and analysis of a multiple-input power converter traditionally uses either switched or average value models. The switched model provides the most detailed and accurate results but requires significant computational effort. The averaged-value model is easier to compute but accuracy is reduced and most switching details are omitted. In this study, a multi-frequency dynamic model is being developed. It allows the user to trade off between accuracy and computational effort, which benefits the design process as well as overall system analysis. A sample comparison of the results from the three different models is shown.

Charles M. Davis

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Status:	Working towards Ph.D. at UIUC
Professional Interests:	Power system analysis, operational reliability, cyber security, visualization, contingency screening, and computational methods.

Cyber Security and the Power System

C. M. Davis with advisor T. J. Overbye

ABSTRACT

Regulatory and economic pressures are requiring grid operators to consider multiple element contingencies. However, as one increases the number of elements in a contingency the size of the contingency list quickly becomes intractable. My research explores a method of prescreening contingencies by detecting interactions between the contingent lines as well as other lines in the system. Lines that do not impact each other are screened out. The method reduces the $O(n^3)$ computational order that screening double outages would ordinarily require. The ultimate goal is to greatly reduce the number of contingencies to be considered, making it possible to use typical contingency screening methods.

Ali Davoudi

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M.S.: May 2005, The University of British Columbia, Vancouver, Canada
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Professional Interest: Computational prototyping of power electronics-based systems

Multi-Resolution Simulation of Power Electronics-Based Systems

Ali Davoudi with advisor Patrick L. Chapman

ABSTRACT

Flexible simulation tools for switching power converters are needed for dynamic characterization, transient studies, and real-time simulation. Simulation of power converters includes the mixture of continuous and discrete events, where the presence of parasitic and switching transients introduces a wide range of time scales that span several orders of magnitude. Thus multi-rate simulations of the power electronics-based systems become necessary. An approach for simulating linear switched networks, such as PWM dc-dc switching converters, is set forth. A highly detailed model, that includes parasitic elements and precise representation of switch and passive components, is considered first. The state equations are automatically extracted based on the netlist of the converter under study. When a switching event is detected, the simulator proceeds among different state vectors while a succession of initial value boundary problems is solved. For each possible switching instance (two instances in continuous conduction mode and three in discontinuous conduction mode), standard state equations are formulated in detail. Lower resolution models are numerically formed by automated model order reduction. The order reduction techniques used here include state elimination, modal reduction, pole-zero cancellation, and Krylov subspace. The user determines the bandwidth (i.e., level of resolution) that is desired for a specific phase of design. In the proposed multi-resolution framework, several resolutions of the reduced model are constructed. This results in different state matrices and state vectors for a given switching instance, where the state continuity is insured across resolutions as well as switching events. The simulation proceeds with the assigned resolution level until a higher resolution is desired (e.g., to inspect a switching transient), where analyst changes the simulation resolution for a short time. The bandwidth of the reduced-order model may be adjusted, even during a simulation run, yielding different simulation resolutions and speeds.

Sairaj Vijaykumar Dhople

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Professional Interest:	Power Electronics, Photovoltaics.

Solar Decathlon - 2009

Sairaj Dhople with advisor P.L. Chapman

Supported by the Grainger Center for Electric Machinery and Electromechanics

ABSTRACT

The Solar Decathlon is a biannual competition in which twenty university teams design and build a sustainable and energy efficient house completely powered by solar energy. In the 2007 Solar Decathlon, the University of Illinois placed 9th overall, while winning first place in market viability and comfort zone.

The Illinois proposal for the next Solar Decathlon to be held in October 2009 was recently accepted. In preparation for the competition, engineering teams for power, control, comfort conditioning and appliances have been formed. A new web-site for the team, www.solardecathlon.uiuc.edu is already up and running. Some of the novel concepts that will be considered for the 2009 house include Building Integrated Photovoltaics (BIPV), real-time power monitoring and passive house design.

Trishan Esram

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Status:	Working towards Ph.D. at UIUC
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Cycloconverter Theoretical Model

Trishan Esram with advisor P. L. Chapman

ABSTRACT

Laboratory experiments have shown that a state-machine control can solve current commutation problems commonly related to a square-wave high-frequency link, pulse-width modulation cycloconverter (Figure 1). The cycloconverter, along with the state-machine control, has also been simulated in Dymola, producing results matching the empirical ones. Despite its success in hardware and simulation, the cycloconverter has never been modeled theoretically. Our goal now is to derive an average-value model based on multiple reference frames for the cycloconverter. Using the model, the behavior of the cycloconverter with a photovoltaic (PV) source, while connected to the utility grid, will then be investigated. The model will further help in formulating additional algorithms, not only to perform maximum power point tracking of the PV source, but also to monitor and control the interface with the utility grid to meet all the regulatory codes and standards.

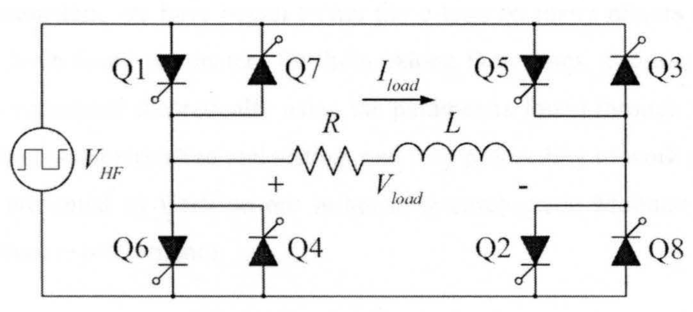

Figure 1. Cycloconverter

Andrew Friedl

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Professional Interests: Power Electronics, Electric Machine Design, and Motor Control.

High Performance Induction Machine Control

Andrew Friedl with Advisor P.T. Krein

Supported by the Grainger Center for Electric Machinery and Electromechanics

ABSTRACT

Unique methods of induction machine control researched at UIUC in the early 1990's by Francisco Carli from UIUC - such as nonlinear flux-observer based control, reduced-order model control, and his input-output decoupling control- have yet to be implemented in hardware. To implement these methods, one must have a very accurate model of the induction motor to be controlled, and thus a parameterization of the motor must be done. It is well documented in the literature which tests one can use to parameterize an induction motor; some of which include a no-load test, locked rotor test, DC test, and rotor inertia test, to name a few. To gain a broader understanding of different induction motors and their parameters, we have begun to run these tests on many motors that are currently in our laboratory, and have found parameters for them. Along these lines, a torque speed curve can be observed as well as calculated theoretically using the parameters found through testing. Future work includes finishing the parameterization and testing, and then proceeding to work on implementing the control algorithms presented by Carli on our in-house research-grade Modular Inverter in hope of achieving higher dynamic performance.

Xin Geng

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Switching Signal Spectrum Management

Xin Geng with advisor P. T. Krein

Supported by the Grainger CEME and by the

Motorola-UIUC Center for Communications

ABSTRACT

Switching power converters are designed to convert electrical power from one form to another at high efficiency. The control of switching converters relies on appropriate modulation of the switches. Pulse-width modulation (PWM) technique becomes the primary control scheme due to its simplicity and effectiveness. However, switching signals generated by original PWM method generally contain rich harmonics which have detrimental effects to the converter working environments. For instance, unpleasant acoustic noise, mechanical resonance and electromagnetic interference (EMI) are all caused by the harmonic components existing in the power conversion devices.

The main objects of this project is to address above issues which requires *spectrum shaping*, the technology to modify harmonic characteristics of switching signals without sacrificing signal-band integrity. Two directions are attempted. First, a modulating-function based approach is studied based on previous work on multi-carrier and multi-signal PWM architectures. Predistortion signals are added into the modulating function to change the characteristics of the switching signal spectrum. Second, a carrier-based approach is proposed in which the carrier waveform is altered either in a random fashion or a deterministic way. Both methods show potentials to reshape the signal spectrum. Further research on systematic design criteria and digital implementation are being conducted.

Christophe Guille

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Place of Birth: Paris, France

B.S.: July 2007, Supélec, France

Status: Working towards M.S. at UIUC

Professional Interests: Power System economics, Electricity markets, Finance.

Design Of A Conceptual Framework For The Vehicle-To-Grid (V2G) Implementation

Christophe Guille with advisor George Gross

ABSTRACT

The major increases in oil prices and the rising environmental concerns are key drivers in the growing popularity of electric and plug-in hybrid vehicles. Car manufacturers understand this trend quite well and are developing new models, e.g., the *Chevrolet Volt* to be released next year. For the 90% of Americans who use their car to go to work every day, the average daily commute distance is 28 miles and the average daily time that cars remain parked is 22 hours. A salient feature that these vehicles have in common is the batteries, which provide good storage capacity that can be effectively integrated into the grid.

We focus on the design of a conceptual framework needs to integrate the electric vehicles into the grid – the so-called V2G concept. The basic premise we use is to treat the battery vehicles as distributed energy resources that can act both as supply and demand resources. We assess the deployment of an aggregation of battery vehicles for the provision of frequency regulation – requiring very fast response times – and peak shaving. We also investigate the impacts of the aggregated battery vehicle-charging load on the low load generation schedules and on regulation requirements. The assessment of these impacts takes into consideration the explicit representation of uncertainty and the importance of the state of charge as a key variable in the use of the batteries for the supply and demand roles. For the framework completeness, we also explore the role of the energy services provider in the V2G integration.

Teoman Güler

Date of Birth: November 14, 1976
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M.S.: May 2001, Rensselaer Polytechnic Institute
Status: Working towards Ph.D. at UIUC

Professional Interests: Electricity Market Monitoring and Mitigation, Market Behavior and Market Power.

Electricity Markets and System Reliability

Teoman Güler with advisor G. Gross

ABSTRACT

In the restructured electricity systems, market forces induce system operators to drive the system to operate near or at the limits of operational reliability. Under such conditions, the maintenance of system security is of paramount importance for ensuring effective and efficient market operations. The objective of this study is to exploit the impacts of the system security criteria on market operations. We analyze the extensive test results on various systems in terms of different criteria including costs, reliability performance and benefits. The work also assesses the additional opportunities for strategic behavior by sellers and the effects of spatially distributed generation reserves under different security criteria. We are also undertaking some analytical tool development to predict the impacts of changing the security criterion.

Melanie Johnson

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Place of Birth:	South Charleston, West Virginia
B.S.:	May 2006, University of Texas at Austin
M.S.:	May 2008, University of Illinois at Urbana-Champaign
Professional Interests:	Power Electronics and Power Systems

Modeling The Magnetic Field Generated By Corroding Metals

Melanie Johnson with advisor P. L. Chapman

ABSTRACT

Damage caused by corrosion of reinforcing steel plagues civil infrastructure in the United States. Corrosion damage causes an estimated 6 to 10 billion dollars of damage per year to bridge decks alone. Despite this cost, no reliable non-destructive testing method exists to detect the presence of corrosion or the rate at which corrosion occurs. Existing methods, such as visual inspection and half-cell potential measurements, are unable to fully characterize damage. The goal of this project is to develop a new sensing technique based on magnetic field measurements that will accurately measure both the state and rate of corrosion in reinforcing steel.

Working jointly with a group in the Civil Engineering Department, the project seeks to employ giant magneto-resistive (GMR) sensors to measure the small magnetic field generated by electric currents caused by corrosion. However, to extract the magnetic field information from background noise, a model is necessary to determine the defining characteristics of the corrosion magnetic field. Three models have been developed to simulate the corrosion magnetic field. These models calculate the magnetic field based on random current distributions designed to reflect the behavior of currents in general micro-cell corrosion. The models use finite element analysis and two variations on Biot-Savart law to calculate the magnetic field. Measuring the change in this simulated magnetic field shows promise in revealing corrosion magnetic field characteristics.

Steven L. Judd

Date of Birth: April 30, 1984
Place of Birth: Houston, Texas
B.S.: December 2006, University of Illinois at Urbana-Champaign
M.S.: May 2008, University of Illinois at Urbana-Champaign

An Evaluation Of Plug-In Hybrid Electric Vehicle Contributions To Power System Disturbances And Economics

Steven Judd with advisor Thomas Overbye
Supported by PSERC

ABSTRACT

During 2005, the United States imported 10.4 million barrels of crude oil per day in addition to the 5.18 Mb/day that are produced domestically. Over two-thirds of this fossil fuel is refined into gasoline to power passenger vehicles and trucks. The effects of this "addiction" have greater effects on our economy and political elements every day. With world-wide demand increasing and OPEC controlling 75% of the world's proven reserves, market prices have recently sky-rocketed to over $110 per barrel. This along with increasing pressure to reduce greenhouse gas emissions from the burning of fossil fuels has intensified the pursuit of alternate technologies. It becomes critical for our nation to find a solution to reducing our overall consumption of oil and finding an alternative for the future.

Several solutions have been proposed to solve this enormous problem: finding more oil (for example the drilling of ANWR in Alaska), increasing the fuel economy of our vehicle fleet, implementing the use of ethanol, and widening the use of conventional hybrid electric vehicles (HEVs). A newer option has emerged in the past few years, the Plug-In HEV (PHEV). The only difference between a standard hybrid and a PHEV is an increase in the capacity of the battery pack and a modification to the power electronics. PHEVs have a new advantage of running in all-electric-mode for longer distances, typically 30-60 miles, and could become a new source of energy storage for the bulk power grid.

Current HEVs charge their batteries from the cars' internal combustion engine and by using regenerative breaking then deplete their energy while the car is stationary. This method is referred to as *charge-sustaining* since the batteries will maintain a set state of charge. The major change in a PHEV is the use of a *charge-depleting* strategy where the car batteries will be steadily used while driving to maximize fuel efficiency and the state of charge will decrease over time. The car will also be connected to the power-grid while not in use to provide energy to the batteries from the grid and/or provide support to the grid in time of emergency during hours.

This thesis will focus on the support PHEVs can provide to the grid security and the economic benefit for grid operation. PHEVs have a large potential to save money to those that own one. An analysis of the economic benefit to individual owners will be described. An in-depth formulation of how much power PHEVs can provide will also be shown. To show the economic benefit of grid connection, the IEEE 24, IEEE 118, and a utility 2,574 bus test system will demonstrate costs associated with PHEVs. Simulating these systems with several different levels of support will be tested to see what potential cost benefits and increased grid security can be achieved.

Anupama Kowli

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Investement Analysis of Demand–Side Resources in Competitive Electricity Markets

Anupama Kowli with advisor George Gross
Supported by the Grainger Endowments

ABSTRACT

Load is a key driver in power system operations and planning decisions. The load needs to be met reliably and economically, using both supply-side as well as demand-side resources. We aim to assess the impacts of investments in demand- and supply-side resources on a consistent basis under competitive electricity market conditions. Since load plays a crucial role in the planning, implementation and operation of supply- and demand-side resources, we construct a probabilistic model of the load useable in our investigations. The load model is required to be able to interface with market analysis tools that incorporate the impacts of transmission congestion. In light of these requirements, we introduce a load classification scheme that is particularly appropriate for the interface with the market analysis tools, that use snapshot representations of the power system with transmission considerations and market clearing represented. The load classes effectively capture the critical peak loads, with which congestion events and demand-side resource deployment are associated. We investigate the characteristics of the load model numerically and analyze the results using actual data of large-scale ISO networks. The objective is to quantify the impacts of demand-side resources, particularly those of demand-response programs offered by grid operators and energy service providers. Such impacts are key considerations in the analysis of demand- and supply-side investment alternatives on a consistent basis.

Ryan Carter Kroeze

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Electrical Battery Model for Use in Dynamic Electric Vehicle Simulations

Ryan Kroeze with advisor P. Krein

ABSTRACT

Simulation of electric vehicles, hybrid electric vehicles, and plug-in hybrid electric vehicles over driving schedules within the University of Illinois (UIUC) Hybrid Electric Vehicle Simulator requires a new battery model capable of predicting the state-of-charge and I-V characteristics of different battery types. A Lithium-ion battery model capable of reproducing nickel-metal hydride and lead-acid I-V characteristics (with minimal model alterations) has been proposed. A multiple (three) time-constant battery model suitable for modeling Lithium-ion batteries is currently being verified in the Matlab/Simulink programming environment; model time constants in the second/minute and hour ranges have already been verified in numerous research articles and a time-constant in the millisecond range has been verified with experiments. Accurate state-of-charge (SOC) prediction is attained through a separate circuit model which includes self-discharge of the battery, capacity-fade during high-current charging and discharging profiles, as well as SOC deterioration due to cycling. Comparisons of driving schedules run in the software environment on modeled battery packs and current discharge/charge profiles on real battery packs show minimal error between the simulated and actual battery packs terminal voltage, SOC, and discharging/charging power.

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DC-DC Converter Design and Integrated Circuit Implementation

Yingying Kuai with advisor P. L. Chapman

Supported by the Power Affiliates Program and Grainger CEME

ABSTRACT

Voltage Regulator Modules (VRMs) are low-output-voltage, high-current DC-DC converters that supply power to microprocessors. With more transistors and higher processing speeds, next generation microprocessors impose stringent challenges to VRM design. State-of-the-art VRMs need to supply 1.5 V at 125 A and maintain the output voltage within 75 mV overshoot during load transients. In addition, Intel's guidelines specify repetitive load transients with slew-rates up to 50A/μs. To achieve such strict voltage regulation without increasing output capacitance, several novel schemes were proposed.

In the proposed predictive control (also called anticipatory control) scheme, the load current is estimated and future load transients are predicted. A warning signal is then made available to the VRM before the transient actually occurs. The VRM takes advantage of this signal to prepare for the transient and enhance the response. A generic block diagram of the proposed scheme is shown in Figure 1. The development of this scheme includes two steps. First, the input current dynamics and the digital signals of a microprocessor are observed and analyzed. Then, algorithms to predict transients will be developed. Second, once the warning signal was made available, several ways to prepare the converter for the transient will be investigated. A MOSFET could be controlled as a ballast load to the system, in addition to the processor, to serve as a temporary energy dissipation device. The control system could switch between two or several modes to optimize converter operation.

Hysteretic control shows great promise for VRM applications and has attracted great attention during recent years. A novel hysteretic control scheme for microprocessor VRMs is being developed as the next stage of the project.

Alexis Kwasinski

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A Microgrid Architecture With Multiple-Input DC/DC Converters: Applications, Reliability, System Operation, and Control

Alexis Kwasinski with advisor P. T. Krein
Supported by Grainger CEME

ABSTRACT

This study proposed the use of a microgrid with multiple-input converters to achieve ultra-available electric supply. The suggested architecture avoids the single point of failure present in traditional highly reliable power plants by using local generation units to achieve power input diversity. This objective was achieved by paralleling clusters of microsources with multiple-input converters that integrate the various microsource outputs into a common main system bus. Both system-level design and component-level analysis issues were addressed. System-level issues include a systematic design approach that considers cost and availability to be the main characteristics. At a component level, several issues related to the proposed architecture operation and control were analyzed. Multiple-input converter power budget equations were derived and verified through simulations and experiments. Issues in distributed architectures, such as autonomous control, and fault detection and mitigation were also addressed. An autonomous control strategy that relies only on monitoring the main bus voltage was presented. To provide adequate fault detection and mitigation, energy storage location and magnitude were also discussed. This project also analyzed constant-power loads behavior and utilized a passivity-based control technique to derive a control law that stabilizes the converters. The analysis was supported with simulations and experiments.

Alexis Kwasinski was awarded the 2005 Joseph Suozzi INTELEC Fellowship for this work.

Shanshan Liu

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The Development of Power System Load Models Using PMU Data

Shanshan Liu with advisor P. W. Sauer

Supported by the Grainger Foundation

ABSTRACT

The accuracy of system models are essential for system analysis, planning and design in electrical power systems. Having accurate load models can help to understand the dynamic phenomena and design the control system. More important, load representation has a significant impact on system stability analysis.

While scientifically accurate and detailed models have been proposed for generators, lines, transformers and control devices, the same has not occurred for load models because of the random nature of a load composition. We can determine the aggregate load model parameters if the parameters of all separate loads are well known, which is often not available. In the absence of the precise information, one of the most reliable ways to obtain the trustable load model is to apply identification techniques. Now with the installation of PMU, it is possible to get the real-time data of the power system. Since the loads are actually evolving with time, it is more useful and also more challenging to update the load model timely to assure the best performance.

This project is to develop an automatic method for the determination of variable parameters of the dynamic load model under normal operation condition of power system

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Impacts of Wind Power Intermittency On Electrical System Operating Costs

Nicolas Maisonneuve with advisor G. Gross

ABSTRACT

The rapid increase of wind power capacity over the past ten years has benefited tremendously from the technology developments that resulted in significantly reducing the capital investment costs. In addition, with increasing concern about climate change, several countries have adopted policies that foster the use of renewable energy sources so as to reduce CO_2 emissions. Several jurisdictions around the world have specified ambitious targets of the fraction of capacity to come from renewable resources, thereby further stimulating the investment in wind. As a result, wind is the fastest growing source of new capacity for electricity. As the fraction of wind resources becomes larger, the solution of some of the challenging issues in the integration of these resources becomes more pressing. One key issue is the wide variability and difficulty in predictability of wind energy. The intermittent nature of wind and the attendant lack of dispatchability present major difficulties to system operators. In order to operate the system securely, operators must take steps that result in additional operating costs. Such costs have been quantified and analyzed in a number of wind integration studies indicating that these costs become pronounced as the penetration of wind energy approaches the 20% level of the total installed capacity of a system. We are focusing our analysis on developing an improved understanding of the nature of these costs by investigating the impacts of wind integration in a production costing framework. Specifically, we are investigating the modelling of the intermittency impacts and the manner in which they effect the unit commitment schedules. The objective is to construct a practical procedure to explicitly represent the uncertainty in wind regimes in areas with wind farms.

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Data-Driven Power Systems Analysis

Linda Monge-Guerrero with advisor Pete Sauer
Supported by the Grainger Endowments and The University of Puerto Rico

ABSTRACT

We focus on the application of time-synchronized phasor measurements in power systems dynamic modeling and voltage stability analysis. These time-synchronized phasor measurements are currently available from phasor measurement units (PMUs). PMUs being a fairly new technology, there has not been a significant amount of work on the applications of PMUs data for voltage stability analysis, much of which is solely based on static analysis of the system. In this work, we aim to perform voltage stability studies by using equivalent dynamic models of the system obtained from PMUs data. First, a method is developed to simplify the model of a large power system network connected to a load bus into a simple equivalent dynamic model. This simplified model consists of a single generator, which is modeled using the synchronous generator classical model, and a single lossless transmission line connected behind the load bus. The model parameters are estimated using the PMU data available at the load bus and the Gauss-Newton method to solve nonlinear least-squares problems. Next, possible applications of the equivalent dynamic models for voltage stability analysis, such as small signal stability, will be studied.

Brett M. Nee

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Integration of Filter Elements in Electric Drives

Brett Nee with advisor P.L. Chapman

Supported by the
National Science Foundation
and
Grainger Center for Electric Machinery and Electromechanics

ABSTRACT

Electric machines are a part of our everyday lives, often taken for granted, and consume sixty percent of our nation's electricity. Most, electric machines in US and the world are fractional-horsepower, single-phase induction motors. They are widely used for their reliability, mature manufacturing process, low cost, and nearly speed-independent torque. However, the single-phase machine has a significant flaw, low efficiency. The efficiency can be improved if the single-phase machines are replaced equally reliable and fundamentally more efficient three-phase (polyphase) electric machines. However, the voltage source in the fractional horsepower applications is single-phase. As a result, a power conversion process is needed for the polyphase machine operation. Conventionally, this process is a series string of power electronic converters, each focusing on an individual stage's function, such as regulating an output voltage, reference current, or speed.

The research conducted focused on a system level design that considered all attributes, electrical and mechanical. The design resulted in an integrated drive that utilizes the beneficial characteristics in each power transfer stage, which increases reliability and energy savings. Research demonstrated the feasibility of using the electric machine's magnetic steel as an input inductor for an electric drive front-end circuits. In addition, the machine's mechanical characteristics were used as a power filtering element. This was achieved by controlling machine torque such that it contained the same harmonic content as the desired frequency to be filtered. The resulting machine control technique increases the drive lifetime by placing the filtering burden on a mechanical dynamics of the rotor. The control technique was implemented in simulation on a permanent magnet synchronous machine (PMSM) and on an induction machine. The simulation results were verified with experimentally with an induction motor drive system. The integrated drive concept along with experimental result is presented in the dissertation "Integration of Filter Elements in Electric Drives," by Brett M. Nee.

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Management of Uncertainty in Supply Contract Auctions

Matias Negrete-Pincetic with advisor G. Gross

ABSTRACT

Uncertainty management becomes a key challenge in the restructured electricity industry as the implementation of market processes increases the sources of uncertainty beyond those faced in the former vertically integrated industry. We focus on the assessment and management of uncertainty in the area of contracting for short- and mid-term supply contracts. Such contracts are drawn up with the successful sellers in an auction held to determine the lowest priced supplies to meet the requirements of various classes of load. The essential issues in the auction design are the product definition – the way in which the load is going to be categorized and what the basic unitary product is – and the auction format – the way in which the sellers and the buyers are brought together and the method to clear the underlying product. The primary focus of the analysis is the auction design product definition issues and their impacts on the resulting outcomes. The high prices attained in the 2006 Illinois Electricity Auction reflect the impacts of shifting uncertainty from the distribution companies to the sellers of the needed electricity supply. We assess the impacts and provide some insights we obtain to formulate an improved uncertainty management design in short- and mid-term electricity supply auctions.

Rajesh Nelli

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Impacts of Demand Response Resources on Scheduling and Prices in Day-Ahead Electricity Markets

Rajesh Nelli with advisor G. Gross

ABSTRACT

We consider the explicit representation of demand-side resources as participants in the day-ahead electricity markets and assess their impacts on scheduling and prices. These resources offer to reduce their loads and compete side-by-side with the supply-side resources in the hourly auctions in the day-ahead markets for energy and capacity-based ancillary services. We refer to these demand-side market participants as demand response resources (*DRR*s). We use the unit commitment problem as the vehicle for our study and evaluate the changes in the operating schedules of the supply-side resources and the resulting prices. In the study, we assess the load recovery effects that accompany the load curtailment that *DRR*s provide. We use a mixed integer programming solver to explicitly represent the integral nature of the decision variables involved in determining the optimal schedules for next day system operations. We study the solutions of the unit commitment problem to develop appropriate insights into the impacts of *DRR*s on the prices and quantities of *MWh* of energy and *MW* of capacity-based ancillary services in the hourly auctions for the next day. The testing is performed on a number of systems, including a test system with 24 supply-side resources, to quantify the role of the *DRR*s in the joint electricity markets for energy and capacity-based ancillary services.

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Biomechanical Energy Conversion Technology

Penglin Niu with advisor P. L. Chapman

Supported by the Office of Navy Research

ABSTRACT

Traditionally, mobile electronic devices have the problem of changing batteries or recharging batteries often. This is sometimes troublesome, especially for military field operations. One possible solution is to convert the wasted biomechanical energy, the human body movement energy to the useful electrical energy for the electronic devices. This will require both high efficiency and low physical influence on the human movement. In this research, we have evaluated actuation methods, including magnetic, piezoelectric, electrostatic, and electrical polymers for various motions in terms of energy, power, mass, and cost. We also discuss the practical issues associated with each, especially in terms of the power electronics required to connect the biomechanical sources to useful loads.

Currently, we are working on three potential human motions for energy harvesting and design of one energy harvesting device for each motion. Arm swing, horizontal foot movement, and up-down center of gravity movement during walking are analyzed for energy harvesting. Given commonality among the three motions, a general linear moving coil magnetic generator model is proposed. Based on a linear motor finite-element model, prototype devices are designed and built for each motion to match their biomechanical characteristics. Based on the testing of the prototype devices, second stage devices have been built for better mechanical and electrical performance. A self-powered power electronic conditioning and filtering system with high efficiency is designed and built for the charging of the battery from the generator. In the future work, the relationships between the human motions and operations of the generators will be analyzed, and the generators for each motion will be optimized based on these relationships.

Tim O'Connell

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Boundary-Based Field Analysis of Electromechanical Systems

Timothy C. O'Connell with advisor P. T. Krein

ABSTRACT

Boundary-based field analysis methods for electromechanical systems are examined as an alternative to the well-known domain-based finite element analysis (FEA). Boundary methods are well-suited to electric machines where the majority of the important force-generating electromechanical interaction occurs in the air gap close to its interface with the rotor. Thus, boundary methods may have benefits in both accuracy and computational efficiency since they can focus computational resources on the most important regions.

Work is being conducted to apply the boundary element method (BEM) to three-dimensional (3D) problems. BEM is a numerical solution procedure utilizing an integral equation formulation of a system's governing differential equations. This is in contrast to FEA, which solves the differential form of the system equations. As a first step a BEM analysis of a two-dimensional (2D) electromechanical actuator has been successfully carried out. This preliminary study verifies that the 2D BEM solution tracks both experimental data and a known idealized analytical solution. The current work aims to implement a 3D BEM electromechanical model capable of modeling eddy currents. Experiments using a linear induction motor with various rotor arrangements are planned to verify the theory.

Grant Pitel

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High Performance Dc-Dc Converters

Grant Pitel with advisor P. T. Krein
Supported by the Grainger Endowments

ABSTRACT

High-performance power electronics are essential components in the microelectronics industry. They must deliver clean voltage in the presence of fast load steps, maintain low cost, and achieve high efficiency. Limits in IC fabrication have spawned processors that run at low voltages and use multiple cores and on-board power management in order to improve instructions per Watt. These design choices have greatly stressed the capabilities of power electronics. In my research I explore the fundamental performance limits in power processing and propose digital control and topology strategies that will overcome these challenges.

A common problem with high-performance large-signal and optimal controllers is that they need knowledge about attached loads. The best dc-dc converter performance occurs only when the controller has complete knowledge of its components and the load—the latter being the more difficult to obtain.

I am investing online load identification, a process where a digital controller can find load values in real-time and in a way that does not drastically affect output voltage. With this knowledge a dc-dc converter can achieve performance that approaches its theoretical limit.

Hector Pulgar

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Wide Area Voltage Control

Hector Pulgar with advisor P. W. Sauer
Supported by Fulbright Fellowship

ABSTRACT

Based on current power systems' stress and the recent blackouts experienced in several systems around the world, there is a compelling need to operate power systems adequately improving their transfer capability and avoiding collapse. The appearance of new devices, e.g., phasor measurement units and flexible AC transmission systems, allows us to have better monitoring and control of the system. New analysis and control can be done. As a matter of fact, voltage control can be coordinated over the whole system by a wide area control while the available transfer capability and the resources for voltage control are optimized. Keeping this goal, a literature review of the remedial action for increasing the system transfer capability under emergency condition has been done. The importance of time dependence of remedial actions, FACTS modeling, techniques for location of reactive compensators, load shedding and tap blocking have been studied.

Liyan Qu

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Reduction of Dynamic Nonlinear Models of Magnetic Devices

Liyan Qu with advisor P. L. Chapman

ABSTRACT

Nonlinear model order reduction (MOR) methods for extracting low-order, dynamic models of nonlinear magnetic devices from a high-order physics-based (finite element) model are proposed. These methods use the piecewise linear approach, with the linear MOR methods. They enable physics-based models to be implemented without heuristic assumptions or excessive computation. These methods are demonstrated with an example inductor model and verified experimentally. Simulation results show that the original, nonlinear high-order system is well represented by a piecewise set of connected low-order, linear systems. Synthesis of these methods can be fully automated so the end user can rapidly model new devices without repeating sophisticated mathematics. This work provides a foundation for modeling more complicated magnetic devices, such as multiphase coupled inductors, actuators, and machines.

Brian Raczkowski

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Ensuring Survival of Equilibrium after Any Single Line Outage

Brian C. Raczkowski with advisor P. W. Sauer
Supported by the Grainger Endowments

ABSTRACT

For a given power system network, many lines contribute to the goal of delivering power from point A to point B - some more important than others. There exists the challenge of identifying the lines that need to be upgraded to ensure the existence of an equilibrium condition after any single line outage. The concepts of Static Transfer Stability Limits (STSLs) and Transfer Loss Stability Limits (TLSL) have a strong relation in minimum cutsets of lines. The Line Outage Loss Condition (LOLC) arise from making a discrete event of a line outage into a continuous set of events. These ideas help reveal more information about the system as it approaches static collapse. A method based on the LOLC is proposed for detecting the limiting lines. This method recommends the amount of change in line impedance of the limiting lines to avoid static collapse from line outages. Multiple power system models are analyzed to experimentally support the conjecture and the method.

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Load Frequency Control Using Plug-in Hybrid Electric Vehicles

Renata A. Revelo with advisor Thomas J. Overbye

Supported by PSERC

ABSTRACT

Plug-in Hybrid Electric Vehicles (PHEVs) are emerging as the answer to many questions in Automotive Technology, Clean Energy advancements and potentially Power Systems. With their grid-connection capability, it has been stated that PHEVs will be able to perform different grid operations to the advantage of customers and energy entities. One of the possible grid operations is regulation in Power Systems otherwise known as Automatic Generation Control (AGC). Regulation is an ancillary service managed by a Balancing Authority (BA) or an Independent System Operator (ISO) used to maintain the system frequency by matching generation to load demand. A control system is used to maintain the Area Control Error (ACE) signal nearly at zero. PHEVs could be advantageous for load frequency control because they have the ability to respond in real time to power commands from the BA or ISO. In addition, only a small number of vehicles are necessary for this operation. PHEVs could also be used as additional load to provide valley-filling during off-peak conditions. This, in turn would allow the system to accommodate more non-dispatchable generation such as wind.

Currently, a Load-Frequency Control model is being developed using three different battery types: Lithium Ion, Nickel Metal Hydride and Lead Acid. These batteries are most used presently for PHEVs. This model will help determine the impact that PHEVs could have on Load-Frequency Control. The model is being developed in MATLAB/SIMULINK.

Katherine Rogers

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Application of D-FACTS Devices for Increasing Transmission Capacity

Katherine Rogers with advisor T.J. Overbye

Supported by the Trustworthy Cyber Infrastructure for the Power Grid
and the Power Systems Engineering Research Center

ABSTRACT

Distributed Flexible AC Transmission System (D-FACTS) devices can be placed on transmission lines and used to effectively change line impedances and thus control real or reactive power flow. They are an improvement over earlier FACTS devices since they are small enough to attach directly to the transmission line and are powered from the line itself. The distributed nature of D-FACTS devices allows devices to be deployed over a period of time corresponding to demand growth. Earlier FACTS devices tend to be large, expensive, and difficult to install. The improved cost of D-FACTS devices may make implementation more practical, and potentially beneficial, for public power utilities; thus, they seem to be a better candidate for wide scale deployment than their predecessors. Some of the power electronics work to develop these devices has been done at Georgia Tech by Prof. D. Divan.

In examining the effects of changing line impedance on the power grid, there are many issues to be researched and tested. Currently, this project is investigating the effect of D-FACTS devices on real power losses in a study system. Since reduction of losses can lead to more economical operation of a power system, it is crucial to understand the impact these devices could have on system losses. Examining where in the system more losses occur and understanding how those losses are affected by the changing the line impedances can help illustrate which lines, if any, are better choices for installing these devices. Additionally, communication and control of FACTS devices are likely to be deciding factors for whether widespread deployment would be feasible in practice. Implementation without a secure communication system to control the devices could have negative consequences, thus making it unacceptable to use D-FACTS technology.

Pablo Ariel Ruiz

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Pablo Ariel Ruiz with advisor P. W. Sauer

Supported by a Roberto Rocca Fellowship, Grainger Endowments and AREVA T&D.

ABSTRACTS

Uncertainty Management in the Unit Commitment Problem

Multi-stage decision making, a fundamental tenet of stochastic programming, resonates well with electricity markets. The day-ahead market, used to commit the generators, bears uncertainty in the power demand and physical conditions of the generators and transmission lines. The situation becomes less uncertain in the real-time market, where the dispatch is decided. Although traditional approaches such as operating reserve requirements have been effectively employed to ensure reliable system operations, the incorporation of stochastic methods offer the potential for superior solutions. In this project we propose a general approach for uncertainty management in the unit commitment problem by combining stochastic methods with reserve requirements. Numerical results show that a proper amount of reserve requirement in a stochastic formulation leads to superior unit commitment policies.

Reserve Valuation in Power Systems

Operating reserve is idle capacity connected to the system with the purpose of ensuring reliable system operations in the case of equipment outages and unexpected load variations. The reserve has an economic value since it prevents load shedding. In several electricity markets, reserve demand functions have been implemented to take into account the value of reserve in the market clearing process. These often take the form of a step-down function at the reserve requirement level, and as such they may not appropriately represent the reserve value. The value of spinning reserve is impacted by the reliability and dynamic characteristics of system components, the system operation policies, and the economic aspects such as the risk preferences of the demand. The objective of this project is to compute the reserve value explicitly taking into account all these aspects. The value of reserve is used to build reserve demand functions for electricity markets and to obtain improved reserve requirements for vertically integrated utilities. Numerical results show that the demand functions constructed satisfy the usual reliability criteria.

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Automated Power Distribution

Sean Safavinejad with advisor Peter Sauer
Supported by Grainger Foundation and ECE Department

ABSTRACT

Advanced distribution automation is a revolutionary approach to managing and controlling distribution systems. It achieves a fully controllable and automated distribution system including the integration of distributed resources to optimize system performance. Designing and operating the distribution system efficiently and economically requires distribution engineers to perform various analytical studies frequently. This project is currently studying automated analysis of such distribution systems.

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Degradation Mitigation of Ferroelectric Electrodes

Jonathan Sander with advisor P.L. Chapman and Charles Marsh

Supported by U.S. Army Corps of Engineers CERL

ABSTRACT

Ferroelectric electrodes provide a promising new means of high-density electron current emission for use in a variety of applications including X-ray devices and lasers. Application of a high voltage signal induces breakdown on the surface of the crystals yielding electron beams with currents in excess of 0.2A/cm^2. Unfortunately, a serious limitation of the devices is their short lifespan due to surface degradation and pitting. It is believed that plasma formed on the surface of the crystal strips atoms off of the crystal face in an effort to sustain its discharge. Also, charge imbalance as a result of electron emission may cause heavy ions in the plasma to impact the surface at high velocities, further exacerbating the degradation effect. This project aims to address these issues by offering alternative means for plasma formation while still maintaining the high current densities as well as investigating the addition of sacrificial electrodes to minimize sputtering from ion bombardment.

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Harvesting Walking Energy for Mobile Electronics

Arash Sayyah with advisor P.L. Chapman

Supported by the National Science Foundation

ABSTRACT

The growing use of portable electronic devices, such as cellular phones, personal digital assistants, music players, and so forth, has caused increasing demand for mobile power delivery. Power is a limiting factor in the use of mobile devices, which is currently served mainly by lithium-ion batteries that are nearing their practical limits. By harvesting energy normally wasted from ordinary human activity, this problem may be alleviated. So far researchers in the field have concentrated on putting devices in the shoe. Due to almost no mechanical work (force times distance) on a hard surface under normal circumstances, such "heel-strike" devices have permitted only small levels of electrical energy generation (10 mW to 20 mW). Although one can make the shoe compliant so that the foot moves a small distance, this is problematic because increasing compliance leads to declining maneuverability and stability. Although considerable effort has done in this field, the small magnitude of the mechanical energy source still remains a limitation.

In prior works, it has been shown that magnetic generators are likely to have the highest power output, showed significantly more power than heel-strike devices, but was inefficient and heavy due to the complicated mechanical apparatus. Small electric generators, connected to loads through sophisticated power electronics, would provide an alternative power source. The project seeks to minimize the parasitic weight of such a generating device while also providing electrical power storage and utilization. In addition, the effort would seek to optimize the effects of the other human loading such as carrying efficiency.

Pradeep Shenoy

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Digital Control of Power Electronics with Field Programmable Gate Arrays

Pradeep Shenoy with advisor Phil Krein

Supported by the National Science Foundation under grant ECS 06-21643

ABSTRACT

The current focus on this research is on implementing digital control strategies in power electronics using a field programmable gate array (FPGA). FPGAs are programmable logic devices that can perform a number of functions needed for digital control much faster than a digital signal processor (DSP). This approach opens up new options for digital control and allows us to reexamine existing control paradigms. The goal of this research is to lay the groundwork for implementing nonlinear, large signal digital control techniques that are implemented in the time domain.

The applications of this research include almost any digitally controlled power electronic device. This summer research will be conducted on digital control of matrix inverters at Tsinghua University in Beijing, China. This project is conducted through the National Science Foundation's East Asia and Pacific Summer Institutes program. This program aims to provide US graduate students with collaborative research opportunities at some of the top universities in East Asia, exposure to the host country's science policies and infrastructure, and experience in the local language, culture, and customs.

Viboon Sithimolada

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Power Distribution System for Large Data Centers: Design Challenges

Viboon Sithimolada with advisor G. Gross

ABSTRACT

Today's large data center facilities, such as server farms and supercomputer centers, constitute about 1.2% of the total electricity load in the U.S. and represent some of the most highly energy-intensive and fastest growing loads. The National Center for Supercomputer Application (NCSA) on the UIUC campus is planning to install a peta-scale supercomputer center, which will go online in 2011. We investigate the supply of electricity to this installation in this research project. The new center will be the single largest electrical load on campus both in terms of demand and energy and its supply presents multiple challenges to meeting the load requirements in a reliable and cost-effective manner. We are constructing a detailed steady-state power flow model of the UIUC campus electricity system to assess the transfer capability issues in the network and to perform a thorough analysis of the possible ways to feed the center load. Our study will also investigate the potential application of DC distribution and generation for high power quality and efficiency of the supply to such a facility.

Zeb Tate

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Current Research Topics:

- Event detection based on phasor measurement unit (PMU) data
- Rapid visualization of power system information using graphics processing unit (GPU) programming techniques
- Development of interactive educational materials for K-12 education

Line Outage Detection with Phasor Measurement Units

Zeb Tate with Advisor T. Overbye

Supported by a NSF Graduate Research Fellowship and the Trustworthy Cyber Infrastructure for the Power Grid project

ABSTRACT

The deployment of phasor measurement units (PMUs) throughout the power grid has increased substantially in recent years, and this growth is expected to continue. With these new measurement devices, new techniques must be developed to take advantage of the wealth of information that they provide. My work focuses on how the voltage and current phasor angles obtained from these PMUs can be used to increase the wide-area situational awareness of grid operators through improved processing and presentation techniques. Using PMU data to detect single line outages on both small- and large-sized power systems has already been demonstrated, and we are continuing to investigate the applicability of these methods in detecting other event types, e.g., generator outages and simultaneous line outages. In addition, we are investigating how utilizing graphical processing units (GPUs) can significantly improve the performance of power system visualizations and allow for direct visualization of PMU data.

Gui Wang

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Resource Adequacy Issues in the Competitive Electricity Environment

Gui Wang with advisor G. Gross

ABSTRACT

Adequacy is "the ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements." In competitive electricity markets, individual market participants rather than the traditional vertically-integrated utilities build and maintain generating capacity to meet the adequacy requirements. Many studies indicate the inability to maintain adequate capacity levels in the energy and ancillary services markets in operation. The generator revenues from these markets are insufficient to recover the fixed capacity costs incurred with the investment to add new capacity. To provide incentives to build new capacity and retain existing capacity, different resource adequacy designs have been implemented in various jurisdictions. However there is considerable controversy on the efficiency and effectiveness of these mechanisms. Our objective is to develop a thorough understanding of the resource adequacy needs and formulate the design of market mechanisms to meet the identified needs.

Piotr Wiczkowski

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Wind Powered Electrical Systems – Highway Rest Areas and Weigh Stations and Team Section Buildings

Piotr Wiczkowski with advisor P.L. Chapman

Supported by the Illinois Department of Transportation

ABSTRACT

The Illinois Department of Transportation (IDOT) has expressed interest in supplying many of their sites with clean renewable wind energy. These sites include all of their rest areas, weigh stations, and team section buildings operated by IDOT within Illinois. For every of the more than 75 sites historical minute-by-minute data is being analyzed and compared with wind turbines available on the market to maximize potential power output. The project also includes a financial analysis that will help the IDOT come to final decisions on an individual site by site basis.

Leilei Xiong

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Visualizing Market Power in Real-Time Electric Power Systems

Leilei Xiong with advisor T. J. Overbye

Supported by the Consortium for Electric Reliability Technology Solutions

ABSTRACT

Identifying the abuse of market power by generating firms in deregulated electricity markets is frequently difficult, because the true costs of generation have become private information, which are not disclosed to market operators except by special request. Rapid identification of market power abuse is increasingly important as government oversight of the market has been drastically reduced. The ability to visualize market power will aid in spotting trends in abuse of market power, and will facilitate an understanding of the complex dynamics of the deregulated energy market. Effective visualization tools will be developed to communicate the scale and severity of abuses to policymakers and to the public.

Rodney Yeu

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Fast Post-Contingency Eigenvalue Calculation

Rodney Yeu with adviser P. W. Sauer
Supported by Grainger Endowments

ABSTRACT

Dynamic security assessment (DSA) is an analysis of a power system done to determine if the system can withstand contingencies or certain probable disturbances and operate in a satisfactory manner. A part of this assessment is the small signal stability assessment of a power system that is traditionally done by looking at the eigenvalues of a linearized system. The eigenvalues of the power system can move from the left hand side to the right hand side of the complex plane after a contingency. This would indicate that the system is unstable and that corrective measures need to be used to stabilize the system.

Eigenvalue analysis is a very helpful tool in determining the stability of a power system. However, it is computationally burdensome to calculate the eigenvalues for all the considered contingencies and cannot be done online. The current research is looking to develop a fast method to compute the eigenvalues of a power system after line outages. Initial work is investigating the use of a decoupled system that separates the machines from the network.

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. These laboratories have generated wide interest.

The Grainger Power Engineering Software Laboratory is located near the office areas on the third floor of Everitt Laboratory. The Laboratory has eleven 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. Software is based on Windows XP. Some of the commercial software packages currently in use include:

Mathematica (an advanced symbolic mathematics package)
Matlab and Simulink
Mathcad
PSS/E (Power Technologies Inc. Software Package)
RISKSYM (Henwood package for energy market analysis)
PowerWorld
Power System Tool Box (PST Version 2.0)
Dymola (general-purpose simulation environment with hierarchy)
acslXtreme (general-purpose simulation environment)
ANSYS (finite element modeling)
Ansoft Maxwell and RMxprt (finite element modeling specific to electromagnetics)
The software library is being expanded continually.

The **Grainger Electrical Machinery Laboratory** is located on the ground floor of Everitt Laboratory. This facility is primarily for undergraduate teaching, and is used for ECE 431, ECE 469, many ECE 445 projects, and student projects including the Future Energy Challenge. Ten self-contained machinery workstations are available. Each has an integral horsepower machine set with a servo-based dynamometer. Instrumentation includes digital wattmeters, oscilloscope, speed and torque displays, and other electronic support instruments. 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 units, capacitors, SCR circuits, 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 225 kVA three-phase supply and a 50 kW dc rectifier bank.

The **Advanced Power Applications Laboratory** is adjacent to the Grainger Electrical Machinery Laboratory. This laboratory serves as a general research facility for all hardware aspects of power electronics, machines, and power systems. The laboratory shares motor test sets with the Machinery Lab, with an additional precision dynamometer for more advanced studies. Additional equipment is available for the study of harmonic effects, high-performance switching converters, and digitally-controlled converters and drives. Computers are available throughout the laboratory for automation of experiments using LabView, Matlab, and other software environments. The Simulink Real-Time Toolbox is an important component. Additional laboratory space is available on the third floor of Everitt for low-power experiments.

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