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NINETEENTH ANNUAL REPORT OF THE POWER AFFILIATES PROGRAM

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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 1997. 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.

ComEd

Electrical Manufacturing & Coil Winding Association, Inc.

Illinois Power Company

MidAmerican Energy

Rockwell Collins

S&C Electric Company

Sargent & Lundy

City Water, Light & Power, Springfield, IL

Wisconsin Power & Light Company

1997 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-industrial interaction at all levels of education and research in electric power engineering.

The program is described in considerable detail in Reference [1].

Throughout the past nineteen 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 crucially important source of support.

This annual report is organized as follows. A financial statement for the calendar year 1997 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 enrolment 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 1997 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 1997 was prepared from a detailed University statement as of December 31, 1997, Reference [2].

Income carried over from the calendar year 1996	$ 16,809
Total income during calendar year 1997	88,826
Total available income during calendar year 1997	$105,635

Expenditure Category	Expenditure Amount
Personnel and Services	$ 57,851
Materials/Supplies/Equipment	10,762
Transportation/Travel	9,871
Total	$ 78,484

Summary

Amount of funds available during calendar year 1997	$105,635
Amount of expenses during calendar year 1997	-78,484
Balance as of December 31, 1997	$ 27,151

3. THE POWER PROGRAM WITHIN THE DEPARTMENT

Electrical engineering 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) and complete 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 12% 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 1997 - 1998 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 is given in Reference [5].

Two of the primary responsibilities of the Power and Energy Systems Area Committee are to update and staff the courses assigned to the Power and Energy Systems Area. In 1997-1998 those courses were:

ECE330	Power Circuits and Electromechanics
ECE333	Electric Machinery (with laboratory)
ECE336	Advanced Electromechanical Energy Conversion
ECE364	Power Electronics
ECE369	Power Electronics Laboratory
ECE371GG	Engineering Decision Techniques
ECE371SUN	Solar Powered Vehicle
ECE376	Power System Analysis I
ECE378	Power System Analysis II
ECE468	Modeling and Control of Electromechanical Systems
ECE473	Operation and Control of Power Systems
ECE476	Dynamics and Stability of Power Systems
ECE490	Power and Energy Systems Area Seminar
ECE488	Electricity Resource Planning
ECE497PWR	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, ECE473 and ECE476 were not taught during the 1997-1998 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 annual enrollment for the 1997-1998 academic year is also given for each course.

ECE330 Power Circuits and Electromechanics

ECE330 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. Notes by M. A. Pai were available for the course. The total enrollment for the academic year 1997-1998 was 133.

ECE333 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 Basic Electric Machines by Del Toro. The total enrollment for the academic year 1997-1998 was 33.

ECE336 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 1997-1998.

ECE364 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 enrollment for the academic year 1997-1998 was 39. The course has been produced on videotape.

ECE369 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 1997-1998 was 18.

ECE371GG 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 total enrollment for the academic year 1997-1998 was 20.

ECE371SUN/ME393 DRW Advanced Electric Vehicles (Solar Powered Vehicle)

During 1994, a new project to initiate the design of a solar-powered vehicle was the focus of the course. This is a project oriented course which involves the design and construction of a solar power car. On the electrical side there is an array of solar cells, d-c to d-c connected to charge batteries, and an electrical drive system including an induction motor. The course enrollment during the 1997-1998 academic year was 85.

ECE376 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 1997-1998 was Power System Analysis and Design by Glover and Sarma. The enrollment was 22.

ECE378 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 required text was Power Generation, Operation and Control, 2nd edition, by Wood and Wollenberg. The enrollment was 14 in the 1997-1998 academic year.

Graduate Courses:

ECE468 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 enrollment was 11 during the 1997-1998 academic year. The course has been produced on video tape.

ECE473 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 was not offered during the 1997-1998 academic year.

ECE476 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. This course is available on video tape. The course was not offered during 1997-1998.

ECE488 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 had an enrollment of 6 during the 1997-1998 academic year.

ECE490 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 enrollment for 1997-1998 was 27.

ECE497PWR 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, numerical integration of differential plus algebraic equations. The enrollment for the academic year 1997-1998 was 8.

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

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 1997. The major events are listed below:

- IEEE Power Engineering Society 1997 Winter Meeting
  - Pete Sauer chaired the working group on Dynamic Security Assessment.
  - George Gross chaired the newly established Power System Analysis, Computing and Economics Committee meeting.
  - Stan Helm participated in committee meetings.
- IEEE Applied Power Electronics Conference
  - Phil Krein attended committee meeting and presented a paper on a new battery equalizer.
- ECE333 and ECE378 student class trip to the ComEd control center and Joliet generating station
- Engineering Open House
  - ECE333 students presented machinery demonstrations.
  - George Gross acted as a Judge of the Engineering Open House activities/displays.
- American Power Conference
  - Stan Helm coordinated the UI participation in the sponsored student, sponsored faculty program.
  - Eight students and faculty sponsored by Ameren CIPS, ComEd, Soyland Power Co-op., Sargent & Lundy, Wisconsin Power and Light.
  - George Gross, Stan Helm and Pete Sauer attended.
  - George Gross organized and chaired a session at the American Power Conference.
- IEEE Power Electronic Specialists Conference
  - Phil Krein chaired the 1997 Conference, which was held in St. Louis.
  - Four students attended, and two of them presented papers.
- IEEE Conference on Decision and Control
  - M. A. Pai presented two papers.

- IEEE Power Engineering Society 1997 Summer Meeting

  - George Gross chaired the Power System Analysis, Computing and Economics Committee meeting.

- North American Power Symposium (NAPS)

  - Tom Overbye and Ian Hiskens attended.
  - Ian Hiskens (visitor from Newcastle, Australia) presented a paper on behalf of Eugene Khutoryansky and M. A. Pai.
  - Jamie Weber received the prize paper award for his paper co-authored with Tom Overbye.

- IEEE Industry Applications Society Annual Meeting

  - Bob Turnbull became Chair of the Electrostatic Processes Committee.
  - Bob Turnbull participated in committee meetings.

- WILL TV "Talking Point" April 17, 1997, George Gross was a panelist on this public affairs program covering electricity restructuring in Illinois

- 1997 Electrical Manufacturers and Coil Winding Association and Conference Exposition

  - Pete Sauer and 10 undergrads participated. Two students presented papers.

- "Implementing Electric Retail Access in Illinois," Conference in Springfield, Illinois, September 5, 1997

  - George Gross was the co-organizer of this conference on regulatory and legislative issues in moving to retail access in electricity in Illinois.

- Portable Power for Communications, London, England

  - Phil Krein presented an invited talk.

- Intelligent Systems Application to Power Systems Conference

  - Tom Overbye participated in a panel session on power system visualization.

- Hosted the following guest speakers

  - Hiroshi Sasaki, Hiroshima University, "Neural Net Based Approaches to Large Scale Power System Optimization"
  - Farqad Al-Khal, Purdue University, "Function Smoothing Towards A Global Optimum"
  - Tim McCoy, Naval Surface Warfare Center, "The Integrated Power System for U.S. Navy Ships"
  - Ian Hiskens, The University of Newcastle, "Hybrid System Modeling and Trajectory Sensitivity Analysis: New Tools for Power System Analysis"

- Paolo Marannino, University of Pavia, "First- and Second-Order Methods for Voltage Collapse Assessment and Security Enhancement"
- Caroline Marzinzik, Mid-American Interconnected Network, Inc. (MAIN), "MAIN's Experiences In Calculating and Posting Transmission Capability Values"
- Chee-Mun Ong, Purdue University, "Dynamic Simulation of Electric Machinery Using MATLAB/SIMULINK"
- Ian Hiskens, University of Newcastle, "Power System Applications of Trajectory Sensitivity Analysis"
- Chaman Singh, University of Newcastle, "Assessment of Vulnerability To Protection Operation"

- Participated in multi-university seminar exchange over the internet for the following seminars:

  - Fernando Alvarado, University of Wisconsin, "The Dynamics of Power System Markets"
  - Bob Thomas, Cornell University, "Power Web: An Internet Power Market Simulation"
  - Bernard Lesieutre, MIT, "Results on the Existence of Solutions to Power System Quasi-Static Network/Load Equations"

- Presented the following seminars by UIUC faculty/students:

  - Richard Muyshondt, "Wavelet Transforms In Image Compression"
  - Dan Logue, "Hybrid Electric Vehicle Modeling, Simulation and Design"
  - Angus Rockett, "Options and Opportunities for Renewable Energy Generation"
  - Jon Locker, "Development of a Solar-Powered Electric Vehicle"
  - Jamie Weber, "Application of a Simple Genetic Algorithm to Power System Distribution Optimization"
  - Jon Locker, "Nonlinear Control Techniques In Motor Control and Power Conversion"
  - Jamie Weber, "Power system Visualization Through Contour Plots"
  - Shu Tao, "Introduction of Financial Derivatives and Their Application to the Electricity Markets"
  - M. A. Pai, "Robust D-Stability Analysis Using the Edge Theorem: An Application In Power Systems"

- Presented 20 Grainger Outstanding Power Engineering Student Awards

- Organized the 1997 Grainger Lecture Series on Power Systems

  - The 1997 Grainger Lecture Series focused on technical issues associated with the WSCC Summer 96 outage. It featured the following list of speakers and respective topics:

    Dennis Eyre, WSCC, "Policy Implications Resulting from the 1996 WSCC Disturbances"
    David Nevius, NERC, "NERC's Strategic Initiatives for Maintaining Reliability"
    John F. Hauer, Pacific Northwest National Laboratory, "Information Needs of the New Power System"
    Carson W. Taylor, BPA, "System Engineering For Power Systems Under Restructuring"
    Kellan Fluckiger, Idaho Power Company, "Lessons Learned From The 1996 Disturbances: Development of Security Processes For INDEGO"
    Paul Carrier, DOE, "A Framework For Regulation of Reliability"

Connie White, Utah Public Utility Commission, "The State Role In Reliability Regulation"
Jack E. Rosenthal, U.S. Nuclear Regulatory Commission, "Grid Reliability Concerns"

- 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.

- Data Base Short Course

  - George Gross directed this short course for training of ComEd technical personnel.

- Edison Electric Institute Power System Planning and Operations School, March 1997

  - G. Gross is the director of this annual School administered with the support of the Office of Continuing Engineering Education at UIUC.
  - G. Gross is part of the faculty of the School.
  - Tom Overbye gave a presentation on the basics of power system operations.

- 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

- Prof. Ian Hiskens from the University of Newcastle visited the University of Illinois for six months (July-December)

- R. J. Turnbull is the chairman of the Electrostatic Processes Committee of the IEEE Industry Applications Society

- P. T. Krein presented a series of seminars at the University of Surrey in England

- The solar power 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

- P. T. Krein presented a seminar on low-voltage dc systems to Intel Corporation

- George Gross organized an NSF Workshop on Available Transfer Capability, hosted the University of Illinois

  - The workshop featured the following presentations:

    George Gross, University of Illinois, "ATC Challenges"
    Frank Galiana, McGill University, "Concepts of Transmission Capability and System

Security Measures"

Alexander Flueck, Illinois Institute of Technology, "Mathematical Formulation and Evaluation of Total Transfer Capability"

Davis Hwang and David Sun, ESCA, "Functional Requirements for Modeling and Analysis of Maximum Transfer Limits"

Mark Gravener, PJM Interconnection and Chika Nwankpa, Drexel University, "Network Uncertainty and a Method of Calculating Available Transfer Capability"

Bruce Wollenberg, University of Minnesota, "Problems with ATC"

Stephen Miller, Commonwealth Associates, Inc., "Transfer Capability: Data Sources and Limitations"

Carl Imparato, Tabors, Caramanis and Associates, "Market-Based Management of Available Transfer Capability"

Gerald Sheble, Iowa State University, "Utility of ATC Information for Auctions"

Fernando Alvarado, University of Wisconsin, "Preliminary Results of Market Dynamics Effects on ATC Determination"

Mariesa Crow, University of Missouri-Rolla and Alexander Flueck, Illinois Institute of Technology, "Summary of Track 3 Session"

Ian Dobson, Scott Greene, Fernando L. Alvarado, University of Wisconsin and Peter W. Sauer, University of Illinois, "Initial Concepts for Applying Sensitivity to Transfer Capability"

Raymond Shoults and L. D. Swift, University of Texas at Arlington, "Methods for Evaluating Flows Attributable to Each Generator"

Vijay Vittal, Iowa State University, "Derivation of On-Line Dynamic Security Limits for ATC Calculations"

M. Vaziri and Anjan Bose, Washington State University, "Effects of ATC and Congestion Definitions on Computation"

Ross Baldick, University of Texas at Austin, "Summary of Track 4 Session"

Roberto Paliza, MAIN, "MAIN's Approach to ATC Evaluation and Posting"

Glenn Ross, Virginia Power Company, "MUST - Maximizing Utility System Transfer"

Sarosh Talukdar, Carnegie Mellon University, "ATC Measures: Some Suggestions"

- A final report called the "Proceedings of the Workshop on Available Transfer Capability" was edited by G. Gross

- P. T. Krein was selected as a Fulbright Scholar for a year of research in the United Kingdom

- George Gross presented a seminar on his work at the University of Hong Kong in December 1997

- U.S. National Committee of CIGRE

  - George Gross is a member of the Executive Committee with responsibility for strategic Planning
  - George Gross is an Expert Advisor to the U.S. Representation for CIGRE Technical Committee 39

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.

Determination of Transmission Transfer Capability

G. Gross,* P. W. Sauer

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. We are interested in deriving a set of criteria under which dispersed generation is an acceptable alternative. A side-by-side comparison with the conventional central planning paradigm will be undertaken. We will also explore the deployment of the notion of financial options to the dispersed generation area.

Effective Deployment of Financial Instruments in Competitive Electricity Markets

G. Gross,* S. Tao

Grainger Foundation; Power Affiliates Program

With the recent emergence of the well defined electricity spot markets and the establishment of the trading of electricity futures on specific exchanges, the application of financial instruments such as options, futures and forwards provides significant new tools to players in electricity. Such instruments can be used for risk management as well as speculation. Our focus is on the effective incorporation of these instruments 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 by these instruments for the trading of electricity and their impacts on the spot markets. In this research project, we will investigate the salient uniqueness of electricity derivative contracts due to the physical power system. We will investigate the possibility of developing new financial instruments and strategies to accommodate the different risk preference of various participants in the spot electricity market. Moreover, we will study 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 see 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 asses the functioning of the Independent Grid Operator and the critical role of transmission services.

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.

Optimal Bidding Strategies in Competitive Electricity Markets

G. Gross,* P. Correia

Grainger Foundation; Power Affiliates Program

We have developed a general framework for the analysis of competitive electricity markets modeled after the so-called Poolco concept. Under the assumption of perfect competition, we formulated optimal bidding strategies for supply-side bidders. We are extending this framework to include the consideration of demand-side bidding in electricity markets. Strategies for maximizing profits of demand-side bidders are studied. Additional areas of investigation are the relaxation of the perfect competition assumption, the study of market power, the explicit

incorporation of uncertainty, the impacts of transmission, the effects of longer term contracts and the incorporation of financial contracts into the strategies of bidders.

PEBB*NET*: The Development of a Conceptual Framework for a Network of Power Electronic Building Blocks and Its Application to the HEV

G. Gross, P. Krein, D. Logue, C. Pascual

SRI International

The UIUC team is developing a conceptual framework for the design, analysis and implementation of an interconnected network of power electronic building block (PEBBs). In addition the deployment of this framework to the HEV as a testbed for validating its applicability is being undertaken. Key aspects of the work are the formulation and evaluation of conceptual approaches for the hierarchical control of large-scale interconnections of PEBBs and the development and analysis of models for the HEV. The UIUC efforts support the SRI work for the U.S. Navy in furthering the objective of the Navy of becoming "more electric".

Power Electronic Building Blocks Interconnected Network

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

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.

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 (FERC) 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 OASIS*NET* 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 multi-node OASIS network operations and to accept simultaneous access from remote users through use of client/server technology. The simulation focuses on the dissemination and use of the available transmission capability information. Applications of the new simulator for training and analysis are under study.

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.

Computer-aided Design for Power Electronics

P. T. Krein,* F. Najm,* L. Amaya

Semiconductor Research Corp.; Power Affiliates Program

Power supplies and other electronic circuits for energy processing are usually designed on a case-by-case basis. In this project, a general framework leading to a step-by-step design process, suitable for automation, is being developed. A user would provide specifications, then select from alternatives presented by this CAD system. The system would establish a baseline design, then perform an optimization procedure to refine it and meet the user's specifications. The heart of this CAD system is a component selection algorithm that takes an alternative circuit and establishes component values needed to establish the baseline design.

Geometric Approaches for Control of Switching Power Converters

P. T. Krein,* J. Kimball, R. Muyshondt, M. Greuel

Power Affiliates Program; 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.

Hybrid Electric Vehicle Systems

P. T. Krein,* R. A. White* (Mech. & Indus. Engr.), Scott Splater, C. Hidrovo, D. Logue

National Renewable Energy Laboratory; Xantrex Technology, Inc.

(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%. Objectives are to characterize major subsystems of a practical hybrid car in depth. Tests of efficiency, fuel economy, and emissions are being conducted. Parametric studies of subsystems are in progress. The data and information will assist industrial firms in the evaluation, design, and development of hybrid vehicle technology.

Low-Voltage Power Supplies – Operation and Control

P. T. Krein,* L. Amaya, J. Kimball, M. Greuel

Power Affiliates Program

Modern microprocessors and both analog and digital circuits are being designed for lower voltages to support high densities and fast operation. This project considers solutions for power supplies operating in the range of 1 V to 3 V. Synchronous rectifiers and related techniques are being developed for this operating range. Control methods to minimize power loss and provide robust operation have been identified. A complete integrated circuit power converter for this range has been designed and fabricated in the MOSIS process. This converter will help support extensive experimental work.

Nonlinear Methods for Induction Motor Control

P. T. Krein,* J. Locker, H. Maase

Grainger Fellowship; U.S. Army Construction Engineering Research Laboratories, DACA88-97-G001/DO 125

Field orientation is a widely used control method for ac induction motors. Recent results in nonlinear control theory, including feedback linearization and integrator backstepping, offer possible alternatives for ac servo systems. Observer techniques allow high performance without expensive sensors. This project examines the operating performance of new motor control

alternatives. Methods are studied analytically, through detailed simulation, and experimentally. A digital signal processing motor drive system has been designed and built for tests.

Parallel Inverters

P. Krein,* L. Pairitz

Danfoss, Inc.

Pulse-width-modulated inverters are experiencing growing application for control of ac motors. Modern systems support motors at power levels up to about 100 Kw, although cost increases rapidly above 20 Kw or so. An alternative at high power levels is to use several inverters in parallel. To make such an arrangement reliable, tight coordination of individual inverters is necessary. The project is studying coordination techniques. Both device-level and system-level approaches are being examined through analysis, simulation, and experimental tests.

Simulation Methods for Power Electronics Analysis

P. T. Krein,* D. Beck

Teltrend, Inc.

Comparisons are being made among various simulation approaches for switching power conversion systems. The switching nonlinearities of these systems are well suited to piecewise simulation approaches, but less well suited to conventional methods. The project compares SPICE-based circuit simulators and mathematical simulation methods such as MATLAB. The objective is to learn the considerations needed when preparing a simulation tool suitable for power electronics modeling and analysis.

Switched Capacitor System for Automatic Series Battery Equalization

P. T. Krein,* C. Pascual

La Caixa de Pensions Fellowship

Rechargeable batteries are used in long series strings for many industrial applications. The recharge process is not uniform, and the weakest battery in the string limits the performance of the set. An equalization process is required to restore battery balance. In this project, a clocked switched-capacitor circuit has been developed to exchange charge between adjacent batteries in a series string. This exchange drives all batteries to identical voltages, without regard to component values, battery technology, or state of charge. This equalization process can proceed while the batteries are in use or under charge, or separately.

Analysis Methods for Real-Time Control of Dynamically Insecure Power Systems

T. J. Overbye,* R. P. Klump

National Science Foundation, ECS 95-26146

As power systems become more heavily loaded, system operation will be increasingly constrained by contingent cases for which the power flow equations have no real solution. The goal of this project is to develop a measure to quantify the unsolvability of such cases and to determine the optimal controls to restore the case to solvability. A Euclidean norm is used in parameter space to measure the degree of unsolvability. The sensitivity of this measure to different system controls is then used to determine the best controls to restore the case to solvability. Both the static and dynamics aspects of the problem are considered.

Simulation Tools for Analysis of Alternative Paradigms for the New Electricity Business

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

Power Affiliates Program, American Public Power Assn.

In the restructuring of the electric power industry, a number of alternative paradigms for the future industry structure are under consideration. We are developing a modular simulation/visualization tool to effectively analyze and evaluate the effects these proposed paradigms will have on power system operations. Key research goals include methods to assess transmission system capacity, pricing of transmission capacity, and development of criteria for an equitable and consistent comparison alternative paradigm.

Dynamic Sensitivity Functions for Security Analysis In Power Systems

M. A. Pai,* M. Laufenberg

National Science Foundation, ECS 95-22547; Grainger Foundation

In this research, we compute trajectory sensitivities of the post-fault system with respect to prefault loading conditions and for a given set of contingencies. From this we compute whether the system is stressed and, if so, identify the critical machines. Thus we develop an alternative to the transient energy function (TEF) method. Results on a 17-machine IEEE test system as well as systems described by differential-algebraic equations have been obtained. In view of the fast computing power available these days, sensitivity theory offers an alternative to existing techniques for security assessment and preventive control.

Hopf Bifurcation Analysis with FACTS Devices

M. A. Pai,* M. Laufenberg

National Science Foundation, ECS95-22547; Grainger Foundation

In this research, we expand upon the MATLAB-based small-signal analysis formulation developed at the University of Illinois to include FACTS devices such as the Static Var Compensator (SVC) and Thyristor Controlled Series Capacitor (TCSC). In particular, we will focus on controlling Hopf bifurcation through proper placement of these devices. Auxiliary controllers are used when necessary to improve system damping.

Iterative Solvers for Fast Power System Simulation

M. A. Pai,* P. W. Sauer,* I. Hossain

National Science Foundation ECS 95-22547

Physically based preconditioners will be developed for fast nonlinear simulation of power systems using the general minimal residual (GMRES) iterative solver technique. It will be compared with the LU factorization method. Both will be developed on the MATLAB platform and integrated with the existing small-signal stability program and the transient energy function program. Ultimately, the idea is to develop a power system dynamics toolbox useful for R&D of small to medium sized systems.

Parallel Processing in Dynamic Simulation of Large-Scale Power Systems

M. A. Pai,* A. Kulkarni

National Science Foundation, ECS 95-22547; Grainger Foundation

Parallel processing algorithms for dynamic response calculations of large power systems have been developed. The differential-algebraic system of 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 conjugate gradient method which belongs to the family of iterative solver techniques. Use of preconditioners such as the ILU(s) speeds up the convergence. Further enhancement in speed-up is obtained by using the preconditioner only when the number of iterations increase. The general minimal residual (GMRES) method suitable for matrices that are unsymmetric and not positive definite was found to be more robust than other iterative solver algorithms.

Robust Stability in Power Systems

M. A. Pai,* C. D. Vournas (National Technical University, Greece)

National Science Foundation, ECS 93-19352

We used interval matrix theory to see if the linearized model of a power system is Hurwitz stable with respect to variations of the elements of the matrix in a given interval. The initial application has been with respect to power system stabilizer (PSS) parameter variation, which can be expressed in a matrix polytope form. Using interval matrix theory, we can plot the stability region in the parameter space with respect to uncertainties in the parameters. Multimachine application is now being done with loads being taken as perturbations.

Robust Stability of Power Systems Using Kharitonov's Theorem

M. A. Pai,* E. Khutoryansky

National Science Foundation, ECS 93-19352

There is rich literature in control theory regarding Kharitonov's theorem and its extensions for robust stability. We plan to use it for power systems where load variations are considered as uncertainties. In particular we will focus on matrix equivalents of Kharitonov's theorem where parameters appear explicitly.

Small-Signal Stability of Electric Power Systems

M. A. Pai,* D. P. Sen Gupta* and K. R. Padiyar* (Indian Inst. of Science, Bangalore)

National Science Foundation, INT 93-02565

The purpose of this project under the Indo-U.S. Science Cooperative Program is to collaborate in the area of small-signal analysis of large-scale power systems. Specifically, the topics to be addressed are the design of power system stabilizers, investigation of torsional oscillations, and computation of selected eigenvalues of the system. The goal of the project is to produce a research monograph in this area useful to the power engineering community. A preliminary set of lecture notes has been developed. Also, some collaborative research work in the area of Flexible AC Transmission System (FACTS) controllers for system damping is being pursued.

Two Time-Scale Simulation of Power Systems

M. A. Pai,* E. Khutoryansky

National Science Foundation, ECS 91-19428 IREU)

We used the asymptotic expansion theory for the "inner" and "outer" solutions of a singularly perturbed two time-scaled system to systematically integrate the fast and slow subsystems in their respective time scales thus removing the "stiffness" of the original system. This is an alternative

to using the integral manifold theory. The two approaches are compared in terms of their computational speed and convenience for simulation using the example of a synchronous machine subjected to a disturbance.

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.

Delivery of Electrical Energy to Railroad Freight Cars

R. J. Turnbull

Association of American Railroads

For improved braking and to detect problems, it is desirable that each car in a freight train have available a source of electrical energy. The goal of this project is to determine all the possible ways this energy can be supplied and to evaluate them. More detailed studies of the most promising schemes will be conducted.

Solar Electric Vehicle

R. A. White (Mech. & Indus. Engr.), P. T. Krein, R. J. Turnbull, A. Rockett (Mater. Sci. & Engr.), N. Kashhari, J. Locker, L. Bogusch, E. Weldy

University of Illinois; U. S. Department of Energy; various industrial sponsors

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

A solar electrical car is being designed and constructed by students

A solar electrical car is being designed and constructed by students to compete in a cross-country solar car race (SunRayce 1997) to be held in June 1997. Mechanical engineering considerations include the minimization of drag coefficient, rolling resistance, and weight. Electrical engineering considerations include optimizing the amount of power transferred from a solar array to storage batteries and maximizing the efficiency of the drive motor and the inverter that supplies its energy. All this must be done while producing an operating vehicle that conforms to the rules of the competition. This project involves approximately 100 students.

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:

Beatty, Shekita (M.S.)
Chaniotis, Dimitrios (M.S.)
Correia, Pedro (Ph.D.)
Dalton, Andrew (M.S.)
Greuel, Matt (M.S.)
Grijalva, Santiago (M.S.)
Haidacher, Steffen (M.S.)
Hossain, Izzat (M.S.)
Khutoryansky, Eugene (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.)
Muyshondt, Richard (Ph.D.)
Mwase, Naomi (M.S.)
Nguyen, Trong (M.S.)
Patten, Kollin (M.S.)
Tao, Shu (Ph.D.)
Tian, Yong (M.S.)
Troitskaia, Svetlana (M.S.)
Weber, Jamie (M.S.)
Zhu, Yiqing (M.S.)

Shekita Beatty

Date of Birth: August 1, 1974

Place of Birth: Whiteville, NC

B.S.: December 1996, North Carolina A&T State University

M.S.: In progress

Professional Interests: Power Electronics, Power Systems Control

REAL-TIME OPTIMIZATION OF INDUCTION MOTOR OPERATING EFFICIENCY

Shekita Beatty with advisor R. Turnbull

Supported by Sandia National Laboratories One Year On Campus Program

ABSTRACT

Under normal operating conditions, induction motors perform at levels below their optimum efficiency. A control loop that includes a power electronics circuit drive and the induction motor can be developed to reduce power losses in the motor. By measuring the instantaneous power and voltage/frequency characteristics of the motor, a converter can be used to internally adjust the optimum voltage/frequency ratio. This ratio is defined as the ratio that uses minimum power for desired torques and speeds. The control loop will allow the converter to continuously monitor and adjust the motor's characteristics around an optimal operating point. Research will include theory, design, and implementation of the control technique mentioned above.

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.

APPLICATION OF GMRES METHOD IN VOLTAGE SECURITY CALCULATIONS AND MODEL REDUCTION

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. Specifically, we investigate voltage security computations and application to model reduction. A comparison with the currently used technique of sparse LU decomposition with optimal reordering will be made. Currently we have implemented the modified GMRES, which involves the use of eigenvectors corresponding to the eigenvalues away from the spectrum. Results for voltage security calculations for the IEEE 118 and 300 bus systems are promising.

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.: In progress

Professional Interests: Electric drives, power electronics, control of machines.

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 is investigating 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 is being performed in cooperation with the Mechanical Engineering Department, which intends to implement the results on a generic hydraulic test stand.

Matt Greuel

Date of Birth: April 5, 1972

Place of Birth: Effingham, IL

B.S.: December 1995, University of Illinois

M.S.: In progress

Professional Interest: dc-dc conversion.

HIGH PERFORMANCE DRIVERS FOR PLASMA DISPLAY PANELS

Matt Greuel with advisor P. T. Krein

Supported by LG Electronics

ABSTRACT

Plasma display panels must be driven with an ac voltage on the order of 100 volts to sustain operation. The bulk capacitance of these panels poses problems in the design of a driver circuit. Traditional methods based on linear amplifiers, result in very poor efficiency. This project develops new circuits for driving a capacitive load and examines various methods for controlling the switching in these circuits.

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.

Steffen Haidacher

Date of Birth: February 19, 1973

Place of Birth: Munich, Germany

B.S.: November 1995, Technical University, Munich, Germany

M.S.: August 1997, University of Illinois

Professional Interests: Power electronic applications for use in alternative energy projects.

System Control for Hybrid Electric Vehicle

Steffen Haidacher with advisor P. T. Krein

Supported by Xantrex, Technology Inc.

ABSTRACT

Air pollution is a major concern in modern cities in particular, but also in the open countryside. One important cause for this are emissions from the increasing number of cars. One proposed way of facing that problem is a reduction in the emissions form individual cars. This goal can be achieved by a concept called hybrid-electric, which takes advantage of decoupling the processes of energy conversion in a standard combustion engine from the dynamics of vehicle propulsion. In the Hybrid Electric Vehicle of the University of Illinois, this separation consists of two systems linked electrically, with a battery pack as energy buffer. In this development, it is essential to control the combustion unit and the connected generator to ensure stable operation as well as to reduce emissions while maintaining the performance of a modern car. In contrast to large power systems, the operating conditions may alter drastically within a very short time due to the unpredictably changing environmental conditions and the varying power demand. Whereas the last two components of control deal with real time events, there is a need of a general system controller that adapts to long term processes and maintains the state of charge of the vehicle's batteries. This thesis proposes and tests a possible strategy for these controls.

Izzat Hossain

Date of Birth: December 27, 1970

Place of Birth: Dhaka, Bangladesh

B.S.: May 1995, Bangladesh University of Engineering & Technology

M.S.: October 1997, University of Illinois

Professional Interest: Parallel computation and algorithms in power systems.

Nonlinear Simulation of Power Systems Using Iterative Solver Techniques

Izzat Hossain with advisor M. A. Pai and P. W. Sauer

Supported by the National Science Foundation

ABSTRACT

This research investigated and compared different iterative solver techniques in the numerical solution of differential-algebraic systems such as the power system. The implicit method was used and the code was developed on the MATLAB platform. In particular, it investigated physically based pre-conditioners to speed up the simulation. Comparisons were made with the Power Technologies PSS/E software.

Eugene Khutoryansky

Date of Birth: March 19, 1975

Place of Birth: Ukraine, Russia

B.S.: May 1996, University of Illinois

M.S.: August 1997, University of Illinois

Current Status: Commonwealth Edison
Chicago, IL

Robust Stability Analysis of Power Systems Using A Generalization of Kharitonov's Theorem

Eugene Khutoryansky with advisor M. A. Pai

Supported by the National Science Foundation and the Grainger Foundation

ABSTRACT

In this work we have used the edge theorem and segment Lemma to compute the region of robust stability in power systems. Specifically, we have taken the single machine infinite bus case with a single as well as two stage PSS. The uncertain parameters are in the PSS. Given a stable operating point in the left half plane, we compute the range within which the parameters must lie so that the operating point stays within a prescribed region in the left half plane. Although computationally intensive, the technique presented is the first application of generalized Kharitonov's theorem in power system stability. Uncertaintities in nonlinear voltage dependent load indices are also solved in a similar manner.

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 Capacity

Ray Klump with advisor T. J. Overbye

Supported by the Grainger Foundation

ABSTRACT

The power industry is currently in the midst of a fundamental restructuring. The previous structure of vertically integrated utilities providing power at regulated rates is giving way to a more open marketplace with equal access to the transmission system for all wholesale buyers and sellers. Key to the development of such an open market is the ability to quantify and, hence, price, transmission system capacity in near real time. Transmission system capacity is limited by a number of factors, including thermal line limits, transient stability concerns, and the need to maintain voltage stability. All these issues must be addressed in the computation of transmission system capacity. This work focuses on quantifying transmission system capacity from the voltage stability viewpoint. In particular, it seeks a technique for identifying the limits placed by voltage stability requirements on energy transactions, as well as a scheme for pricing such limitations.

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

Ph.D.: In progress

Professional Interests: Power systems analysis, economics and planning.

Analytical Framework For Dispersed Generation

Yan Lin with advisor G. Gross

Supported by the Grainger Foundation and Power Affiliates Program

ABSTRACT

Increasing competition of electricity supply industry, increasing cost of transmission and distribution upgrades, greater pressure on cleaner environment, higher energy efficiency and decreasing marginal cost of new and smaller generation technologies are some of the factors that are going to influence the future utility planning to consider the option for so-called dispersed generation. The benefits associated with this type of generation are diverse and numerous. The principal objective is to formulate an analytical framework for dispersed generation in the context of economic, technological and environmental aspect with improved system reliability so as to assess each type of newly emerged energy resources which are considered potential candidates for future electricity generation.

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. These will be related to real-time phasor measurements of bus voltages.

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.: In progress

Professional Interests: DC to DC conversion and analog/digital integrated circuit design.

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.

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Development of Market Power Analysis Methods for Electricity Markets

Kollin Patten with advisor T. J. Overbye

Supported by the Grainger 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.

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Optimal Bidding Strategies in Competitive Electricity Markets

Shu Tao with advisor G. Gross

Supported by the Grainger Fellowship

ABSTRACT

We have developed a general framework for the analysis of competitive electricity markets modeled after the so-called Poolco concept. Under the assumption of perfect competition, we formulated optimal bidding strategies for supply-side bidders. We are extending this framework to include the consideration of demand-side bidding in electricity markets. Strategies for maximizing profits of demand-side bidders are studied. Additional areas of investigation are the relaxation of the perfect competition assumption, the study of market power, the impacts of transmission, and the incorporation of financial contracts into the strategies of bidders.

Yong Tian

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Current Status:

OASISNET: An OASIS Network Simulator

Yong Tian with advisor G. Gross

Supported by the Grainger Fellowship

ABSTRACT

This describes a Web-based simulator of the Federal Energy Regulatory Commission (FERC) mandated Open Access Same-Time Information System (OASIS) network. OASIS is the real-time information network/electronic bulletin board whose specification are spelled out in FERC Order 889. The purpose of the simulator is to provide a tool for study of the various aspects of a multinode OASIS network and to gain a strong intuitive feel for its operations. For a specified simulation period, the OASISNET simulator reproduces the behavior of an OASIS network using the same communications medium as the actual system, the Internet, and with multiple players using the simulator simultaneously. Users dynamically interact with the simulator through World Wide Web (WWW) browsers. Salient features of the simulator are its modular architecture, the ability to simulate multi-node OASIS network operations and to accept simulation focuses on the dissemination and use of the available transmission capability information. Sample applications of the new simulator are discussed. These include the study of effects of delay in information transmission, the illustration of the uses of ATC information by a broker for undertaking transactions, and a case study to show the difference between recallable and non-recallable transmission service.

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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.

Simulation of Various Electric Power System Environments

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 need for innovative new approaches to power system analysis. Most importantly, new economic analysis tools are needed for 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. This is one step closer to a true market simulator. New development is under way to more closely simulate an individual's behavior explicitly within the OPF framework. 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.

Yiqing Zhu

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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. They contribute significantly to growth in the Area.

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 three IBM RS6000s and four advanced personal computers. A laser printer serves the 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 MS-DOS. Some of the commercial software packages currently in use include:

Mathematica (an advanced symbolic mathematics package)
ETMSP (EPRI Extended Transient Midterm Stability Program)
ATP (Alternate electromagnetics Transients Program)
MatrixX (system analysis software)
SYMNON (system analysis and design software)
IPFLOW (Interactive Power Flow)
SSSP (Small Signal Stability Analysis)
INSITE (Interactive Nonlinear Systems Investigative Toolkit for Everyone)
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.

Student participation continues to grow. The equipment allows experimental work to be more complete without sacrifice of hands-on experience for students.

The Advanced Power Applications Laboratory is located 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 has extensive computer facilities, which communicate with the Grainger Power Engineering Software Laboratory through the building network. Current projects include harmonic effects in uninterruptible power systems, high-performance distributed power supplies, advanced ac motor controllers, and electric vehicle drives.

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