SIXTH ANNUAL REPORT
OF THE
POWER AFFILIATES PROGRAM

Amoco Oil Company
Central Illinois Light Company
Central Illinois Public Service Company
Commonwealth Edison Company
Dover Electric Corporation
General Electric Company
Illinois Power Company
Iowa-Illinois Gas and Electric Company
Northern Illinois Service Company
Pacific Gas and Electric Company
Public Service Utilities
Pepco & Midamerica
Pennsylvania Corporation
Union Electric Company
Municipal Electric Power Company
Lake Shore Power and Light Company

M. S. HELM
P. W. SAUER

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

PAP-TR-85-1

May 1985
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 1984. The information is intended to be a progress report to the affiliate companies. These companies are:

Amoco Oil Company
Central Illinois Light Company
Central Illinois Public Service Company
Commonwealth Edison Company
Doerr Electric Corporation
General Electric Company
Illinois Power Company
Iowa-Illinois Gas and Electric Company
Northern Indiana Public Service Company
Pacific Gas and Electric Company
Public Service Indiana
Sargent & Lundy
Sundstrand Corporation
Union Electric Company
Wisconsin Electric Power Company
Wisconsin Power and Light Company

This report was prepared for presentation at the Sixth Annual Review.
# TABLE OF CONTENTS

1. INTRODUCTION .................................................. 1
2. FINANCIAL STATEMENT .......................................... 2
3. THE POWER PROGRAM WITHIN THE DEPARTMENT .............. 3
4. COURSES AND ENROLLMENT ..................................... 6
5. GRADUATE STUDENTS AND PROJECTS ............................ 14
6. UNDERGRADUATE PROJECTS ..................................... 29
7. ACTIVITIES ....................................................... 32
8. LABORATORY FACILITIES ....................................... 35
9. DIRECTORY ....................................................... 37
10. REFERENCES AND PUBLICATIONS ............................... 46
1. INTRODUCTION

The electric power and energy systems area at the University of Illinois has been a significant part of the electrical engineering curriculum for well over 100 years. In the 1950's and 60's, a large portion of electrical engineering students and faculty left the power area in favor of the rapidly growing fields of communications, electronics and control. In the 1970's, the national interest in electric power systems coupled with an oversupply of engineers in other areas contributed to a substantial return of interest in the power area.

The 1980's have brought record-breaking enrollments in electrical engineering as the digital computer age matures. With reduced federal funding of research in power and energy systems, the support provided by the Power Affiliates Program is more important now than ever before. The support shows the strong interest which still endures for an active power program at the University of Illinois.

This report is a summary of the sixth-year activities directly related to the Power Affiliates Program as well as those indirectly related but perhaps stimulated by the existence of such a program. The detailed objectives and organization of the program are described in Reference [1].
2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 1984 was prepared from a detailed University statement as of December 31, 1984, Reference [2]

| Income carried over from the calendar year 1983 | -$23,191.00 |
| Total income during calendar year 1984 | 58,500.00 |
| Total available income during calendar year 1984 | $35,309.00 |

<table>
<thead>
<tr>
<th>Expenditure Item</th>
<th>Expenditure Amount</th>
<th>Percentage of Total Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate Assistantships</td>
<td>$30,791.00</td>
<td>60</td>
</tr>
<tr>
<td>Class trips, travel</td>
<td>3,975.00</td>
<td>8</td>
</tr>
<tr>
<td>Communications, clerical, supplies, reports, conference fees, and administration</td>
<td>16,587.00</td>
<td>32</td>
</tr>
<tr>
<td>Total expenditure:</td>
<td>$51,353.00</td>
<td>100</td>
</tr>
</tbody>
</table>

Summary

| Amount available during calendar year 1984 | $35,309.00 |
| Amount expended during calendar year 1984 | -51,353.00 |
| Balance as of December 31, 1984 | -$16,044.00 |
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 6 units (18-24 credit hours) and complete a graduate thesis. 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:

Physical Electronics
Atmospheric Sciences and Propagation
Computers and Information Processing
Electromagnetics
Communication and Control
Circuits and Signal Processing
Power and Energy Systems
Bioengineering and Acoustics

A faculty committee is assigned to each area and given the responsibility for "maintaining" that area within the department. The Power and Energy Systems Area Committee and associated faculty for the 1984-1985 academic year together with their general interests are:
J. M. Crowley (Chairman, Applied Electrostatics)

S. Ahmed-Zaid (Visiting, Machine Theory)

R. W. Burtness (Solid State Motor Drive Systems)

M. S. Helm (Emeritus, Power System Analysis)

M. A. Pai (Dynamics and Control of Power Systems)

P. V. Kokotovic (Optimization and Control of Power Systems)

P. W. Sauer (Computer Simulation of Machines and Power Systems)

M. Ilic-Spong (Analysis and Control of Power Systems)

M. E. VanValkenburg (Network Analysis)

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

One of the primary responsibilities of the Power and Energy Systems Area Committee is to update and staff the courses assigned to the Power and Energy Systems Area. In 1984-1985 those courses were:

EE260 Introduction to Circuit Analysis (Joint responsibility)
EE330 Electromechanics
EE331 Introduction to Electric Power Engineering
EE333 Electric Machinery
EE336 Advanced Electromechanical Energy Conversion I
EE356 Applied Electrostatics
EE368 Solid State Motor Drive Systems
EE376 Power System Analysis I
EE378 Power System Analysis II
EE371PTK Power Electronics
EE452 Computer Methods in Electric Network Analysis (Joint responsibility)

EE497MKS Advanced Electric Machine Modelling and Dynamics

EE497PS Operation and Control of Power Systems

EE497SP Dynamics and Stability of Power Systems

EE497MIS Advanced Control of Electrical Machine Systems

The three-hundred level courses are undergraduate courses, while the four-hundred level courses are graduate. Of these courses, EE336, EE378, EE497MKS, EE497PS were not taught during the 1984-85 academic year. The Power and Energy Systems Area Committee is currently evaluating 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.
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 1984-1985 academic year is also given for each course.

**EE260 Introduction to Circuit Analysis** (Primary responsibility for this course is assigned to the circuits and signal processing area committee.)

EE260 is a three-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, basic principles of circuit analysis including d-c, transient and sinusoidal steady-state analysis. The topical outline includes R, L, C and source elements, Kirchhoff's laws, node and mesh equations, Thevenin and Norton equivalents, controlled sources, transient switching d-c analysis, and impedance and transfer functions for steady state. The course is also taken by many non-electrical engineering students. The required text was: J. Nilsson, "Electric Circuits." The total enrollment for academic year 1984-1985 was 924.

**EE330 Electromechanics**

EE330 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 Kirchoff's Voltage Law (KVL). Conservation of power and
energy is emphasized in energy balance analysis. An introduction to rotating machines is generally included as illustrative examples. Particular emphasis is given to the interaction between the electrical system (KVL) and the mechanical system (NSL). The required text is "Electromechanical Dynamics," Part I by H. H. Woodson and J. R. Melcher. This course is not required, but is in a list of three advanced three-hour EE courses of which one must be taken. The other two are probability and solid state devices. The total enrollment for the academic year 1984-1985 was 91.

EE331 Introduction to Electric Power Engineering

EE331 is an introductory three-hour course in the theory and analysis of electric machinery and power systems. The machinery analysis is limited to a presentation and manipulation of steady-state equivalent circuits. The power system analysis is limited to fundamental concepts unique to power circuits. A topical outline includes an overview of power system structure and the role of individual components, basic magnetic circuits including transformer fundamentals, elementary machine models, steady-state balanced symmetrical three-phase systems, one-line diagrams and per-unit representation of balanced symmetrical wye-connected systems, and introduction to nonlinear problems including constant power constraints. The required texts were: O. I. Elgerd, "Basic Electric Power Engineering" and R. D. Shultz and R. A. Smith, "Introduction to Electric Power Engineering." The total enrollment for the academic year 1984-1985 was 41.

EE333 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, over current relay operation, an interconnected multimachine system, and a written plus oral project presentation on power and energy system topics. The required text in 1984 was Fitzgerald, Kingsley and Umans, "Electric Machinery." The total enrollment for the academic year 1984-1985 was 22.

EE336 Advanced Electromechanical Energy Conversion I

This three-hour course contains advanced theory and analysis of power system devices including transformers and all rotating machines. It includes the steady-state as well as dynamic analysis of unbalanced operation of three-phase transformers, induction, synchronous and d-c machines. The analysis uses symmetrical components and dq transformations. Emphasis is placed on the time scale modelling of electromechanical devices and the solution of differential dynamic as well as algebraic steady-state equations. This course is an advanced EE elective.

EE356 Applied Electrostatics

EE356 is a comprehensive course in the theory and applications of electrostatics. Examples are selected from a wide variety of areas, including computer peripherals, copying equipment, electric power systems, biomedical instrumentation, and smoke detectors. A topical outline includes electrostatic fields, free charge, surface charge, volume charge, corona, individual charge dynamics, behavior of charged surfaces and volumes, and high voltage generation and measurement. This course is an advanced three-hour EE elective. The
current required text is "Applied Electrostatics" by J. M. Crowley. The total enrollment for the academic year 1984-85 was 11.

EE368 Solid State Motor Drive Systems

The silicon controlled rectifier and the integrated circuit have opened wide the field of both d-c and a-c motor drive systems for electric automobiles, trucks, locomotives, track vehicles, off-highway vehicles and countless industrial drive systems. This course describes the general principles involved in the systems as well as the general characteristics of the various component parts of the systems including inverters, frequency converters, motors, generators and control systems. This course is an advanced EE three-hour elective. The current required text is "Solid-State D-C Motor Drives" by A. Kusko. The total enrollment for the academic year 1984-1985 was 20.

EE371PTK Power Electronics

This three-hour course is a comprehensive treatment of power electronic devices and their use in the control of power systems. Topics included are switching matrices, existence functions, phase angle control, voltage control and pulse modulation, all converters and the high power considerations in diodes, thyristors, bipolar transistors and field effect transistors. This course is an advanced EE elective. The required text in academic year 1984-1985 was "Switching Power Converters" by Peter Wood. The enrollment was 19. This course is available on video tape.

EE376 Power System Analysis I

This three-hour course is the first of two courses on power-system analysis. Topics included are power system equivalents, network analysis, load flow, fault analysis, symmetrical components, unsymmetrical fault analysis, and
introductions to economic dispatch and reliability. 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 EE elective. The required text in the academic year 1984-1985 was "Elements of Power System Analysis" by W. D. Stevenson. The enrollment was 16.

EE378 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, modelling for dynamic and transient stability, and d-c transmission. This course is an advanced EE elective.

EE452 Computer Methods in Electric Circuit Analysis

EE452 is a graduate course designed for both electric power and electronics students. The course presents the fundamental computer algorithms utilized to analyze large scale circuits. Applications in both the power and electronics area 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 texts are "Computer Aided Analysis of Electronic Circuits" by Chua and Lin, and "Computer Techniques in Power System Analysis" by Pai. This course is a graduate 1 unit (three hour) elective. The total enrollment for academic year 1984-1985 was 25.
EE497MKS Advanced Electric Machine Modelling and Dynamics

EE497MKS is a proposed new 1 unit (three-hour) graduate course in the machines area. It has been offered once as a special topics course and is currently being proposed for permanent listing. The course includes the detailed analysis of single-phase machines, unbalanced polyphase machines, arbitrary reference frame theory, reduced order modelling by singular perturbation, operational impedances and time scales, stability of machines, and control of machines by power electronics. There is no text available at this time. Notes and journal articles are currently used to supplement lectures.

EE497PS Operation and Control of Power Systems

EE497PS is a proposed new 1 unit (three-hour) graduate course in the power systems area. It has been offered twice as a special topics course and is currently being proposed for permanent listing. 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. There is currently no text available. Notes and journal articles supplement the lectures.

EE497SP Dynamics and Stability of Power Systems

EE497SP is a proposed new 1 unit (three-hour) graduate course in the power systems area. It has been offered three times as a special topics course and is currently being considered for permanent listing. 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 texts available are "Power System Control and Stability" by Anderson and Fouad, "Power System Stability" by Pai, and "Time Scale Modeling of Dynamic Networks with Applications to Power Systems" edited by Chow. The total enrollment in this course during academic year 1984-1985 was 4. This course is available on video tape.

**Video-Taped Course Work**

The graduate committee of the department has finalized plans to offer both an M.S.E.E. and M.E.E. degree for students through video tape course credit. The requirements for an M.S.E.E. would be the same as those for "on campus" students consisting of a minimum of six courses plus a thesis. The six courses could be completed through video tape instruction off campus. The thesis could also be completed off campus although periodic visits with the thesis advisor would be expected.

The requirements for an M.E.E. would be satisfactory completion of 9 video taped graduate courses and no thesis. There are certain restrictions on these 9 courses just as in the restrictions for breadth and depth in the M.S.E.E. program. Proposals for both degree offerings have been forwarded by the ECE Department to the University Administration for approval.
NUMBER OF POWER 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

1981-1982 Power Area Graduates

B.S.E.E. - 44
M.S.E.E. - 4

1982-1983 Power Area Graduates

B.S.E.E. - 33
M.S.E.E. - 5
Ph.D.E.E. - 2

1983-1984 Power Area Graduates

B.S.E.E. - 25
M.S.E.E. - 3
Ph.D.E.E. - 1

1984-1985 Power Area Graduates (expected)

B.S.E.E. - 20
M.S.E.E. - 4
Ph.D.E.E. - 2

These figures do not include the significant number of graduates in related fields who have performed research in the application of control to power systems.
5. GRADUATE STUDENTS AND PROJECTS

This section of the report contains the listing of graduate students whose major research efforts were influenced directly by the Power Affiliates Program during the calendar year 1984. 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 their work will be made available to all affiliate companies in the form of technical reports. The following students were associated with the Power Affiliates Program, and their work is described in the following pages:

Baranek, Mark (M.S.)
Behera, Anup (Ph.D.)
Christensen, John (Ph.D.)
Clain, Tom (M.S.)
Dobraca, Fadil (M.S.)
Dugar, Abijheet (M.S.)
Khorasani, K. (Ph.D.)
Mak, Fong (M.S.)
Martina, Mark (M.S.)
Rajagopalan, Chithra (M.S.)
Stupar, Mark (M.S.)
Varghese, Abe (M.S.)
Vens, Jim (M.S.)
Wojciechowski, Roy (M.S.)
Name: Mark R. Baranek
Date of Birth: August 18, 1961
Place of Birth: England
Received B.S.: June 1983 (U. of I.)
Received M.S.: August 1984
Advisor: P. W. Sauer/M. A. Pai
Support: Power Affiliates Program
Research Title: "A Closed Form Energy Function for Fast Transient Stability Analysis of Electric Power Systems"
Status: Report available (PAP-TR-84-2)

ABSTRACT

There is a rapidly emerging need for fast stability analysis both in off-line as well as on-line operation of power systems. In this project, trajectory approximations were used to obtain closed form expressions for energy functions as functions of time. Quadratic angle time trajectories were assumed for the fault on period and used with the post fault potential energy function to develop a time series expression for the potential energy. The potential energy boundary surface method was then applied to obtain rapid stability results.
Name: Anup K. Behera
Date of Birth: September 24, 1958
Place of Birth: India
Received B.S.: May 1980 (I.I.T. India)
Received M.S.: May 1982 (U. of I.)
Started Ph.D.: August 1983
Advisor: P. W. Sauer/M. S. Pai
Support: Partial Power Affiliates Program, Partial U. of I. T.A.
Research Title: "Fast Stability Analysis"
Status: Continuing

ABSTRACT

This project is a continuation of efforts to produce algorithms for transient stability analysis suitable for on-line application in Dynamic Security Assessment. The features of constant acceleration fault on trajectory approximations and the Potential Energy Boundary Surface (PEBS) method are being used together with area and time scale decomposition techniques. This work is currently focusing on understanding the time scale behavior of multimachine systems during transients.
ABSTRACT

Pilot point voltage/var control is considered a secondary control because it involves modifying the reference voltage values of the voltage regulator, which in turn controls the output voltage. The project seeks an optimal pilot point structure to be used for system wide voltage coordination.
Name: Thomas J. Clanin
Date of Birth: June 23, 1956
Place of Birth: Chicago, Illinois
Received B.S.: May 1979 (U. of I.)
Received M.S.: August 1984
Advisor: P. W. Sauer
Support: Construction Engineering Research Laboratory
Research Title: "Digital Static Pressure Control of a Variable Air Volume Heating, Ventilating and Air Conditioning System"
Status: Report available (PAP-TR-84-3)

ABSTRACT

The U.S. Army Construction Engineering Research Laboratory has developed a test facility for advanced heating and air conditioning systems. They are considering variable speed operation of an inverter fed induction motor for constant air duct pressure during normal damper operation. In this project, a microprocessor was used to implement real-time control of the fan motor speed to obtain the constant pressure. The problem is complicated by noise in the pressure transducer output and by operation requirements to obtain rapid response when all dampers are closed.
ABSTRACT

This project is investigating the use of adaptive control strategies in protective relaying schemes. The plan is to work on a systemwide formulation of the protection problem. Fadil Dobraca has considerable experience in realistic power systems abroad.
Name: Abhijeet Dugar
Date of Birth: October 30, 1961
Place of Birth: Calcutta, India
Received B.S.: July 1984 (Delhi College of Eng.)
Started M.S.: August 1984
Advisor: P. W. Sauer (nonthesis)
Support: CERL - USA
Research Title: "Computer Power Compatability"
Status: Continuing

ABSTRACT

This project has been funded by the U. S. Army Construction Engineering Research Laboratory as a special investigation of the power requirements of current and future computer systems. The specifications for uninterruptible power supplies currently used by the military have been found to be inadequate. They do not address the propagation of electrical transients. This work will investigate the propagation of transients (voltage pulses) through typical power supplies. The objective is to formulate an acceptable specification for power acceptability in terms of voltage transients.
Name: Khashayar Khorasani
Date of Birth: March 23, 1960
Place of Birth: Tehran, Iran
Received B.S.: May 1981 (U of I)
Received M.S.: December 1982 (U of I)
Started Ph.D.: January 1983
Advisor: M. A. Pai
Support: Illinois Office of Advanced Engineering Studies
Research Title: "Modal Energy Functions"
Status: Continuing

ABSTRACT

When transients occur in power systems, the dynamic responses can be separated into time scales which reflect slow and fast phenomena. The computation time for stability analysis can be greatly reduced if the critical information can be extracted from only the relevant time scales. Preliminary results based on the analysis of mass spring systems indicate that the dynamics can be described through the fast and slow exchanges of energy. This work is currently being extended to the nonlinear power system models. The effects of neglecting certain dynamics (i.e., fast) on stability characteristics is being investigated. Examples have been found where models with fast transients included are unstable while classical reduced order models of the same machine with fast transients are stable. Methods to recover the proper stability information without resorting to the addition of the fast differential equations are being investigated.
This project is concerned with induction motor control using power electronics. Initial emphasis is on the proper modeling techniques for the dynamic performance of variable speed drive systems. The project will consider nonlinear control methods.
ABSTRACT

Power system stabilizers are being considered in connection with detailed machine models. Current design configurations are based primarily on models including field flux decay and mechanical modes together with the excitation system. Effects of damper windings are being included in the PSS design.
ABSTRACT

This project seeks to discover the dynamic nature of voltage collapse. A full steady-state stability study is being performed on sample systems to determine which mode becomes unstable when the voltage collapse phenomenon occurs. Most reported analyses of the voltage collapse phenomenon describe only steady-state characteristics coupled with tap changing underload transformer (TCUL) operation. Dynamic TCUL modeling will be included if necessary.
Name: Mark Stupar
Date of Birth: November 9, 1949
Place of Birth: Springfield, Illinois
Received B.S.: January 1972 (U. of I.)
Started M.S.: August 1983
Advisor: M. A. Pai
Support: University of Illinois (Teaching Assistant)
Research Title: "Multiple Time Scale Modeling of Synchronous Machines"
Status: Continuing

ABSTRACT

The mathematical model of a single synchronous machine can be shown to exhibit at least three distinct time scales. These models are being analyzed to obtain improved reduced order models in each of the three time scales. These are the stator transients (fast), the mechanical dynamics (medium) and the field transients (slow). The project will also consider additional time scales to include damper winding models.
Name: Abraham Varghese
Date of Birth: July 30, 1962
Place of Birth: Tiruvalla, India
Received B.S.: January 1984 (IIT-Madras)
Started M.S.: August 1984
Advisor: P. W. Sauer/M. A. Pai/M. Ilic-Spong
Support: NSF-PYI, Power Affiliates Program
Research Title: "Generator Power Capability Coordination with Minimum Excitation Limiters"
Status: Continuing

ABSTRACT

Generator power capability curves give regions of acceptable real and reactive power operations. While these curves are based on both thermal and steady-state stability constraints, this project focuses on the stability limits. The dynamics of the Minimum Excitation Limiter connected to an excitation system will be coordinated with the loss of field relay to determine the appropriate power capabilities for expected transients.
Name: James R. Vens
Date of Birth: September 22, 1960
Place of Birth: Michigan
Received B.S.: June 1984 (GMI)
Started M.S.: August 1984
Advisor: P. W. Sauer
Support: U.S.A.-CERL, (50% Employee)
Research Title: "Return Fan Control"
Status: Continuing

ABSTRACT

This project has just begun under the mutual direction of the U. of I. and the U.S. Army CERL. The project involves the continuation of research into advanced control concepts for heating, ventilating and air conditioning systems. Return fan control is being investigated as part of a complete control strategy for the test system at CERL.
Roy Wojciechowski

September 9, 1961

La Salle, Illinois

June 1983

August 1983

P. W. Sauer (Nonthesis)

University of Illinois (Teaching Assistant), Power Affiliates Program

"Digital Torque Angle Meter"

Continuing

ABSTRACT

This abstract does not address the M.S. research of Mr. Wojciechowski, rather it summarizes a special project which he has been undertaking for the power group. A digital torque angle meter has been developed. The meter obtains a rotor position pulse from an optical coupler and a stator voltage zero crossing pulse from a sensing transformer. The digital circuit computes the time between pulses and converts that time into an angle display. The meter computes this angle once every electrical cycle, making it valid for transient analysis where the torque angle can be assumed constant over one cycle.
6. UNDERGRADUATE PROJECTS

While the majority of research projects funded through the Power Affiliates Program are oriented towards graduate students, a substantial effort is made to interest undergraduate students in the challenges of the power area. In many cases, juniors and seniors select special projects which supplement their required coursework. These projects often involve considerable time and effort of both the students and faculty. Funds are used to purchase small pieces of equipment and provide hourly income to summer students.

A Model Power System for Laboratory Experiments

The goal of this project is to develop a realistic system to allow laboratory work in power system analysis, operation, and control. An eight-bus three-machine system rated at 30 kVA has been built and used as a demonstration in the existing laboratory course. A commercial speed controller (Cutler Hammer) provides speed control for one of the three shunt d-c motors which serve as prime movers. A locally designed pulse-width-modulated d-c converter is available to provide automatic voltage control, and will eventually serve as an electronic speed control.

The power laboratory Apple IIe computer system (Furnished by General Electric Co.) is currently being prepared to serve as a SCADA device for the system. Software for load flows, system modifications, and graphic display have been written and tested. Hardware and software for direct computer control of relays have been successfully demonstrated. Efforts on data acquisition and other aspects are continuing.
Large Scale System Software

The entire system planning software package used by Philadelphia Electric Co. has been obtained for use by the power area. The package has been loaded onto the University of Illinois Cyber computing system. Since the P.E.C.O. programs are written for use on an IBM machine, they must be modified to be usable on the CDC machine. This project will involve several students and will continue for some time. When operational, the programs will be useful in both teaching and research. The programs can simulate virtually any modern day interconnected power system using conventional modeling techniques. The programs will be used in course work to familiarize students with large scale software and in research to test new models and new algorithms.

Self Excited Induction Generators

This project involves the use of induction machines as generators without a firm AC supply voltage. The principal of self excitation as is common in DC generators is being investigated. The ability to self excite induction machines has been known for some time, but never considered practical. This project is looking at simulation techniques, steady state and transient behavior, and will eventually involve actual machine testing.

Propagation of Transients Through Power Supplies

There is a considerable interest among computer manufacturers in understanding how typical disturbances propagate through conventional as well as proposed power supplies. In this project, the newly proposed IEEE low voltage transient tests are being analyzed in connection with motor generator sets, uninterruptible power supplies, and DC converters. The objective is to determine acceptable power criterion for sensitive equipment.
Averaging and Time Scales in Single Phase Machines

Unbalanced machines such as single phase induction motors exhibit speed and torque oscillations in steady state. The traditional modeling of these devices has essentially ignored these oscillations and assumed some average slip or speed. In this project, a single phase induction motor is being modeled in instantaneous time steady state to determine appropriate and yet practical mathematical circuit models.
7. ACTIVITIES

The following chronological listing of 1984 events and highlights is a brief outline of the direct and indirect influence of the Power Affiliates Program on the University of Illinois and Industrial Affiliates.

January
- S. Ahmed-Zaid stays as Visiting Research Associate.
- Spring Semester began with seven power courses offered and taught.
- Tom Clanin begins M.S.

February
- Power area graduate listing mailed to companies.
- Marija Ilic-Spong selected as NSF Presidential Young Investigator.

March
- Electrical Engineering Open House held with displays of power projects and machinery demonstrations.
- Sargent and Lundy Faculty Engineering Conference attended by M. S. Helm and P. W. Sauer.

April
- American Power Conference attended by the following faculty and students with sponsors:

  M. S. Helm (A.P.C.)   J. E. Neale (I.P.)
  P. W. Sauer (U.E.)   B. S. Jones (C.E.)
  M. A. Pai (C.E.)    J. Parker (U.E.)
  D. F. Hang (Harza)  T. A. Thollott (W.P.L.)
  P. T. Krein (C.E.)  D. D. Darling (C.E.)
  C. S. Larson (S.L.)  B. A. Dobbs (Harza)
  B. Micklich (C.E.)  G. A. Huelsmann (I.P.)
  N. R. Miller (Brown & Root)  G. Unger (S.L.)
  Said Ahmed-Zaid (Brown & Root)

- Prof. Chee-Mun Ong visits and presents Seminar on Control and Simulation of HVDC.
May

- Fifth Annual Review of the Power Affiliates Program
- Spring Semester closes with 18 B.S. and 2 M.S. graduates in Power.
- D. Kirschen visits and presents Seminar on Optimal Control of Induction Machines.

June

- P. T. Krein makes video tape course on Power Electronics.
- K. R. Padiyar visits and presents Seminar on Transient Stability with Voltage Dependent Loads.

July

- IEEE PES Summer Power Meeting attended by M. S. Helm and P. W. Sauer.
- M. A. Pai attends IFAC World Congress and presents a paper.

August

- Abe Varghese, Chithra Rajagapalan and Mark Martina start M.S.
- Power graduate listing mailed to recruiting companies.
- Fall semester begins with seven power courses offered and taught.
- Mark Baranek and Tom Clannin complete M.S.
- Graduate Course on Dynamics and Stability of Power Systems offered on video tape.
- Dr. Marija Ilic-Spong joins Power Faculty.

September

- Marija Ilic-Spong presents Seminar on Modern Control of AC Drives.
- K. Khorasani presents Seminar on Time-Scales in Stability.
- M. A. Pai and P. W. Sauer receive notice of funding by E.P.R.I. through E.C.C.
October

- Pete Sauer presents research results to Office of Advanced Engineering Study in Rockford, Illinois.


- R. Marino visits and presents Seminar on Geometric Techniques in Power System Swing Equations.

- Pete Sauer is awarded two U.S.A. C.E.R.L. Contracts.


- Prof. M. Harris visits and presents Seminar on Switched Reluctance Drives.

November

- P. W. Sauer and M. A. Pai receive notice of funding by D.O.E. through G.E.

December


- P. W. Sauer, K. Khorasani and Marija Ilic-Spong attend 1984 Conference on Decision and Control. They each presented a paper.

- P. W. Sauer and Said Ahmed-Zaid visit Los Angeles Department of Water and Power to discuss participation in the Power Affiliates Program.
Virtually all of the University of Illinois laboratories are available to students studying in the power and energy systems area of Electrical Engineering. The electric machinery laboratory is located on the ground floor of the Electrical Engineering Building. It is primarily an instructional laboratory capable of accommodating classes of 12 with potential to expand to classes of 24. Although much of the equipment is at least 20 years old, it is sufficient and plentiful for introductory undergraduate instruction in rotating machinery, transformers, elementary system concepts, and other power fundamentals. The laboratory is being equipped for real-time monitoring and control of four interconnected machines and loads. The small model power system is used for undergraduate instruction and has the potential for use in graduate research in the control of interconnected machines.

The high-voltage laboratory was dismantled some time ago, and converted into the current bioengineering laboratory. While there has been some interest recently in high-voltage phenomenon by both undergraduate and graduate students, there are no current plans to revitalize the high-voltage lab. The electric machinery laboratory students have in the past taken field trips to Kearney Corporation in Chicago to observe actual high-voltage testing procedure and demonstrations.

Perhaps the most widely used laboratory for both education and research is the Digital Computer Laboratory of the University of Illinois. Two Control Data Corporation CYBER 175's are available through a remote job site on the first floor of the Electrical Engineering Building. The Electrical Engineering remote job site is controlled by a PDP 11 computer to support a card reader, high-speed line printer and 23 remote interactive time-sharing terminals. The use of the
digital computer has been integrated into virtually all of the power courses. The facilities are also used extensively by the members of the power and energy systems area faculty and their graduate students in research efforts. The facilities are very useful in the development of interactive programs. The DEC 10 computer located in the Coordinated Science Laboratory is also available for graduate research. The PLATO system, which was initially created by the Computer Science Department, is used extensively in many areas of the undergraduate curriculum.
9. DIRECTORY

THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN COLLEGE OF ENGINEERING

Dean M. E. Van Valkenburg, 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 J. J. Stukel, Director of Engineering Experiment Station
College of Engineering
106 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-2152

Asst. Dean Bob Mosberg, Director of Placement
College of Engineering
109 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-3836

Prof. M. E. Krasnow, Coordinator, University-Industry Relations
College of Engineering
204 Engineering Hall
University of Illinois at Urbana-Champaign
1308 W. Green St.
Urbana, Illinois 61801
(217) 333-3836

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

Prof. G. W. Swenson, Jr., Head (On Sabbatical)
Department of Electrical and Computer Engineering
155 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2301

Prof. E. W. Ernst, Assoc. Head for Instruction (Acting Head)
Department of Electrical and Computer Engineering
155 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2302
Prof. J. B. Cruz, Jr., Assoc. Head for Research
Department of Electrical and Computer Engineering
155 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green Street
Urbana, Illinois 61801
(217) 333-2302

Mr. H. B. Lawler, Assistant to the Head
Department of Electrical and Computer Engineering
147 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2810

POWER AND ENERGY SYSTEMS AREA COMMITTEE

Prof. Emeritus M. S. Helm
Department of Electrical and Computer Engineering
329B Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-2452 or (217) 333-0716 (Sec.)

Prof. P. W. Sauer
Department of Electrical and Computer Engineering
337 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-0394

Prof. M. A. Pai
Department of Electrical and Computer Engineering
345 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-6790

Prof. M. Ilic-Spong
Department of Electrical and Computer Engineering
343 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-4463
Prof. J. M. Crowley
Department of Electrical and Computer Engineering
341 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-4732

Prof. R. W. Burtness
Department of Electrical and Computer Engineering
339 Electrical Engineering Building
University of Illinois at Urbana-Champaign
1406 W. Green St.
Urbana, Illinois 61801
(217) 333-4461
AMOCO OIL COMPANY

University Liaison: Prof. Peter W. Sauer

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

Industrial Liaison: Mr. Jim F. Solari (Technical)
Electrical Engineering Section
Amoco Oil Co.
225 N. Michigan Ave.
Chicago, IL 60680
(312) 856-7085

Industrial Liaison: None (Non-technical)

CENTRAL ILLINOIS LIGHT COMPANY

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: Mr. Thomas J. Ptasnik (Technical)
Electric Engineering Manager
Central Illinois Light Company
300 Liberty Street
Peoria, Illinois 61602
(309) 691-6615

Industrial Liaison: None (Non-technical)

CENTRAL ILLINOIS PUBLIC SERVICE COMPANY

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: Mr. Harley G. Grim (Technical)
Central Illinois Public Service Company
607 East Adams Street
Springfield, Illinois 62701
(217) 523-3600

Industrial Liaison: Mr. H. Lawrence Gaffney (Non-technical)
Employment Supervisor
Central Illinois Public Service Company
607 East Adams Street
Springfield, Illinois 62701
(217) 523-3600
COMMONWEALTH EDISON CO.

University Liaison: Prof. M. Stanley Helm

Industrial Liaison: Mr. James W. Johnson
(Technical) Vice President
Commonwealth Edison Co.
One First National Plaza
P. O. Box 767
Chicago, IL 60690
(312) 294-4321

Industrial Liaison: Mr. Arthur M. Roberts
(Non-technical) Commonwealth Edison Co.
One First National Plaza
P. O. Box 767
Chicago, IL 60690
(312) 294-4321

DOERR ELECTRIC CORPORATION, SUBSIDIARY OF W. W. GRAINGER, INC.

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: Mr. James P. Dries
(Technical) Vice President, Sales
Doerr Electric Corporation
P. O. Box 67
Cedarburg, WI 53012
(414) 377-0500

Industrial Liaison: None
(Non-technical)

GENERAL ELECTRIC COMPANY

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: Dr. James R. Winkelman
(Technical) E.U.S.E.P.
General Electric Co.
1 River Road
Schenectady, NY 12345

Industrial Liaison: Mr. J. R. Britt
(Non-technical) General Electric Co.
Bldg. 1, Room 209
Appliance Park
Louisville, KY 40225
ILLINOIS POWER COMPANY

University Liaison: Prof. M. Stanley Helm

Industrial Liaison: (Technical) Mr. Gerald E. Huck
Manager of Planning
Illinois Power Company
500 South 27th Street
Decatur, Illinois 62525
(217) 424-6700

Industrial Liaison: (Non-technical) Mr. Jerome P. O'Grady
Vice President
Illinois Power Company
500 South 27th Street
Decatur, Illinois 62525
(217) 424-6808

IOWA-ILLINOIS GAS AND ELECTRIC COMPANY

University Liaison: Prof. M. Stanley Helm

Industrial Liaison: (Technical) Mr. Karl H. Schafer
Vice President - Energy Supply and Engineering
Iowa-Illinois Gas and Electric Company
206 East Second Street
Davenport, Iowa 52808
(319) 326-7196

Industrial Liaison: (Non-technical) None

NORTHERN INDIANA PUBLIC SERVICE COMPANY

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: (Technical) Mr. Glen K. Dippon
Manager of General Engineering
Northern Indiana Public Service Co.
5265 Hohman Ave.
Hammond, Indiana 46325
(219) 853-5200

Industrial Liaison: (Non-technical) Mr. Richard Kalmas
Employment
Northern Indiana Public Service Co.
5265 Hohman Ave.
Hammond, Indiana 46325
(219) 853-5200
<table>
<thead>
<tr>
<th>Company</th>
<th>University Liaison</th>
<th>Industrial Liaison</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PACIFIC GAS AND ELECTRIC COMPANY</strong></td>
<td>Prof. M. Stanley Helm</td>
<td>Mr. V. N. Mesa / Electrical Engineer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pacific Gas and Electric Co.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>77 Beale St. / San Francisco, CA 94106</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(415) 781-4211</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. R. Scott Irby / Supervisor, Professional Employment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pacific Gas and Electric Co.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>215 Market St., Room 1300 / San Francisco, CA 94106</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(415) 781-4211</td>
</tr>
<tr>
<td><strong>PUBLIC SERVICE INDIANA</strong></td>
<td>Prof. Peter W. Sauer</td>
<td>Mr. T. W. McCafferty / Manager Research</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public Service Indiana</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 East Main Street / Plainfield, Indiana 46168</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(317) 838-1482</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Jim L. Stanley / Personnel Services Coordinator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public Service Indiana</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 East Main Street / Plainfield, Indiana 46168</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(317) 838-1790</td>
</tr>
<tr>
<td><strong>SARGENT AND LUNDY</strong></td>
<td>Prof. M. Stanley Helm</td>
<td>Mr. Lowell E. Ackmann / Senior Partner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sargent &amp; Lundy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55 E. Monroe Street / Chicago, Illinois 60603</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(312) 269-3510</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ms. Carol Talaronek / Employment Supervisor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sargent &amp; Lundy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55 E. Monroe St. / Chicago, Illinois 60603</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(312) 269-3554</td>
</tr>
</tbody>
</table>
SUNDDRAN D CORPORATION

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: Mr. Don A. Straznickas
(technical)
Director of Research Engineering
Sundstrand Aviation Operations
4747 Harrison Ave.
P. O. Box 7002
Rockford, IL  61125
(815) 226-6763

Industrial Liaison:
(Non-technical)
Mr. Michael Trotter
College Relations Coordinator
Sundstrand Corp.
4751 Harrison Ave.
Rockford, IL  61101
(815) 226-6233

UNION ELECTRIC COMPANY

University Liaison: Prof. M. Stanley Helm

Industrial Liaison: Mr. F. R. Lengefeld
(technical)
Vice President of Engineering
and Construction
Union Electric Company
1901 Gratiot Street
P. O. Box 149
St. Louis, MO  63166
(314) 554-2334

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

WISCONSIN ELECTRIC POWER CO.

University Liaison: Prof. Peter W. Sauer

Industrial Liaison: Dr. Robert Bischke
(technical)
Wisconsin Electric Power Co.
231 W. Michigan
Milwaukee, WI  53201
(414) 277-2565
Industrial Liaison:  
(Non-technical)  
Mr. Cory Erickson  
Wisconsin Electric Power Co.  
231 W. Michigan  
Milwaukee, WI 53201

WISCONSIN POWER AND LIGHT COMPANY

University Liaison:  
Prof. M. Stanley Helm

Industrial Liaison:  
(Technical)  
Mr. Charles G. Kerndt  
Vice President, Engineering  
and Procurement  
Wisconsin Power and Light Company  
222 West Washington Ave.  
P. O. Box 192  
Madison, Wisconsin 53701  
(608) 252-3325

Industrial Liaison:  
(Non-technical)  
Mr. Alan B. Auby  
Employment Manager  
Wisconsin Power and Light Company  
222 West Washington Ave.  
P. O. Box 192  
Madison, Wisconsin 53701  
(608) 252-3325
10. REFERENCES AND PUBLICATIONS


