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TWELFTH ANNUAL REPORT OF THE POWER AFFILIATES PROGRAM

M. S. HELM
P. T. KREIN
M. A. PAI
P. W. SAUER

Power Affiliates Program
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

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FOREWORD

This report is a summary of the activities of the Power Affiliates Program in the Department of Electrical and Computer Engineering at the University of Illinois for the calendar year 1990. The information is intended to be a progress report to the affiliate companies. The following companies have provided support for the Power Program at Illinois in the past year:

Amoco Oil Company
Bechtel Power Corporation
Central Illinois Light Company
Central Illinois Public Service Company
Commonwealth Edison Company
Illinois Power Company
Iowa-Illinois Gas and Electric Company
Northern Indiana Public Service Company
Public Service Indiana
S&C Electric Company
Sargent & Lundy
Sorensen Company
Union Electric Company
W. W. Grainger, Inc.
Wisconsin Power and Light Company

We would like to express our thanks to these companies for their continued support.

Stan Helm
Phil Krein
M. A. Pai
Pete Sauer

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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 provide financial assistance to students studying electric power engineering and to increase university-industrial interaction at all levels of education and research in electric power engineering. The program is described further in Reference [1].

Thoughout the past twelve 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 crucial source of research support.

This annual report is organized as follows. A financial statement for the calendar year 1990 is given in Section 2. This statement reflects our commitment to utilizing the majority of funds for student support. 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 specialization in this area by a group of faculty members and courses. Section 4 gives a brief description of the courses specializing in electric power and gives the latest enrollment figures. Included in this section is a historical record of the number of graduates who have taken three or more of these courses. The record shows that student interest has been maintained and even broadened in recent years. Section 5 itemizes the activities of both the students and faculty members during the 1990 calendar year. Section 6 gives information about the graduate students in the power area. In addition to personal data and interests, each student has written a brief abstract of his/her research work. Since 1987, the power faculty members have focused on enhancing the laboratory aspects of the curriculum and research efforts. The Grainger Foundation has funded three major new laboratories ranging from electric machinery to power engineering software. These facilities are discussed in Section 7.

2 FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 1990 was prepared from a detailed University statement as of December 31, 1990, Reference [2].

Income carried over from the calendar year 1989	-$2,095.00
Total income during calendar year 1990	60,000.00
Total available income during calendar year 1990	$57,905.00

Expenditure Item	Expenditure Amount	Percentage of Total Expenditures
Graduate Assistantships	$27,847.00	49.6
Class trips, travel	1,535.00	2.7
Communications, clerical, supplies, reports, conference fees, and administration	26,796.00	47.7
Total expenditure:	$56,178.00	100

Summary

Amount available during calendar year 1990	$57,905.00
Amount expended during calendar year 1990	-56,178.00
Balance as of December 31, 1990	$1,727.00

3 THE POWER PROGRAM WITHIN THE DEPARTMENT

As of 1979, all entering electrical engineering students are required to complete 128 hours of course work for a B.S.E.E. degree. A detailed description of the undergraduate program as well as a 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 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 areas as follows:

Bioengineering and Acoustics
Circuits and Signal Processing
Computer Engineering
Communication and Control
Electromagnetics
Physical Electronics
Power and Energy Systems
Remote Sensing and Propagation

While the Department does not have official options in each of these areas, the eight areas serve as a representative grouping of major faculty activity and interest. In terms of size, the Power and Energy Systems area represents about 1/20 of the total active faculty and about 1/10 of the total student enrollment. A faculty committee is assigned to each area and given the responsibility for administering courses in that area within the Department.

The Power and Energy Systems Area Committee and associated faculty for the 1990-1991 academic year together with their general interests are:

M. S. Helm (Emeritus, Power System Analysis)
P. V. Kokotovic (Optimization and Control of Power Systems)
P. T. Krein (Power Electronics, Machines, Electrostatics)
M. A. Pai (Dynamics and Stability of Power Systems)
P. W. Sauer (Modeling and Simulation of Machines and Power Systems)
R. J. Turnbull (Energy and Conversion Technology)
M. E. VanValkenburg (Emeritus, Network Analysis)

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 1990-1991 those courses were:

ECE270	Introduction to Circuit Analysis (Joint responsibility)
ECE330	Electromechanics
ECE333	Electric Machinery
ECE336	Advanced Electromechanical Energy Conversion
ECE364	Power Electronics
ECE369	Power Electronics Laboratory
ECE376	Power System Analysis I
ECE378	Power System Analysis II
ECE452	Computer Methods in Electric Network Analysis (Joint responsibility)
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

The three-hundred level courses are advanced undergraduate or beginning graduate courses, while the four-hundred level courses are graduate. Of these courses, ECE378 and ECE468 were not taught during the 1990-1991 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.

4 COURSES AND ENROLLMENT

As one of eight major areas in Electrical and Computer Engineering, the Power and Energy Systems Area is responsible for a considerable number of courses. The current courses assigned to the power area are described briefly below. The total annual enrollment for the 1990-1991 academic year is also given for each course.

ECE270 Introduction to Circuit Analysis (Primary responsibility for this course is assigned to the circuits and signal processing area committee.)

ECE270 is a four-hour course and is the first course that all electrical engineering students must take after their math, physics and computer science requirements. The course introduces elementary signal waveforms, electrical component models, and basic principles of circuit analysis including d-c, transient and sinusoidal steady-state analyses. The topical outline includes resistance, inductance, capacitance and source elements, Kirchhoff's laws, node and mesh equations, matrix methods, Thevenin and Norton equivalents, controlled sources, operational amplifiers, transient switching d-c analysis, impedance and transfer functions for steady state, frequency response, Bode plots, filters, mutual inductance, and transformers. The required text was: J.W. Nilsson, "Electric Circuits." The total enrollment for academic year 1990-1991 was 624.

ECE330 Electromechanics

ECE330 is an introductory course in electromechanics, presenting both the electric and magnetic quasi-static fields for analysis of energy conversion devices. The origin of forces and torques, together with the full mechanical dynamics of Newton's Second Law (NSL), are discussed. The concepts of flux linkage, energy, coenergy and the resulting induced voltages are presented for their inclusion in Kirchhoff's Voltage Law (KVL). Conservation of power and energy is emphasized in energy balance analysis. An introduction to rotating machines is included with illustrative examples. Particular emphasis is given to the interaction between the electrical system (KVL) and the mechanical system (NSL). The required text was "Electromechanical Dynamics, Part I, Discrete Systems" by H. H. Woodson and J. R. Melcher and supplementary notes by M. A. Pai. This course is a suggested advanced three-hour ECE elective. The total enrollment for the academic year 1990-1991 was 96.

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 laboratory component closely follows the three hour lectures. 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 V. Del Toro. The total enrollment for the academic year 1990-1991 was 26.

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. This course is an advanced EE elective. The current required texts are "Analysis of Electric Machinery" by P. C. Krause and "Control of Electrical Drives" by W. Leonhard. The enrollment for the academic year 1990-1991 was 9.

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. This course is an advanced ECE elective. Internal notes by P. Krein are available for the course. The enrollment for academic year 1990-1991 was 44.

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 as an advanced ECE elective laboratory. A lab manual by P. Krein is available for the course. The total enrollment for the academic year 1990-1991 was 20.

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 introductions to economic dispatch and relaying. The course is designed to give the basic fundamentals of power system analysis and give preparation for the follow-on course. This course is an advanced ECE elective. The required text in the academic year 1990-1991 was "Power System Analysis and Design" (with software manual) by Glover and Sarma. The enrollment was 28.

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, relaying and protection, classical transient stability, modeling for dynamic and transient stability, and d-c transmission. This course is an advanced ECE elective. Classnotes are used as a text. The course was not offered during the academic year 1990-1991.

ECE452 Computer Methods in Electric Circuit Analysis (Primary responsibility for this course is assigned to the circuits and signal processing area committee.)

ECE452 is a graduate course designed for both electric power and electronic students. The course presents the fundamental computer algorithms utilized to analyze large scale circuits. Applications in both electronic circuit design and power system analysis are given. The following topics are presented: Network topology and circuit equations, branch constraints and problem formulation, solution of sparse linear algebraic equations, solution of nonlinear algebraic equations, power and electronic system applications, solution of piecewise linear algebraic equations, explicit and implicit numerical integration methods, transient analysis of power and electronic circuits, sensitivity analysis and decomposition. The course text was "Circuit Analysis, Simulation, and Design," Parts 1 and 2, by A. E. Ruehli. The text was supplemented by class notes. This course is a graduate 1 unit elective. The total enrollment for the academic year 1990-1991 was 18.

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 was not offered during the academic year 1990-1991.

ECE473 Operation and Control of Power Systems

ECE473 is a 1 unit graduate course in the power systems area. 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 load flow, security constrained economic dispatch, multistage rescheduling and equivalents. The course typically also includes a trip to a local energy control center. The course text was "Power Generator, Operation, and Control," by A. J. Wood and B. F. Wollenberg. Notes and journal articles supplement the text. The enrollment during 1990-1991 was 3.

ECE476 Dynamics and Stability of Power Systems

ECE476 is a 1 unit graduate course in the power systems area. 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 a set of notes prepared by P. W. Sauer and M. A. Pai. This course is available on video tape. The enrollment for the 1990-1991 academic year was 8.

ECE490 Power and Energy Systems Area Seminar

This course is a variable credit 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.

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

1971-1980 Annual Average Power Area Graduates

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

1981-1985 Annual Average Power Area Graduates

B.S.E.E. - 30
M.S.E.E. - 5
Ph.D. - 2

1986-1990 Annual Average Power Area Graduates

B.S.E.E. - 33
M.S.E.E. - 6
Ph.D. - 2

1990-1991 Power Area Graduates

B.S.E.E. - 44
M.S.E.E. - 5
Ph.D. - 2

5 ACTIVITIES

The faculty and students in the Power and Energy Systems Area participated in a considerable number of special activities during 1990. The major events are listed below:

a. IEEE Power Engineering Society Winter Meeting

b. Sargent and Lundy Faculty Engineering Conference

c. IEEE Applied Power Electronics Conference

d. EE333 Student Class Trip to S&C Electric

e. Engineering Open House

f. American Power Conference

g. IEEE Power Electronics Specialists Conference

h. IEEE Power Engineering Society Summer Meeting

i. IEEE Industry Applications Society Annual Meeting

j. North American Power Symposium

k. Hosted Guest Lecturers from Industry

l. National Science Foundation Workshops

6 STUDENTS AND 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:

Baphna, Rajiv (M.S.)
Bass, Dick (Ph.D.)
DiSilvestro, Francisco (M.S.)
Dobraca, Fadil (Ph.D.)
Ellerthorpe, Scott (M.S.)
Kulkarni, Ajit (M.S.)
Lesieutre, Bernie (Ph.D.)
Loh, Yoon-Kian (M.S.)
Maase, Hannon (M.S.)
Mak, Fong (Ph.D.)
McCann, Roy (M.S.)
Midya, Pallab (M.S.)
Morling, Scott (M.S.)
Savignon, Dan (M.S.)
Sterling, Jennifer (M.S.)
Varghese, Abe (Ph.D.)
Wingate, Kevin (M.S.)
Wright, Graham (Ph.D.)

Rajiv K. Baphna

Date of Birth:	November 15, 1966
Place of Birth:	Detroit, Michigan
B.S.:	June 1989, Gujarat University (India)
M.S.:	May 1991, University of Illinois
Currently Employed at:	Harris Corporation Rochester, NY

A Flexible Switching Converter with Microprocessor Control

R. K. Baphna with advisor P. T. Krein

Supported by the National Science Foundation
and the Power Affiliates Program

ABSTRACT

It is universally accepted that new concepts or designs for switching power converters must be scrutinized in depth through experiments. Details are sufficiently important that relatively minor changes require complete retesting. In the distant future, circuit simulation will replace early breadboard steps. However, detailed experimental confirmation of switching converters will be needed at all levels of design for the immediate future. Power electronic converters can be constructed with arrays of semiconductor switches, organized in matrix fashion. Control of switches requires manipulation of switching function timing and duty ratios. This project created a general switch matrix, with microprocessor control over the action. The device can be programmed to act as a rectifier, inverter, cycloconverter, ac motor drive, or any other type of switching converter, at power levels up to 5kW. It serves as a generic power electronic test bed which can be configured quickly for a given experiment. This converter will be used to evaluate switching power supply topologies, motor control techniques, new PWM schemes, new converter control methods, and resonant conversion approaches, among many topics of current interest.

Richard M. Bass

Date of Birth:	November 10, 1959
Place of Birth:	Jacksonville, Florida
B.S.:	June 1982, Georgia Tech
M.S.:	December 1983, Georgia Tech
Ph.D.:	October 1990, University of Illinois
Currently Employed at:	Georgia Institute of Technology

Analytical Methods in Power Electronic Systems

R. M. Bass with advisor P. T. Krein

Supported by the National Science Foundation, Grainger Endowment, and the Power Affiliates Program

ABSTRACT

The thesis explores the application of nonlinear methods to the practical problems of switching power converter analysis and design. Based on switching algebra, a formalism for large-signal component modeling is developed. The governing equation is formulated for a general class of mixed-mode circuit models containing ideal switches. The geometric interpretation of the governing equation in the state space is developed. This interpretation provides a cogent framework for understanding feedback control and unusual instability phenomena. The classical theory of averaging for systems of ordinary differential equations is applied to power electronic systems. A theoretical basis for widely used averaging approximation techniques is developed. Three new large-signal tools are introduced which are an outgrowth of the basic theory developed. Three large-signal experiments are reported which test the modeling formalism and the geometric and averaging concepts introduced.

Francisco DiSilvestro

Date of Birth:	February 26, 1965
Place of Birth:	Caracas, Venezuela
B.S.:	May 1988, Universidad Metropolitana (Venezuela)
M.S.:	In progress
Professional Interests:	Industrial applications, factory automation.

Observers and Estimators For AC Drives

F. DiSilvestro with advisor P. T. Krein

Supported by Sivensa Scholarship, sponsored by
Sivensa Siderurgiea Venezolana S.A., Caracas

ABSTRACT

The control schemes for an induction motor require knowledge of the dynamic states (currents, speed and flux). Measurement of the magnetic flux is difficult and requires modification of the machine. Stator coil taps and Hall-effect flux sensors have been used in previous designs. The implementation of observers and state estimators for use with the feedback linearization control method will be analyzed. In addition, effects of nonlinear characteristics of the magnetic elements and variations in motor parameters will be taken into consideration.

Fadil Dobraca

Date of Birth:	September 20, 1953
Place of Birth:	Sarajevo, Yugoslavia
B.S.:	November 1976, University of Sarajevo
M.S.:	May 1986, University of Illinois
Ph.D.:	January 1990, University of Illinois
Currently Employed at:	Empros Systems International Plymouth, MN

Dynamic Security Assessment in Power Systems Including Protective Action

F. Dobraca with advisor M. A. Pai

Supported by the National Science Foundation

ABSTRACT

Current approaches to dynamic security assessment in power systems rely on direct methods using energy functions. They have limitations in terms of including simple models of machines and difficulty in computing the region of attraction of the post-fault system accurately. New advances in computer technology and operator requirements would suggest a fast simulation approach including both detailed modeling and inclusion of relay action. Instead of a stability margin we have postulated a relay margin concept. This helped in ranking different contingencies and also suggesting preventive action. Good results have been obtained on a 10 machine 39 bus system. For numerical simulation we have used a trajectory approximation which uses a look-up table depending on successive linearization. This approximation is found to be faster than regular integration. Sensitivity of the relay margin is computed so that due to a contingency, generation can be rescheduled to improve the relay margin.

Scott A. Ellerthorpe

Date of Birth:	November 26, 1966
Place of Birth:	Battle Creek, Michigan
B.S.:	December 1988, Purdue University
M.S.:	In progress, expected May 1992
Professional Interests:	Applied controls, power electronics, drive systems.

Implementation of a Feedback-Linearized Induction Motor Controller

S. A. Ellerthorpe with advisor P. T. Krein

Supported by a National Science Foundation Fellowship

ABSTRACT

Feedback linearizing control of an induction motor offers a potential advantage over traditional field-oriented methods. While the general theory has been proven, no actual implementation exists. This project involves construction of a drive system which uses this scheme. The system will serve to illustrate the improvements offered by feedback linearization. Issues such as the sensitivity of the transformations to parameter variations will also be explored.

Ajit Kulkarni

Date of Birth:	April 10, 1967
Place of Birth:	Chicago, Illinois
B.S.:	May 1988, Arizona State University
M.S.:	January 1990, University of Illinois
Ph.D.:	In progress
Professional Interests:	Development and applications of computer methods for large scale power system analysis, including application of supercomputers. Interested in a career in the electric utility industry.

Parallel Processing in Dynamic Simulation of Large Scale Power Systems

A. Kulkarni with advisor M. A. Pai

Supported by the National Science Foundation and Grainger Endowment

ABSTRACT

The focus of this research is to investigate the use of parallel processing in power system dynamic simulation. Efficient use of computer hardware of the supercomputer such as Cray machines and research into better numerical algorithms which are parallelizable is being looked into. Currently the linear multi-step predictor corrector method has been successfully used on the Cray-2 machine with four processors both in the autotasked mode and the macro-tasked mode. A classical model for the machine is used. Systems up to 50 machines have been tested and for the numerical integration portion a speed up of 3.79 compared to a theoretical speed of 4 has been obtained. Current research involves extending the technique to systems containing both differential and algebraic equations. Parallelizing the simultaneous implicit method is also being investigated.

Bernie Lesieutre

Date of Birth:	January 19, 1964
Place of Birth:	Detroit, Michigan
B.S.:	May 1986, University of Illinois
M.S.:	August 1988, University of Illinois
Ph.D.:	In progress
Professional Interests:	Research interests include machine modeling and power system dynamics, stability and control.

Dynamic Modeling and Simulation of Multimachine Power Systems

B. Lesieutre with advisor P. W. Sauer

Supported by Power Affiliates Program and Grainger Endowment

ABSTRACT

This research is investigating several aspects of multimachine dynamic analysis with emphasis on the network algebraic equations and dynamic load modeling. Initial work is focusing on properly capturing the frequency dependence of the network and loads during transients. One objective is to provide a physically meaningful load model which allows the algebraic network plus load equations to be solved for any disturbance. The work also includes a study of the relationship between the dynamic load model and stability phenomena related to maximum loadability.

Yoon-Kian Loh

Date of Birth:	July 17, 1967
Place of Birth:	Singapore
B.S.:	May 1990, University of Illinois
M.S.:	In progress
Professional Interests:	Adaptive feedback control systems

Adaptive Feedback Linearization of Induction Motors

Y-K. Loh with advisor P. W. Sauer

Supported by the National Science Foundation

ABSTRACT

This project is investigating the possible use of new results in nonlinear control theory for induction motor control. The fifth-order dynamic model can be made to appear as a decoupled linear system through a nonlinear state feedback transformation. A flux observer is used to avoid flux measurement. Parameter estimation is used to allow uncertainty in rotor resistance and load torque. The theory is being tested by simulation.

Hannon Maase

Date of Birth:	June 13, 1967
Place of Birth:	Urbana, Illinois
B.S.:	May 1990, University of Illinois
M.S.:	In progress
Professional Interests:	Research and development in the power and energy systems area with interests in power electronics, motor and lighting control, and large power systems.

Adjustable Speed AC Drive Simulation

H. Maase with advisor P. W. Sauer

Supported by the U.S. Army Construction Engineering Research Laboratory

ABSTRACT

The motors used in Heating, Ventilating and Air Conditioning (HVAC) system fans, blowers, compressor drives, pumps and chillers can constitute the largest source of electrical energy consumption in commercial buildings. The use of variable speed drives can often reduce energy consumption by controlling the speed of a motor to match its load. In this research Current Source Inverter (CSI), Voltage Source Inverter (VSI) and Pulse Width Modulated (PWM) drive types will be investigated on how their dynamic performance compares when applied to the above induction motor applications. Each system will be modeled mathematically and analyzed via computer simulation.

Fong Mak

Date of Birth:	June 27, 1960
Place of Birth:	Johor Bahru, Malaysia
B.S.:	December 1983, West Virginia University
M.S.:	May 1986, University of Illinois
Ph.D.:	May 1990, University of Illinois
Currently Employed at:	Gannon University Erie, PA

Voltage Dynamics in Electric Power Systems Analysis

F. Mak with advisor M. Ilic

Supported by the National Science Foundation and the University of Illinois

ABSTRACT

This research involved studies of the voltage dynamic of power systems subject to large disturbances. The work is divided into two parts, namely, analysis and control of voltage dynamics. As part of the analysis, the interaction of machine dynamics with the dynamics of decentralized load voltage controls, such as under-load tap changers, was investigated. A detailed reduced-order machine dynamical model was proposed for more reliable studies of voltage related problems. In the latter, a nonlinear excitation controller was proposed so that system reactive power reserve, which is believed to be the main cause of any voltage problems, is more efficiently used. The performance of the proposed controls subject to small and large disturbances, respectively, was compared with the conventional IEEE excitation controls which include power system stabilizer and governor dynamics as well.

Roy McCann

Date of Birth:	January 31, 1961
Place of Birth:	Hawthorne, CA
B.S.:	May 1990, University of Illinois
M.S.:	In progress
Professional Interests:	Electric machine design

Simulation of Induction Machine Transient Response Under Automatic Bus Transfer

R. McCann with advisor P. W. Sauer

Supported by the Grainger Endowment and the Power Affiliates Program

ABSTRACT

The reliable and economical operation of many process industries relies upon the continuous availability of electric power. Most industrial facilities use an automatic bus transfer scheme to switch essential motor loads to an alternate source in the event of a failure of the normal supply. This project simulates the electrical and mechanical transients present in an induction machine during bus transfers. In particular, the effect of momentary unbalanced operation during sequential pole opening and the effects of shaft torsional dynamics are accounted for in the simulation. Furthermore, the transient responses from using the fast transfer switch (Randolph Industries, Downey, CA) is examined as a new fast bus transfer method.

Pallab Midya

Date of Birth:	January 31, 1967
Place of Birth:	Bhilai, India
B.S.:	Indian Institute of Technology, Kharagpur
M.S.:	May 1990, Syracuse University
Ph.D.:	In progress
Professional Interests:	Research in electronic power conversion, teaching.

Control Of Switching Power Conversion

P. Midya with advisor P. T. Krein

Supported by the Power Affiliates Program

ABSTRACT

Switching power conversion involves transferring power from one voltage level to another through a network of reactive elements and switches. The only control over the system is the state of the switches. Thus this represents a considerable variation from modern control theory, where there is normally a continuously variable input to the system. Some concepts of optimal control have been used to develop a controller that governs the timing of the switches. The aim is to obtain a controller that is optimal based on specified error criteria.

Scott E. Morling

Date of Birth:	December 20, 1966
Place of Birth:	Forest Park, Illinois
B.S.:	June 1989, Northwestern University
M.S.:	August 1990, University of Illinois
Currently Employed at:	GM Delco Electronics Dayton, OH

Electromagnetic Control of Liquid Metal Spraying

S. E. Morling with advisor P. T. Krein

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

ABSTRACT

Arc spraying of liquid metal is a standard industrial process used for galvanizing, electromagnetic shielding, and other metal coating applications. The application of magnetic fields for propulsion in arc spraying systems was examined. A standard geometry with a ring projectile was studied intensively. A more practical prototype geometry with a spherical projectile was also tested. Both geometries were found to behave in accordance with simulations. Electrical scaling laws from the work show that higher frequencies can offset the reduction in forces at small scales. The two major factors which are likely to affect working designs are the need for magnetic field gradients on a scale similar to that of the objects being propelled and the need for fields which vary at 10 kHz or more. Heat transfer in the magnetic coil structure will also be a concern. Propulsion was demonstrated at submillimeter dimensions.

Dan Savignon

Date of Birth:	October 28, 1964
Place of Birth:	Urbana, Illinois
B.S.:	August 1987, University of Illinois
M.S.:	In progress
Professional Interests:	Research interests in area of power system dynamics and control. Career interests in university teaching and research.

Dynamic Modeling of Automatic Generation Control

D. Savignon with advisor P. W. Sauer

Supported by the Power Affiliates Program and the Grainger Endowment

ABSTRACT

This project involves developing a model of automatic generation control that includes the synchronous machine dynamics. A question that arises is how should the interface between the midterm and long term model dynamics be performed such that results are accurate and iteration steps are optimized. Examples of midterm dynamics would be synchronous machine stator transients and voltage regulator dynamics whereas long term dynamics would include area frequencies and tie-line power flows.

Jennifer Sterling

Date of Birth:	August 8, 1967
Place of Birth:	Cincinnati, Ohio
B.S.:	May 1989, University of Illinois
M.S.:	October 1990, University of Illinois
Currently Employed at:	Commonwealth Edison Chicago, IL

Stability Constrained Optimal Power Flow

J. Sterling with advisor M. A. Pai

Supported by the National Science Foundation and the Grainger Endowment

ABSTRACT

In this research, the energy margins obtained through the energy function methods for a set of contingencies are used to steer the current generation to a secure state in an optimal manner. The sensitivity method is used to decide if and which of the generations have to be rescheduled. The objective function for rescheduling is the same as in optimal power flow. The methodology has been tested on small systems.

Abe Varghese

Date of Birth:	July 30, 1962
Place of Birth:	Tiruvalla, India
B.S.:	June 1984, IIT-Madras
M.S.:	January 1986, University of Illinois
Ph.D.:	In progress
Professional Interests:	Research and development in electrical machine power systems. Career interests in power industry - manufacturing, utilities etc.

Modeling of Power System Dynamics in the Medium Time Scale

A. Varghese with advisor P. W. Sauer

Supported by the National Science Foundation and the University of Illinois

ABSTRACT

Two trends in dynamic modeling of power systems have emerged. The first is a desire to simulate larger systems for longer times. The second is to increase the complexity of individual component models. This research focuses on ways to incorporate higher-order effects of systems without including their full differential equation description. Integral manifolds have been shown to give excellent results on single machine type models. In the multimachine case, the elimination of fast damper dynamics using an integral manifold approximation was found to result in damping coefficients in the swing equation, providing a basis for the D_{ij} coefficients used in transient stability studies. Another useful application has been the recovery of the electromechanical damping provided by the power system stabilizer into a lower-order model that does not include the PSS dynamics.

Kevin L. Wingate

Date of Birth:	February 24, 1963
Place of Birth:	Woodstock, Illinois
B.S.:	May 1986, University of Illinois
M.S.:	May 1990, University of Illinois
Currently Employed at:	Sundstrand

Modeling of Synchronous Machine Saturation

K. Wingate with advisor P. W. Sauer

Supported by the Power Affiliates Program

ABSTRACT

This research formulated a general approach to saturation modeling in machines. It resulted in a clear explanation of the constraints which apply to saturation models which depend on more than one dynamic state. These constraints can be used to test existing models or to guide the formulation of new models. While developed for synchronous machines, the concepts apply also to induction machines.

Graham Wright

Date of Birth:	December 12, 1961
Place of Birth:	Madison, Wisconsin
B.S.:	May 1984, Washington University
M.S.:	May 1987, University of Illinois
Ph.D.:	In progress
Professional Interests:	Research interests are application of electrostatic processes, computational fluid dynamics, advanced propulsion concepts and space technology, quantum mechanics, and analog circuits. Career interests in research and development in industry, academia, or government.

Electrohydrodynamics of a Liquid Meniscus

G. Wright with advisor P. T. Krein

Supported by Tektronix, Inc., and the Power Affiliates Program

ABSTRACT

Electric fields can exert attractive force on the surface of conducting liquids. This is the basis of the electrostatic atomization (or spraying) phenomenon, which has found such diverse applications as crop dusting, paint spraying, ink jet printing, and ion propulsion of spacecraft. The existing literature mainly examines cases in which the liquid surfaces are unmoving or the electric fields are static, and appears not to have addressed the theory of dynamic field-surface interactions. The project will analyze theoretically and experimentally the dynamics of a conductive meniscus formed with a Newtonian liquid and exposed to an electric field, in axisymmetric geometry. An improved understanding of electrified meniscus dynamics could open possibilities for dynamic manipulation of liquid surfaces using time-varying electric fields, which could be of benefit in the various applications.

7 LABORATORY FACILITIES

Two exciting new laboratory facilities were dedicated in 1989. They were made possible by funding from the Grainger Foundation. The new labs demonstrate a renewed emphasis on experimental work in power engineering. They have created a new image for the power program, and are already serving to attract students.

Laboratory facilities operated by the Power Area faculty are described briefly in the following paragraphs.

The Grainger Power Engineering Software Laboratory was established in 1988. It is located on the third floor (327 EL) near the faculty and student offices. The laboratory currently has four DEC workstations in a server configuration, and two H-P Vectra 80386 personal computers. There is one VAXstation II/GPX network server, three VAXstation 2000's, a 456 megabyte hard disk unit, and tape drive. Two of the four stations have full-color graphics. The lab has a Postscript-compatible laser printer and dot-matrix printers. All six workstations are connected to the campus Ethernet system. This network in turn provides access to major national and international networks, including NSFNET, BITNET, and ARPANET. The workstations are in heavy use. Expansion to include two additional workstations and larger disk space is currently underway.

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)
PECO (Philadelphia Electric power system software collection)
ETMSP (EPRI Extended Transient Midterm Stability Program)
ATP (Alternate electromagnetics Transients Program)
MSC-Maggie (finite element software for electromagnetics)
MatrixX (system analysis software)
SYMNON (system analysis and design software)
Several EPRI packages

The software library is being expanded continually.

The Grainger Electrical Machinery Laboratory was dedicated in October 1989, after a six-month remodelling project. It is located on the ground floor (50 EL). The lab is used primarily for instruction of ECE 333 and ECE 369. There are ten machinery workstations. The stations have integral horsepower machine sets, wattmeters, digital oscilloscopes, tachometers, torque meters, personal computers, and various electronic instruments and support equipment. The facility has a dedicated 225 kVA three-phase ac supply and a 50 kW electronic dc supply.

During Spring 1990, the Electrical Machinery course was updated for the new lab. Student interest was the highest in many years. The new equipment allowed the experimental work to be more complete without sacrifice of hands-on experience for the students. We are excited about the unlimited possibilities for power equipment, power converter, and even power system experiments in the new facility.

The Advanced Power Applications Laboratory was also dedicated in October 1989. It is located adjacent to the Grainger Electrical Machinery Laboratory on the ground floor (50N EL). The laboratory emphasizes advanced technologies for electrical energy conversion. Current projects are concerned with switching converters and with advanced motor drive concepts. Equipment is available for the study of harmonics, converters and drives rated up to 75 HP, and superconducting electromechanical systems. The lab has an H-P Vectra personal computer and two 80286 personal computers for use with the instrument sets. The computers have access to the Grainger Power Engineering Software Laboratory through the building network.

The Applied Electrostatics Laboratory is located in the Mechanical Engineering Laboratory. It is administered jointly with the Department of Mechanical and Industrial Engineering. The facility complements the Advanced Power Applications Laboratory with its concentration on interactions between electric fields and liquids. Future projects in ultraminiature electrostatic motors are planned.

8 DIRECTORY

THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
COLLEGE OF ENGINEERING

Dean W. R. Schowalter, Dean of Engineering
College of Engineering
106 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-2150

Assoc. Dean A. F. Graziano, Director of Engineering Experiment Station
College of Engineering
102 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-2152

Assoc. Dean C. J. Altstetter, Assoc. Dean for Academic Affairs
College of Engineering
103 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-7870

Assoc. Dean Bob Mosborg, Director of Placement
College of Engineering
206 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-1960

Assoc. Dean Preston L. Ransom, Director of Continuing Engineering Education
College of Engineering
422 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-6634

William A. Dick, Director, Corporate Programs
College of Engineering
109 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-3850

THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING ADMINISTRATION

Prof. T. N. Trick, Head
Department of Electrical and Computer Engineering
155 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2301

Prof. N. N. Rao, Assoc. Head
Department of Electrical and Computer Engineering
155 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2302

Prof. A. W. Dipert, Assistant Head
Department of Electrical and Computer Engineering
156 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-0716

Mrs. Molly Tracy, Assistant to the Head
Department of Electrical and Computer Engineering
147 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2810

POWER AND ENERGY SYSTEMS AREA

Mrs. Karen Chitwood
Secretary, Power and Energy Systems Area
339 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-6592

Prof. Emeritus M. S. Helm, Coordinator
Power Affiliates Program
329B Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2452 or (217) 333-6592 (Sec.)

Prof. P. W. Sauer, Director
Power Affiliates Program
337 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-0394

Prof. M. A. Pai
345 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-6790

Prof. P. T. Krein
341 Everitt Laboratory
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-4732

AMOCO OIL COMPANY

Industrial Liaison: Mr. John H. Rannells
Amoco Oil Co.
225 N. Michigan Ave.
Chicago, IL 60680
(312) 856-4312

Industrial Liaison: Mr. Jim F. Solari
Amoco Oil Co.
2300 Standard Ave.
Whiting, IN 46394
(219) 473-1250

BECHTEL POWER CORPORATION

Industrial Liaison: Mr. Ron L. Castleberry
Bechtel Associates Professional Corp.
777 East Eisenhower Parkway
P.O. Box 1000
Ann Arbor, MI 48106

Industrial Liaison: Mr. Kenneth Y. Lee
Bechtel Eastern Power Co.
15740 Shady Grove Road
Gaithersburg, MD 20877-1454

CENTRAL ILLINOIS LIGHT COMPANY

Industrial Liaison: Mr. Joseph A. Glad
Supervisor-Substation Engineering Projects
Central Illinois Light Company
300 Liberty Street
Peoria, IL 61602-1404
(309) 693-4771

CENTRAL ILLINOIS PUBLIC SERVICE COMPANY

Industrial Liaison: Mr. G. B. Fritz
Manager, Electric System Engineering
Central Illinois Public Service Company
607 East Adams Street
Springfield, IL 62739
(217) 525-5408

Industrial Liaison: Mr. H. Lawrence Gaffney
Employment Supervisor
Central Illinois Public Service Company
607 East Adams Street
Springfield, IL 62739
(217) 523-3600

COMMONWEALTH EDISON CO.

Industrial Liaison: Mr. Ronald R. Tanton
Technical Services Manager
Commonwealth Edison Co.
Fossil Stations Division
P.O. Box 767
Chicago, IL 60690
(312) 294-3951

Industrial Liaison: L. Del Butterfield
1400 Opus Drive
Downers Grove, IL 60515
(708) 515-7623

Industrial Liaison: Mr. Michael J. Kurzeja
Administrative Engineer
Commonwealth Edison Co.
One First National Plaza
P.O. Box 767
Chicago, IL 60690
(312) 294-4321

W. W. GRAINGER, INC.

Industrial Liaison: Mr. Emil E. Bahnmaier
Chief Engineer
W. W. Grainger, Inc.
5959 Howard St.
Niles, IL 60648

ILLINOIS POWER COMPANY

Industrial Liaison: Mr. Porter Womeldorff
Vice President
Illinois Power Company
500 South 27th Street
Decatur, IL 62525
(217) 424-6700

Industrial Liaison: Mr. P. Jay Caspray
Director, System Planning
Illinois Power Company
500 South 27th Street
Decatur, IL 62525
(217) 424-6463

IOWA-ILLINOIS GAS AND ELECTRIC COMPANY

Industrial Liaison: Mr. Stephen E. Shelton
Vice President - Energy Supply and Engineering
Iowa-Illinois Gas and Electric Company
P.O. Box 4350
206 East Second Street
Davenport, IA 52808
(319) 326-7196

NORTHERN INDIANA PUBLIC SERVICE COMPANY

Industrial Liaison:	Dr. Robert A. Kramer Director, Electric Operations Northern Indiana Public Service Co. 5265 Hohman Ave. Hammond, IN 46320 (219) 853-5200
Industrial Liaison:	Mr. Robert J. Schacht Director of West Region Northern Indiana Public Service Co. 5265 Hohman Ave. Hammond, IN 46370 (214) 886-5555
Industrial Liaison:	Mr. M. L. Stutz Supervisor, Recruiting Northern Indiana Public Service Co. 5265 Hohman Ave. Hammond, IN 46320 (219) 853-5200

PACIFIC GAS AND ELECTRIC COMPANY

Industrial Liaison:	Mr. V. N. Mesa Electrical Engineer Pacific Gas and Electric Co. 77 Beale St. San Francisco, CA 94106 (415) 781-4211
Industrial Liaison:	Mr. William R. Blastic Manager, Operations Control Distribution Business Unit Pacific Gas and Electric Co. 2740 Gateway Oaks Drive Sacramento, CA 95833 (916) 923-7075
Industrial Liaison:	Mr. Steve Leder Supervisor, College Relations Pacific Gas and Electric Co. 245 Market St. San Francisco, CA 94106

PUBLIC SERVICE INDIANA

Industrial Liaison:	Mr. T. W. McCafferty Director, Power System Services Public Service Indiana 1000 East Main Street Plainfield, IN 46168 (317) 838-1482
Industrial Liaison:	Mr. Jerry R. Land Manager, College Recruiting and Employee Services Public Service Indiana 1000 East Main Street Plainfield, IN 46168

S & C ELECTRIC COMPANY

Industrial Liaison: Mr. John Zulaski
Director, Electronic Products
S&C Electric Company
6601 North Ridge Blvd.
Chicago, IL 60626
(312) 338-1000

Industrial Liaison: Mr. Bill Kennedy
Administrator, College Recruitment
S&C Electric Company
6601 North Ridge Blvd.
Chicago, IL 60626
(312) 338-1000

SARGENT AND LUNDY

Industrial Liaison: Mr. William A. Chittenden
Senior Partner
Sargent & Lundy
55 E. Monroe Street
Chicago, IL 60603
(312) 269-3510

Industrial Liaison: Ms. Carol Talaronek
Employment Supervisor
Sargent & Lundy
55 E. Monroe St.
Chicago, IL 60603
(312) 269-3554

SORENSEN COMPANY

Industrial Liaison: Mr. Leon Blackwell
Sorensen Company
P.O. Box 179
Route 45 North
Paxton, IL 60957
(217) 379-2171

Industrial Liaison: Mr. Kelepi Veikoso
Chief Engineer
Sorensen Company
P.O. Box 179
Route 45 North
Paxton, IL 60957
(217) 379-2171

UNION ELECTRIC COMPANY

Industrial Liaison: Mr. G. J. Haven
Vice President of Research and Development
Union Electric Company
1901 Gratiot Street
P.O. Box 149
St. Louis, MO 63166
(314) 554-2334

Industrial Liaison: Mr. Herbert W. Loeh
Vice President, Human Resources
Union Electric Company
1901 Gratiot Street
P.O. Box 149
St. Louis, MO 63166
(314) 621-3222

WISCONSIN POWER AND LIGHT COMPANY

Industrial Liaison: Mr. David E. Ellestad
Vice President-Electrical Engineering
and Procurement
Wisconsin Power and Light Company
222 West Washington Ave.
P.O. Box 192
Madison, WI 53703
(608) 252-3123

Industrial Liaison: Mr. Alan B. Auby
Employment Manager
Wisconsin Power and Light Company
222 West Washington Ave.
P.O. Box 192
Madison, WI 53703
(608) 252-3325

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