UILU-ENG-99-2501

TWENTIETH ANNUAL REPORT OF THE POWER AFFILIATES PROGRAM

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PAP-TR-99-1

May 1999

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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 for the calendar year 1998. 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. There are fourteen active affiliates associated with the PAP. They are:

Ameren - UE
Amoco Oil Company
Burns & McDonnell
Central Illinois Light Company
Cinergy Corp.
City Water, Light & Power
ComEd
Electrical Manufacturing & Coil Winding Association, Inc.
Illinois Power Company
MidAmerican Energy
PowerWorld Corporation
Rockwell Collins
S&C Electric Company
Sargent & Lundy

1998 was an active year for the PAP and the highlights are covered in this report. We acknowledge the valuable support of the Affiliates and are most thankful to these companies for their continued support.

George Gross
Stan Helm
Phil Krein
Tom Overbye
M. A. Pai
Pete Sauer
Bob Turnbull

1. INTRODUCTION AND SUMMARY

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

- bring focus to the power and energy systems area;
- provide financial assistance to students studying electric power engineering;
- increase university-industry 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 1998 under the PAP umbrella clearly were in support of these objectives. The program is described in considerable detail in Reference [1].

Throughout the past twenty years, the Power Affiliates Program has maintained a stable base during times of rapid change. 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. A financial statement for the calendar year 1998 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 an 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 1998 calendar year. Section 6 provides a brief summary of research projects that are funded by various sources. Section 7 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 8.

2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 1998 was prepared from a detailed University statement as of December 31, 1998, Reference [2].

Income carried over from the calendar year 1997	$27,153.
Total income during calendar year 1998	48,966.
Total available income during calendar year 1998	$76,119.

Expenditure	Expenditure Amount
Personnel and Services	$49.909.
Materials/Supplies/Equipment	13,090.
Transportation/Travel	7,653.
Total expenditures	$70,652.

Summary

Amount of funds available during calendar year 1998	$76,119.
Amount of expenses during calendar year 1998	-70,652.
Balance as of December 31, 1998	$5,467.

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 Reference [3]. All M.S.E.E. students are required to complete a minimum of 8 units (32 credit hours) 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 Reference [4].

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

Bioengineering and Acoustics
Circuits and Signal Processing
Communication and Control
Computational Science and Engineering
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 eight 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 1998 - 1999 academic year together with their general interests are:

G. Gross	(power system economics, planning and operations; electric regulatory policy; industry restructuring; competitive market mechanisms)
M. S. Helm, Emeritus	(power system analysis)
P. T. Krein	(power electronics, machines, electrostatics)
T. J. Overbye	(dynamics, stability and operations 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)
R. J. Turnbull	(energy and conversion technology, sensors)

A detailed summary of each faculty member's research activities in 1998 is given in [5].

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 1998-1999 those courses were

ECE 330	Power Circuits and Electromechanics
ECE 333	Electric Machinery (with laboratory)
ECE 336	Advanced Electromechanical Energy Conversion
ECE 364	Power Electronics
ECE 369	Power Electronics Laboratory
ECE 371GG	Engineering Decision Techniques
ECE 371HEV	Hybrid and Electric Automotive Systems
ECE 376	Power System Analysis I
ECE 378	Power System Analysis II
ECE 468	Modeling and Control of Electromechanical Systems
ECE 473	Operation and Control of Power Systems
ECE 476	Dynamics and Stability of Power Systems
ECE 488	Electricity Resource Planning
ECE 490	Power and Energy Systems Area Seminar
ECE 497PWR	Power System Modeling and Analysis

The three-hundred level courses are advanced undergraduate or beginning graduate courses, while the four-hundred level courses are graduate. Of these courses, ECE336, ECE468 and ECE488 were not taught during the 1998-1999 academic year. The Power and Energy Systems Area Committee continuously evaluates each course outline for possible revision in future semesters. A brief description of each of these courses, together with the enrollment of the past year, are included in the next section. In addition, Power Area faculty are active in ECE345, Design Projects. This is the capstone design course for our seniors.

4. COURSES AND ENROLLMENT

As one of eight 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 1998-1999 academic year is also given for each course.

ECE 330 Power Circuits and Electromechanics

ECE 330 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 Foundations of Electric Power by I. R. Cogdell. The total enrollment for the academic year 1998-1999 was 205.

ECE 333 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 Machines by Turan Gonen. The total enrollment for the academic year 1998-1999 was 22.

ECE 336 Advanced Electromechanical Energy Conversion

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. Class notes are used. The course was not offered during the academic year 1998-1999.

ECE 364 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 1998-1999 was 41. The course has been produced on videotape.

ECE 369 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 ECE364. A lab manual by P. Krein is available for the course. The total enrollment for the academic year 1998-1999 was 17.

ECE 371GG Engineering Decision Techniques

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 1998-1999 was 15.

ECE371 HEV/ME 393 DRW Hybrid and Electric Automotive Systems

This four-hour course is a large-team design program directed at advanced vehicle technology and automotive electronics. A multidisciplinary team addresses all the design, implementation, and operating issues for a high-performance practical hybrid automobile. Students learn about physical and engineering considerations in battery systems, electric traction, engines, emission controls, and

other automotive system issues. The total enrollment for the academic year 1998-1999 was approximately 50.

ECE 376 Power System Analysis I

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 in the academic year 1998-1999 was Power System Analysis and Design by Glover and Sarma. The total enrollment for the academic year 1998-1999 was 23.

ECE 378 Power System Analysis II

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 was Power Generation, Operation and Control, 2nd edition, by Wood and Wollenberg. The total enrollment for the academic year 1998-1999 was 7.

Graduate Courses:

ECE 468 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. Internal notes by P. Krein are available for the course. The course was not taught during the 1998-1999 academic year. The course has been produced on video tape.

ECE 473 Operation and Control of Power Systems

The course includes energy control center functions, power system operating states, supervisory control and data acquisition, state estimation, on-line load flow, security assessment, economic dispatch, automatic generation control, optimal power flow, security constrained economic dispatch, multistage rescheduling and equivalents. The course had an enrollment of 8 during the 1998-1999 academic year.

ECE 476 Dynamics and Stability of Power Systems

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 current course text is the book "Power Systems Dynamics and Stability" (Prentice Hall 1998) by P. W. Sauer and M. A. Pai. The course had an enrollment of 11 during the 1998-1999 academic year.

ECE 488 Electricity Resource Planning

This course provides coverage of the basic techniques in electric utility 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. The course was not offered during the 1998-1999 academic year.

ECE 490I Power and Energy Systems Area Seminar

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. The course had an enrollment of 15 for the 1998-1999 academic year.

ECE 497PWR Power System Modeling and Analysis

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. The course uses the notes of George Gross for a text. The course had an enrollment of 8 for the 1998-1999 academic year.

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

1950-1970 Annual Average Power Area Graduates

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

1970-1980 Annual Average Power Area Graduates

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

1980-1990 Annual Average Power Area Graduates

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

1990-1995 Annual Average Power Area Graduates

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

1995-1996 Power Area Graduates

B.S.E.E. - 45
M.S.E.E. - 8
Ph.D. - 1

1996-1997 Power Area Graduates

B.S.E.E. - 43
M.S.E.E. - 9
Ph.D. - 2

1997-1998 Power Area Graduates

B.S.E.E. - 28
M.S.E.E. - 6
Ph.D. - 3

1998-1999 Power Area Graduates

B.S.E.E. - 30
M.S.E.E. - 12
Ph.D. - 3

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 1998. The major events are listed below:

- IEEE Power Engineering Society 1998 Winter Meeting
  - Pete Sauer chaired the working group on Dynamic Security Assessment.
  - George Gross chaired the Power System Analysis, Computing and Economics Committee meetings.
  - Tom Overbye attended committee meetings.
- ECE 333 and ECE 378 student class trip to the ComEd control center and S&C Electric
- Engineering Open House
  - ECE333 students presented machinery demonstrations.
- 1998 American Power Conference
  - Stan Helm coordinated the UI participation in the sponsored student, sponsored faculty program.
  - Fifteen students and faculty were sponsored by ABB Power Generation Ventures, Alliant Utilities, Ameren-CIPS, ComEd, Doyen and Associates, Inc., Electric Power Research Institute, MidAmerican Energy, Sargent and Lundy, Soyland Power Cooperative.
  - The faculty was represented by George Gross, Stan Helm and Pete Sauer.
  - George Gross organized and chaired a session at the American Power Conference.
- IEEE Power Electronic Specialists Conference
  - Phil Krein participated in the 1998 conference in Fukuoka, Japan.
- IEEE International Symposium on Circuits and Systems
  - M. A. Pai presented a paper.
- IEEE Power Engineering Society 1998 Summer Meeting
  - Pete Sauer chaired the Working Group on Dynamic Security Assessment.
  - George Gross chaired the Power System Analysis, Computing and Economics Committee meeting.
  - Stan Helm participated in committee meetings.
  - Tom Overbye participated in a panel session on market power analysis.
- IEEE Workshop on Computers in Power Electronics
  - Phil Krein presented a paper and served on a panel session.
- North American Power Symposium (NAPS)
  - Pete Sauer and Trong Nguyen attended; Trong Nguyen presented a paper and Pete Sauer chaired a session.
- IEEE Industry Applications Society Annual Meeting
  - Bob Turnbull became Vice Chair of the Manufacturing Systems Department.

- 1998 Electrical Manufacturers and Coil Winding Association and Conference Exposition
  - Pete Sauer and 11 undergrads participated; two students presented papers.
- Hosted the following guest speakers
  - Mania Pavella, University of Liege, "The SIME Approach To Preventive and Emergency Transient Stability Assessment and Control
  - Pallab Midya, Motorola Corporate Research, "Direct Digital Audio Power Amplifier"
  - F. T. Sparrow and Douglas J. Gotham, Purdue University, "Electric Utility Restructuring: What Is Purdue Doing?"
  - Len Crane, Coilcraft Company, "Trends and Challenges For Surface Mount Power Magnetic Components"
  - Ed Stoneburg, Illinois Power Company, "Deregulation of The Electric Industry"
  - Ludwig Arnold, University of Bremen, "Bifurcation In The Presence of Noise: Concepts and Examples"
  - Alexander J. Flueck, "Illinois Institute of Technology, "Voltage Collapse Contingency Screening"
  - Bob Harbour and Bob Hunzinger, Soyland Power Cooperative, Inc., "Recent Power Disturbances in The Upper Midwest"
  - T. W. Kay, ComEd, "Stability Analysis of MAPP - MAIN 345Kv Interface"
  - Dennis Friend, "ComEd, "The NERC Tagging System"
  - Charles R. Sullivan, "Optimization Techniques For Low-Cost Magnetics In High-Frequency Soft-Switching Power Converters"
  - Stephen Hoffman, ComEd, "Interconnected Operations Services"
  - Ian Hiskens, University of Newcastle, "Analysis of Power System Dynamics Using Trajectory Sensitivities"
- Participated in multi-university seminar exchange over the internet for the following seminars:
  - Ray Zimmerman, Cornell University, "Experimental Testing of Electricity Market Issues"
  - Chris DeMarco, University of Wisconsin-Madison, "Network Structure In Swing Mode Bifurcations"
  - Carlos Murillo-Sanchez, Cornell University, "Thermal Unit Commitment Including Optimal AC Power Flow Constraints"
  - Shu Tao, UIUC, "A Loss Allocation Mechanism For Power System Transactions"
- Presented the following seminars by UIUC faculty and students:
  - Matt Greuel, "An Introduction To Averaging In Modeling Switching Power Converters"
  - Jamie Weber, "Inclusion of Price-Dependent Load Models In The Optimal Power Flow"
  - Matt Greuel, "Modeling of Switching Power Converters Operating In Discontinuous Conduction Mode"
  - George Deltas, Dept. of Economics, UIUC, "A Two-State Approach To Structural Econometric Analysis of First Price Auctions"
  - Richard Muyshondt, "Practical Implementation of Boundary Control For DC-DC Power Conversion"
  - James F. Stubbins, "Copper Alloy Development for Nuclear Applications: From Alloy Design to Fabrication of Component Structures"
  - Shekita Beatty, "Rotor Time Constant Identification Using Field-Oriented Vector Control"
  - Dimitrios Chaniotis, "A Modified GMRES Method for Power Flow and PV Curve Calculations"

- Neil Pearson, Dept. of Finance, UIUC, "Financial Derivatives and Risk Management"
- Cesar Pascual, "Theory and Practice of a Direct Digital Audio Amplifier"
- Jeong Woo Lee, "The Nordic Power Market"
- Santiago Grijalva, "Reactive Power Considerations In Linear ATC Computation"
- Shu Tao, A Transmission Loss Compensation Mechanism In A Multiple-Transaction Network"

- The 1998 Grainger Awards were presented to 20 graduating BS, MS and Ph.D. students in power
- Energy Modeling Forum (EMF)
  - George Gross made presentations at and participated in the meetings of the EMF. The focus of interest is the restructuring in the electricity industry.
- "Topics in Power System Analysis, Operations and Control under Open Assess Transmission" Short Course
  - George Gross directed this short course for training of ComEd technical personnel.
  - George Gross and Pete Sauer were part of the faculty for the course.
- Edison Electric Institute Power System Planning and Operations School, March 1998
  - George Gross is the director of this annual School administered with the support of the Office of Continuing Engineering Education at UIUC; the 1998 School was held in Clearwater Beach, FL.
  - George Gross is part of the faculty of the School.
  - Tom Overbye gave a presentation on the basics of power system operations.
- George Gross organized a series of seminars under the sponsorship of IGPA on the restructuring of electricity in Illinois; the seminars addressed the regulatory policy issues from the customer, utility and regulator points of views.
- George Gross gave a presentation electricity in the ECE 400 Graduate Seminar
- Engineering Strategies for Open Access Transmission Systems
  - George Gross directed and participated in teaching this short course given in Houston, TX in April 1998.
- George Gross was an invited lecturer at the University of Hong Kong in Hong Kong in December 1997 and January 1998.
- George Gross was an invited lecturer at the Symposium of Specialists in Electric Operational and Expansion Planning held in Brazil in May 1998
- George Gross appeared on a "Policy Soundings" audio tape produced by IGPA under the title "Electricity Restructuring in Illinois: how it Affect Us," August 1998
- George Gross was the convenor of the "Electric Utility Deregulation Technical Roundtable" of the joint annual dinner meeting of the Western Society of Engineers and the IEEE Chicago Chapter
- George Gross was named Editor of IEEE Transactions on Power Systems
- M. A. Pai is on the Editorial Board of `Sadhana' Journal of Engineering Sciences of the Indian Academy of Sciences, Bangalore, India

- Prof. D. P. Sen Gupta visited the University of Illinois for three weeks under the Indo-US NSF cooperative science program
- Bob Turnbull is the vice chairman of the Manufacturing Systems Department IEEE Industry Applications Society
- Phil Krein presented a series of seminars at the University of Surrey in England
- The hybrid car was taken to a number of industries and meetings. Talks were given by the participating students.
- M. A. Pai is the Editor for the research monograph series in Power Electronics and Power Systems for Kluwer Publishers
- Phil Krein is Vice President and President-elect of the IEEE Power Electronics Society
- Phil Krein continued activities as a Fulbright Scholar for a year of research in the United Kingdom
- George Gross presented a seminar entitled "The Changing Face of Electricity in Illinois" at the IGPA in October 1998
- CIGRE
  - George Gross is a member of the Executive Committee of the U.S. National Committee of CIGRE with responsibility for strategic planning.
  - George Gross is an Expert Advisor to the U.S. Representation for CIGRE Technical Committee number 39
  - George Gross was appointed Vice Chairman of ACCOPE, the Committee changed with assessing the future publication policies of CIGRE, the international council on high voltage networks.
- Tom Overbye was the featured speaker at the CIGRE Australian Panel 38 Conference in Newcastle, NSW, Australia in October 1998
- Tom Overbye presented a paper at the Hawaiian International Conference on Systems Sciences in January 1998 in Hawaii
- Tom Overbye gave a presentation on power system visualization at the PSERC review meeting held in June in Montreal Canada
- Tom Overbye gave a presentation on how the power grid operates at the DOE National Energy Modeling Conference in Washington DC in March 1998
- Tom Overbye gave a presentation how the power grid operates at the Illinois Electric Council Annual Meeting in Springfield, IL in April 1998
- Tom Overbye gave a presentation on power system visualization at the University of Newcastle, NSW, Australia in October 1998
- T. Overbye gave a presentation on power system visualization and restructuring at the University of Sidney, Sidney, NSW, Australia in November 1998
- T. J. Overbye, "American Public Power Association (APPA) Power System Simulator Development Training," APPA, Washington, DC, May 18-19, 1998

6. RESEARCH FUNDED BY OTHER SOURCES

The Power Affiliates Program is a source of seed money which enables the faculty to obtain support from major funding agencies. The following pages summarize the projects which have been made possible through this growth.

Allocation of Losses in a Transaction-Based System

G. Gross,* S. Tao

Grainger Foundation; Power Affiliates Program

We are studying the allocation of losses as a function of power flows in a transaction-based system. We have recast the power flow problem in a transaction-based system and are studying the issue of allocating losses on the basis of the physical flows that the transactions bring about. The use of appropriate approximations is part of the approach. Extensive tests of the approach are being carried out on systems of varying sizes. The objective is to extend this research to other ancillary service such as reactive power.

Analysis and Evaluation of VAr Support as an Ancillary Service

G. Gross,* S. Tao

Power Engineering Research Center through Cornell University

The unbundling of electricity services has brought about the need to evaluate and quantify the various services. VAr support is one such service. We are developing an analytic basis for the evaluation of the VAr support needs associated with transactions. The objective is to develop a mechanism to allocate the VAr support requirements effectively and equitably among the transactions on the system.

A Simulation Tool for the Analysis and Visualization of Market Power in Electric Power Systems

T. J. Overbye,* P. W. Sauer, G. Gross, Kollin Patten

National Science Foundation, DMI-9760532

Due to the unique nature of electricity markets, market power issues cannot be analyzed like traditional markets. This is chiefly due to the existence of transmission constraints. Present-day models that attempt to analyze market power in electricity markets do not address capacity or transmission issues, do not consider simultaneous transfer capability, do not simulate losses, and do not consider future retail restructuring methods. The goal of this research project is to begin to

address these shortcomings. In particular, a basic prerequisite is the effective representation and analysis of the impact of the transmission system. The ultimate aim of this project is to develop algorithms for the assessment of market power in transmission networks that may include congestion.

Available Transfer Capability of Power Systems

P. W. Sauer,* T. J. Overbye,* M. A. Pai, G. Gross

National Science Foundation, EEC 96-15792

This project examines new approaches to the rapid computation of available transfer capability in electric power systems. It focuses on efficient techniques to simultaneously include thermal, voltage, voltage collapse, and transient stability margin constraints. New approaches to quantify the transmission reliability margin and capacity benefit margin are investigated.

Determination of Available Transfer Capability

G. Gross*

Grainger Foundation; Power Affiliates Program

In a restructured environment, electric utility consumers will eventually choose providers of electrical energy. Hence, there will be greater use of the system for transmission between various players and a much higher level of power flowing through the power grid. This, in turn, will bring about the need to quantify the amount of transmission service that a network can provide. Our research aims to develop a consistent definition of transmission transfer capability and a general set of procedures for its evaluation. We will investigate the information requirements and the computational aspects and will study the use of a real-time information network as a medium for sharing the necessary information among various parties involved in the transmission of electricity.

Development of an Analytical Framework for Dispersed Generation

G. Gross,* Y. Lin

Grainger Foundation; Power Affiliates Program

Increased competition in the electricity supply industry, increasing costs of transmission and distribution upgrades, greater pressures on cleaner environment, higher energy efficiency, and decreasing marginal costs of new and smaller generation technologies are some of the factors that are going to impact on alternatives for adding electricity supplies. The so-called dispersed generation option has associated benefits that are diverse but at the same time may impact negatively on the

system reliability. The principal objective is to formulate a comprehensive analytical framework for dispersed generation within which the economic, technological, environmental, and reliability aspects can be studied.

Direct Digital Class-D Audio Amplifier

P. T. Krein,* C. Pascual

Motorola, Inc.; University of Illinois

Conventional "linear" audio amplifiers have low power efficiency. In modern digital audio systems, amplifiers require digital-to-analog conversion, with the associated noise sensitivities and signal problems. Class-D amplifiers operate by direct pulse-width modulated (PWM) switching, and in principle can be free of power loss. Since Class-D circuits operate by switching, it is feasible to maintain the audio information in digital form right through t the amplifier output. In this project, we explore audio processing to convert from conventional digital formats to PWM. Class-D circuit design methods are being developed to support audiophile performance with very low power loss.

Dynamic Available Transfer Capability Computations

M. A. Pai,* P. W. Sauer, T. Nguyen, I. A. Hiskens (University of New Castle, Australia)

National Science Foundation, ECS98-03055; Grainger Foundation

Stability limits place restrictions on the available transfer capability (ATC) of power systems. Calculation of these limits is therefore very important, but has traditionally been quite difficult. This research proposes an iterative algorithm for determining parameter values, which result in marginal stability of a system. (A system is marginally stable for a particular disturbance if the post-disturbance trajectory lies on the stability boundary.) A knowledge of the critical parameter values allows the dynamic ATC to be determined. The algorithm is based on the Gauss-Newton solution of a nonlinear least-squares problem. This solution process uses trajectory sensitivities. The method has been validated on a small system and is being extended to larger systems.

Dynamic Security Boundary Computations for Inter-area Transfers

M. A. Pai,* T. Nguyen, I. A. Hiskens (University of New Castle, Australia)

National Science Foundation, ECS 95-22547

In this research we apply the trajectory sensitivities to compute the impact of contingencies on inter-area transfers in a multi-area system. Both numerical and analytical sensitivities were used to confirm the accuracy of the latter. Results on a 10-machine system have been completed.

Effective Deployment of Financial Instruments in Competitive Electricity Markets

G. Gross,* S. Tao

Grainger Foundation; Power Affiliates Program

Our focus is on the effective incorporation of financial instruments (options, futures, etc) in the operation of electricity trading. We will investigate certain design and definitional issues in the deployment of financial derivative concepts to electricity markets. Of particular interest is the evaluation of the risk mitigation capabilities provided in these instruments for the trading of electricity and their impacts on the spot markets. We will investigate (1) the salient uniqueness of electricity derivative contracts attributable to the physical power system, (2) the possibility of developing new financial instruments and strategies to accommodate the different risk preferences of various participants in the spot electricity market, and (3) the impact of financial derivatives on various players of the market.

Evaluation of the Automated Interchange Matching System (AIMS)

G. Gross,* Naomi Mwase

Grainger Foundation; Power Affiliates Program

AIMS is a computerized hourly interchange matching system whose goal is to promote the maximum economic savings among all the participating players. This is accomplished by matching of bids to sell and offers to buy so that the sum of the savings for all the participants is maximized. We are evaluating the matching scheme from the point of view of the system, a buyer, and a seller. Our interest is to study the strategic behavior of players in formulating their bids to sell and offers to buy. We are investigating the truth revelation characteristics of the bids/offers, the role of transmission availability and the overall impact on system operations.

Evaluation of the Bilateral - Transaction - Based Electricity Markets

George Gross,* Jeong W. Lee

Grainger Foundation; Power Affiliates Program

We are investigating the structure and functioning of the bilateral-transaction-based electricity markets brought about the restructuring in Norway and Sweden. The objective is to analyze the salient characteristics of the Nord Pool market and to perform a side-by-side comparison with the England and Wales Electricity Pool. The development of a mathematical model representing the market structure and rules governing the operation of the Nord Pool market will be developed. The

study will assess the functioning of the Independent Grid Operator and the critical role of transmission services.

Futurecar Challenge

R. A. White* (Mech. & Indust. Engr.), P. T. Krein,* R. J. Turnbull*

University of Illinois; U.S. Dept. Of Energy, various industrial sponsors

A mid-sized car is being converted to a hybrid gasoline-electric vehicle to try and meet the goals of the "Partnership for a New Generation of Vehicles." These goals are a mid-sized car that gets three times the mileage of present vehicles with performance, space, comfort, and driving ease comparable to today's vehicles. The car will be entered in a competition with 13 other engineering schools to see who has come closest to the goals. The contest will be held in June 1999. This project involves a large number of students.

High Speed Dynamic Simulation Using Krylov Subspace Method

M. A. Pai,* D. Chaniotis

National Science Foundation, ECS 98-03055; Grainger Foundation

The differential-algebraic system of equations of the power system are algebraized using the simultaneous-implicit method. The resulting system of linear equations of the power system are algebraized using the simultaneous-implicit method. The resulting system of linear equations at each time step are solved using the generalized minimal residual (GMRES) method which belongs to the family of iterative solver techniques. In the previous research the use of preconditioners such as the ILU(s) was found to speed up the convergence. Further enhancement in speed-up was obtained by using the preconditioner only when the number of iterations increase. The GMRES method was found to be more robust than other iterative solver algorithms. Proposed improvements include investigating GMRES (m) method where the method is restarted after m iterations. Retention of eigenvector information before restart improves the convergence. Combined with suitable preconditioners we expect the method to be faster than current techniques for dynamic simulation.

Hybrid Electric Vehicle Systems

P. T. Krein,* R. A. White* (Mech. & Indus. Engr.), D. Logue, S. West, J. Cellarius

University of Illinois, various industrial sponsors

(In conjunction with the Department of Mechanical and Industrial Engineering)

A complete hybrid electric car, combining an electric traction system with an engine-generator set, has been built and is now under study in the laboratory and on the highway. The car is designed to meet all performance, safety, and convenience characteristics of standard automobiles, while reducing exhaust emissions by as much as 90% and tripling gas mileage. Objectives are to characterize major subsystems of a practical hybrid car in depth. Tests of efficiency and fuel economy and parametric studies of subsystems have been conducted. Strategies for system operation and control are being tested through simulation and experiments.

Large-Signal Approaches for Control of Switching Power Converters

P. T. Krein,* L. Amaya, R. Muyshondt, M. Greuel

Sandia National Laboratory

Power conversion circuits are large-signal nonlinear networks controlled exclusively through the action of switches. Several new approaches are being developed for power converter control. One approach explains on geometric methods, such as sliding mode control, used successfully in other nonlinear applications. In this boundary control approach, geometric structures in state space are used to control the evolution of converter voltages and currents. Methods such as boundary control offer precise, reliable converter operation with minimum influence by unknown parameters and external noise.

Metering Requirements and Metering Data Applications in Open Access Bulk Electricity Systems

G. Gross,* J. W. Lee

Power Engineering Research Center through Cornell University; Grainger Foundation

The FERC Order No. 888 specified six unbundled ancillary services that may be provided to transmission customers. The NERC has developed a classification of twelve separate interconnected operations services. The unbundling of the services accompanied by the disintegration of the vertical structure of the electricity business have set up new requirements for information acquisition, metering and the communications. This project will examine the communication protocols and the data management aspects of the metering activities.

Multiarea Power Systems Production Costing

G. Gross*

Grainger Foundation; Power Affiliates Program

The most challenging aspects of multiarea studies is to model realistically the loads and resources in each area and to construct computationally efficient schemes for their simulation. Typical applications are to interchange contract evaluation, geographically differentiated marginal costing studies, transmission services pricing, and strategic and resource planning. The multiarea production cost simulation model must correctly take into account the impacts of transmission constraints as well as interconnection operational policies. Our objective is to build a general model to simulate the operation of multiarea power systems under various operational policies, ranging from totally centralized dispatch to decentralized bidding dispatch.

New Methods for Visualization of Large-Scale Power System Data

T. J. Overbye,* Jamie Weber

National Science Foundation, EEC 98-13305

The electric power business is restructuring its institutional arrangements to allow more competition, especially among suppliers of electricity. One of the tools that will be needed by engineers and market practitioners alike will be methods for visualization of common data to ensure that there are no "unintended consequences" due to the decisions made by either party. The overall goal of this research project is to develop innovative methods for visualizing the wealth of data associated with power system network flows, with emphasize on the use of interactive animation techniques.

Nonlinear Induction Motor Control

P. W. Sauer,* Eric Thomas, Eric Cunningham

Power Affiliates Program; Grainger Endowments

This project is investigating new induction motor control strategies using nonlinear observers and controls. The current work is focusing on controlling a standard induction motor to create a torque-speed behavior identical to an internal combustion engine. The control utilizes a mathematical model of both the induction motor and the engine. The results will be tested in a Mechanical Engineering hydraulic test bed.

Power Electronic Building Blocks Interconnected Network

G. Gross,* P. Krein,* D. Logue

SRI International

Conceptually, Power Electronic Building Blocks (PEBBs) are smart power electronic modules that are superior to conventional power devices in that they have increased sensing, protection control and interfacing capability. This research is directed toward development of a conceptual framework for an interconnected network of PEBB devices. The objective is to use the framework for addressing analysis, design and control issues. The University of Illinois' hybrid electric vehicle is intended to be used as a test bed for this framework and other conceptual developments.

Pricing and Costing of Ancillary Services of Power Systems

P. W. Sauer,* T. J. Overbye, G. Gross

Power System Engineering Research Center through Cornell University

This project is investigating ways to evaluate the cost and reasonable price for the "non-energy" services associated with the supply of electricity. The initial focus is on the service of voltage control and reactive power.

Ripple Correlation Control for Power Converters and Motor Drives

P. T. Krein,* R. Turnbull,* J. Locker

Xantrex Technology, Inc.

Ripple correlation control is a new technique that might be unique to power electronic systems. According to this control approach, internal ripple signals in a power converter are correlated with gate drive signals or other internal converter signals. The results provide information about state variables and converter operating points. It is known, for example, that certain correlations can be used to drive a solar power processing converter to its maximum power point. A wide range of applications and related techniques is being explored.

Simulation of the Multinode, Open Access, Same-Time Information System

G. Gross,* Y. Tian

Grainger Foundation; Power Affiliates Programs

A Web-based simulator of the Federal Energy Regulatory Commission mandated Open Access Same-Time Information System (OASIS) network was implemented. The purpose of the simulator is to provide a tool to study the various aspects of an OASIS network, to gain a strong intuitive feel

for its operations, and to train users. For a specified time period, the OASISNET simulator reproduces an OASIS network of multiple nodes using the same communications medium as the actual system, the Internet, and with multiple players using the simulator simultaneously. Salient features of the simulator are its modular architecture, the ability to simulate multinode OASIS network operations, and to accept simultaneous access from remote users through use of client/server technology.

Structure Paradigms for Power System Restructuring

G. Gross*, P. Correia

Grainger Foundation; Power Affiliates Program

The entrenchment of competition, the drive for unbundling of services and products, and the new regulatory decisions are resulting in the development of new structures for power systems. A key consideration in the formulation of new structures is the need to have minimum requirements for coordination to ensure the integrity, reliability, and security of the system. This investigation is focusing on the economic efficiency, engineering/technical considerations/constraints, and critical informational aspects of various structural paradigms.

Structures for Coordination in Power Systems

G. Gross*

Grainger Foundation; Power Affiliates Program

Power pooling among electric utility companies aims at effectively harnessing operating economics and reliability benefits through coordinated interchange of power, energy, and related services. In the existing utility industry structure, the operation of power pools brings about the necessary level of coordination to maintain the integrity of large interconnections. In light of growing competition, the continuation of such pools is difficult. This project examines the structures of existing and proposed power pools. It aims to construct analytical frameworks for such coordinated operations. The work will explore the minimal requirements for coordination to maintain system reliability and security. The frameworks will also be used to assess the economic efficiency of pooling.

Technical Challenges of Restructuring the Electric Power Industry

P. W. Sauer,* T. J. Overbye,* G. Gross*

Electric Power Research Institute through Cornell University

This project is investigating the technical issues associated with the deregulation of the electric utility industry and the resulting competitive market places. The initial focus is on evaluating various "rules of the road" which are being proposed nationwide.

Trajectory Sensitivities of Differential-Algebraic Discrete Systems

M. A. Pai,* I. Hiskens (University of New Castle, Australia)

National Science Foundation, ECS 95-22547; Grainger Foundation

In this study, the previous work on trajectory sensitivities for the differential equations of the post-fault system only has been extended to include the faulted systems as well. Also, the algebraic constraints in the form of network equations and discrete event operations such as tap-changers and relay operations are included. Applications to dynamic available transfer capacity as well as dynamic security assessment calculations were proposed.

Trajectory Sensitivity Analysis of Hybrid Systems

M. A. Pai,* I. A. Hiskens (University of New Castle, Australia)

National Science Foundation, ECS 98-03055

The development of trajectory sensitivity analysis for hybrid systems, such as power systems, is the main focus of this research. Crucial to the analysis the development of jump conditions describing the behavior of sensitivities at discrete events such as switching and state resetting. Sensitivity analysis provides a useful by product along with dynamic simulation and can be used in preventative mode in real time operation of power systems.

Transmission Congestion Management and Pricing

G. Gross,* P. Correia

Ministerio da Ciencia e Tecnologia, Portugal, Fellowship

A number of new transmission organizations has come to be established in the restructured electricity industry. These organizations have implemented different schemes for managing and pricing congestion. We are formulating a set of criteria for use in a comparative analysis to assess the performance of the various schemes. Evaluation of the efficiency of each scheme and the ability

to provide appropriate economic signals for the removal of congestion will be analyzed. The necessary modifications and a set of incentives will be proposed.

Voltage Security Calculations in Power Systems

M. A. Pai,* D. Chaniotis

National Science Foundation, ECS 95-22547; Grainger Foundation

In this research we investigated the use of modified general minimal residual method (GMRES) for power flow calculations. This class of methods is iterative in nature and converges in a finite number of steps. Hence the traditional LU factorization is avoided which is not vectorizable or parallelizable. Even on a serial machine using suitable pre-conditioners and effective use of the system eigenvectors during GMRES iteration, the modified method is comparable in speed to the LU method. Applications to fast computation of the P-V curve were made.

7. 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:

Chaniotis, Dimitrios (M.S.)
Correia, Pedro (Ph.D.)
Dalton, Andrew (M.S.)
Grijalva, Santiago (M.S.)
Klump, Ray (Ph.D.)
Lee, Jeong (Ph.D.)
Lin, Yan (Ph.D.)
Locker, Jonathan (Ph.D.)
Logue, Dan (Ph.D.)
Mak, Frankie (M.S.)
Murphy, Christian (M.S.)
Muyshondt, Richard (Ph.D.)
Mwase, Naomi (M.S.)
Nguyen, Trong (M.S.)
Pascual, Cesar (Ph.D.)
Patten, Kollin (M.S.)
Reinhard, Karl (Ph.D.)
Tao, Shu (Ph.D.)
Thomas, Eric (M.S.)
Troitskaia, Svetlana (M.S.)
Weber, Jamie (M.S.)
West, Sean (M.S.)
Zhu, Yiqing (M.S.)

Dimitrios Chaniotis

Date of Birth:	October 31, 1973
Place of Birth:	Athens, Greece
B.S.:	October 1996, National Technical University of Athens
M.S.:	In progress
Professional Interests:	Power systems, automatic control and computer engineering.

Iterative Solver Techniques In High Speed Calculations of Power Systems

Dimitrios Chaniotis with advisor M. A. Pai

Supported by the National Science Foundation Grant NSF ECS 93-19352

ABSTRACT

The Generalized Minimal Residual (GMRES) method is an alternative way to solve large sparse systems of the form Ax = b. In this research we seek to implement recent modifications/improvements in this technique to the power system problems to improve performance and robustness. We target three areas of application. The first one is the fast computation of P-V curves for normal as well as contingency cases. New pre-conditioners as well as an improvement to current methods have been tested with good results on systems of 4000 buses. The second area under investigation is dynamic simulation which will be helpful in a fast dynamic security assessment (DSA) framework. Finally applications for model reduction of large systems will be.

Pedro Correia

Date of Birth:	July 29, 1969
Place of Birth:	Lisbon, Portugal
B.S.:	July 1993, Instituto Superior Tecnico
M.S.:	May 1996, Instituto Superior Tecnico
Ph.D.:	In progress
Professional Interests:	Power system analysis; competitive electricity markets; system protection.

Analytical Framework for Strategic Bidding In Competitive Electricity Markets

Pedro Correia with advisor G. Gross

Supported by Foundation for Science and Technology
of the Ministry of Science and Technology, Portugal

ABSTRACT

We are constructing an analytical framework that will provide a testbed for policy experiments. The key aspects of the work focus on the incorporation of uncertainty, demand-side bidding, auction rule design and the evaluation of the impacts of long term contracts. The development of a solid analytic foundation will enable the analysis of some important issues in competitive electricity markets.

Andrew C. Dalton

Date of Birth: April 11, 1975

Place of Birth: Philadelphia, PA

B.S.: May 1997, University of Illinois

M.S.: August 1998, University of Illinois

Current Status: Allison Engine Company
Indianapolis, IN

Tailored Control of Induction Motors

Andrew C. Dalton with advisor P. W. Sauer

Supported by the Grainger Foundation and the Power Affiliates Program

ABSTRACT

This project investigated the theoretical and practical aspects of controlling an induction motor such that it responds with the same dynamic and steady-state characteristics as an internal combustion engine. The project was performed in cooperation with the Mechanical Engineering Department, which intends to implement the results on a generic hydraulic test stand. The results include a nonlinear observer to estimate load torque from a full dynamic induction motor model.

Santiago Grijalva

Date of Birth:	November 25, 1970
Place of Birth:	Quito-Ecuador
B.S.:	National Polytechnic University - Ecuador, 1994
M.S.:	In progress
Professional Interest:	Power system energy management systems, real time control of power systems, software algorithms, integrated information systems.

Computation of Available Transfer Capability In Power Systems

Santiago Grijalva with advisor P. W. Sauer

Supported by Fulbright Fellowship and Power Affiliates Program

ABSTRACT

Current computation of Available Transfer Capability (ATC), utilizes a range of algorithms from distribution factors to full AC load flow and transient stability analysis. This project is investigating enhancements to the distribution factor approach by considering errors due to linear projection, reactive power modeling, and data uncertainty. The objective is to produce improved estimates of ATC without considerable increases in computation time. Initial work is focusing on parameter and power flow sensitivities, reactive power flow approximations, and estimation of maximum loadability.

Ray Klump

Date of Birth:	March 31, 1971
Place of Birth:	Berwyn, IL
B.S.:	May 1993, University of Illinois
M.S.:	May 1995, University of Illinois
Ph.D.:	In progress
Professional Interests:	Power systems.

Assessment of Transmission System Capability

Ray Klump with advisor T. J. Overbye

Supported by the Grainger Foundation

ABSTRACT

The increases use of the transmission system that has accompanied the move to open-access operation during the past few years has increased the importance of considering voltage stability and how it limit transfer capability. The amount of power that can be transferred from one region to another is limited not only by the more familiar constraints imposed by equipment thermal ratings, but also by the profound effects that transfers can have on voltage magnitudes and system var reserves. This research aims to develop a methodology for quantifying transfer capability as it is limited by voltage stability and voltage magnitude limitations. The resulting set of tools will measure the proximity of a system to voltage collapse and will assess the effect that power transfers have on this measure, both for the base case and under contingency conditions.

Jeong Lee

Date of Birth:	December 14, 1970
Place of Birth:	Seoul, Korea
B.S.:	1994, Seoul National University, Seoul, Korea
M.S.:	1996, Seoul National University, Seoul, Korea
Ph.D.:	In progress
Professional Interests:	Power system analysis and control, power system communication, Restructuring of electricity company.

Development of a Metering Framework for Unbundled Power Systems

Jeong Lee with advisor G. Gross

Supported by the Grainger Foundation

ABSTRACT

The restructuring of the electricity business is bringing about major changes in the operation of the system. The advent of open access, the unbundling of electricity services, the vertical disintegration of the electric utility industry, the increasing number of wholesale transactions and eventually retail transactions are just some of the visible changes. These changes entail major requirements in metering. This project focuses on the development of a comprehensive framework for metering under unbundling. The scope of the project includes the assessment of information requirements, the evaluation of the measurement and sensoring equipment needs, the formulation of protocols, the design of the data structure and the analysis of the application of metering. The approach is from a systems point of view with an emphasis on the effective collection and storage of required information. The project addresses the power system, communications, measurement and computing aspects.

Yan Lin

Date of Birth:	February 7, 1968
Place of Birth:	Yangon, Myanmar
B.S.:	August 1993, Yangon Institute of Technology
M.S.:	August 1997, Asian Institute of Technology
M.S.:	January 1999, University of Illinois
Professional Interests:	Power systems analysis, economics and planning.

Evaluation of Dispersed Generation Options In Transmission-Constrained Load Pockets of an Interconnected System

Yan Lin with advisor G. Gross

Supported by the Grainger Foundation and Power Affiliates Program

ABSTRACT

This project considers a two-area system with a load pocket problem. The problem concerns a system with a larger area and a smaller area connected by tie lines whose transfer capability is severely limited. The focus of the study is on meeting the markedly higher forecasted load growth of the smaller area. Due to a variety of factors, the expansion of the transmission system is virtually impossible. As such the only practical means of meeting the load growth in the smaller area is by installing additional generating capacity in the area. We developed various expansion plans, whose variable economic aspects are evaluated and compared on a consistent basis. The modeling of the two-area system for performing probabilistic simulation to evaluate the production and marginal energy costs is described. In addition, the representation of photovoltaic (PV) generation is discussed. The set of expansion alternatives constructed makes use of both conventional and dispersed generation (DG) technologies. The key focus of the study is the analysis of the variable aspects of the expansion alternatives. The metrics used are the expected production costs and the short run marginal energy costs over a 10-year planning horizon. The economics of DG are investigated and compared to those of conventional resources. The reference expansion case is constructed using combined-cycle units only. The alternative expansion cases use three types of DG resources - PV, fuel cells, and microturbines. A wide range of sensitivity studies was performed to assess the impacts of several key parameters including load growth, fuel cost, PV penetration, and insolation availability. The results of these studies are summarized and the conclusions reached are discussed.

Jonathan Locker

Date of Birth:	September 14, 1970
Place of Birth:	Peoria, IL
B.S.:	May 1992, Washington University
M.S.:	January 1995, University of Illinois
Ph.D.:	In progress
Professional Interests:	Control systems for industrial applications.

Singular Perturbation Methods Applied to Induction Motor Control

Jonathan Locker with advisor P. T. Krein

Supported by the U.S. Army Construction Engineering Research Laboratory
and the Grainger Endowments

ABSTRACT

Advanced methods such as field-oriented control allow induction motors to be used in high-performance applications where quick position, speed, or torque response are desired. Although their benefits are well-known, many of the methods are difficult to tune or simply perform poorly when applied to high-quality, low-leakage motors. In some cases, this apparent contradiction can limit the use of induction motors for applications requiring both excellent control and high efficiency.

The goal of this project is to examine the induction motor model under a variety of singularity assumptions and to determine suitable control algorithms for each assumption. The algorithms are then to be implemented on a test bench such that we may compare and contrast their actual operating performances.

Daniel Logue

Date of Birth:	July 28, 1970
Place of Birth:	Pana, IL
B.S.:	January 1996, University of Illinois
M.S.:	October 1997, University of Illinois
Ph.D.:	In progress
Professional Interests:	Power electronics and control systems.

The PEBB*NET* Application to the Hybrid Electric Vehicle

Daniel Logue with advisor P. T. Krein

Supported by SRI International

ABSTRACT

The Hybrid Electric Vehicle (HEV) is a collection of highly interactive power electronic based subsystems. Independent control of these subsystems poses many problems in regard to overall system stability and reliability. Each of these power electronic subsystems can be called a Power Electronic Building Block (PEBB) within the PEBB*NET* framework. Under the PEBB*NET* framework, each subsystem would contain a local controller to provide the basic functionality of that subsystem. The entire distributed network of PEBBs (the so called PEBB*NET*) is to be managed by a global PEBB*NET* Coordinator. The Coordinator's job is to manage the subsystems in order to meet the overall system objectives as well as maintain global stability.

Frankie Mak

Date of Birth:	February 2, 1974
Place of Birth:	Hong Kong
B.S.:	May 1997, University of Illinois
M.S.:	In progress
Professional Interests:	Electric power.

Modeling Frequency During Power System Transient

Frankie Mak with advisor P. W. Sauer

Supported by the University of Illinois

ABSTRACT

This project is investigating the various definitions for frequency during power system transients. Using a quasi-steady-state dynamic model of the electrical system the frequency can be defined as nominal plus the time derivation of the "phase angles" of voltages and currents. These are "local" frequencies. In addition, the center-of-inertia speed definition gives a "system" value for frequency. The distribution of power and energy during a unit outage is being examined to determine methods to allocate reimbursement for energy served.

Christian Murphy

Date of Birth:	March 11, 1976
Place of Birth:	Chicago, IL
B.S.:	June 1998, Williams College
M.S.:	In progress
Professional Interests:	Power conversion, control, lighting, devices, low power conversion, Alternative energies, and power storage.

Design and Optimization of DC-AC Converter for A PDP

Christian Murphy with advisor P. T. Krein

Supported by LG Electronics

ABSTRACT

Plasma display panels (PDPs) are a good technology to replace currently bulky television and computer displays with a much thinner flat-panel alternative. A PDP can be modeled as a capacitor driven by a high frequency ac waveform. The majority of energy from each ac voltage pulse remains stored in the PDP. This energy should be recovered, resulting in a significant boost in the ac driver efficiency. We are investigating resonant converter designs for this device in order to maximize its efficiency. To accomplish this three different areas are being investigated. First, the power converter is being modeled using Spice as well as Simulink to determine effective devices, control methodologies, and possible optimizing waveforms. Second, a prototype of the power converter has been built to understand how the models can be realized physically. Third, using off-the-self equipment an example panel's performance is being investigated in lab to determine optimum driving methods.

Richard Muyshondt

Date of Birth:	December 12, 1969
Place of Birth:	San Salvador, El Salvador
B.S.:	May 1992, Texas Tech University
M.S.:	December 1995, Texas Tech University
Ph.D.:	October 1998, University of Illinois
Current Status:	Intel Hillsboro, Oregon

Application and Design of DC-DC Converters With Boundary Control Methodologies

Richard Muyshondt with advisor P. T. Krein

Supported by Sandia National Laboratory and LGE

ABSTRACT

Boundary control is a geometrically based design technique that uses the state trajectories of a dc-to-dc converter to control the state of the active switch in the converter. The purpose of the research being conducted is to perform a deep analysis of boundary control implementation. To accomplish this task, several thrusts in the research are being supported. First, benchmark circuits based on the standard averaging and linearization techniques have been proposed and designed. These circuits will serve as a benchmark for the boundary controlled converters that will server not only to compare performance but also to study similarities and differences between the control techniques. Second, issues such as robustness and sensitivities of boundary controllers are being addressed. To this end, new state estimators and observers as well as dynamic and nonlinear boundaries are being studied. Third, a boundary controller simulator is being developed. This simulator is intended to give the designer a fast and efficient way to simulate simple converter models under boundary control. Finally, a hardware implementation platform based on a commercially available microcontroller has been designed to digitally implement the control functions of the boundary controller. By having this digital platform, a wide array of boundary controllers can be implemented in hardware in a relatively short amount of time.

Naomi Mwase

Date of Birth:	June 3, 1966
Place of Birth:	Ndola, Zambia
B.S.:	January 1988, Polytechnic of the SouthBank, London
M.S.:	In progress
Professional Interests:	Power systems, control systems.

Evaluation of the Automated Interchange Matching System (AIMS)

Naomi Mwase with advisor G. Gross

Supported by the Grainger Fellowship Foundation

ABSTRACT

AIMS (Automated Interchange Matching System) is a computerized hourly interchange matching system whose goal is to promote the maximum economic savings among all the participating players. This is accomplished by matching of bids to sell and offer to buy so that the sum of the savings for all the participants is maximized. We are evaluating the matching scheme from the point of view of the system, a buyer and a seller.

Our interest is to analyze the strategic behavior of sellers and buyers under AIMS. In particular, we are studying the strategies used by players in formulating their bids to sell and offers to buy. We are investigating the truth revelation characteristics of bids/offers, the role of transmission availability, and bottlenecks in the matching of the bids and offers.

Trong Nguyen

Date of Birth:	September 10, 1966
Place of Birth:	Vietnam
B.S.:	December 1997, University of Illinois
M.S.:	In progress
Professional Interests:	Power system stability, control and computation.

Dynamic ATC Computations Using Sensitivity Functions

Trong Nguyen with advisor M. A. Pai

Supported by the National Science Foundation

ABSTRACT

In this research we wish to investigate the use of trajectory sensitivities as a tool to compute dynamic available transfer capabilities. Currently, TEF method is being proposed but its limitations include inability to handle complex models, difficulty in computing controlling u.e.p, etc. The sensitivity approach is independent of modeling complexity. Both parameter and initial condition sensitivities will be investigated for dynamic ATC computation.

Cesar Pascual

Date of Birth:	June 15, 1968
Place of Birth:	Teruel, Spain
B.S.:	December 1992, Polytechnical University of Catalonia
M.S.:	January 1997, University of Illinois
Ph.D.:	In progress
Professional Interests:	Power electronics, control systems, digital signal processing, very large scale integrated circuit design.

All-Digital Audio Amplifier

Cesar Pascual with advisor P. T. Krein

Supported by Motorola

ABSTRACT

Audio amplifiers have traditionally been analog, built upon Class-A, -B or -AB stages. All of these linear amplifiers exhibit relatively low efficiencies, mainly because their power transistors are always in mid-conduction. More recently, some switching amplifiers have overcome the efficiency problem by using Pulse Width Modulation (PWM) and Class-D stages. This allows the power transistors to work either in the on or off state, and increases the efficiency drastically. However, most of these solutions have difficulties with radiation and with offering a reasonably high quality. If the audio source is digital, as it is the trend nowadays, it would seem more logical to generate the PWM signal directly from the digital input, without using and D-to-A or A-to-D conversion. Careful digital signal processing can improve the audio quality, reduce the radiation, and keep the efficiency at its maximum. This project investigates several approaches to the concept of an all-digital audio amplifier.

Kollin Patten

Date of Birth:	November 26, 1973
Place of Birth:	Sterling, IL
B.S.:	May 1997, University of Illinois
M.S.:	December 1998, University of Illinois
Current Status:	PowerWorld Corporation Urbana, IL 61801

Development of Market Power Analysis Methods for Electricity Markets

Kollin Patten with advisor T. J. Overbye

Supported by the Grainger Foundation and the National Science Foundation

ABSTRACT

Due to the unique nature of electricity markets, market power issues cannot be analyzed like traditional markets. This is chiefly due to the existence of transmission constraints. Present-day models that attempt to analyze market power in electricity markets do not directly address capacity or transmission issues, do not consider simultaneous transfer capability, do not simulate losses, and do not consider future retail restructuring methods. The purpose of this research project is to begin to address these shortcomings. In particular, a basic prerequisite is the effective representation and analysis of the impact of the transmission system. The goal of this project is to develop methods for assessing the impact of the transmission system on market power evaluation and to determine improved methods for calculating the maximum allowable transfers through the transmission system.

Karl Reinhard

Date of Birth:	August 18, 1960
Place of Birth:	Camp Hanford, Washington
B.S.:	May 1982, United States Military Academy
M.S.:	May 1992, University of Texas at Austin
Ph.D.	In progress
Professional Interests:	Power and energy systems.

Lieutenant Colonel Karl Reinhard, U.S. Army, with advisor P. W. Sauer

Supported by the U.S. Army

ABSTRACT

Lieutenant Colonel Karl Reinhard is pursuing the Ph.D. degree and will be assigned to the Department of Electrical Engineering and Computer Science at the United State Military Academy. His recent efforts have focused on completing course requirements and preparation for the Ph.D. qualifying exam.

Shu Tao

Date of Birth: March 19, 1969

Place of Birth: Changchun, China

B.S.: July 1992, Tsinghua University

M.S.: July 1995, Tsinghua University

Ph.D.: In progress

Professional Interests: Power system operation and control

Loss Allocation In Multi-Transaction Networks

Shu Tao with advisor G. Gross

Supported by the Grainger Fellowship

ABSTRACT

We have constructed a general framework for the multi-transaction network. Using the framework, we have developed a physical-flow-based approach to allocating transmission losses in a multiple-transaction system. The proposed scheme is based on expressing losses explicitly in terms of all the transactions in the system. An important property of the allocation scheme is its effective capability to deal with counter flows that result in the presence of specific transactions. Extensive numerical testing indicates that the allocation scheme produces loss allocations that are appropriate and that behave in a physically reasonable manner. In addition, we have developed and applied the equivalent loss compensating losses in a multi-transaction network. The procedures are based on the physical-flow allocation of losses among the transactions. The proposed procedures provide transactions the choice of selecting self-acquisition of loss compensation at designated bus(es) or to purchase the loss compensation service from a central independent grid operator (IGO). The IGO can provide loss compensation as a value-added service to its transmission customers. IGO-acquisition of loss compensation uses a linear program formulation in which network constraints are explicitly represented to determine the solution that gives the least-price at which the IGO can acquire the service. The self-acquisition service may coexist side-by-side with the IGO-acquisition and any physically feasible combination of these acquisition schemes is possible. The effectiveness and flexibility of the procedures are illustrated with extensive numerical results.

Eric Thomas

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B.S.:	December 1997, Michigan State University
M.S.:	In progress
Professional Interests:	Motor design, simulation and control.

Engine Simulation Control of an Induction Motor

Eric Thomas with advisor P. W. Sauer

Supported by the Power Affiliates Program

ABSTRACT

This project is investigating the theoretical and practical aspects of controlling an induction motor to make it behave like an internal combustion engine. The application is a mechanical engineering hydraulic test stand which is being constructed to study alternative hydraulic designs and controls. Since the test stand is in doors, an actual internal combustion engine was not feasible. A sophisticated commercial variable-speed drive is being used as the primary mechanism for the induction motor control. This drive is capable of almost instantaneous speed control in response to load torque on the motor. The drive also includes digital outputs of motor voltage, current and torque. The variable speed drive will receive commands from an engine simulation which will be programmed to duplicate various engine details. The engine simulation will receive inputs from the variable speed drive.

Svetlana Troitskaia

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Professional Interests:	Electrical machines, power systems, systems stability.

Optimization of Induction Motor Powered by Variable Speed Drive

Svetlana Troitskaia with advisor R. Turnbull

Supported by the Power Affiliates Program

ABSTRACT

Motors with varying shaft speed are used in many applications, but most of up-to-date research is concerned only with high motor efficiency at constant speed. The goal of this research is to minimize energy losses in an induction motor for an operating cycle which consists of varying speeds and loads. It will be assumed that the input voltage and frequency can be varied to match the motor parameters. The motor will not be required to start with line frequency.

Jamie Weber

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Professional Interests:	Simulation of power system, economics, visualization.

A Simulation-Based Approach to the Optimization of Electricity Markets Including Consumer and Full Transmission System Modeling

Jamie Weber with advisor T. J. Overbye

Supported by the Grainger Foundation

ABSTRACT

The restructuring within the electric power industry throughout the world has created a need for innovative new approaches to power system analysis. Most importantly, new economic analysis tools are needed by the industry. One tool that will be of interest is an electricity market simulator.

The optimal power flow (OPF) algorithm that was developed during my master's degree has been enhanced to include the modeling of consumer price elasticity. (In other words, consumers who change their consumption based on the price signals they receive). Using this enhanced OPF, we are able to determine the optimal behavior of the market from a global perspective. Over the past year, we have developed techniques to more closely simulate an individual's behavior explicitly within this OPF framework. Nash equilibrium as well as market oscillations have been observed. Participants in the market could use this tool for economic benefit, while regulators could use this to study how participants may behave under a given set of market rules.

Sean West

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Professional Interests:	Hybrid automotive design and power electronic circuits.

Influence of Battery Equalizer Technology on the 1998-1999 Future Car Performance

Sean West with advisor P. T. Krein

Supported by the University of Illinois

ABSTRACT

In the use of electric power storage in current hybrid automobiles there are a lot of considerations that must be taken into account. The battery pack must be light, powerful, and have a long lifetime. Any battery pack that cannot fulfill these requirements will fail the consumer and prevent hybrid automobiles from becoming mainstream. In battery operation as a large "battery pack," all the construction and electrical differences in the individual batteries become important. As the charge-recharge cycle operates on the batteries they will start to become differentiated in terms of battery voltage and state of charge. After sufficient time single batteries will fail due to manufacturing flaws and the stress applied by the hybrid operation. By using battery equalizer boards the differentiation can be prevented and the packs lifetime and power limits should be increased. Working in conjunction with the 1999 Illini Future Car team a patented UIUC battery equalizer circuit will be tested for operation in a hybrid 1998 Dodge Intrepid.

Yiqing Zhu

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Professional Interests:	Power system simulation, operation.

Costing of Ancillary Services

Yiqing Zhu with advisor T. J. Overbye

Supported by the Grainger Foundation and PSERC

ABSTRACT

The focus of this project is to investigate methods for establishing justifiable costs for ancillary services. The initial work has focused on implementing an efficient optimal power flow algorithm. Once this work has been completed, the algorithm will then be used to aid in the costing of reactive power and voltage control. The goal of the project is to seek answers to questions such as what it costs to maintain voltage, what it costs an energy provider to utilize an exciter, what operating costs can be allocated to voltage control, and the feasibility of these services being provided by a third party.

8. 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** was established in 1988 with funds from the Grainger Endowment. It is located near the office areas on the third floor of Everitt Laboratory. The Laboratory has one IBM AIX workstation and eight advanced personal computers. All stations are connected to the campus network, which, in turn, provides access to major international networks via Internet.

A major objective of the laboratory is to develop an extensive library of commercial software and large-scale data bases for power area applications. Software is based on the Unix operating system and on Windows NT. Some of the commercial software packages currently in use include:

Mathematica (an advanced symbolic mathematics package)
SYMNON (system analysis and design software)
IPFLOW (Interactive Power Flow)
SSSP (Small Signal Stability Analysis)
MatLab and Simulink
PSS/E (Power Technologies Inc. Software Package)
PowerWorld

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 333, ECE 369, and the Advanced Electric Vehicle Program. Ten self-contained machinery workstations are available. Each has an integral horsepower machine set, digital watt meters, oscilloscope, optical tachometer, torque sensor, and electronic support instruments. Transformers, resistor units, capacitors, SCR circuits, and power FET units are provided in support of the full range of experiments in all aspects of power. The facility has a dedicated 225 KVA three-phase supply and a 50 kw d-c rectifier bank.

The laboratory has generated a considerable of interest among students and other universities. The equipment allows experimental work to be more complete without sacrifice of hands-on experience for students.

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 lab shares motor test sets with the Machinery Lab. Additional equipment is available for the study of harmonic effects, high-performance switching converters, and digitally controlled drives. This laboratory's computer facilities communicate with the Grainger Power Engineering Software Laboratory through the building network.

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