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OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Athens Automation and Control Experiment

Project Review Meeting

Knoxville, Tennessee December 3–5, 1985

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
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FOREWORD

A review meeting of the Athens Automation and Control Experiment (AACE) was held at the Hyatt Regency Hotel in Knoxville, Tennessee, on December 3-4, 1985. A tour of Athens Utilities Board's (AUB's) facilities and installed electric distribution automation equipment was conducted on December 5, 1985, in Athens, Tennessee. Invitations to attend were extended to numerous people associated with the electric utility industry. Representatives from various electric utilities attended the Knoxville meeting. Also in attendance were individuals from manufacturing companies, universities, consultants in the electric utility industry, and several support personnel from Oak Ridge National Laboratory (ORNL) who are involved with the AACE. One of the principal objectives of the AACE is to transfer the results of the project to the electric utility industry. The review meeting was held to facilitate such a transfer in a timely fashion. Because the major portions of the project are not expected to be completed until 1987, it was felt that waiting until the conclusion of the project to disseminate information would result in less timely communication of information. The meeting reviewed the progress of the AACE, communicated the objectives and experimental plans to those in attendance, and reviewed results from the early experiments, which began in September 1985.

The AACE is a distribution automation project involving research and development of both hardware and software. Equipment for the project has been installed on the electric distribution system of AUB, one of 160 distributors in the Tennessee Valley Authority (TVA) bulk power system. As the host utility, AUB is responsible for the installation and operation of the equipment. The U.S. Department of Energy (DOE), Office of Energy Storage and Distribution, Electric Energy Systems Program, is the sponsoring agency for the AACE; ORNL is providing project management and technical leadership.

A number of organizations are supporting DOE, ORNL, and AUB in the project. The Electric Power Research Institute (EPRI) is sponsoring certain load control experiments and is providing load control expertise, experimental designs, and individual appliance instrumentation. TVA is providing bulk power coordination and technical support. Baltimore Gas & Electric Company (BG&E) has loaned an electric distribution engineer to ORNL to work on the AACE in Oak Ridge. A Utility Advisory Group, comprised of experienced electric distribution engineers from various utilities, is providing expertise and perspective. Thus the AACE has broad-based utility industry support.

AUB is located in McMinn County, Tennessee. Its 100-sq-mile service territory includes the city of Athens and the communities of Englewood and Niota. AUB is a nongenerating utility with TVA as its source of electric power. AUB distributes electric power to more the 9000 customers, of which 7890 are residential and 1235 are commercial. Energy sales by AUB exceed 300,000,000 kWh annually. The system peak of >84 MW occurred in 1985.

The purposes of the AACE are to develop and test load control, volt/var control, and system reconfiguration capabilities on an electric distribution system and to transfer what is learned from this project to the electric utility industry. The project has been designed to test various control techniques, quantify the associated benefits, identify the type and amount of hardware required to accomplish these benefits, and transfer the findings to the electric utility industry so that a utility can use the data to conduct its own internal studies. The thrust of the project is to provide actual installation and operating experience so that utilities considering distribution control systems can implement a system that will satisfy their needs. It is anticipated that the knowledge and experience gained during the AACE will permit the implementation of similar systems in a shorter time period and with an improved cost/benefit ratio.

The AACE involves the implementation of a hardware system referred to as the Integrated Distribution Control System (IDCS) on the three substations—North Athens, Englewood, and South Athens—and on the 12 distribution feeders of the AUB system. The North Athens substation supplies power to six feeders at 13 kV and, via a 69-kV line, supplies power to the Englewood and South Athens substations. The Englewood and South Athens substations each supply three feeders at 13 kV.

IDCS is a system of hardware and software capable of detailed monitoring of the distribution system, switching various distribution devices, turning customer loads on and off, controlling real and reactive power during normal and emergency conditions, and coordinating the control of the distribution system with the operation of the bulk power system.

Three experimental areas were designed to take place on the AUB system. These are (1) load control, (2) volt/var control, and (3) system reconfiguration. The experiments are taking place individually during the first year and then simultaneously during the second year to determine the interaction of the three experimental areas. Evaluation and data analysis will be performed after each experiment is completed.

The Knoxville review meeting was divided into several consecutive sections on the agenda; this document follows the same format. A short summary will be found at the beginning of each set of viewgraphs. A list of attendees of the meeting is also provided.

This publication was compiled primarily for the attendees of the Knoxville project review meeting. Anyone who would like further information concerning the AACE is directed to contact

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ABSTRACT

The U.S. Department of Energy, Office of Energy Storage and Distribution, Electric Energy Systems Program, is the sponsoring agency for the Athens Automation and Control Experiment (AACE). Oak Ridge National Laboratory (ORNL) in collabration with the Athens Utilities Board (AUB) is providing project management and technical leadership. Others involved in the AACE include the Electric Power Research Institute (EPRI), Tennessee Valley Authority (TVA), Baltimore Gas & Electric (BG&E), and an advisory group comprised of experienced electric utility distribution engineers.

The AACE is an electric power distribution automation project involving research and development of both hardware and software. Equipment for the project is being installed on the electric distribution system in Athens, Tennessee.

The purposes of the AACE are to develop and test load control, volt/var control, and system reconfiguration capabilities on an electric distribution system and to transfer what is learned to the electric utility industry. Expected benefits include deferral of costly power generation plants and increased electric service reliability.

A project review meeting was held in Knoxville, Tennessee, on December 3-4, 1985, to review the progress of the AACE and to communicate the objectives and experimental plans to the electric utility industry, represented by those in attendance. An integral part of the meeting was a tour of AUB's facilities and installed distribution equipment, conducted on December 5, 1985, in Athens, Tennessee.

This publication was prepared primarily for the attendees of the Knoxville project review meeting. This document is a compilation of the viewgraphs used by the presenters at the meeting; each set of viewgraphs is preceded by a summary of the presentation.

At the time of the meeting, the experimental test plans had been completed, much of the AACE field equipment had been installed, and the experiments had begun. A computer system, the AACE Test System (AACETS), became operational in 1984. AACETS is being used to develop and test applications software and experimental control strategies prior to their implementation on the AUB system. The AACE experiments began in September 1985 and will continue through October 1987.

PROGRAM AGENDA

Athens Automation and Control Experiment
Project Review Meeting
Hyatt Regency
Knoxville, Tennessee

December 3-5, 1985

AGENDA

December 3, 1985

7:30 a.m.–8:30 a.m.	Registration	
8:30 a.m.–8:40 a.m.	Introductions	S. L. Purucker, ORNL
8:40 a.m.–9:00 a.m.	Welcome Address and Description of ORNL	D. B. Trauger, ORNL
9:00 a.m.–9:20 a.m.	DOE Perspective	D. J. Roesler, DOE/EES
9:20 a.m.–9:50 a.m.	Description of Project and Overall Status	S. L. Purucker, ORNL
9:50 a.m.–10:05 a.m.	Athens Utilities Board Perspective	G. Usry, AUB
10:05 a.m.–10:25 a.m.	EPRI Perspective	C. W. Gellings, EPRI
10:25 a.m.–10:45 a.m.	Break	

HARDWARE DESCRIPTION, STATUS, AND PROBLEMS

10:45 a.m.–11:00 a.m.	Communication and Control System	S. L. Purucker, ORNL
11:00 a.m.–11:20 a.m.	Instrumentation	G. R. Wetherington, ORNL
11:20 a.m.–11:40 a.m.	Appliance Monitoring	E. R. Broadaway, ORNL
11:40 a.m.–12:15 p.m.	Equipment Installation	N. D. Fortson, AUB L. D. Monteen, AUB
12:15 p.m.–1:15 p.m.	Lunch	

EXPERIMENTS

Experimental Data and Data Handling

1:15 p.m.–1:45 p.m.	Experimental Data Available	P. S. Hu, ORNL

Load Control Experiment

1:45 p.m.–2:30 p.m.	Background, Description, and Schedule	J. H. Reed, ORNL S. D. Braithwait, EPRI
2:30 p.m.–2:50 p.m.	Break	
2:50 p.m.–4:20 p.m.	Results and Analysis	J. H. Reed, ORNL B. K. Newton, Minimax

4:20 p.m.–5:00 p.m.	Questions and Discussion	Panel S. L. Purucker, ORNL J. H. Reed, ORNL S. D. Braithwait, EPRI L. D. Monteen, AUB J. M. McIntyre,Consultant B. K. Newton, Minimax E. R. Broadaway, ORNL P. S. Hu, ORNL
6:00 p.m.	Social Hour	

AGENDA

December 4, 1985

Software Test System

8:30 a.m.–9:00 a.m.	Software Test System Description	G. R. Wetherington, ORNL

Voltage and Capacitor Control Experiment

9:00 a.m.–9:30 a.m.	Background, Description, and Schedule	D. T. Rizy, ORNL
9:30 a.m.–10:00 a.m.	Implementation and Operations	L. D. Monteen, AUB
10:00 a.m.–10:20 a.m.	Break	
10:20 a.m.–11:00 noon	Results and Analysis	D. T. Rizy, ORNL R. L. Sullivan, Consultant
11:00 a.m.–11:30 a.m.	Questions and Discussion	Panel S. L. Purucker, Moderator D. T. Rizy, ORNL R. L. Sullivan, Consultant L. D. Monteen, AUB G. R. Wetherington, ORNL
11:30 a.m.–12:30 p.m.	Lunch	

System Reconfiguration Experiment

12:30 p.m.–1:00 p.m.	Background, Description, and Schedule	J. S. Lawler, Consultant
1:00 p.m.–1:30 p.m.	Implementation, Data Required, and Operations	J. B. Patton, Consultant
1:30 p.m.–2:30 p.m.	Results and Analysis	J. S. Lawler, Consultant J. B. Patton, Consultant
2:30 p.m.–2:50 p.m.	Break	

2:50 p.m.–3:15 p.m.	Questions and Discussion	Panel S. L. Purucker, Moderator J. S. Lawler, Consultant J. B. Patton, Consultant K. F. McKinley, BG&E

Cost, Benefits, TVA, & EPRI Projects

3:15 p.m.–3:45 p.m.	Cost Benefit Impacts	K. F. McKinley, BG&E
3:45 p.m.–4:00 p.m.	TVA Perspective	S. James, TVA
4:00 p.m.–4:30 p.m.	Overview of Some Major Utility Distribution Automation and Load Control Projects	L. C. Markel, Electrotek
4:30 p.m.–4:45 p.m.	Summary	S. L. Purucker, ORNL

AGENDA

December 5, 1985

8:00 a.m.–9:00 a.m.	Drive to Athens, Tennessee (Bus Transportation Provided)
9:00 a.m.–12:00 noon	Tour of Athens Utilities Board Distribution System (1) Control Room (2) Substation (3) Feeder Installation (4) Customer Installation (5) Athens Automation and Control Experiment Test System Video (6) SYSRAP Demonstration
12:00 noon–1:30 p.m.	Lunch
1:30 p.m.–3:00 p.m.	Continue Tour
3:00 p.m.–4:00 p.m.	Bus Returns from Athens to Hotel or Airport

PROJECT SUMMARY

BACKGROUND

Electric utilities have been turning more and more to demand-side options and increased control of the distribution system to meet planning objectives and solve operations problems: reducing operating costs, deferring system expansion, operating the power system more efficiently, and improving the quality of service. Pilot projects involving demand-side management (e.g., load management) and/or distribution automation (e.g., distribution system monitoring and control) have proliferated, and these techniques are being implemented systemwide in many North American utilities. A number of common needs or problems have been identified from these installations:

1. Procedures are needed to evaluate both the potential benefits and the effects of these newly implemented technologies on the utilities and their customers.

2. The data requirement for the evaluation procedures—including the type, quality, and accuracy of the data needed for evaluation—must be defined.

3. Integration of demand-side management and distribution automation and coordination of these functions with other utility planning and operating activities will be important in the future for utilities seeking to implement such programs. This is an area that has not received much attention until lately.

4. Actual operating experience, particularly with automated distribution systems, is limited. Such experience is necessary to determine which problems each automation function can solve, to develop practices and procedures for system operators, and to indicate which functions and technologies are worth perfecting through research and development.

To address these needs, the Athens Automation and Control Experiment (AACE) was conceived and implemented. AACE was set up as a test for distribution automation and load control experiments. Located on the Athens Utilities Board (AUB) system in Athens, Tennessee, AACE is a highly instrumented system serving a highly surveyed group of consumers. Deliberately, AACE was created to obtain more information about the electric power system and its customers than would be practical for an electric utility to obtain on its own. The result is a "test bed," an environment in which controlled experiments of different functions, control strategies, and operating procedures can be carried out. Observation of the results will help to show which control functions are worthwhile, what data and instrumentation are needed, and which distribution system elements are justified for control.

OBJECTIVES

The AACE project objectives are to

1. quantify the benefits of automation;

2. develop and test control strategies;

3. determine minimal hardware requirements (i.e., the minimum amount of control hardware, instrumentation, and data needed to implement automation functions);

4. define requirements for the next generation of automation systems;
5. coordinate distribution, generation, and transmission control;
6. quantify socio-economic aspects of the load control programs tested;
7. integrate the design and operation of the three automation functions tested: load control, volt/var control, and distribution system reconfiguration; and
8. transfer results of AACE to utilities.

The last objective especially merits elaboration. The technology transfer for AACE is expected to include not only data but also operating procedures, software, installation methods, evaluation procedures, and candid reports of installation, testing, and operating experiences. As part of this technology transfer, progress reports and interim results have been made available to representatives of several utilities and research organizations. In addition, regular public review meetings to discuss progress, problems, results, and issues have been scheduled.

In addition to this emphasis on technology transfer, AACE is distinguished from other single-utility distribution automation or load control projects in several ways:

1. *Both* distribution automation and load control are being implemented at AUB. Much of the work is aimed at the *integration* of these functions, their interfaces, and complementary characteristics.
2. The saturation of the project is much larger than is typical for a pilot project. Over 20% of AUB's residential customers will be involved.
3. Because this is an "experiment," innovative control strategies and new analysis techniques will be applied.
4. Because the emphasis is on obtaining results that can be generally applied to the industry, the data gathered and control strategies tested will be designed to be relevant to many utility situations.
5. Results, procedures developed, and data gathered will be quickly and widely disseminated throughout the industry.

SPONSORS

The AACE has been funded primarily by the Office of Energy Storage and Distribution Systems of the U.S. Department of Energy (DOE). Additional support for increased appliance load profile metering has come from the Electric Power Research Institute (EPRI). The AUB, the host utility, has provided manpower to review the design and to install, test, and operate the system. The Tennessee Valley Authority (TVA) has also provided technical assistance.

The project management and technical leadership is being provided by Oak Ridge National Laboratory (ORNL), operated by Martin Marietta Energy Systems, Inc., under contract to DOE.

PROJECT SCOPE

The AACE is designed to accomplish five functions:

1. load control,
2. load profile measurement (household and individual appliances),
3. volt/var control,
4. distribution system reconfiguration, and
5. distribution system data monitoring.

To accomplish these functions, customers' households and the distribution equipment on three substations and twelve 13-kV feeders of the AUB system (Fig. 1) have been automated as follows:

1. 2000 load control receivers;
2. 200 "smart meters," which record household load profile;
3. 200 electric appliance research meters (ARMs), which record individual appliance load profiles;
4. 5 substation capacitor banks;
5. 28 feeder capacitor banks;
6. 2 load tap changing transformers;
7. 5 line voltage regulator banks;
8. 34 load break switches;
9. 11 feeder breakers;
10. 11 power reclosers;
11. 47 feeder monitoring locations [pole top units (PTUs) that detect faults and measure voltage, power, and vars]; and
12. 1 weather station.

To monitor and control the AACE feeders and hardware, a central control and dispatch computer has been installed at AUB's headquarters. Another computer installation at ORNL, the AACE Test System (AACETS), is used to simulate the AUB system and test the hardware, software, and control strategies of the AACE before they are actually implemented in the field.

Communications from the substations to the distribution remote terminal units (RTUs) and customer load control receivers is by a Brown-Boveri Control Systems, Inc., (BBCSI) "ripple" system. Communications between the AUB control center and the substations is by leased telephone lines. The data from the PTUs and remote customer metering installations are returned to the AUB control center by telephone (party line for the PTUs, telephone-company-switched network for the remote metering equipment). Figure 2 shows the AACE configuration.

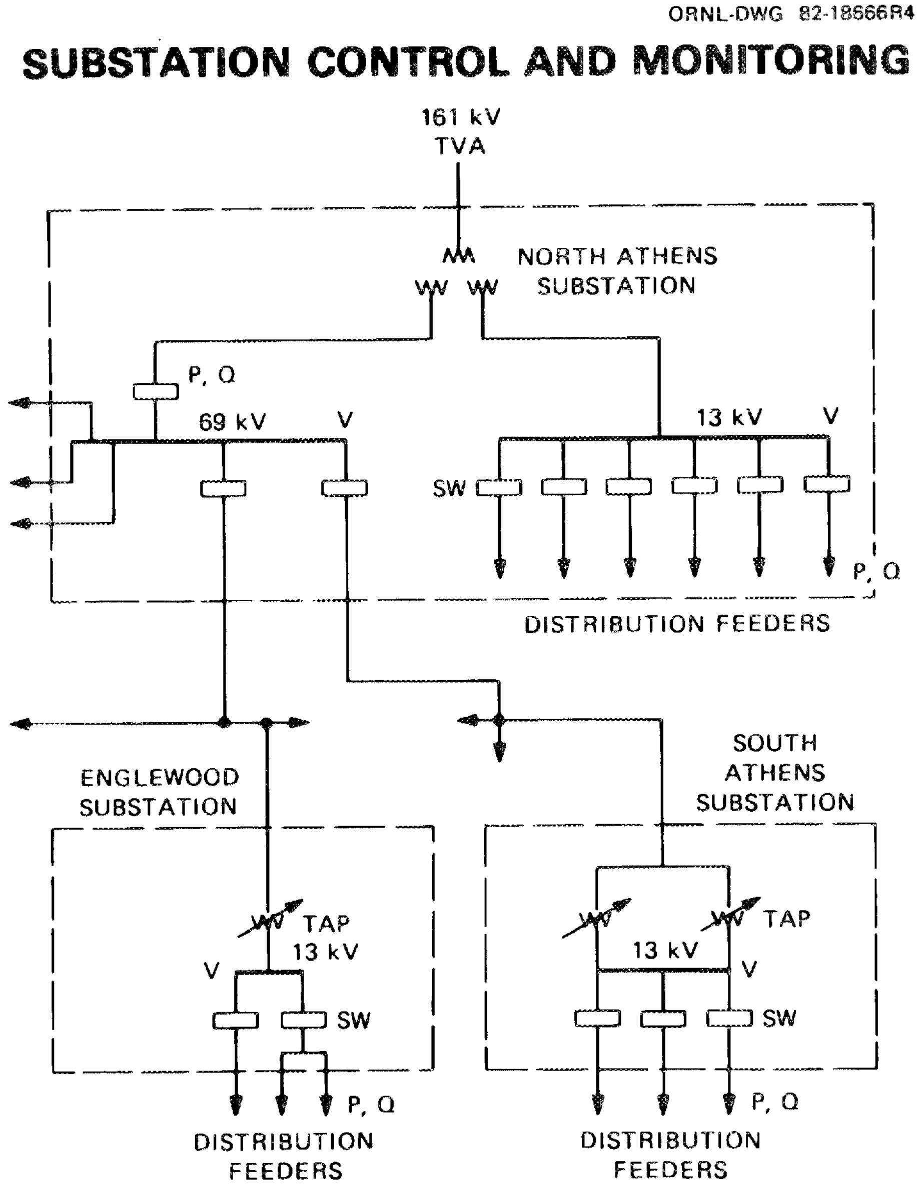


Fig. 1. Simplified AUB one-line diagram.

In addition to the hardware installed, the AACE has made detailed surveys of all participating AUB customers, including

1. customer information;
2. appliance types and sizes;
3. building size, construction, and insulation;
4. customer "lifestyle" (number of inhabitants, work schedule, etc.); and
5. reasons for participating in or dropping out of the experiment.

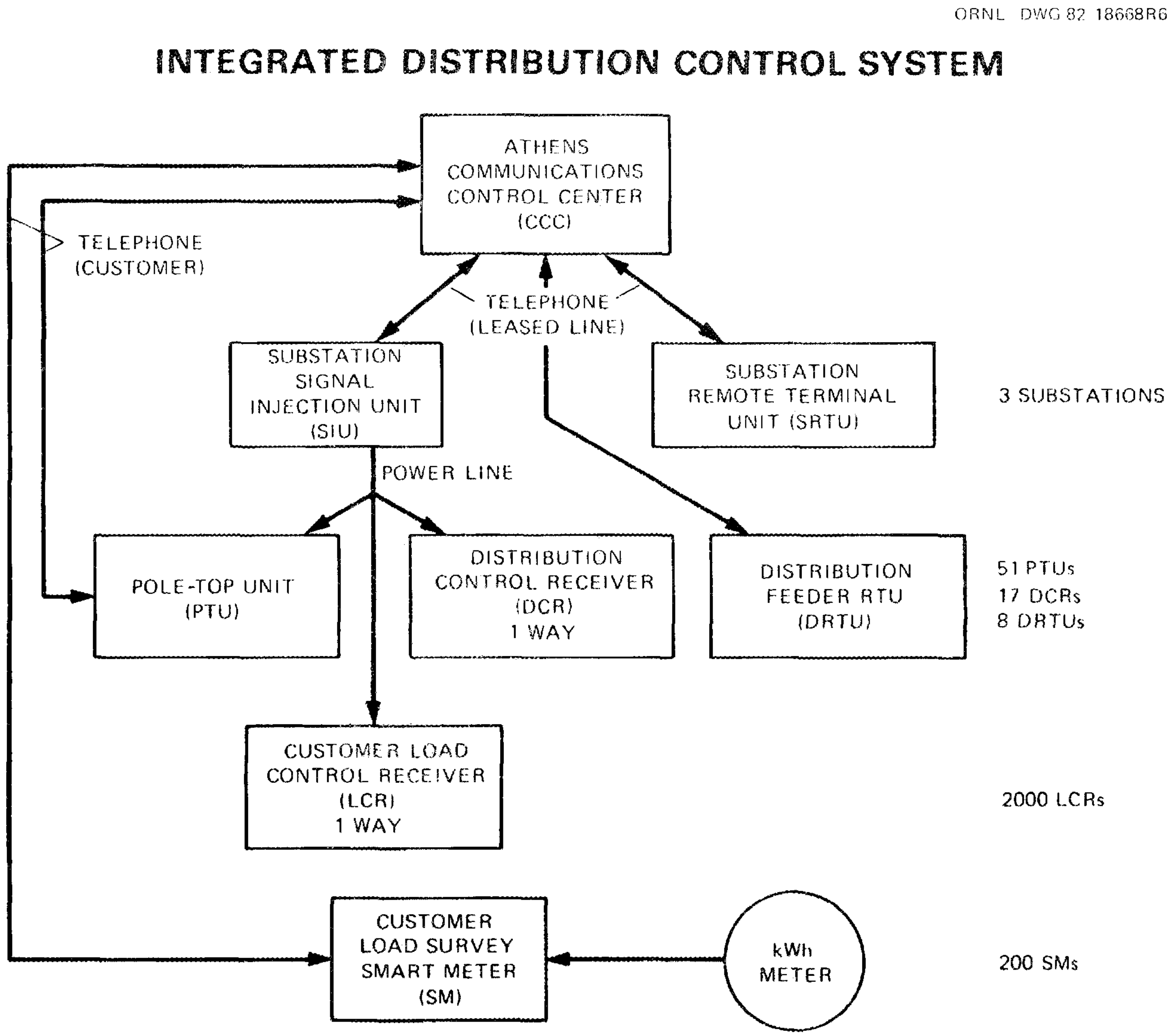


Fig. 2. Integrated distribution control system and appliance monitoring system.

With the abundance of monitoring and control points and the auxiliary data collection efforts, the AACE is designed to provide a well-documented and well-understood test bed suitable for a variety of distribution automation and load control experiments. Three major types of functions will be tested initially: (1) load control, (2) integrated volt/var control, and (3) distribution system reconfiguration.

The scheduled experiments will be conducted in three phases:

1. characterization studies—initial system checkout, testing, and data gathering;

2. learning year—start of individual load control, volt/var control, and distribution automation experiments; and

3. integrated year— simultaneous, integrated operation of the three experiments.

The following is a schedule and list of major milestones for the AACE project.

Milestone	*Completion date*
Selection of host utility	Jan 1979
Specification and vendor selection	Sep 1982
Determine automated points and automation functions	Apr 1983
Final design of communications/control system	Aug 1983
Install AACETS computer	Sep 1984
Enroll AUB customers for participation	Mar 1985–June 1987
Factory acceptance test	Jan 1985
Install control computer	Mar 1985
Install BBCSI communications system	Apr 1985
Field acceptance test	Jul 1985
Characterization and learning year test plan	Jul 1985
Install distribution automation and monitoring equipment	Sep 1985–June 1986
Install load control receivers	Oct 1985–June 1987
Install smart meters	Oct 1985–June 1986
Install electric ARMs	June 1986–Nov 1986
Integration year test plan	Oct 1986
Learning year experiment	Oct 1985–Oct 1986
Integrated year experiment	Oct 1986–Oct 1987
Final report	April 1988

LOAD CONTROL EXPERIMENT

The load control experiment involves control of from 1 to 3 appliances—electric water heaters, central air conditioners, and/or central electric space heaters of heat pumps. Two hundred households will be equipped with electric appliance research meter (ARM) units, which will monitor some combination of appliances, total household load, and/or temperature. ARM data will be recorded in 5-min intervals. Smart meters, which monitor household loads at ~15-min intervals, will be placed in another 200 households.

The objectives of the load control experiments are to

1. evaluate the impact of load control at all levels of the distribution system,
2. assess the potential for real-time control of loads,
3. evaluate alternative strategies for controlling customer loads and customer-class loads, and
4. evaluate customer acceptance of and response to load control.

Experiments will be conducted to

1. control water heaters, central air conditioners, and central space heaters;
2. verify the reliability of the equipment and communications devices; and
3. ascertain customer acceptance of the control strategies.

The AUB system load is quite representative of the TVA system load (Fig. 3). (The peaks of the two systems are almost coincident.) Reduction of the AUB peak will reduce the demand charges that AUB must pay to TVA, its power supplier, as well as reduce the TVA peak load. AUB's load shape is also characteristic of many of the other TVA distributors. The three appliances chosen for control—water heaters, space heaters, and air conditioners—have periods of

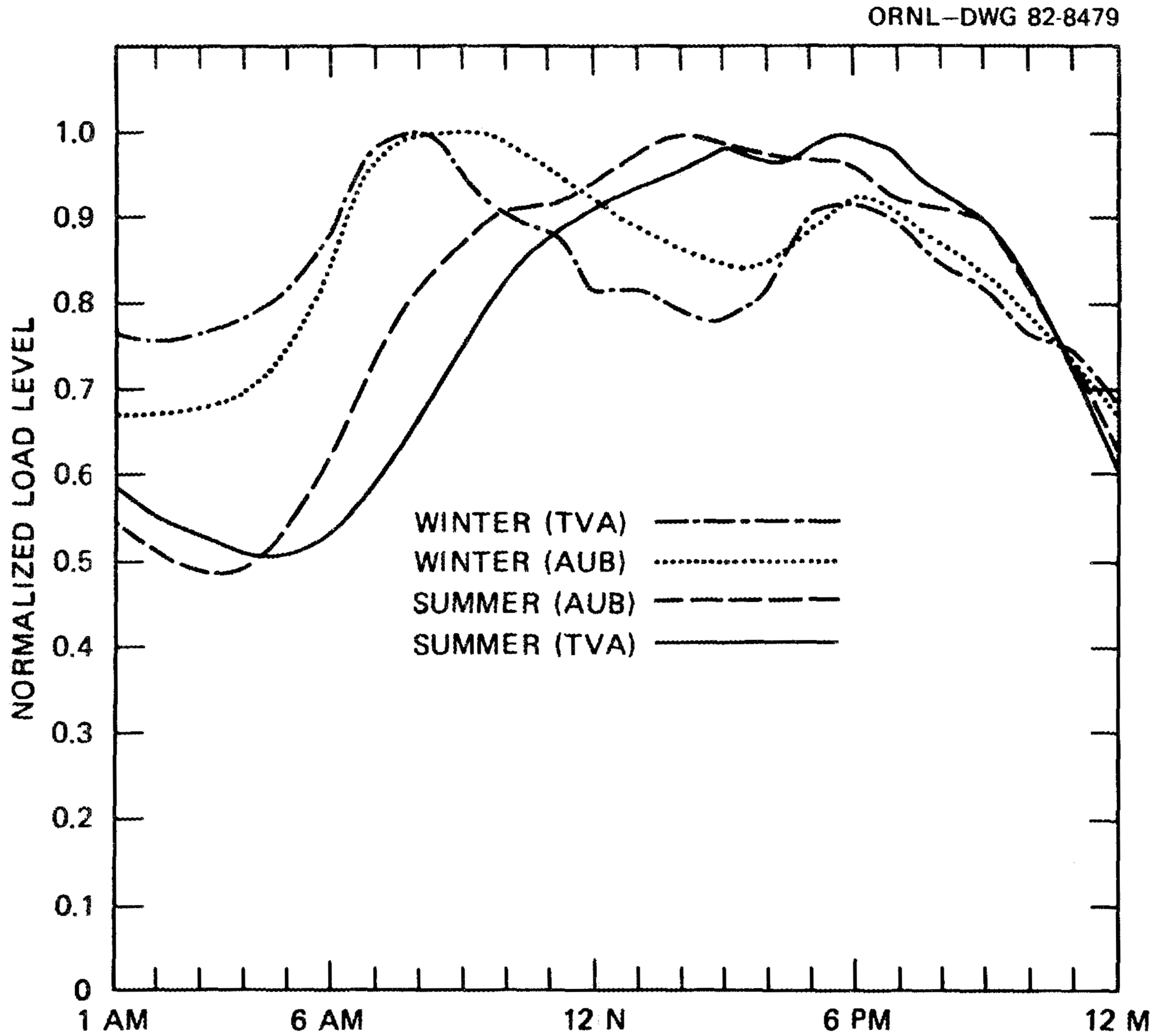


Fig. 3. AUB/TVA load profiles.

high usage coincident with the AUB system peak (Fig. 4). Control of these appliances will meet the peak reduction objectives of an AUB demand-side management program.

Water heater control will be exercised during winter mornings and evenings and during summer evenings. Off-time durations of 2, 3, and 4 hours will be tested. Space heaters will be controlled through duty-cycle limiting between 6:00 a.m. and 9:00 p.m. The intensity of control will be varied to force the space heaters to be off between 0 and 50% of the time during the control period. The control period for air conditioners will be between noon and 10:00 p.m., and control intensity will vary between 0 and 60%.

Load changes from appliance control will be measured at the appliance level (electric ARMs), household level (smart meters), feeder section level (PTUs), and feeder/substation level (substation remote terminal units-RTUs).

Customers were selected for participation in the load control experiment according to strata defined by total monthly energy consumption. The locations for electric ARMs were chosen by randomly sampling 50 customers in each of four strata. Smart meters were installed on 40 randomly chosen homes in each of five strata. Load control receivers are being placed in 2000 residences in the four high-energy-usage strata.

The estimated penetration of load control receivers by appliance stock is as follows:

Customer appliance stock	Number of customers
Water heater, space heater, air conditioner	560
Water heater and air conditioner only	350
Water heater and space heater only	840
Water heater only	250
	2000

This allocation will result in the following number of appliances under control:

Appliance type	Number of appliances
Water heater	2000
Space heater	1400
Air conditioner	910
	4310

The proposed distribution of load control receivers will result in a significant fraction of each type of appliance in the AUB system being controlled:

Appliance	AUB customer stock	Controlled sample	Percent
Water heater	5950	2000	34
Space heater	2870	1400	49
Air conditioner	1890	910	48

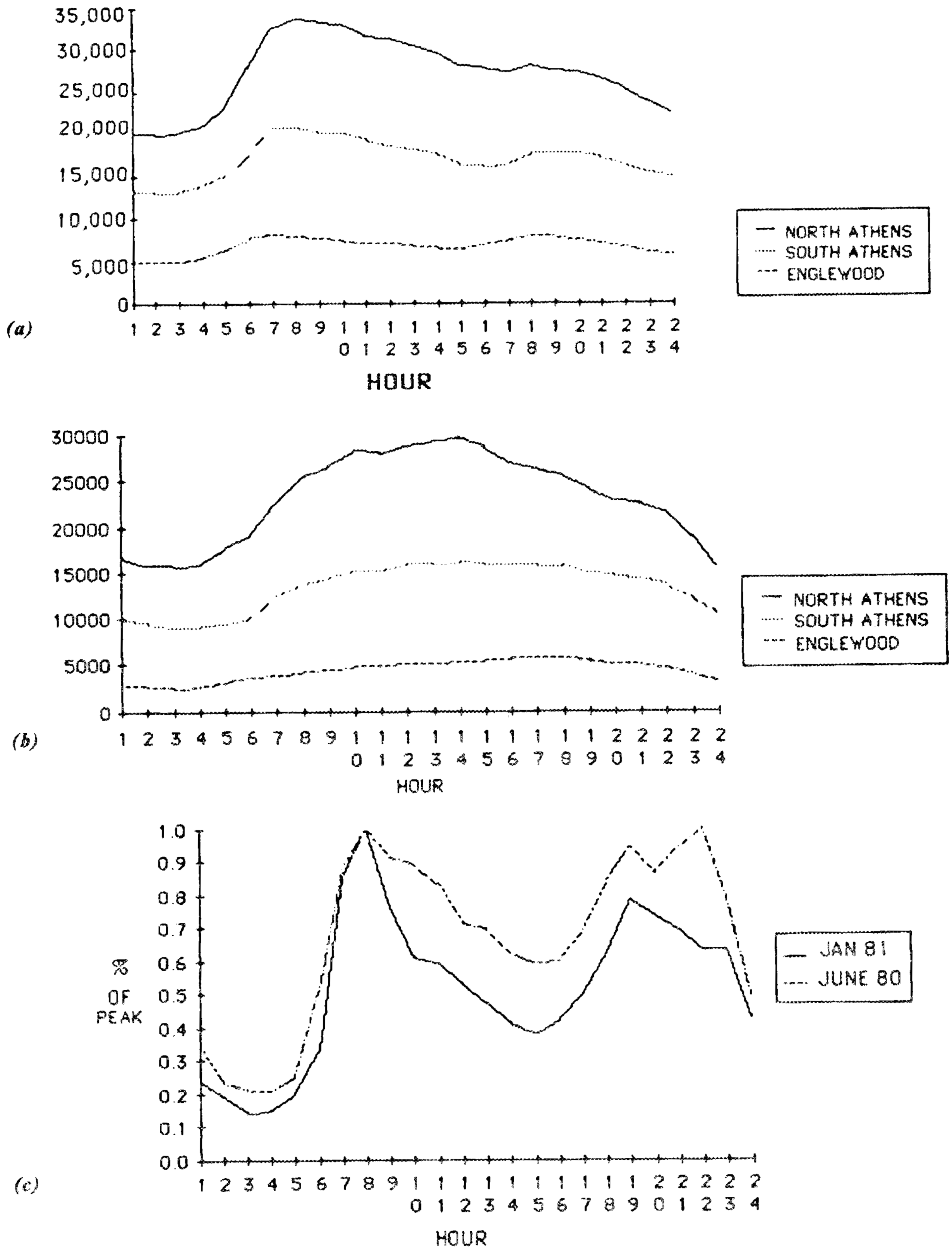


Fig. 4. Appliance Load Profiles on the AUB system. *(a)* Electric water heater, *(b)* Electric space heater, *(c)* Air conditioner.

Because of the limitations imposed by costs of instrumentation, the load control experiment does not, in the classical sense, employ a control group. Instead, repeated measurements of the same household are taken when the house is (and is not) under control. Comparisons are made of observations taken from the same points during load control and noncontrol periods, making it possible to obtain statistically significant data on changes in peak loads with fewer metered points (i.e., houses with ARMS or smart meters) than would be the case if a separate control group were used. The sequential testing procedure used here also makes it possible to test different control strategies (e.g., by varying the intensity and/or times of control) on the same house. The technique was developed for the AACE as part of the EPRI-funded appliance-load-profile data gathering effort. (Elements of this technique have already been applied to other utilities and EPRI projects; this is an early instance of technology transfer from the AACE project.)

All participants are given an "audit," which records lifestyle data; house size, construction, and insulation; appliance mix and size; thermostat settings; and attitudes toward the experiment and the utility. Personal interviews and audits, telephone interviews, and mailed surveys to participants and nonparticipants will seek to determine:

1. any differences between the population represented by the participants and that represented by nonparticipants or the AUB system as a whole;
2. customer acceptance of, knowledge of, and attitude toward load control;
3. customer awareness of load control;
4. modifications to customer behavior in response to load control; and
5. reasons for dropping out of the experiment.

To test the effectiveness and reliability of the load control system, data on the performance of the load control hardware, software, and communications system will be collected. All failures, lost commands, etc., will be tabulated to indicate the availability and reliability of the system and the causes of failures.

INTEGRATED VOLT/VAR CONTROL EXPERIMENT

The volt/var control experiment involves control of capacitor banks, LTC transformers, and regulators to

1. maintain the required voltage profile along the feeder,
2. maintain power factor close to unity,
3. reduce feeder losses, and/or
4. implement voltage reductions for indirect load control.

The volt/var experiments will implement computer-automated control of 28 capacitors, 1 substation LTC transformer, 1 substation regulator, and 5 line regulators on 12 feeders of 3 substations of the AUB system. The experiments will use a two-way communications system with remote terminal units (RTUs) to monitor the status of the capacitors, single-phase and three-phase bus voltages, active power flows, and reactive power flows at an average of four locations on each feeder and near the line regulators and capacitors.

The objectives for implementing real-time volt/var control on the AUB system are to

1. determine whether or not real-time computer-automated capacitor control is effective in reducing line losses and in providing var support for the transmission system;
2. determine whether or not computer-automated regulator control is effective in reducing feeder voltage drops, ensuring acceptable voltages levels, and providing a means of reducing loads;
3. determine the type of application software needed to determine real-time volt/var control;
4. determine whether the type of computer communications and control equipment is adequate for collecting monitored data and for implementing volt/var control actions;
5. determine the benefits of coordinating volt/var control with load control and system reconfiguration; and
6. identify the requirements for future-generation distribution automation systems that will employ volt/var control.

Five volt/var experiments will be implemented on the AUB system:

1. computer-automated capacitor control (shortened in this discussion to "capacitor control"),
2. computer-automated regulator control ("regulator control"),
3. combined computer-automated capacitor and regulator control ("combined capacitor and regulator control"),
4. voltage reduction for indirect load control ("voltage reduction"), and
5. integrated volt/var control with load control and system reconfiguration ("integrated control").

The first two experiments are prerequisities for the third experiment, which involves automating the control of both capacitors and regulators. The fourth experiment will test voltage reduction for reducing load. The last experiment, which will occur in the second year, will examine the benefits of integrating the control of capacitors and regulators with load control and system reconfiguration functions.

During the first year of implementation of the volt/var experiments on the AUB system, the capacitor control, regulator control, and voltage reduction experiments will be tested. Possibly the combined capacitor and regulator control experiment will be tested as well. Also during the first year the application software will determine the capacitor and regulator control actions; however, the system operator will maintain complete control of the capacitors and regulators. During the second year, the system operator will be taken out of the control loop and will only be expected to respond to alarms, such as monitored values out-of-limits, capacitors and/or regulators inoperative, and control methods not converging. Also during the second year the voltage reduction experiment will continue, and the combined capacitor and regulator control and integrated control experiments will be tested.

The benefits of using a distribution automation system to implement volt/var control will be evaluated by identifying

1. the penetration of hardware (e.g., number of capacitors and/or regulators that are controlled);

2. level of intelligence needed to control the capacitors and/or regulators (i.e., var controllers, RTUs, etc.); and

3. the amount of instrumentation (number of monitored points) required to achieve reduced line losses, improved voltage profiles, reduced thermal loading, and improved feeder power factors.

SYSTEM RECONFIGURATION EXPERIMENT

The system reconfiguration experiment involves controlling feeder switches and breakers, monitoring the status of fault detectors, and monitoring other conditions (e.g., load and voltage) at points on the feeder and in the substation. The experiment will seek ways to

1. enhance distribution system reliability through
   a. fault detection,
   b. fault location, and
   c. fault isolation and service restoration;

2. improve capacity utilization and reduce loading through
   a. feeder monitoring,
   b. feeder load transfer, and
   c. substation load transfer.

Installed at AUB to implement these six functions are automated monitoring devices, including

1. potential transformers and current transformers for analog values,
2. switching element status indicators,
3. relay status indicators, and
4. fault current detectors.

The distribution system components to be controlled are

1. feeder circuit breakers,
2. power reclosers, and
3. motor-operated load break switches.

The objectives of the reconfiguration experiments are to determine

1. the improvement in distribution system service reliability that can be achieved by automated fault detection, location, isolation, and service restoration;
2. the improvement in distribution system capacity utilization that can be achieved through automated feeder monitoring, feeder load transfers, and substation load transfers; and
3. the amount of automation hardware required to achieve the above benefits.

The experiments dealing with fault detection and clearing will determine the hardware (control and monitoring) needed to implement these functions, the procedures to be used, and the methods and data required to evaluate the benefits of automated fault handling. The faults addressed will be low-impedance shunt faults. If time permits, detection of high-impedance, or series, faults may be attempted in later years.

Monitoring and load transfer functions will be aimed at discovering and exploiting load diversity between feeders and feeder sections. During the first year, there will be much emphasis on data gathering and load characterization. The only load transfers attempted will be those known to be safe (i.e., will cause no overloads). As greater confidence is gained in load characterization, more extensive load transfers will be attempted. ORNL is developing a computer modeling and analysis tool to facilitate before-the-fact analysis of possible load transfers and feeder reconfigurations. This analysis program will be used to evaluate reserve capacity and identify potential overloads.

RESULTS TO DATE

As of November 1985, the following milestones have been reached by the AACE:

1. The system procurement is completed.
2. The BBCSI hardware and software have passed the factory and site acceptance tests.
3. The central computer has been installed at AUB.
4. The AACETS computer has been installed and is operating successfully at ORNL.
5. The bulk of the control and monitoring hardware has been installed; only customer installations of load control receivers, smart meters, and electric ARMs must be completed.
6. The AACE has been gathering data on the AUB system since July 1985.
7. The test plans for the Learning Year for load control, volt/var control, and system reconfiguration have been completed.
8. The control capabilities have been exercised. That is, capacitors have been switched, regulator settings changed, feeder switches controlled, etc.

Data are available from substation and feeder monitoring equipment and from the installed electric ARMs and smart meters. Analysis of these data is underway, and there are preliminary results showing household and appliance load profiles, feeder and substation load profiles, and the effects of capacitor switching and regulator control on voltage profile and feeder losses. Also, AUB and ORNL personnel are developing and using cathode-ray tube displays on the control computer to analyze feeder conditions and dispatch capacitor and regulator control commands.

The AACE installation and planning for the Learning Year is complete. Currently, ORNL and AUB personnel are in the midst of collecting data, developing models and analysis techniques, and testing the control capabilities of the AACE hardware.

FUTURE PLANS

The following tasks remain:

1. completion of installation of electric ARMs, load control receivers, and smart meters;
2. completion of the AACE load control analysis plan, detailing the requirements to analyze the data and evaluate the experiments;
3. completion of programming for AACETS; and
4. preparation of the test plan for the Integration Year.

Technology transfer of AACE results is already underway; in fact, the installation procedures and designs for automation equipment developed for AACE have already been used by other TVA distributors. Analysis techniques and operator interface procedures have been discussed with other utilities. The sequential testing methods, developed for load profile data gathering and analysis of the effects of load control strategies, have been applied to other EPRI research projects. Finally, several additional technical papers and presentations are planned to document experimental work.

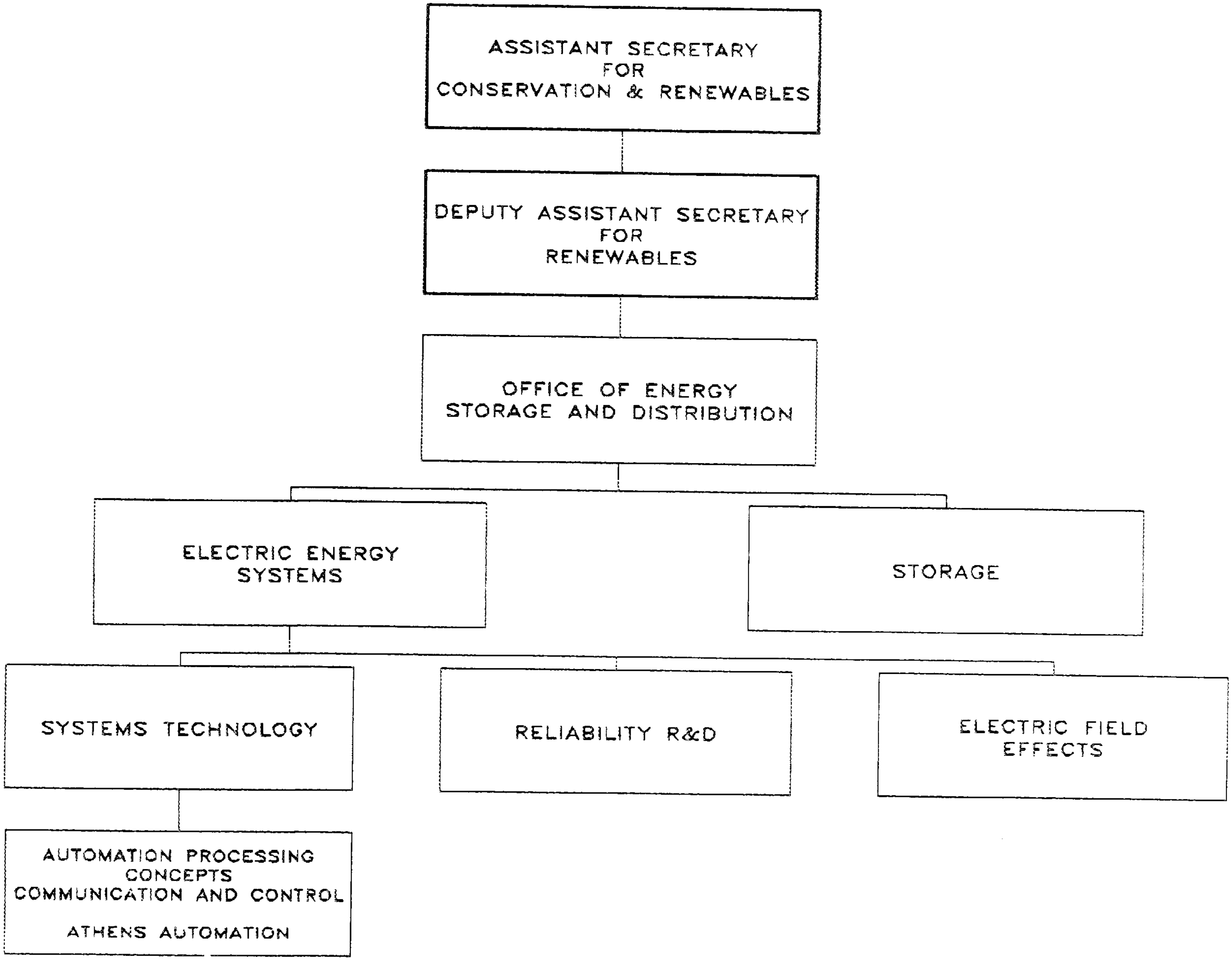
DOE PERSPECTIVE

ATHENS AUTOMATION AND CONTROL EXPERIMENT

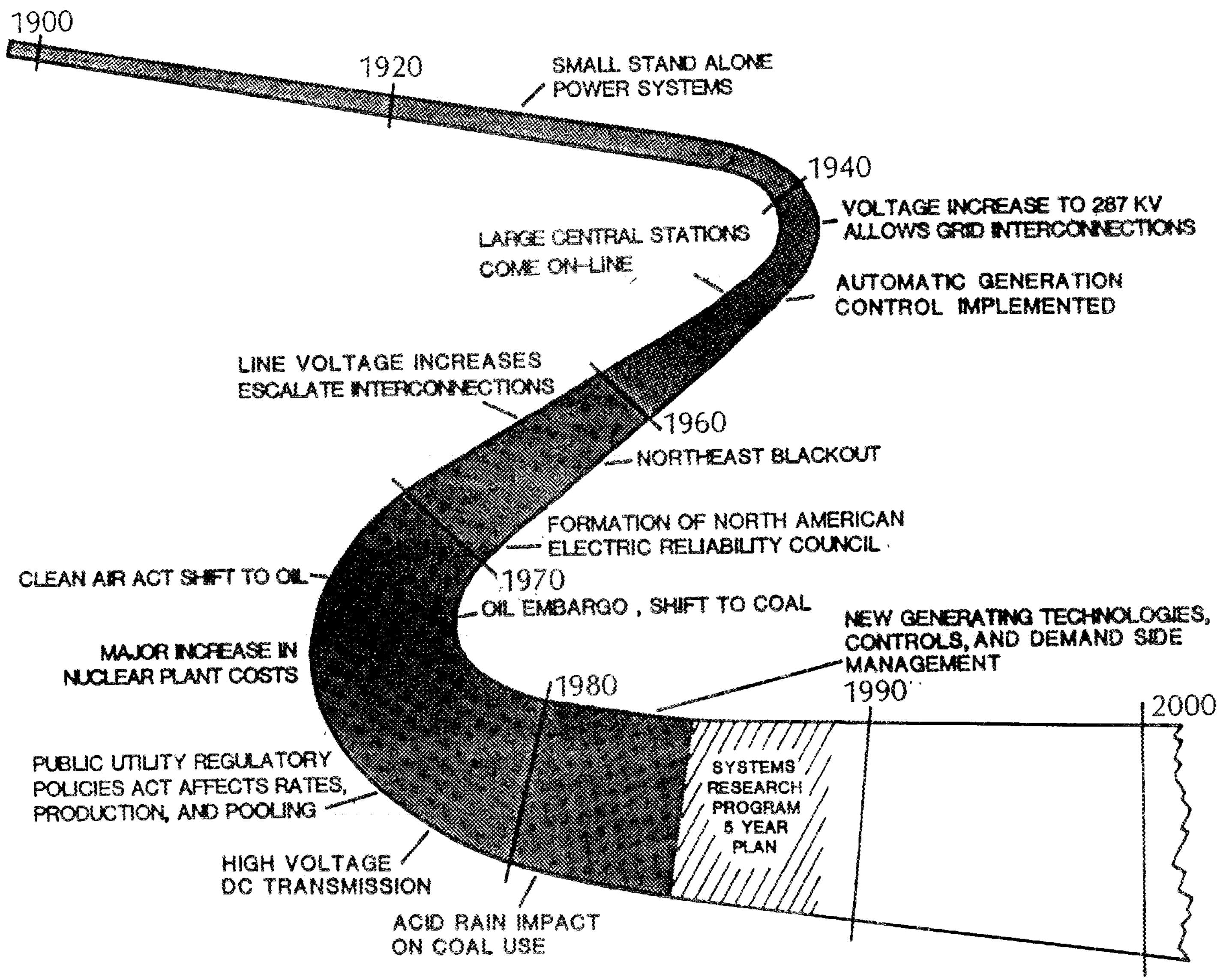
DIETRICH ROESLER, PROGRAM MANAGER

U. S. DEPARTMENT OF ENERGY

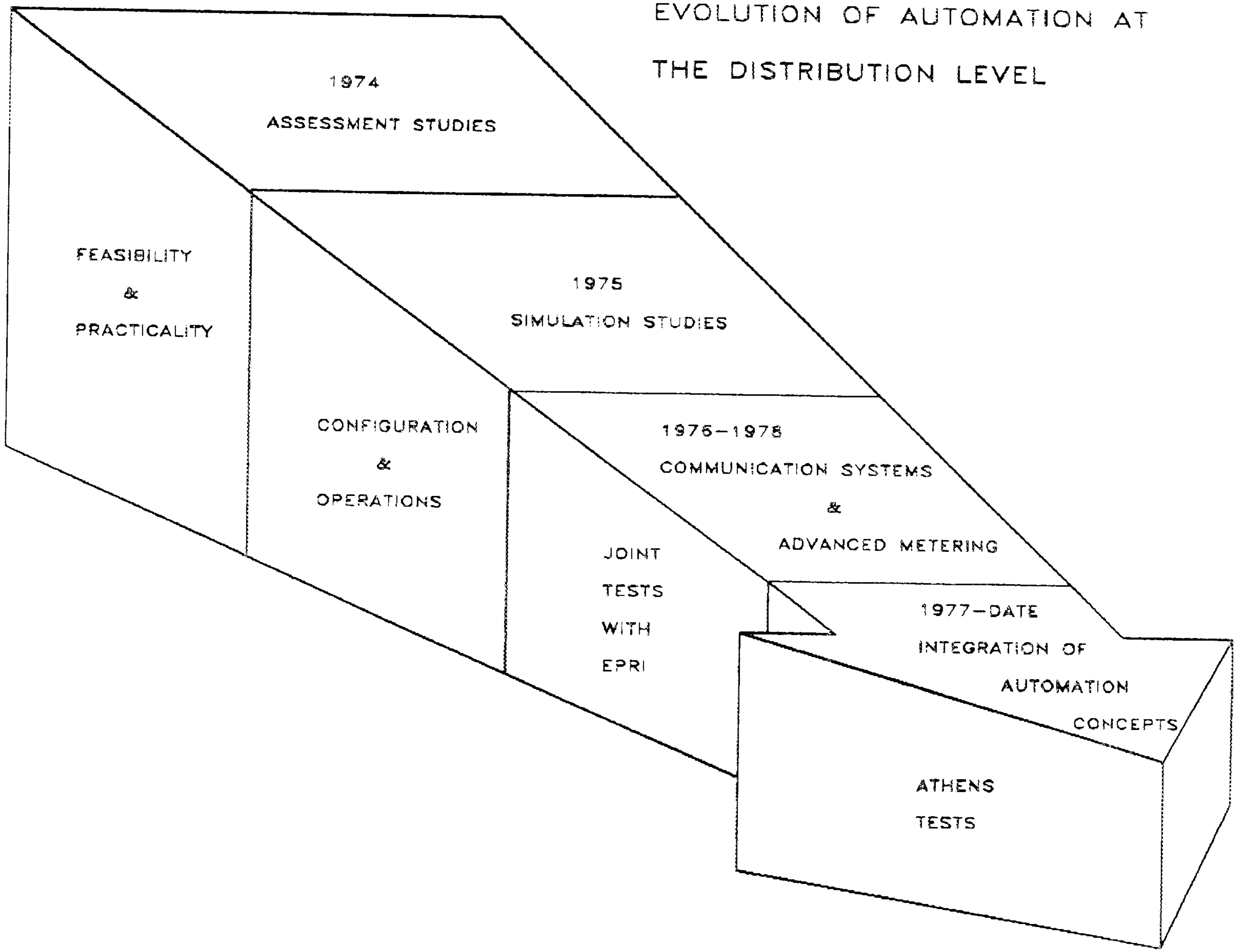
3 DECEMBER 1985


ASSISTANT SECRETARY FOR CONSERVATION & RENEWABLES
DEPUTY ASSISTANT SECRETARY FOR RENEWABLES
OFFICE OF ENERGY STORAGE AND DISTRIBUTION
ELECTRIC ENERGY SYSTEMS
STORAGE
SYSTEMS TECHNOLOGY
RELIABILITY R&D
ELECTRIC FIELD EFFECTS
AUTOMATION PROCESSING CONCEPTS COMMUNICATION AND CONTROL
ATHENS AUTOMATION

HISTORICAL PERSPECTIVE OF ELECTRIC SYSTEMS IN THE U.S.



EVOLUTION OF AUTOMATION AT THE DISTRIBUTION LEVEL



GOAL

TO DEVELOP A LARGE SCALE DISTRIBUTION AUTOMATION TEST BED WHICH WILL ANALYZE AND VERIFY VARIOUS CONTROL STRATEGIES ON THE SYSTEM'S RELIABILITY, ECONOMY, AND EFFICIENCY.

ATHENS TEST BED

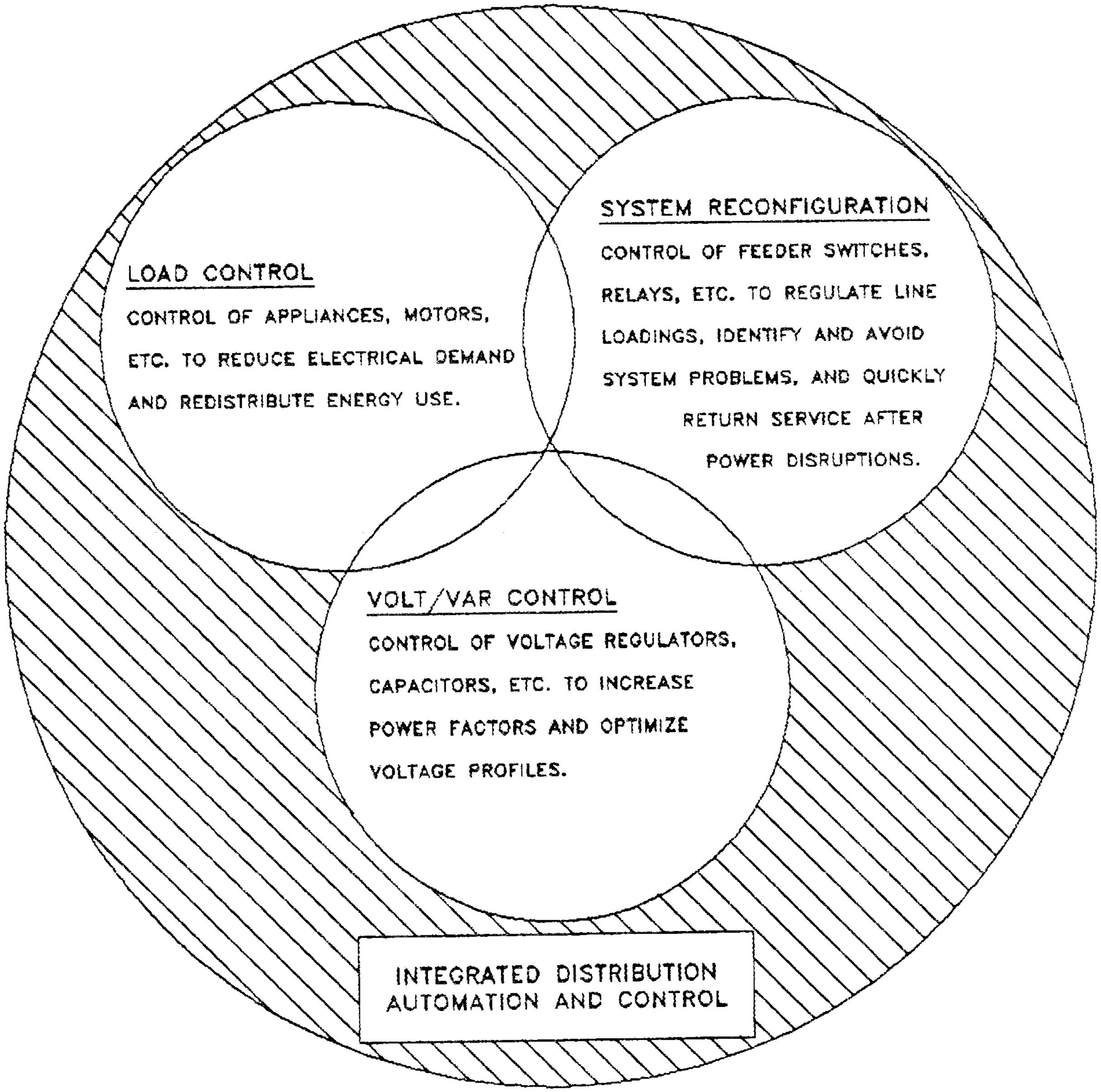
- TWO WAY COMMUNICATION CAPABILITY TO THE SUBSTATION, FEEDER POINTS, AND LIMITED NUMBER OF CUSTOMER POINTS.

- A MAN MACHINE INTERFACE/DATA BASE TO PERMIT OPERATOR INTERACTION WITH THE ELECTRIC SYSTEM.

A SYSTEM TO PERMIT THE TESTING OF A VARIETY OF CONTROL STRATEGIES.

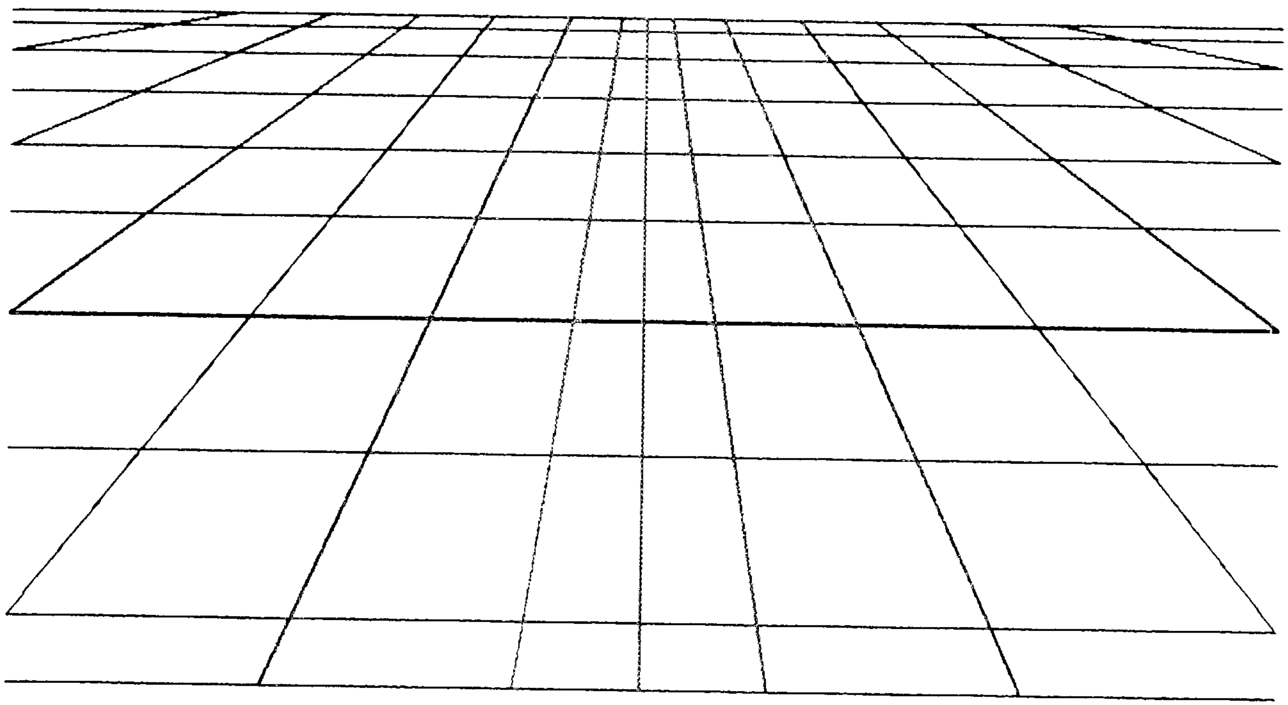
LEVEL	FUNCTION	EQUIPMENT
SUBSTATION (3)	CONTROL VOLTAGE REGULATORS, SWITCHES RELAY COMMAND SIGNALS	REMOTE TRANSPONDER UNIT SIGNAL INJECTION UNIT
DISTRIBUTION FEEDER (12)	CONTROL CAPACITORS, SWITCHES RELAY COMMAND SIGNALS	51 POLE TOP UNITS 17 DISTRIBUTION CONTROL RECEIVERS
CUSTOMER (20% PENETRATION)	CONTROL CUSTOMERS APPLIANCES	2000 LOAD CONTROL RECEIVERS 200 SMART METERS & 200 ARMS

EXPERIMENTS

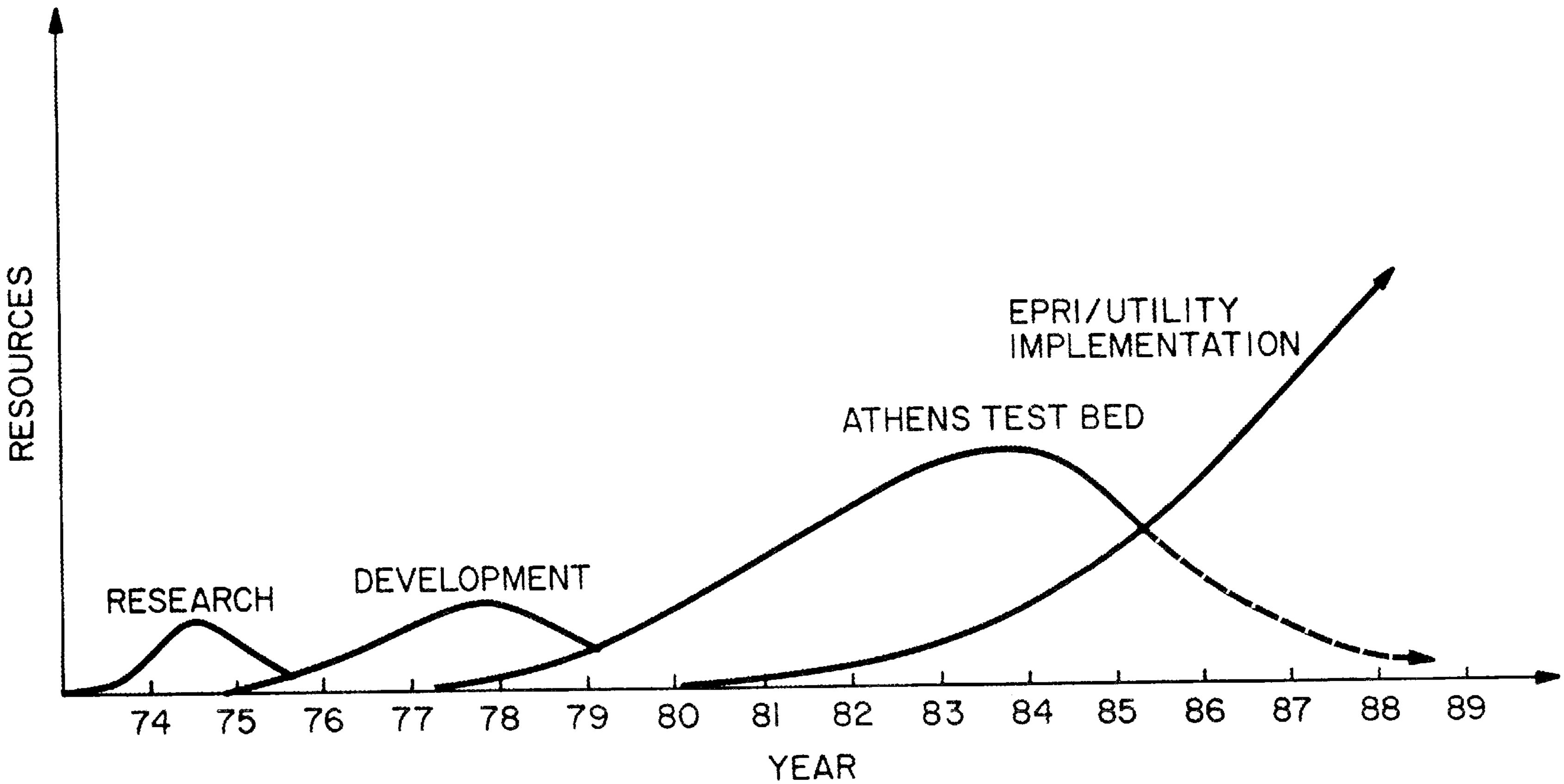


SIGNIFICANT MILESTONES

FY 84	AACE TEST SYSTEM OPERATIONAL	JULY	1985
FY 85	BASELINE DATA OBTAINED	SEPTEMBER	1985
FY 86	SYSTEM OPERATIONAL	OCTOBER	1985
FY 87	LEARNING YEAR EXPERIMENTS COMPLETE	OCTOBER	1986
FY 88	INTEGRATED YEAR EXPERIMENTS COMPLETE	OCTOBER	1987
FY 88	FINAL REPORT	MAY	1988



PHASES OF RESEARCH, DEVELOPMENT,
AND TECHNOLOGY IMPLEMENTATION



TECHNOLOGY TRANSFER

- ENHANCED AWARENESS OF AUTOMATION ACTIVITIES.
  - IEEE WORKING GROUP
  - APPA AUTOMATION MEETING
- EPRI AND UTILITY INVOLVEMENT THROUGH DIRECT PARTICIPATION, PERSONNEL LOANS, AND ADVISORY GROUP PARTICIPANTS.
- EXPERIMENTAL DATA EXCHANGE WITH INTERESTED UTILITIES (CAROLINA POWER & LIGHT).
- PUBLIC AVAILABILITY OF THE <u>SYSRAP</u> CODE.
- REPORTS DOCUMENTING OPERATION, EVALUATION, AND TEST PROCEDURES.

HOW UTILITY INDUSTRY CAN CONTRIBUTE

- FUND ADDITIONAL EXPERIMENTS
- IN–KIND CONTRIBUTION BY LOANING PERSONNEL
- CONDUCT DATA ANALYSIS
- PARTICIPATION IN THE ANNUAL INFORMATION MEETINGS
- CREATE A USERS GROUP FOR AUTOMATION TECHNOLOGY

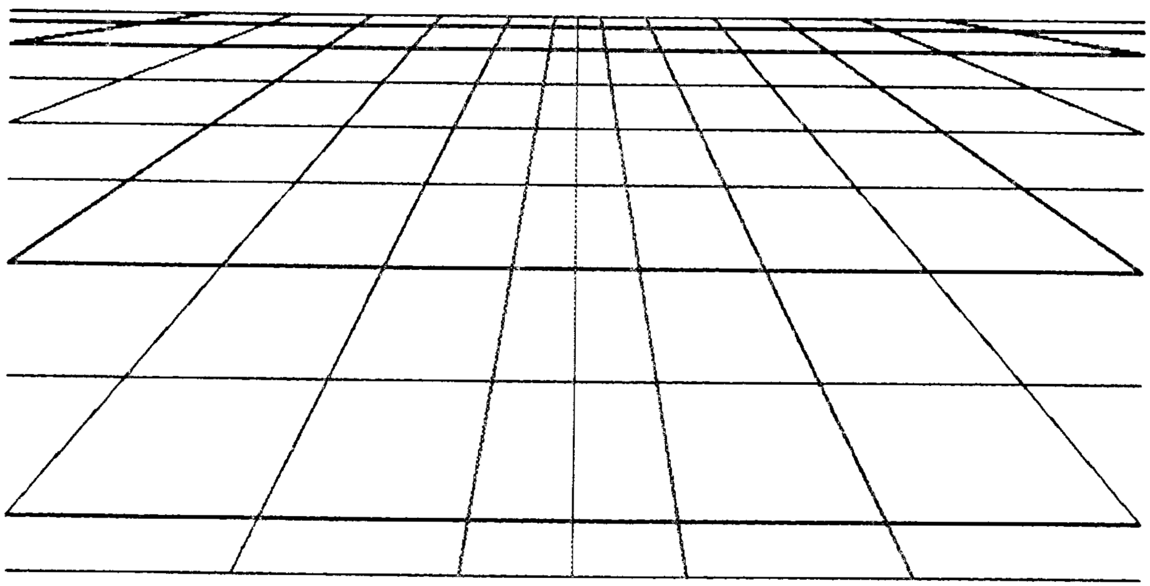
POTENTIAL FUTURE EXPERIMENTS

► SOURCE INTEGRATION

DEVELOP CONTROL STRATEGIES FOR AN AUTOMATED DISTRIBUTION SYSTEM WHICH INCLUDES DISPERSED GENERATION.

► BULK POWER COORDINATION

DETERMINE REQUIRED COORDINATION AND COMMUNICATION BETWEEN THE DISTRIBUTION AND THE BULK POWER SYSTEM TO OPTIMIZE TOTAL SYSTEM EFFICIENCY.



MEETING EXPECTATIONS

- CRITICAL AND CONSTRUCTIVE REVIEW
- TECHNOLOGY TRANSFER
- UTILITY ADVISORY GROUP SPECIFIC COMMENTS
- FEEDBACK FROM PARTICIPANTS

DESCRIPTION OF PROJECT
AND
OVERALL STATUS

DESCRIPTION OF PROJECT AND OVERALL STATUS

Steven L. Purucker

This was an overview presentation designed to (1) establish the project objectives and rationale, (2) identify project organization and industry participation, and (3) communicate project experiment status. The AACE experiments are designed to quantify the benefits associated with automation and, through experimentation, to determine the minimal amount of hardware required to support automation functions. In addition, the experiments are designed to ultimately relate the Athens experimental data on a cost/benefit basis so that utilities considering distribution automation will have the results of "real world" automation experiences. The development and testing of control strategies are required to generate experimental data and to demonstrate the strengths and weaknesses of an automated distribution system.

The experiments are divided into three areas: load control, volt/var control, and system reconfiguration. Load control deals with customer monitoring and control. Volt/var control deals with voltage regulator and capacitor monitoring and control. System reconfiguration deals with breaker and distribution switch control. The experiments will be conducted in two phases: (1) a Learning Year to determine power system and customer responses to various control actions so that models can be verifed, modified, or created; and (2) an Integrated Year to combine operation of customer load control and capacitor and regulator control, as well as breaker and switch control to examine the interaction of control actions and responses.

The personnel organization of the AACE was presented. Distribution automation involves a wide range of expertise and impacts many divisions and departments within a utility. Project personnel are divided into either design and installation or application (experiments). This division permits fuller utilization of the hardware because the application people focused on how the automation system could be used and were not initially concerned with hardware limitations.

ORNL WSC-43296

ATHENS AUTOMATION AND CONTROL EXPERIMENT

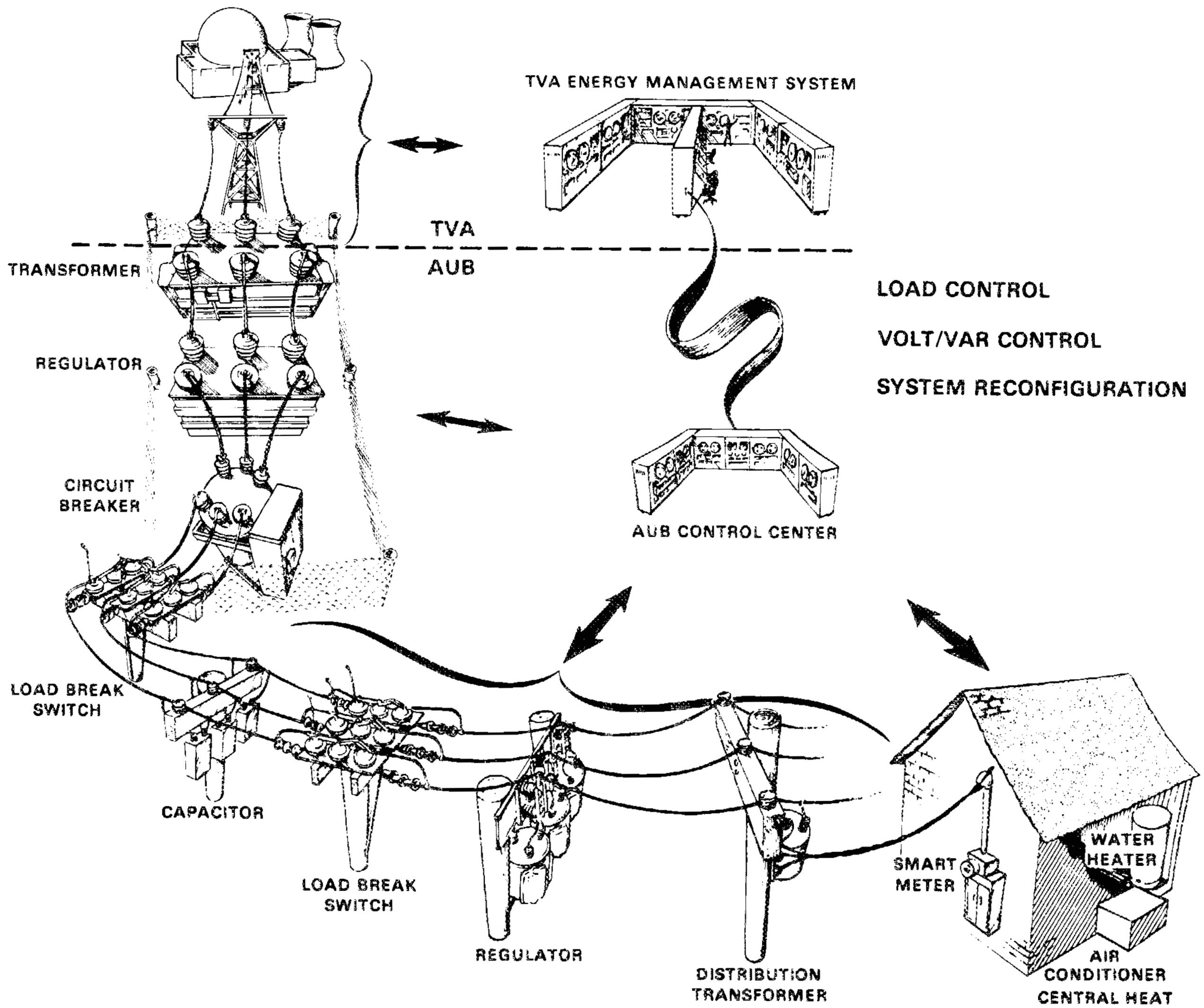
OFFICE OF ENERGY STORAGE AND DISTRIBUTION
ELECTRIC ENERGY SYSTEMS PROGRAM - DOE

Steven L. Purucker
Project Manager

Oak Ridge National Laboratory
Martin Marietta Energy Systems, Inc.

ORNL-DWG 85-17924

ATHENS AUTOMATION AND CONTROL EXPERIMENT



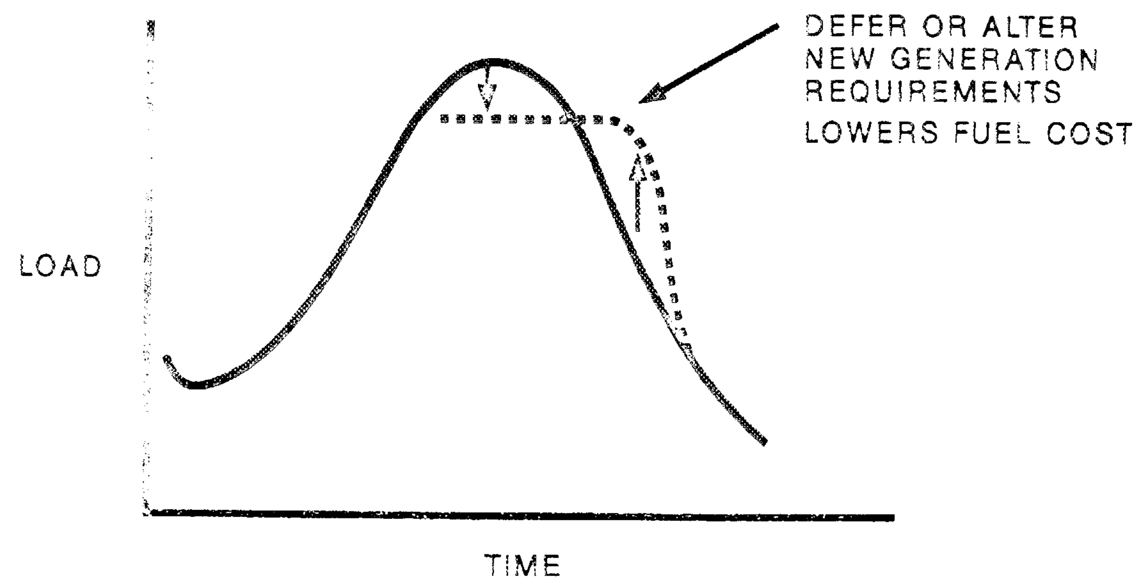
PRESENTATION OVERVIEW

- RATIONALE
- PROJECT STATUS
- INDUSTRY PARTICIPATION
- PROJECT ORGANIZATION
- PROJECT OBJECTIVES
- EXPERIMENT STATUS

ORNL-DWG 85C-17957

SOME REASONS FOR THE ATHENS PROJECT

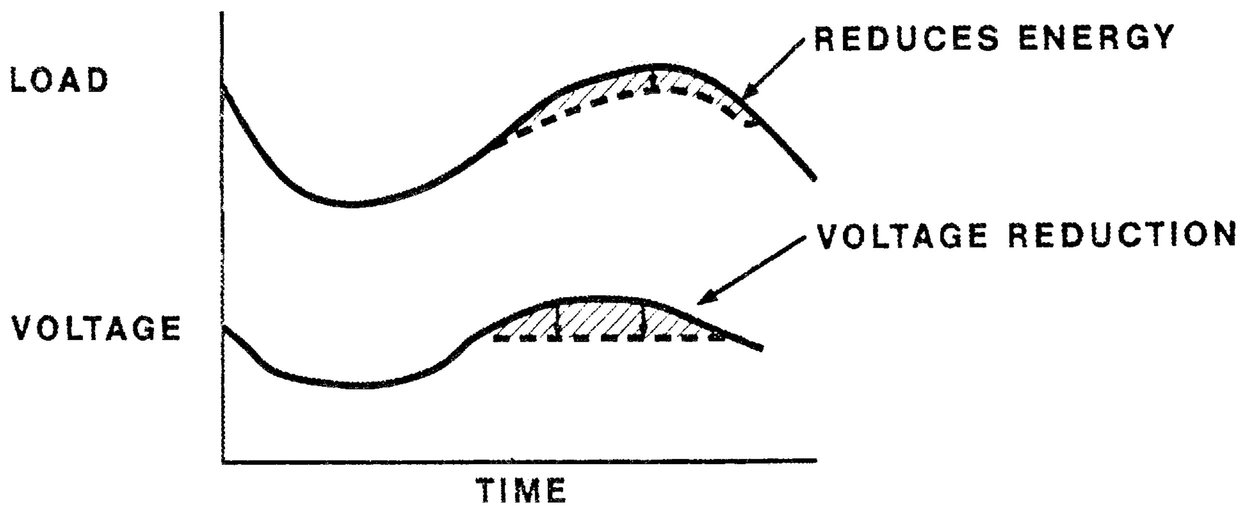
LOAD CONTROL TO REDUCE PEAKS
OR ALTER LOAD SHAPE



ORNL-DWG 85C-17956

SOME REASONS FOR THE ATHENS PROJECT (cont'd)

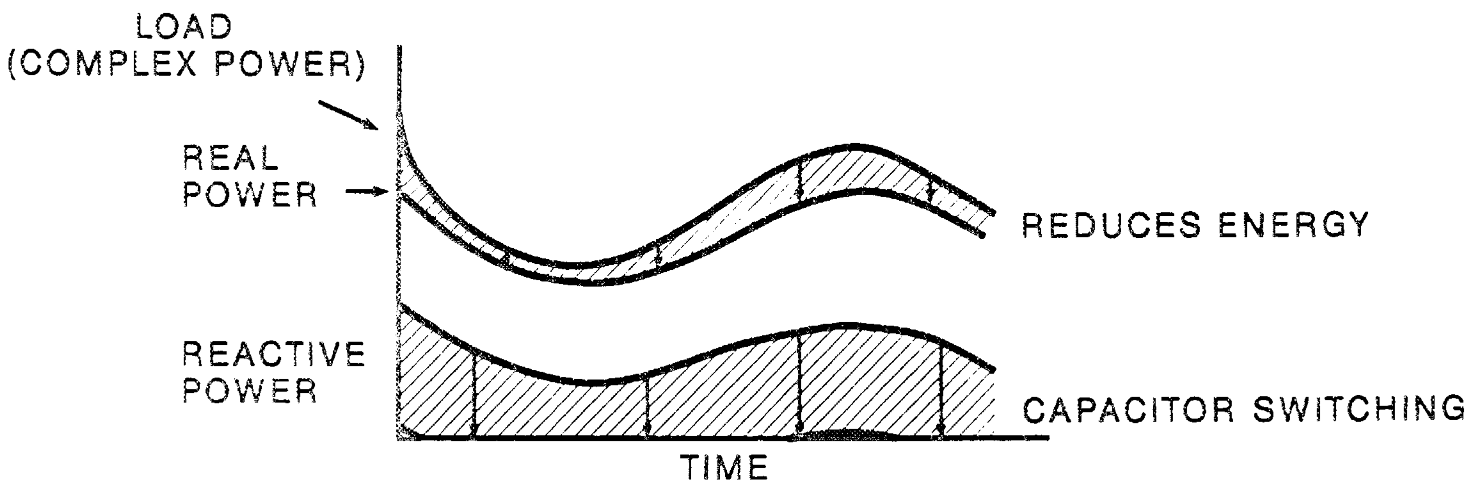
VOLTAGE CONTROL TO REDUCE PEAKS OR CONSERVE ENERGY



ORNL-DWG 85C-17955

SOME REASONS FOR THE ATHENS PROJECT (cont'd)

CAPACITOR CONTROL TO REDUCE ELECTRICAL LOSSES



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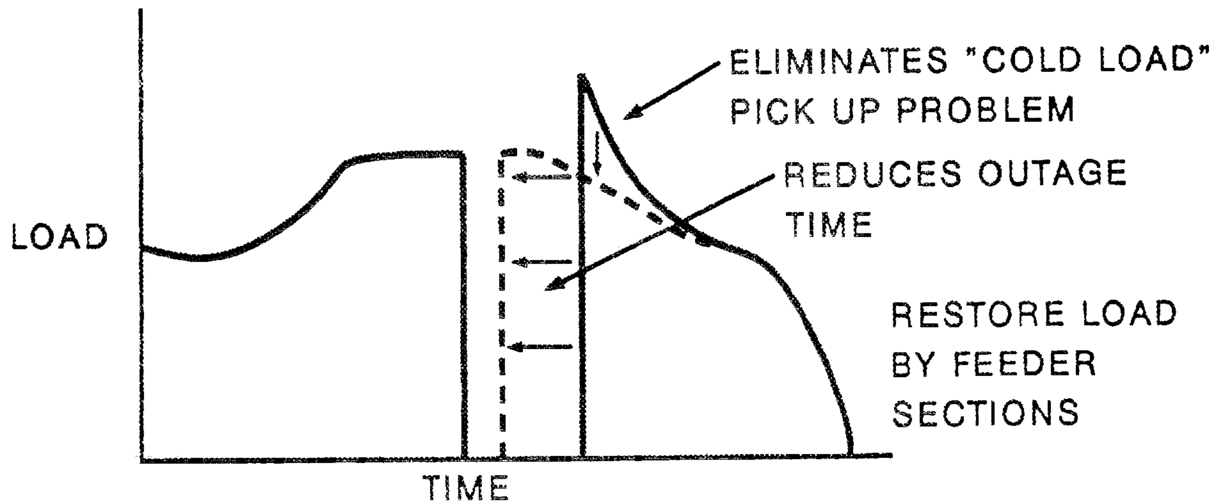
ORNL-DWG 85C-17954

SOME REASONS FOR THE ATHENS PROJECT (cont'd)

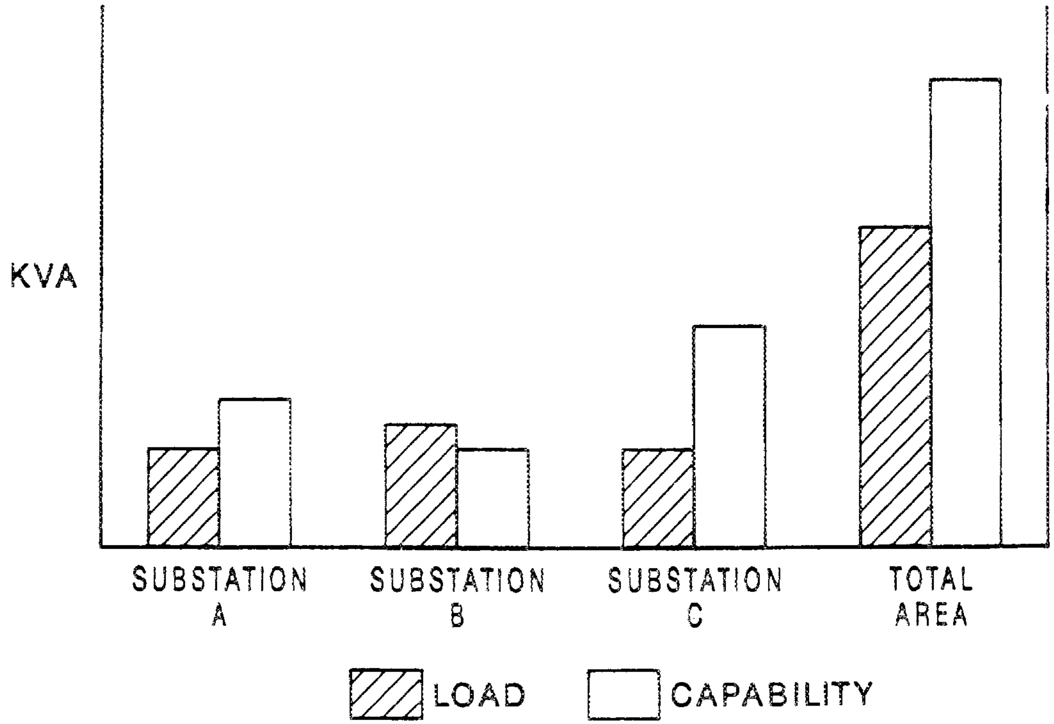
SYSTEM RECONFIGURATION TO IMPROVERESPONSE TO OUTAGES



ORNL WSC-17958

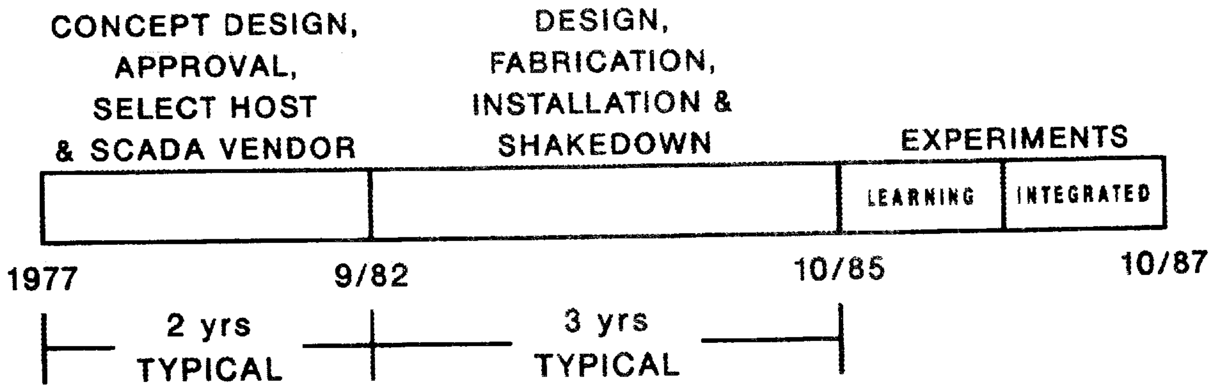
SOME REASONS FOR THE ATHENS PROJECTS (cont'd)

SYSTEM RECONFIGURATION TO INCREASE CAPACITY UTILIZATION



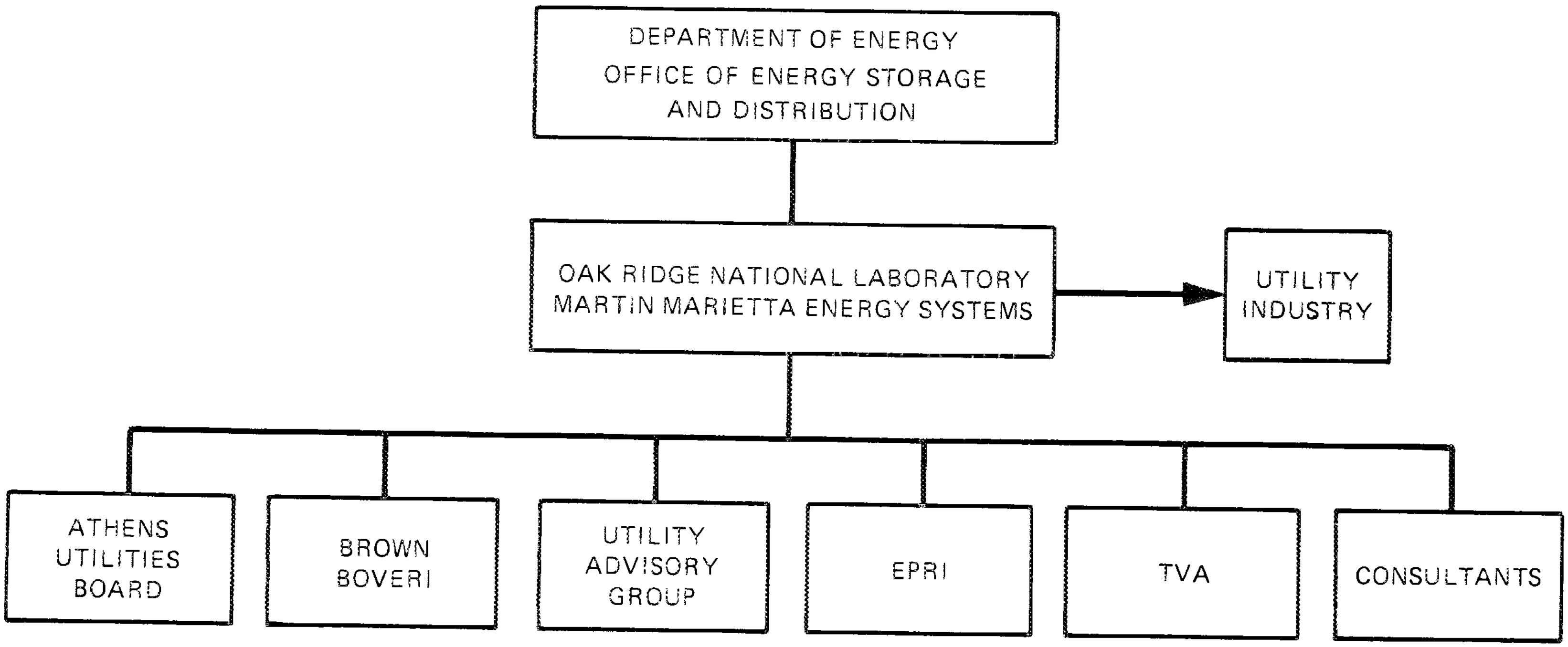
ORNL-DWG 85C-17959

PROJECT STATUS



ORNL-DWG 84-12390R

PARTICIPANTS IN THE ATHENS AUTOMATION AND CONTROL EXPERIMENT (AACE)



ORNL WSC-43299

UTILITY ADVISORY GROUP

LOAD CONTROL

ERNIE DAWSON
CLARK GELLINGS
JOE SKROSKI
MIKE WARWICK

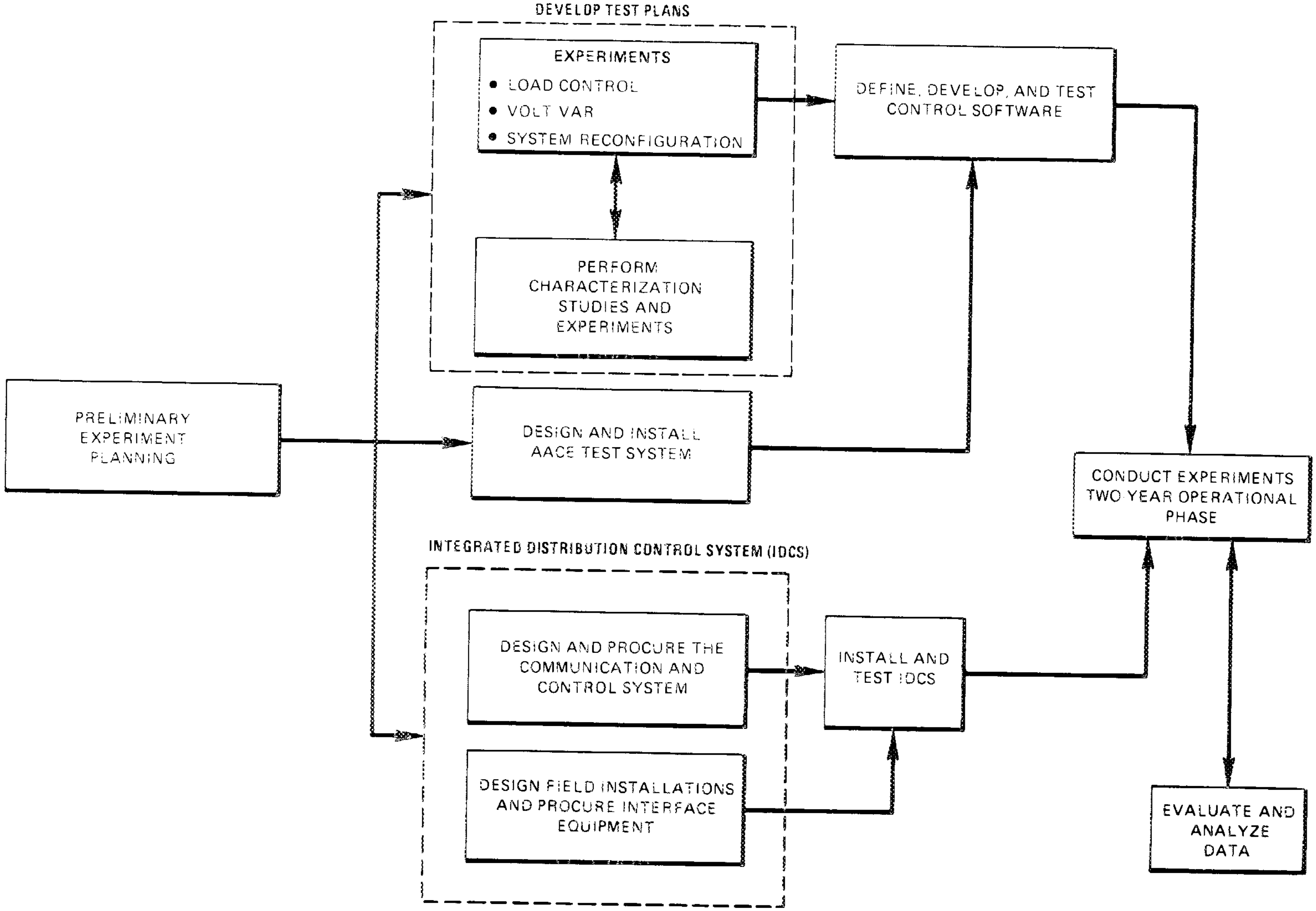
SYSTEM RECONFIGURATION

LARRY McCALL
TOM SHARP

VOLT/VAR CONTROL

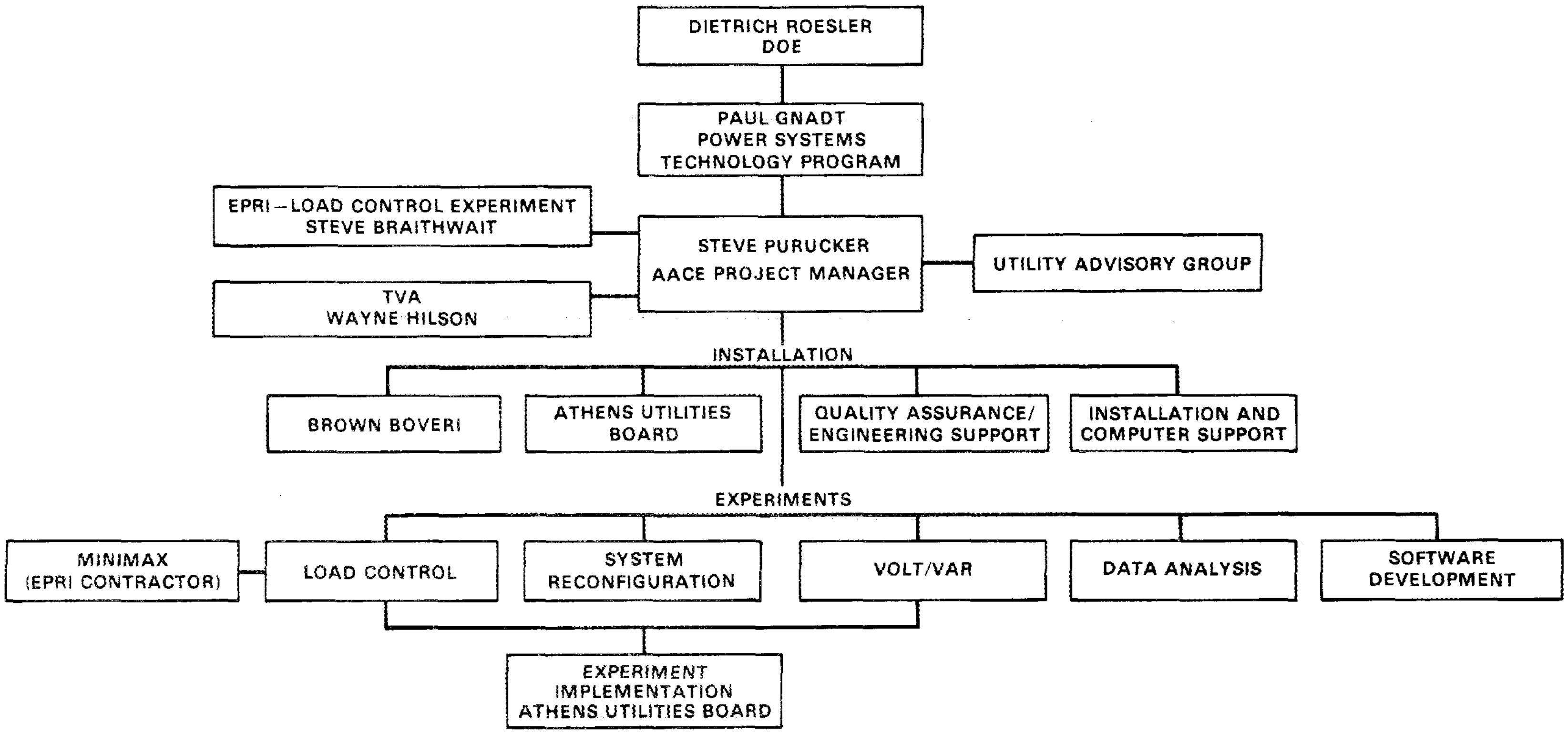
KAY CLINARD
GORDON SLOAN
WAYNE HILSON

ORNL DWG 85 791883



ORNL-DWG 85-17926

ATHENS AUTOMATION AND CONTROL EXPERIMENT (AACE) ORGANIZATION CHART



ORNL WSC-43300

OBJECTIVES OF THE ATHENS AUTOMATION AND CONTROL EXPERIMENT

- QUANTIFY BENEFITS OF AUTOMATION
- DEVELOP AND TEST CONTROL STRATEGIES
- DETERMINE MINIMAL HARDWARE REQUIREMENTS
- DEFINE SECOND GENERATION REQUIREMENTS
- COORDINATE DISTRIBUTION, GENERATION, AND TRANSMISSION CONTROL
- QUANTIFY SOCIO-ECONOMIC ASPECTS
- TRANSFER RESULTS TO THE UTILITY INDUSTRY

ORNL WSC-43301

STATUS OF THE ATHENS AUTOMATION AND CONTROL EXPERIMENT

- PRE-EXPERIMENT DATA ACQUISITION
  - DISTRIBUTION FEEDER LOAD MONITORING (FEB 85)
  - HOUSEHOLD LOAD - 50 CUSTOMERS PROVIDING DATA (JUNE 84 - JUNE 85)
- SYSTEM INSTALLATION STATUS
  - INTEGRATED DISTRIBUTION CONTROL SYSTEM IS OPERATIONAL (JUNE 85)
  - EPRI APPLIANCE MONITORING SYSTEM IS OPERATIONAL (AUG 85)
- EXPERIMENTS (SEPT 85)
  - LOAD CONTROL
  - VOLT/VAR
  - SYSTEM RECONFIGURATION

ORNL WSC-43302

RESULTS

- HARDWARE
- EXPERIMENTS

EPRI PERSPECTIVE

EPRI PERSPECTIVE

Clark W. Gellings

EPRI's involvement in the Athens Automation and Control Experiment (AACE) derives from the desire to develop analytical tools and to obtain results that could be widely used in the utility industry, as well as to capitalize on the availability of a high quality data-collection mechanism—the AACE. By augmenting the direct load control (DLC) experimental design, load monitoring, and analysis efforts of the AACE, EPRI will contribute in three major areas of interest to the utility industry. These areas include the development of transferable analysis tools for demand-side management (DSM) program design, implementation, and evaluation; the construction of a transferable data base for characterizing residential programs; and an assessment of customer response to DLC programs.

At the core of the project is the realizaton that three classes of factors interact to affect both the impact on loads and the response of customers to DLC. These classes can be categorized as environmental, including temperature and humidity; physical, including household characteristics, appliance efficiency and cycling strategy; and behavioral, including thermostat setting, household operations, prices and incentives, and income.

The principal activities for the project RP2342-1 encompass experimental design, analysis design, and impact design. The first two activities have been completed while the impact design continues as the experimentation progresses. These activities have contributed and will contribute to research products for the utility industry. These include the DESIGN Model software, which is now in the pre-release stage, the Handbook for Utility Experiments, which is nearing completion, and the Impact Model, which will be estimated from the data derived from AACE experimentation and validated with data from other utility experiments.

Taken together, these research products and their supporting analyses will contribute to an integrated approach for utility demand-side planning.

ATHENS AUTOMATION AND CONTROL EXPERIMENT
ATHENS, TENNESSEE

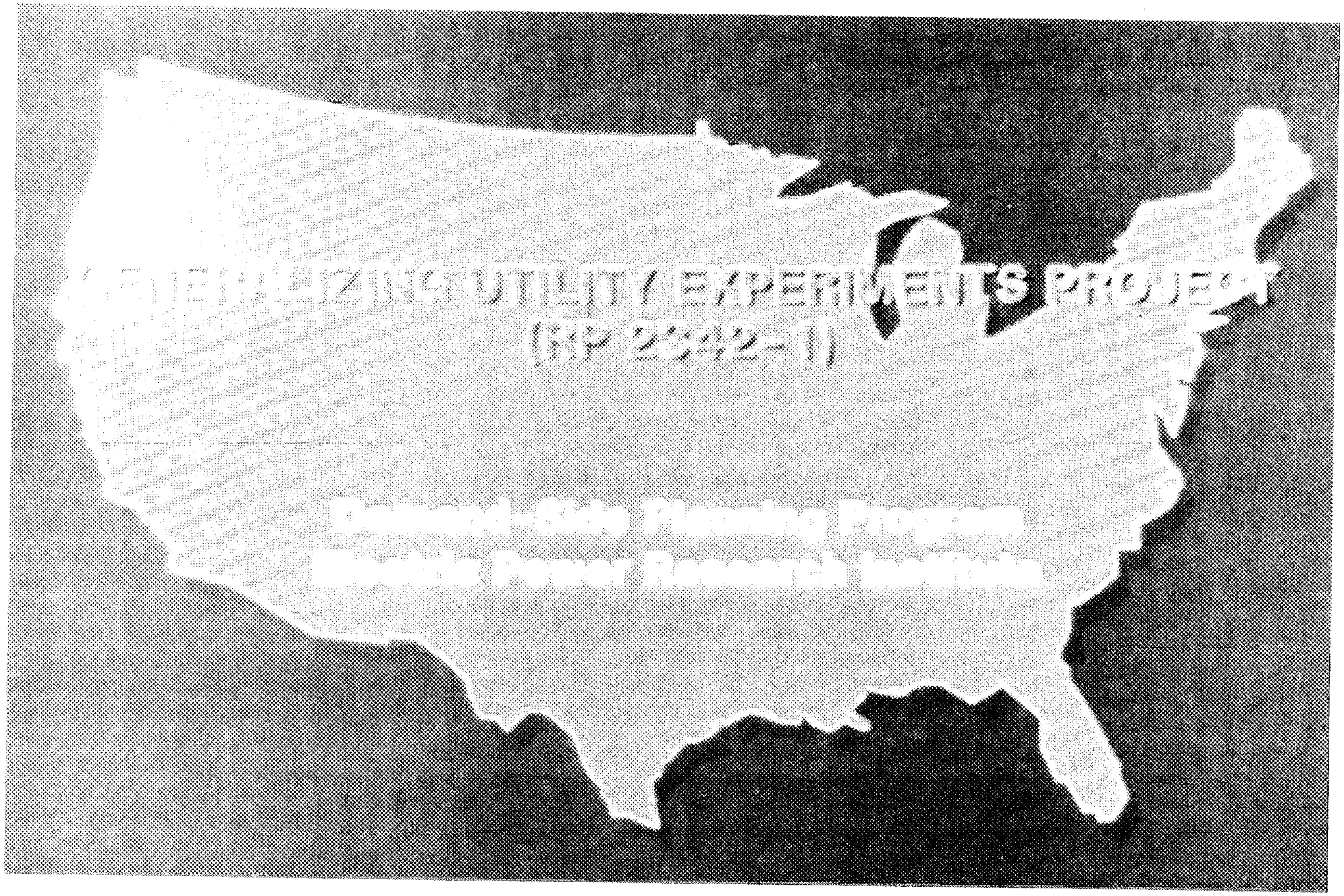
Perspective of

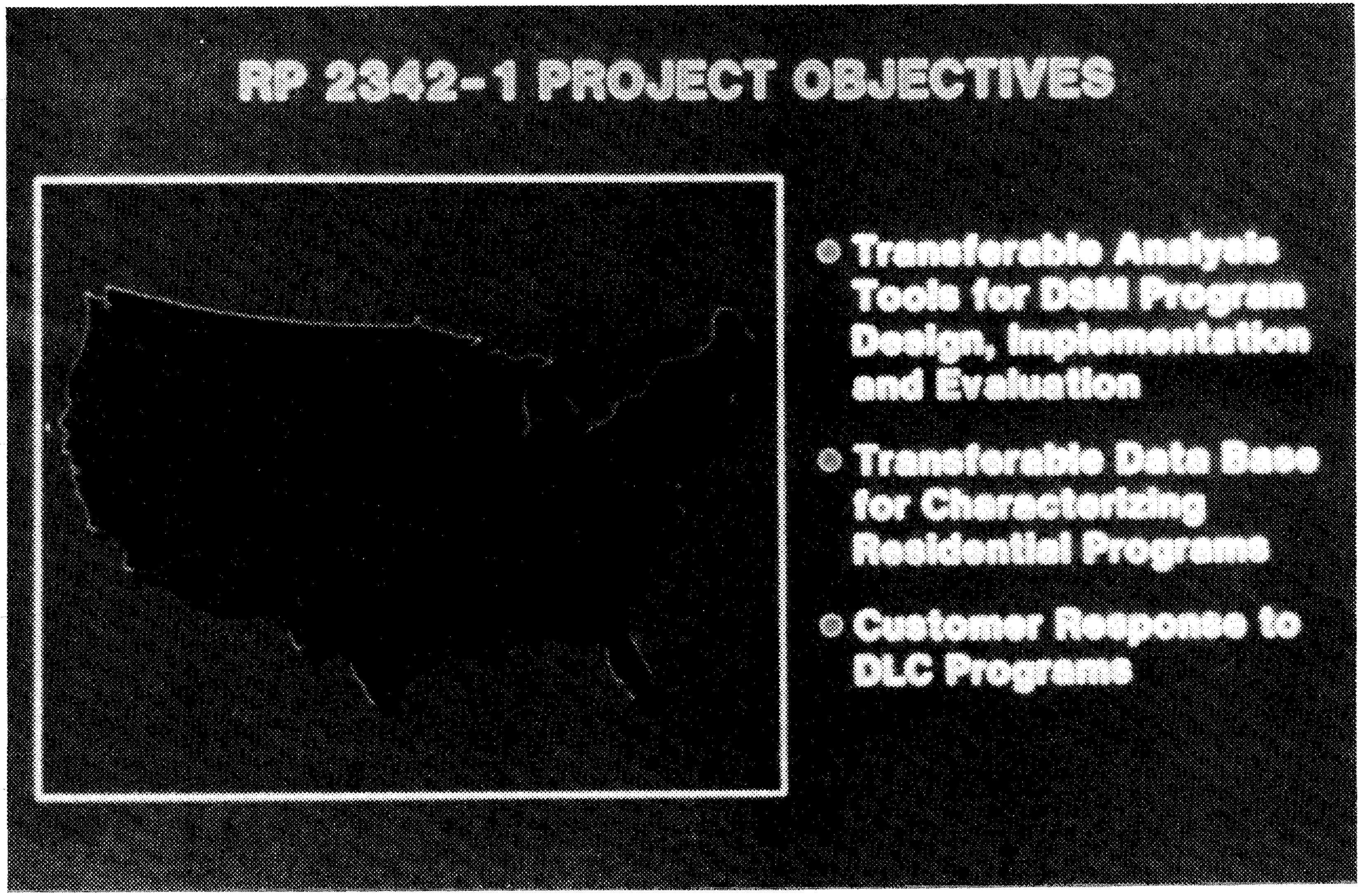
THE ELECTRIC POWER RESEARCH INSTITUTE

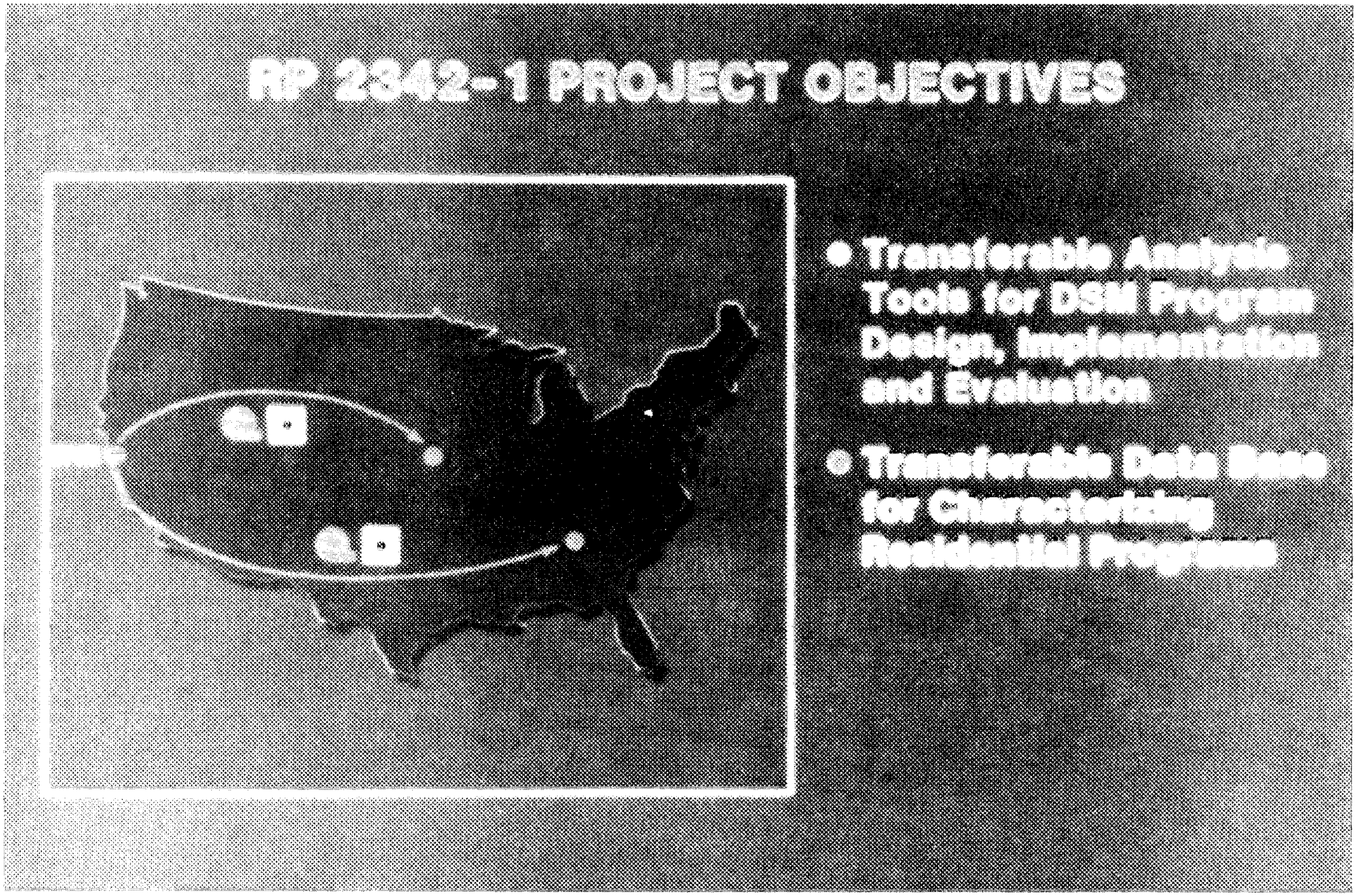
PALO ALTO, CA

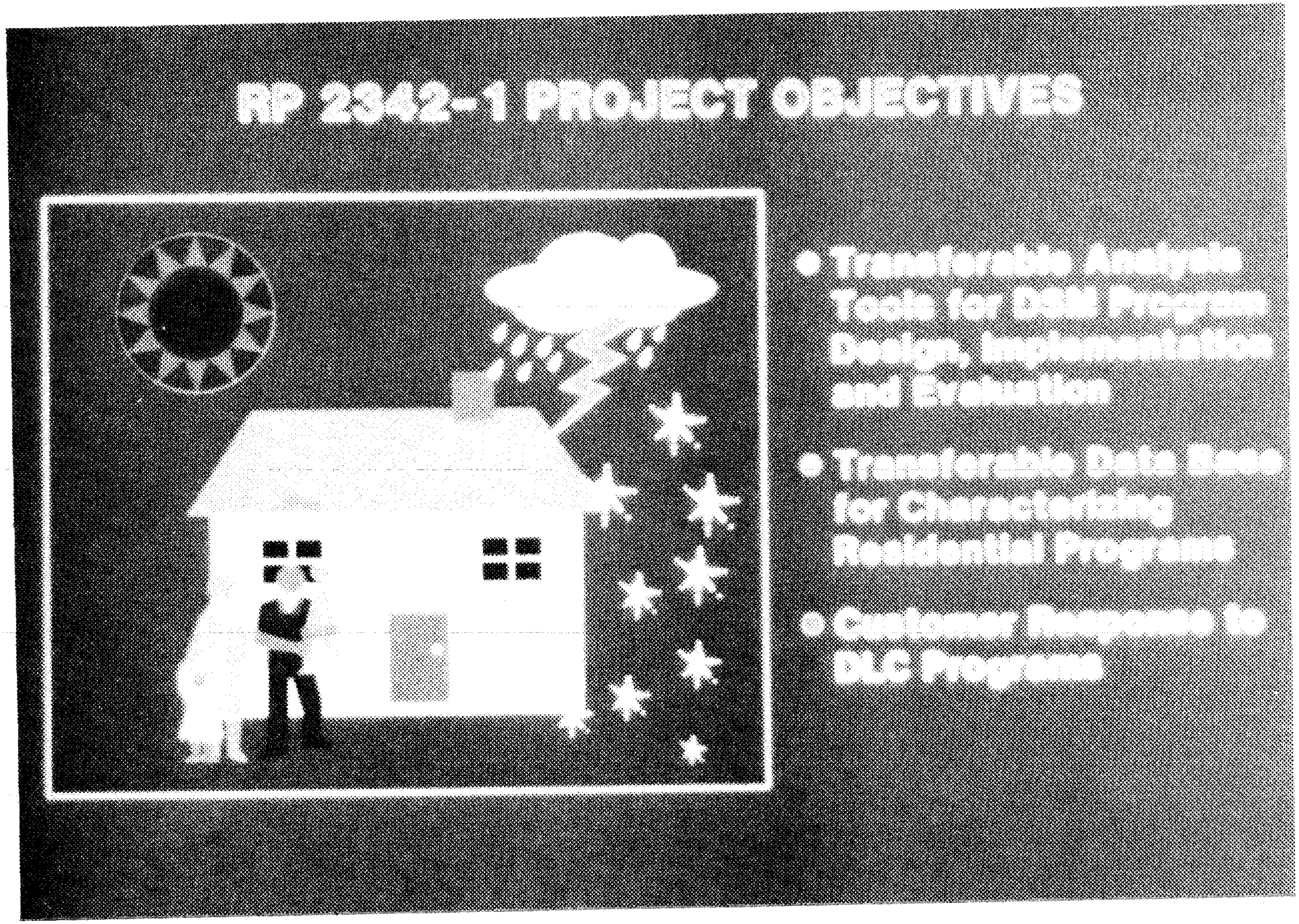
By

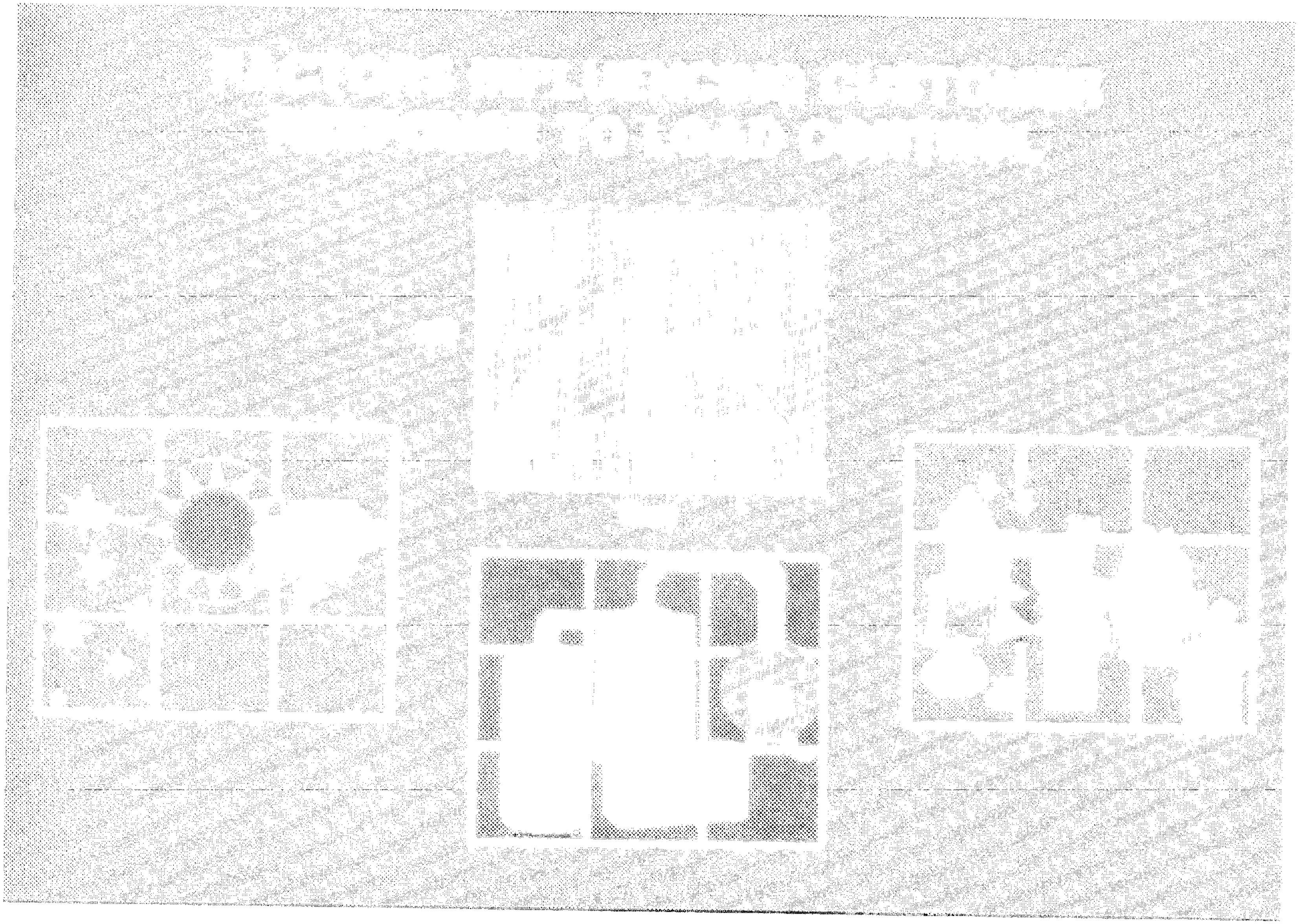
Clark W. Gellings
Senior Program Manager
Demand-Side Planning Program


UTILITY EXPERIMENTS PROJECT
(RP 2342-1)
Demand-Side Planning Program
Electric Power Research Institute


RP 2342-1 PROJECT OBJECTIVES
Transferable Analysis Tools for DSM Program Design, Implementation and Evaluation
Transferable Data Base for Characterizing Residential Programs
Customer Response to DLC Programs

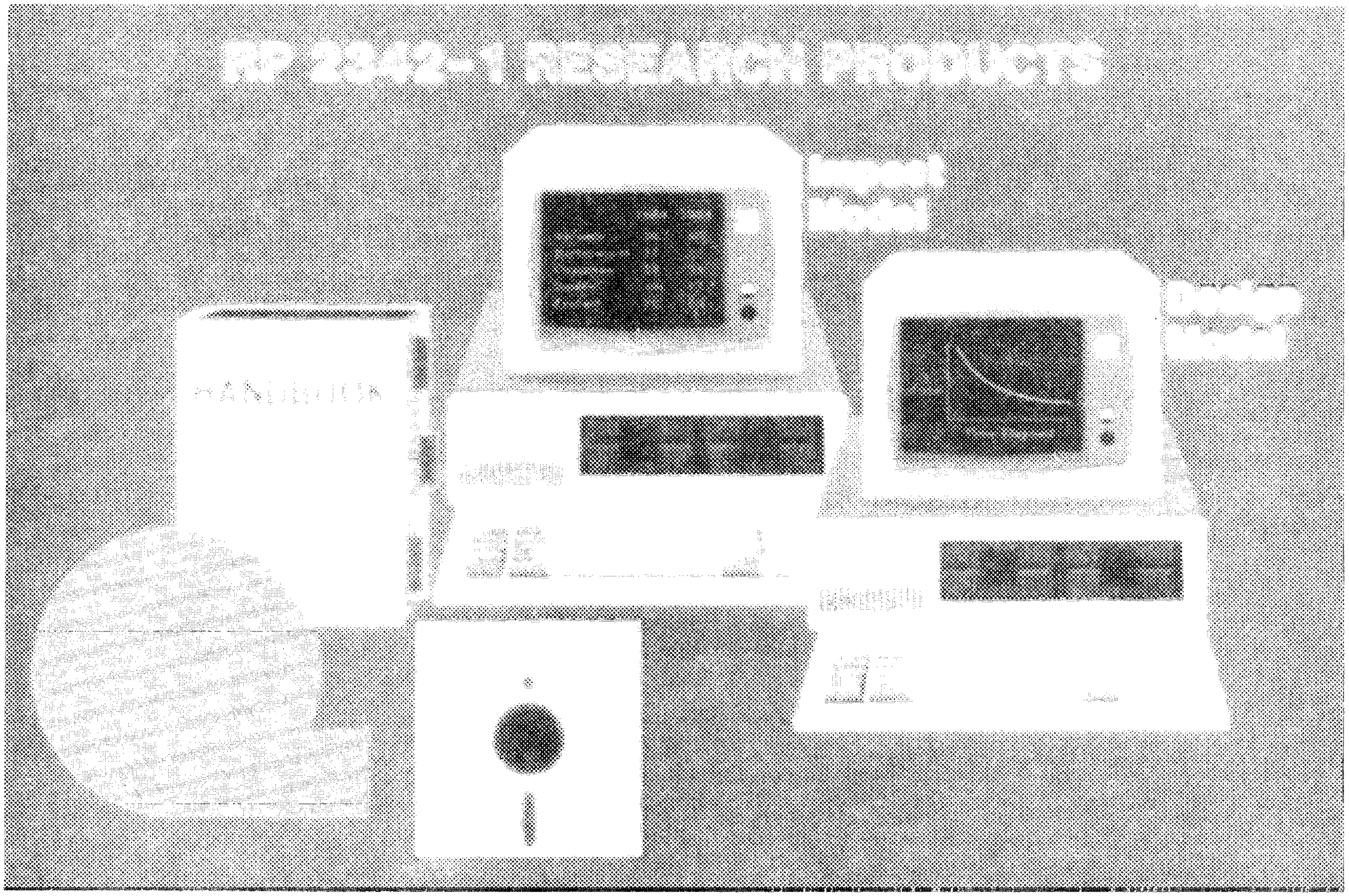

RP 2342-1 PROJECT OBJECTIVES
• Transferable Analysis Tools for DSM Program Design, Implementation and Evaluation
• Transferable Data Base for Characterizing Residential Programs

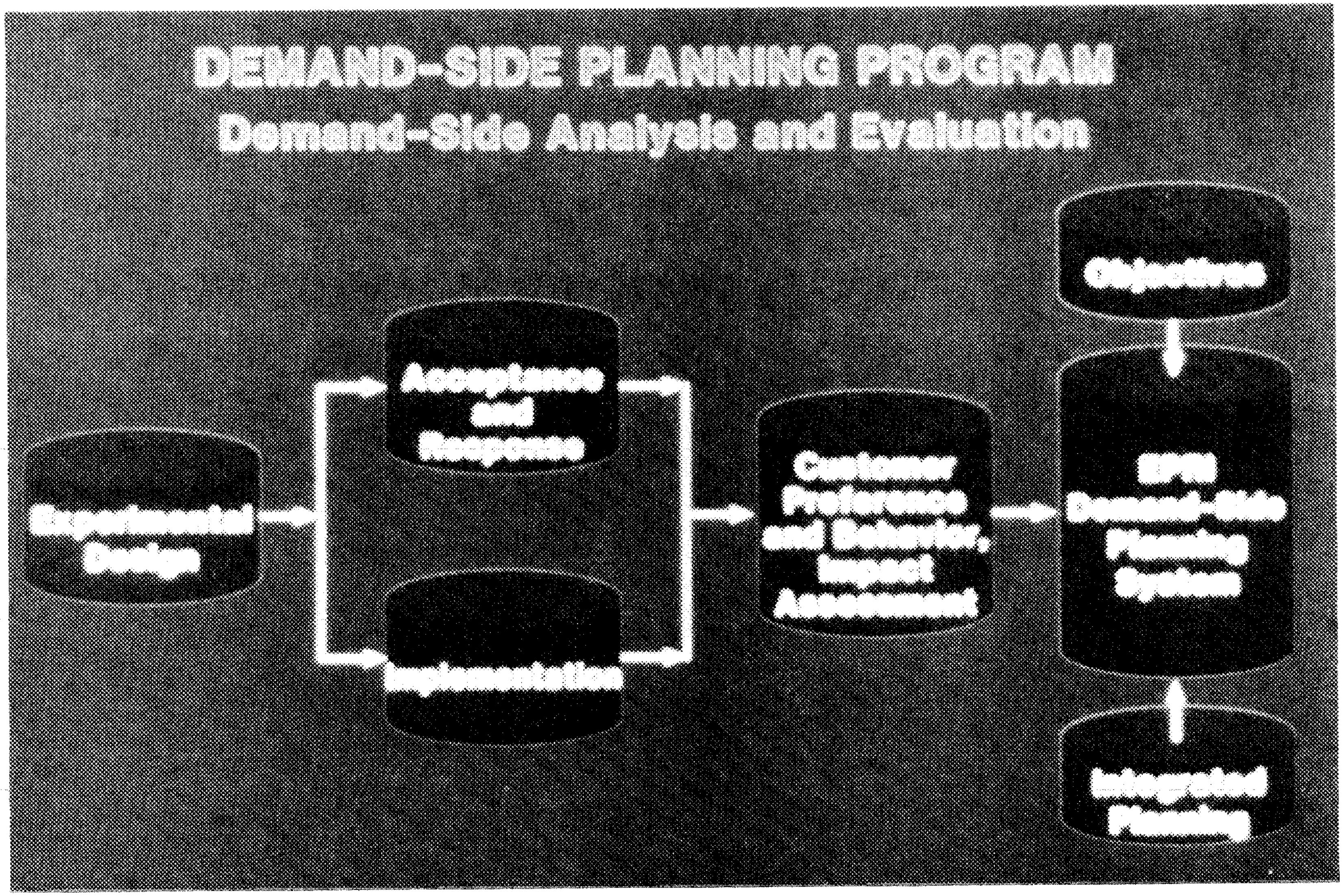

RP 2342-1 PROJECT OBJECTIVES
• Transferable Analysis Tools for DSM Program Design, Implementation and Evaluation
• Transferable Data Base for Characterizing Residential Programs
• Customer Response to DLC Programs

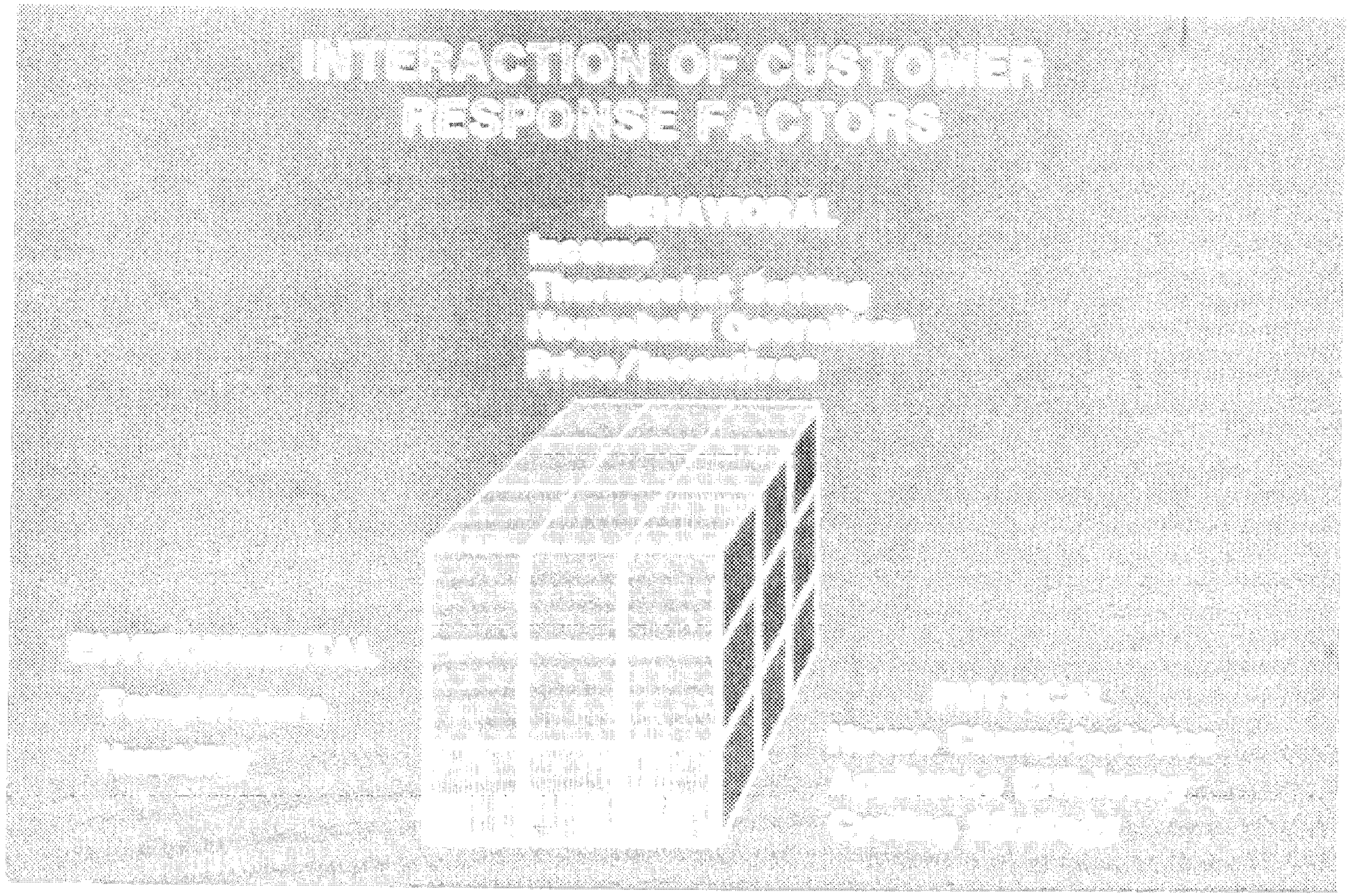


RP 2342-1 ACTIVITIES FOR AACE LOAD CONTROL EXPERIMENTS

- Experimental Design
- Analysis Design
- Impact Design


RP 2342-1 RESEARCH PRODUCTS
Impact Model
Design Model
HANDBOOK


DEMAND-SIDE PLANNING PROGRAM
Demand-Side Analysis and Evaluation
Objectives
Acceptance and Response
Experimental Design
Implementation
Customer Preference and Behavior, Impact Assessment
EPRI Demand-Side Planning System
Integrated Planning


INTERACTION OF CUSTOMER
RESPONSE FACTORS
BEHAVIORAL
Income
Thermostat Setting
Household Operations
Price/Incentives

HARDWARE DESCRIPTION

COMMUNICATION AND CONTROL SYSTEM

Steven L. Purucker

The Intergrated Distribution Control System (IDCS) is the hardware system on which the experiments will be conducted. The IDCS consists of two separate types of equipment: (1) a traditional Supervisory Control and Data Acquisition (SCADA) system modified for distribution automation and (2) the interface equipment, which is that equipment required to link the SCADA system to traditional utility equipment.

Additionally, Electric Power Research Institute (EPRI) is providing a separate customer appliance monitoring system, the Electric ARM system. EPRI is also a codesigner of the load control experiments.

The communication and control system is an "experimental tool" that will be used to conduct the AACE. The communication and control system combines standard and nonstandard (custom) hardware and coordinates both types of hardware through a SCADA software program. This presentation reviews the design and communication capabilities of the communication and control system.

The communication and control system allows system operators to collect data from the Athens Utilities Board (AUB) network and enables them to manipulate the network with load control and distribution control commands. Both data collection and control capabilities must operate under abnormal as well as normal conditions of the AUB network. To ensure this level of reliability, proven components of SCADA hardware and software are used. Standard hardware components of the communication and control system include remote terminal units, signal injection units, and load control receivers from Brown Boveri Controls Systems, Inc. Other major components are Metretek smart meters, Digital Equipment Corporation (DEC) computers, and Aydin display generators. The major software component is Brown Boveri's MODSCAN III SCADA software, running in the environment of DEC's RSX-11M operating system.

Communication among the various hardware elements takes place over three kinds of channels: (1) dedicated (leased) telephone lines, (2) ordinary dial-up telephone lines, and (3) AUB distribution lines themselves (in the form of power line carrier messages). Data collected from the remote units are displayed to system operators and recorded in "history files" for later analysis. Provisions for future expansion and adaption of software will facilitate adding real-time control to experiments and on-line data analysis to accelerate experimentation.

ORNL WSC-43296

ATHENS AUTOMATION AND CONTROL EXPERIMENT

OFFICE OF ENERGY STORAGE AND DISTRIBUTION
ELECTRIC ENERGY SYSTEMS PROGRAM - DOE

Steven L. Purucker
Project Manager

Oak Ridge National Laboratory
Martin Marietta Energy Systems, Inc.

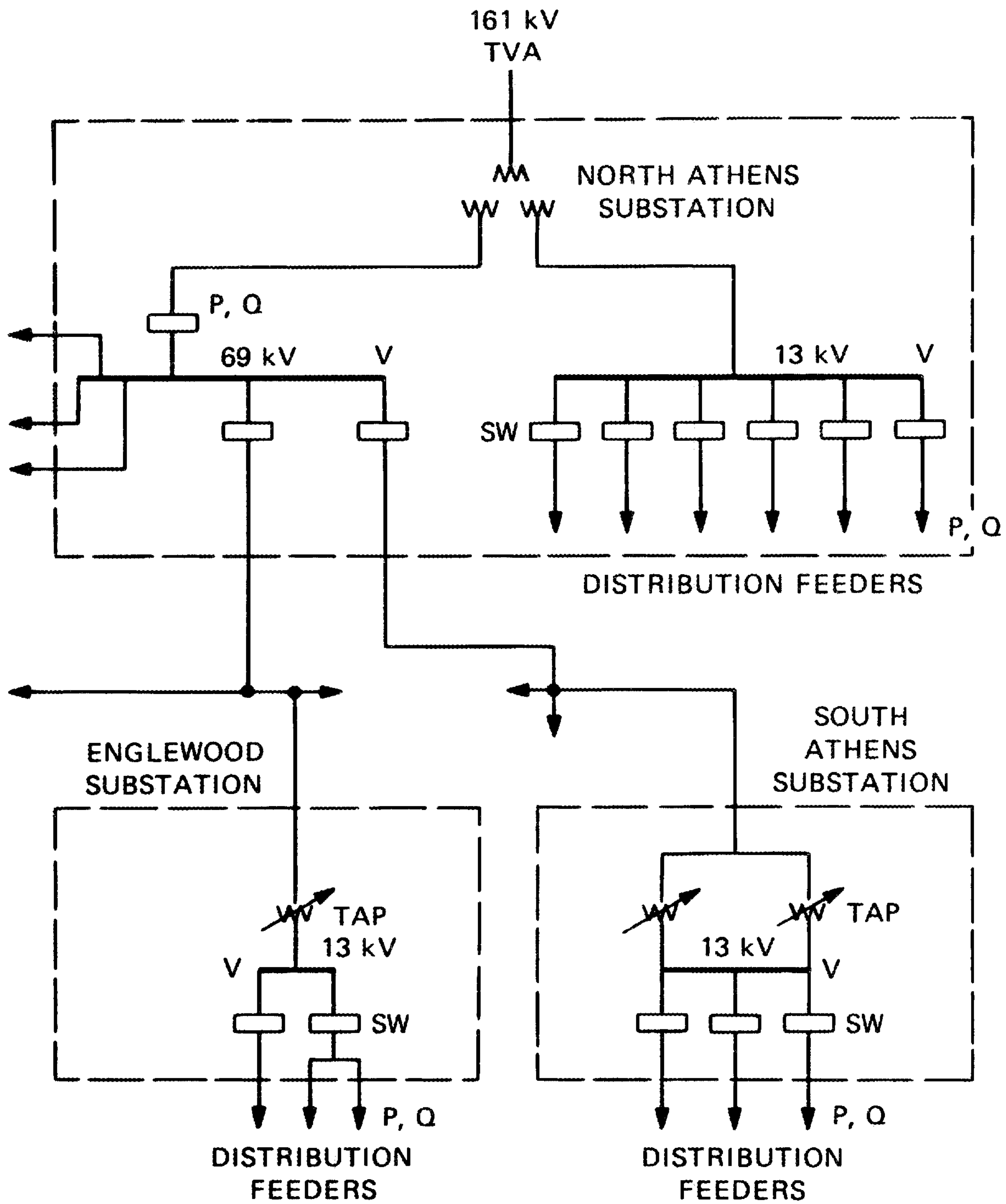
ORNL WSC-43303

HARDWARE SYSTEMS DESCRIPTION

- SUBSTATION CONTROL AND MONITORING
- FEEDER CONTROL AND MONITORING
- IDCS ARCHITECTURE
- IDCS SOFTWARE
- IDCS TESTING
- EPRI APPLIANCE MONITORING SYSTEM

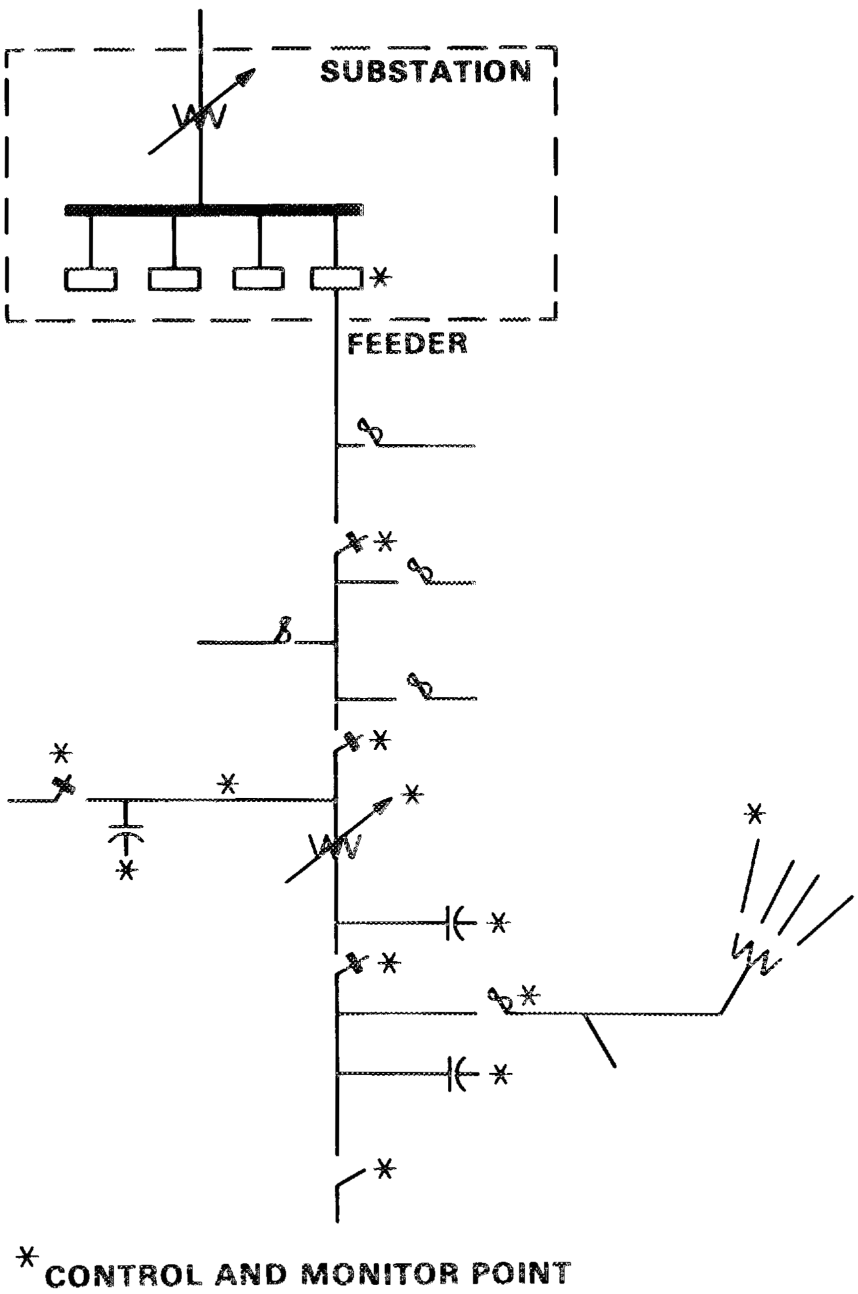
ORNL-DWG 82-18666R4

SUBSTATION CONTROL AND MONITORING



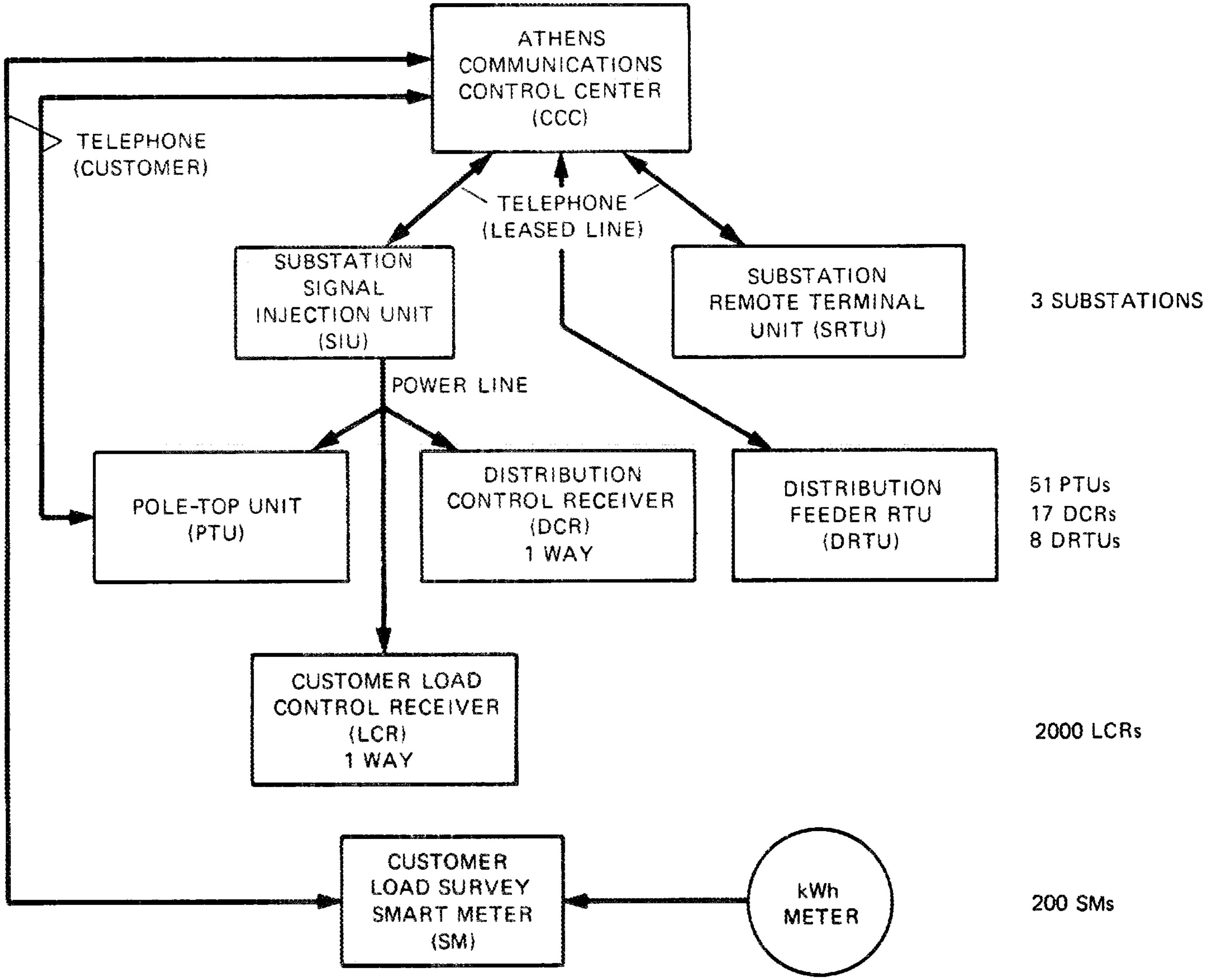
ORNL-DWG 82-18669R4

FEEDER CONTROL AND MONITORING



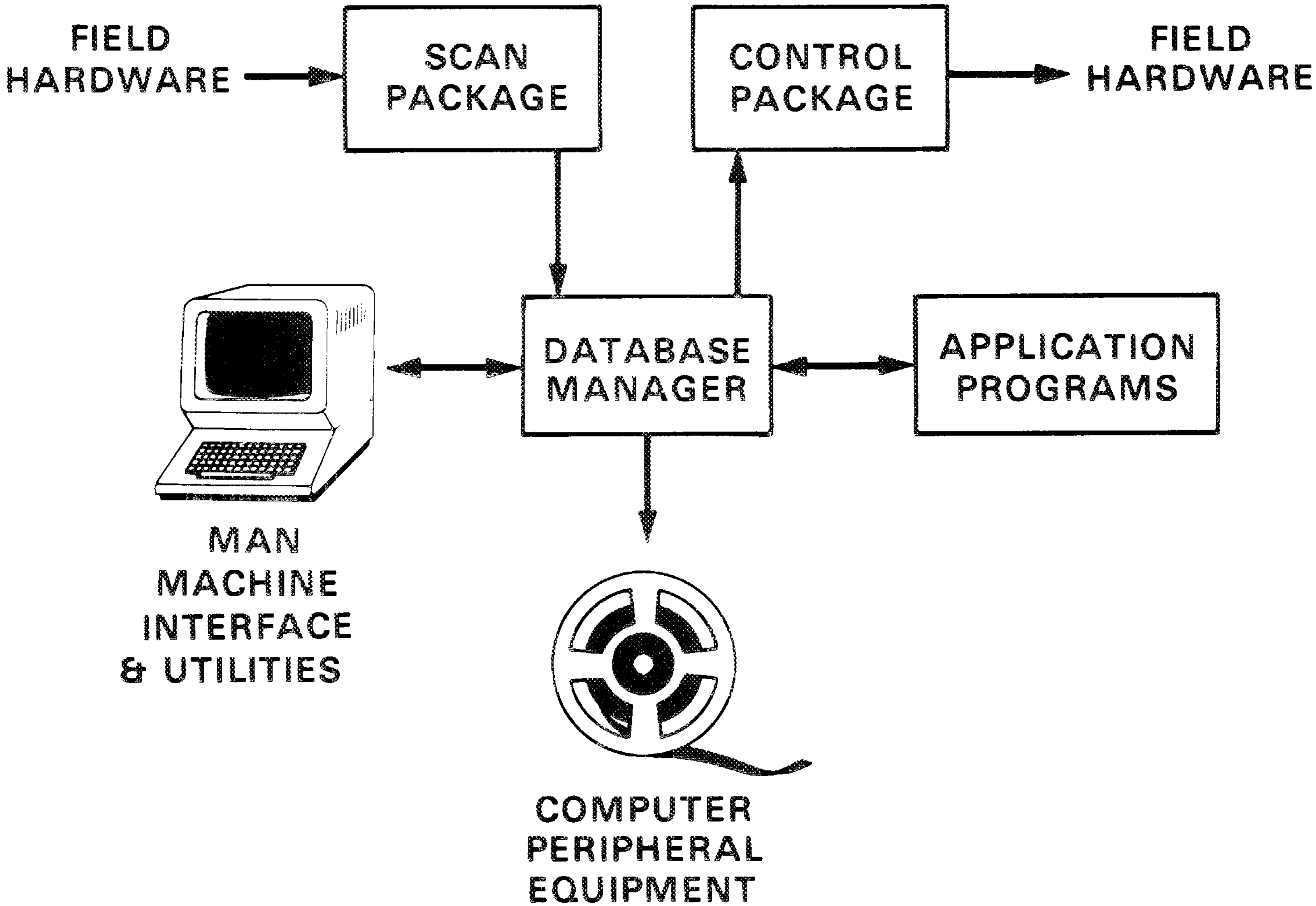
ORNL–DWG 82-18668R6

INTEGRATED DISTRIBUTION CONTROL SYSTEM



ORNL-DWG 85-17925R

IDCS SOFTWARE (MODSCAN)



ORNL WSC-43297

IDCS TESTING

1. COMPONENT LEVEL TEST
2. FACTORY ACCEPTANCE TEST
3. PRELIMINARY SITE ACCEPTANCE TEST
4. FINAL SITE ACCEPTANCE TEST

ORNL WSC-43304

EPRI APPLIANCE MONITORING

- AIR CONDITIONER
- CENTRAL HEAT
- WATER HEATER
- INDOOR TEMPERATURE
- WHOLE HOUSEHOLD

INSTRUMENTATION

G. R. Wetherington, Jr.

Automation systems and their targeted processes may not be directly compatible with one another. Automation systems typically interface with low-level standard signals while processes are usually characterized by physical and nonstandard electrical states. This interface problem is normally solved by the addition of instrumentation between the automation system and the process. In addition to the interface function, instrumentation can also perform useful work, such as information preprocessing and compensation for environmental factors. A particular instrumentation requirement can usually be satisfied by following a plan that consists of four steps:

1. definition of the interfaces,
2. identification of the functional requirements,
3. selection, and
4. maintenance.

Accuracy is an important consideration due to its potential effect on system operation, costs, and reliability. In a research effort such as the Athens Automation and Control Experiment (AACE), accuracy is very important since it directly affects the resulting data quality. Accuracy specifications available from most manufacturers provide the necessary data for identification of instruments that need particular accuracy qualifications, but subsequent calibration is required if specified accuracy is to be achieved after installation. The calibration procedures that are used in the AACE are:

1. prior to installation, test and calibrate all active instrumentation;
2. calibrate the major components (RTUs), and then calibrate instruments that tie to the major components (transducers); and
3. on a routine basis, recheck calibration.

Problems will be encountered, even with the best instrumentation and particularly during initial system shakedown, but they can be approached and successfully corrected by following five basic steps:

1. observe and identify the symptom,
2. duplicate the conditions for study,
3. isolate the problem to a subsystem or component,
4. identify the problem cause, and
5. correct the problem.

INSTRUMENTATION

G. R. WETHERINGTON JR.

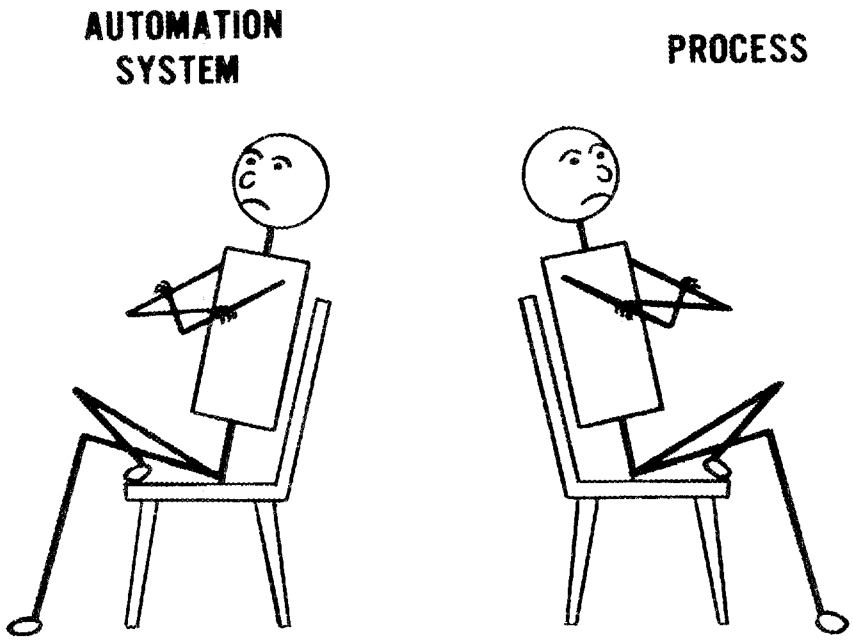
ORNL
INSTRUMENTATION AND
CONTROLS DIVISION

DECEMBER 3, 1985

TOPICS TO BE COVERED

- PURPOSE OF INSTRUMENTATION
- STEPS NECESSARY TO SATISFY INSTRUMENTATION NEEDS
- THE IMPORTANCE OF ACCURACY
- PROBLEMS WE'VE ENCOUNTERED

AN AUTOMATION SYSTEM MAY NOT BE DIRECTLY COMPATIBLE WITH YOUR PROCESS



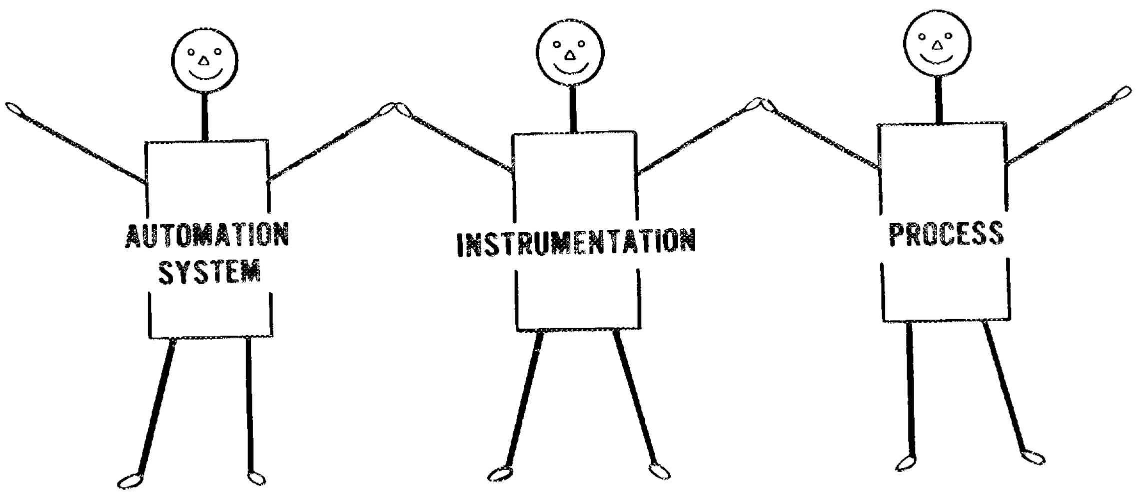
ELECTRICAL STATES

LOW -LEVEL STANDARD SIGNALS

PHYSICAL STATES

MULTI-LEVEL NON-STANDARD SIGNALS

INSTRUMENTATION SERVES AS THE INTERFACE BETWEEN THE AUTOMATION SYSTEM AND THE PROCESS



IN ADDITION TO FULFILLING INTERFACE REQUIREMENTS, INSTRUMENTATION CAN PERFORM USEFUL WORK

- INFORMATION PRE-PROCESSING

MEASURED	OUTPUT AVAILABLE
V (PT)	KW
I (CT)	KVAR
	PHASE ANGLE
	POWER FACTOR

- COMPENSATE FOR ENVIRONMENTAL FACTORS

  ELECTRICAL NOISE FILTERING

MAJOR STEPS NECESSARY TO SATISFY INSTRUMENTATION NEEDS

- DEFINE INTERFACES
- IDENTIFICATION OF FUNCTIONAL REQUIREMENTS
- SELECTION
- MAINTENANCE

INTERFACE DEFINITION CONCERNS IDENTIFICATION OF PHYSICAL CONSTRAINTS IMPOSED BY THE PROCESS AND AUTOMATION SYSTEM

- SIGNAL LEVELS
- ENVIRONMENT
- POWER SOURCES
- MECHANICAL CHARACTERISTICS

FUNCTIONAL REQUIREMENTS CONCERN THE OPERATION CONSTRAINTS IMPOSED BY YOUR NEEDS

- ACCURACY
- REPEATABILITY
- FREQUENCY REPONSE
- MAINTAINABILITY
- ON-LINE BACK-UP/REDUNDANCY
- BATTERY BACK-UP

IMPORTANT POINTS TO CONSIDER IN SELECTION OF INSTRUMENTATION

- VENDOR REPUTATION
- VENDOR SUPPORT
  - APPLICATIONS
  - MAINTENANCE
  - REPAIR
- DELIVERY TIME
- MATURITY OF PRODUCT
- COST
- PROCUREMENT METHOD

THE INSTALLATION OF INSTRUMENTATION REQUIRES CAREFUL PLANNING

- PHYSICAL MOUNTING ARRANGEMENT
- WIRING COSTS
- ENVIRONMENTAL REQUIREMENTS
- SCHEDULING

MAINTENANCE CONSIDERATIONS MUST BE ADDRESSED

- SPARE PARTS
- WHO DOES IT
  - VENDOR
  - OWNER
  - THIRD PARTY CONTRACT
- CALIBRATION
  - RECOGNIZED STANDARDS
  - FREQUENCY
- PERSONNEL
  - EXPERIENCE IS A KEY FACTOR
  - TRAINING CAN FILL THE GAP

ACCURACY IS IMPORTANT

- ACCURACY CAN HAVE MAJOR EFFECTS
  - OPERATION
  - COSTS
  - RELIABILITY
- DATA QUALITY

CALIBRATION PROCEDURES USED FOR THE AACE

- TEST ALL ACTIVE INSTRUMENTATION PRIOR TO INSTALLATION
  - * SIGNAL CONDITIONERS (KW,KVAR, KV, ETC.)
- AFTER INSTALLATION, PERFORM SYSTEM CALIBRATION
  - * CALIBRATE MAJOR COMPONENTS FIRST
  - * CALIBRATE INSTRUMENTATION THAT TIE TO MAJOR COMPONENTS SECOND
- CHECK CALIBRATION ON ROUTINE BASIS

THERE ARE FIVE MAJOR STEPS TO APPROACHING AND CORRECTING INTRUMENTATION PROBLEMS

1) OBSERVE AND IDENTIFY THE SYMPTOM

2) DUPLICATE THE CONDITIONS FOR STUDY

3) ISOLATE THE PROBLEM TO A SUBSYSTEM OR COMPONENT

4) IDENTIFY THE CAUSE

5) CORRECT THE PROBLEM

SUMMARY OF AACE INSTRUMENTATION PROBLEMS

SMART METER COMMUNICATIONS

POLE-TOP-UNIT PHONE LINE ACCESS

SIGNAL-INJECTION-UNIT COMMUNICATIONS

SIGNAL-INJECTION-UNIT BLEED-OVER

POLE-TOP-UNIT FAILURES

SMART METER FAILURES

TRANSDUCER FAILURES

PROBLEM: **SMART METER COMMUNICATIONS**

SYMPTOM: 20% OF SMART METERS WERE IN LATE-CALL ALARM STATE.

CAUSE: SMART METER DESIGN DEFICIENCY PERMITTING THE DEVICES TO BE SUSCEPTIBLE TO COMMUNICATIONS NOISE.

SOLUTION: PROBLEM ELIMINATED WITH RESISTOR-DIODE CLAMPING CIRCUIT.

PROBLEM: **POLE-TOP-UNIT PHONE LINE ACCESS**

SYMPTOM: IN EXTENSION-LINE CONFIGURATION, POLE-TOP-UNITS FAILED TO RECOGNIZE 'BUSY' LINE AND TRANSMITED OVER ONE ANOTHER.

CAUSE: OFF-HOOK SENSING CIRCUIT DESIGN ERROR.

SOLUTION: REPLACED ZENER DIODE IN OFF-HOOK SENSING CIRCUIT.

PROBLEM:	**SIGNAL-INJECTION-UNIT COMMUNICATIONS**
SYMPTOM:	UNRELIABLE COMMUNICATIONS BETWEEN THE SIGNAL-INJECTION-UNITS AND THE HOST COMPUTER.
CAUSE:	IMPEDANCE IMBALANCE IN TRANSMIT/RECEIVE CIRCUIT.
SOLUTION:	INSTALLED IMPEDANCE MATCHING 'BRIDGE'.

PROBLEM: **NORTH ATHENS SIGNAL-INJECTION-UNIT BLEEDS OVER ONTO OTHER PLC AREAS.**

SYMPTOM: UNRELIABLE PLC OPERATION AT SOUTH ATHENS AND ENGLEWOOD SUBSTATIONS.

CAUSE: BLEED-OVER OF NORTH ATHENS PLC TRANSMISSIONS VIA 69KV BUS. NORTH ATHENS USES 3-PHASE INJECTION.

SOLUTION: CONVERT NORTH ATHENS SIGNAL-INJECTION-UNIT TO A SINGLE PHASE INJECTOR.

PROBLEM: **TRANSDUCER FAILURES**

SYMPTOM: < 1% TRANSDUCERS HAVE FAILED PRIOR TO INSTALLATION, (DOA).

CAUSE: UNKNOWN.

SOLUTION: RETURNED TO MANUFACTURER.

PROBLEM: **POLE-TOP-UNIT FAILURES**

SYMPTOM: ~ 20% OF POLE-TOP-UNIT CPU BOARDS HAVE FAILED.

CAUSE: FIRMWARE ERROR, COMPONENT SPECIFICATIONS, AND UNKNOWN.

SOLUTION: REPAIR BY MANUFACTURER,

TESTING BY THE MANUFACTURER IN PROGRESS.

PROBLEM: **SMART METER FAILURES**

SYMPTOM: < 4% OF SMART METERS HAVE FAILED.

CAUSE: ELECTRICAL TRANSIENT CONDITIONS, AND MECHANICAL FAILURE.

SOLUTION: UPGRADE BY MANUFACTURER, RETURNED TO MANUFACTURER FOR REPAIR.

INSTRUMENTATION SERVES AN IMPORTANT ROLE IN THE APPLICATION OF AN AUTOMATION SYSTEM

- IT IS THE INTERFACE BETWEEN THE PROCESS AND THE AUTOMATION SYSTEM.

- IT CAN PERFORM USEFUL WORK.

- SHOULD BE ADDRESSED AS A MAJOR SUBSYSTEM IN PROJECT PLANNING.

- PROBLEMS WILL BE ENCOUNTERED, BUT THEY CAN BE MANNAGED AND CORRECTED BY EXPERIENCED PERSONNEL.

RESIDENTIAL APPLIANCE MONITORING

Eva R. Broadaway

Residential appliance monitoring was included in the load control experiment of the Athens Automation and Control Experiment on the advice of the utility advisory group. The purpose of this monitoring was fourfold.

1. To build load models for transfer to utilities;
2. To allow correlation between individual appliance loads and the total household load;
3. To study the relationship of interior temperature and space heater, air conditioner, or heat pump duty cycles; and
4. To provide support in the other experimental areas of system reconfiguration and volt/var control.

The specific appliances chosen for monitoring are water heater, central space heater, central air conditioner, and heat pump. In addition, total household load and interior temperature will be monitored.

A total of 200 residences will have residential appliance monitoring. From one to four of the selected loads will be monitored at each residence. The residences and monitored loads at each are selected from one of four strata identified by Minimax (EPRI contractor) and ORNL researchers based on energy use patterns. Power consumed is determined on 5-min intervals, and the total for each interval is recorded. These data are stored in hardware at the residence and transferred to the ORNL computer, "AACETS," at a predetermined time using the customer's telephone line.

Hardware and software for residential appliance monitoring are supplied by EPRI, with installation by Athens Utilities Board and overall coordination by ORNL.

COORDINATED EFFORT PROVIDES SUCCESSFUL RESIDENTIAL APPLIANCE MONITORING

EVA R. BROADAWAY
INSTRUMENTATION & CONTROLS DIVISION
OAK RIDGE NATIONAL LABORATORY

RESIDENTIAL APPLIANCE MONITORING TOPICS COMPRISE

- MOTIVATION
- PARTICIPANTS
- HARDWARE AND COMPUTER SYSTEMS
- DATA AND ANALYSIS
- CALIBRATION AND TESTING

AACE ADVISORY GROUP IDENTIFIED NEED FOR MORE DETAILED DATA ON RESIDENTIAL APPLIANCES

- BUILD MODELS FOR TRANSFER TO UTILITIES
- ALLOW CORRELATION BETWEEN APPLIANCE LOADS AND TOTAL HOUSEHOLD LOAD
- STUDY RELATIONSHIP OF INTERIOR TEMPERATURE AND SPACE HEAT OR AIR CONDITIONING DUTY CYCLES
- PROVIDE SUPPORT IN SYSTEM RECONFIGURATION AND VOLT / VAR EXPERIMENTS

ORGANIZATIONS COOPERATING IN THIS EFFORT ARE

- ATHENS UTILITIES BOARD (AUB)
- ELECTRIC POWER RESEARCH INSTITUTE (EPRI)
- OAK RIDGE NATIONAL LABORATORY (ORNL)
- MINIMAX RESEARCH CORPORATION
- ROBINTON PRODUCTS, INC. (MANUFACTURER)

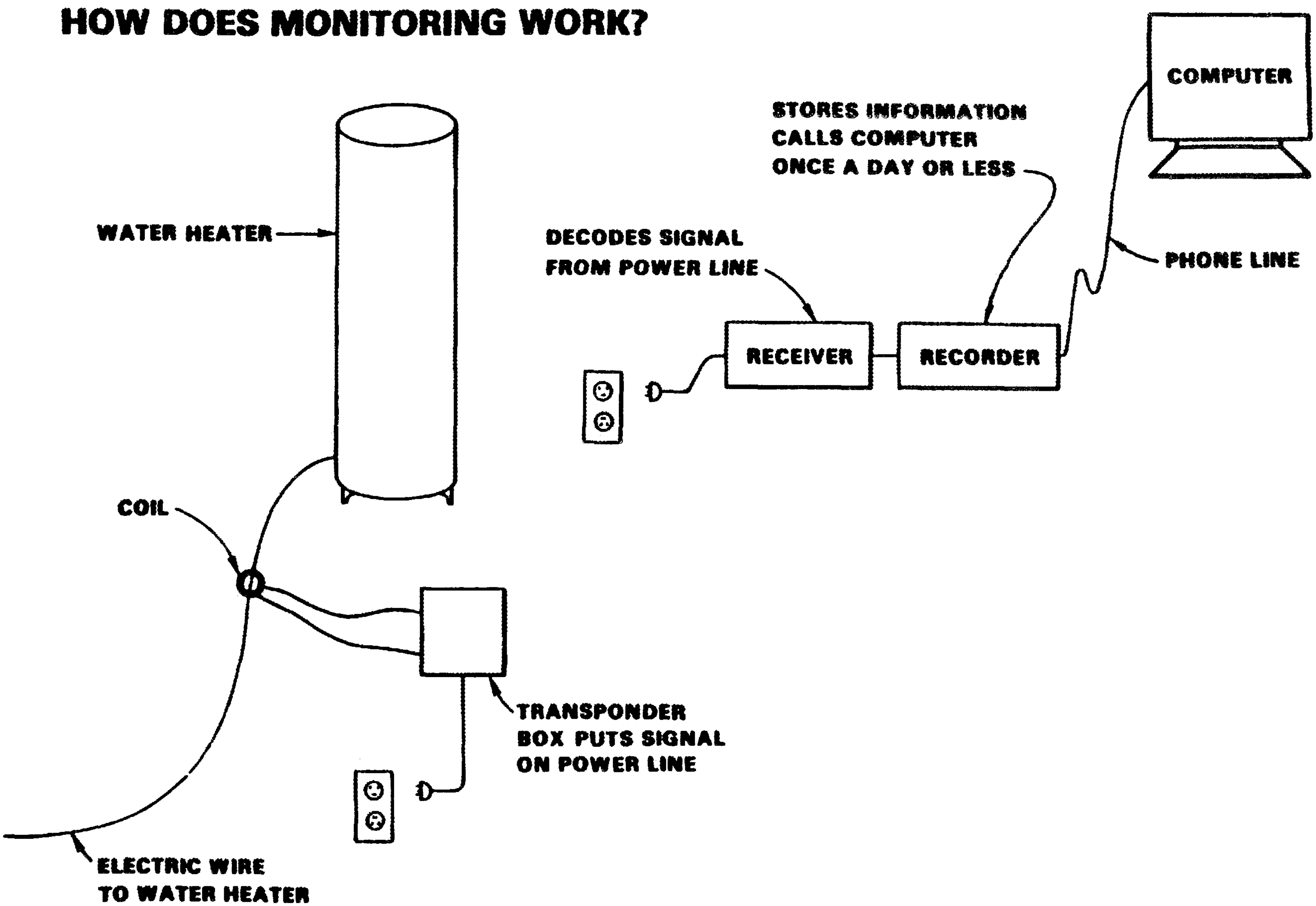
ELECTRIC ARMs ON 200 HOMES WILL MONITOR

- WATER HEATER
- HEAT PUMP
- SPACE HEATING
- AIR CONDITIONER
- TOTAL HOUSEHOLD LOAD
- INTERIOR TEMPERATURE

UTILITIES NEED TO CONSIDER THESE FACTORS WHEN INSTALLING RESIDENTIAL APPLIANCE MONITORING

- MINIMAL ADDITIONAL WIRING AT CUSTOMER SITE
- LOW COST COMMUNICATION MEDIUM
- LITTLE IMPACT ON CUSTOMER
- MINIMAL DAY-TO-DAY OPERATOR INTERACTION
- DATA TRANSFER MEDIA COMPATIBLE WITH COMPUTER SYSTEM USED FOR ANALYSIS

ORNL DWG 84-1


HOW DOES MONITORING WORK?
COMPUTER
STORES INFORMATION
CALLS COMPUTER
ONCE A DAY OR LESS
WATER HEATER
DECODES SIGNAL
FROM POWER LINE
PHONE LINE
RECEIVER
RECORDER
COIL
TRANSPONDER
BOX PUTS SIGNAL
ON POWER LINE
ELECTRIC WIRE
TO WATER HEATER

MAJOR COMPONENTS OF ELECTRIC APPLIANCE RESEARCH METER (ARM) HARDWARE ARE

- CURRENT TRANSDUCERS
- METER / TRANSPONDERS
- RECEIVER / RECORDER

ALSO REQUIRED IS

- RJ31X TELEPHONE JACK

INSTALLATION OF HARDWARE IS PERFORMED BY AUB

- IDENTIFYING RESIDENCES FOR INSTALLATION
- SCHEDULING WITH CUSTOMER
- REQUIRES ABOUT 1 PERSON DAY PER RESIDENCE
- REQUIRES COORDINATION WITH TELEPHONE COMPANY
- MUST BE COORDINATED WITH INFORMATION ENTRY IN COMPUTER SYSTEM

RESIDENTIAL APPLIANCE DATA IS ACQUIRED ON ORNL COMPUTER, "AACETS"

- APPLIANCE DATA ACQUISITION PROGRAMS OPERATE AT NIGHT
- DATA IS LOCALLY SAMPLED ON 5 MINUTE INTERVAL AND STORED FOR 35 DAYS
- DATA RETRIEVAL TAKES 8-10 MINUTES PER RESIDENCE
- ALLOWS OTHER USE OF COMPUTER DURING DAY
- PROVIDES MAGNETIC TAPE GENERATION FOR DATA TRANSFER TO ANALYSIS COMPUTER

CALIBRATION AND TESTING ARE IMPORTANT

PROCEDURES IMPLEMENTED INCLUDE

- CALIBRATION OF ALL METER / TRANSPONDERS BY MANUFACTURER -- VERIFICATION OF ACCURACY WITH RANDOM SUBSET OF UNITS AT ORNL
- FACTORY AND FIELD ACCEPTANCE TESTS OF HARDWARE AND SOFTWARE SYSTEMS
- PRE-INSTALLATION TESTING OF RECEIVER/ RECORDERS TO VERIFY FUNCTIONALITY

ACCEPTANCE TESTS ARE NECESSARY TO ENSURE PROPER PERFORMANCE

- HARDWARE SYSTEM FUNCTIONALITY
- SOFTWARE SYSTEM FUNCTIONALITY
- COMBINED HARDWARE AND SOFTWARE SYSTEMS FUNCTIONALITY

FOUR PROBLEMS HAVE BEEN IDENTIFIED

- PROBLEM: CALL-IN CAPABILITY NOT AVAILABLE
  SOLUTION: EXCHANGE PROM CHIP AND UPDATE COMPUTER PROGRAMS
- PROBLEM: RELEASE OF CUSTOMER TELEPHONE LINE
  SOLUTION: INSTALL DETECTOR / INTERRUPTER BOARD
- PROBLEM: ANSWERED TELEPHONE AFTER 12 RINGS (CUMULATIVE)
  SOLUTION: MODIFY PROGRAM IN FIRMWARE
- PROBLEM: ELECTRIC ARM HARDWARE FAILURES
  SOLUTION: UNDER INVESTIGATION BY MANUFACTURER

AUB, EPRI, MINIMAX, ORNL, AND MANUFACTURERS COORDINATION PROVIDES SUCCESSFUL RESIDENTIAL APPLIANCE MONITORING

- CONSIDERED UTILITY NEEDS
- ESTABLISHED ADEQUATE LEVELS OF CALIBRATION AND TESTING
- RESULTED IN A SYSTEM WHICH ACQUIRES DATA WITH LITTLE DAY-TO-DAY PERSONNEL INTERACTION

EQUIPMENT INSTALLATION

N. D. Fortson
L. D. Monteen

Distribution system interface equipment includes two types of intelligence on the distribution system:

1. Fifty-one pole top units (PTU)
   - (a) Report by exception on an extension-type phone arrangement;
   - (b) As developed, they became pole bottom units (name is a misnomer);
   - (c) Each unit on same line has a time delay built in so as to reduce the chance of a communications collison with another PTU;
   - (d) If they do coincide, each will retry at 5-min intervals until call is completed;
   - (e) Can be made to call in by "Demand Scan;"
   - (f) Report analog values back in volts, watts, and vars. All other values are calculated; and
   - (g) Can monitor 12 analog points, 12 status points, and have 1 latching and 2 momentary relays.
2. Distribution remote terminal unit (DRTU)
   - (a) Functions the same as PTU, except can control and monitor line regulators;
   - (b) Has 4-wire phone with no time delay;
   - (c) Has more expanded capacity than PTU.

When it was possible, all interface equipment (the mounting brackets, holes to be punched, transducers, arrestors, any pre-wiring, fuse blocks, etc.) was mounted on the ground to save time and for ease of installation.

1. Eleven power reclosers
   - (a) Directly controlled through a set of relays;
   - (b) "A" switch (reclosing relay);
   - (c) "G" switch;
   - (d) Open, close;
   - (e) Three-phase monitoring and operated recloser. Installed cost = $3,800.00—82 man hours.
2. Thirty-six motor operated device (MOD) switches
   - (a) Directly controlled through a set of relays;
   - (b) All battery backed up;
   - (c) Motor operated switch only point cost $6,500.00—51 man hours.

3. Fifteen var controllers
   (a) Activated by vars;
   (b) High and low voltage override;
   (c) Neutral current relay will cut out bank due to imbalance.
4. Seventeen distribution control receivers (DCRs)
   (a) Operate cap bank;
   (b) 1 latching, 2 momentary;
   (c) Power line carrier (PLC);
   (d) Also PTU can override—monitoring, manual, or auto;
   (e) Problem with motor-operated oil switches, needed solenoid-operated due to momentary relay in DCR;
   (f) For DCR/VAR installation on 1200 KVAR cap bank including capacitors. Installed cost = $4,600—43 man hours.
5. Current Transformer/Potential Transformer (CT/PT)—18 3-phase, 26 1-phase points
   (a) Pre-assembled on ground;
   (b) Saved a lot of time by doing this, plus a lot of work.
6. Fault sensors
   (a) Also pre-assembled;
   (b) Replaces existing arm;
   (c) Built-in CT converts 60A on primary to 1 VDC;
   (d) Current over 600A will give an alarm output;
   (e) Imbalance problem.

The effort to install this equipment with the work force available in Athens and within the established time frame was a challenge, to say the least. The attitudes of some of the people were negative in the beginning, as with anything new. But as things progressed and the operating and engineering advantages were seen, these negative views changed to positive outlooks. By keeping people informed, asking for input, and complimenting people for work well done, most anything can be accomplished.

EXPERIMENTAL DATA
AND
DATA MANAGEMENT

EXPERIMENTAL DATA AND DATA MANAGEMENT

Patricia S. Hu

The objectives of this presentation are to describe the Athens Automaton and Control Experiment's data bases and the management of these data.

Five major categories of data are being maintained: (1) IDCS (Integrated Distribution Control System) data which monitor the distribution RTUs (Remote Terminal Unit), single- and three-phase PTUs (Pole Top Unit), feeder loads, and total household loads; (2) household appliance-specific data; (3) household audit data; (4) pre-experiment substation loads; and (5) historical data on substation loads and weather.

The data processing procedures for this experiment present a major challenge for the following reasons: (1) the tremendous volume of data that is collected on a daily basis, (2) the need to reduce the repetitious programming tasks for the processing of the data, and (3) the data structure requirements for subsequent data analyses. Computer utility programs were developed to back up the raw data in the event of a possible computer system crash, to create SAS (Statistical Analysis System) files, to condense data volume, and to reorganize the data structure for subsequent data analysis. All of these utility programs were automated to reduce repetitious programming tasks.

There are approximately 20 data sets being maintained, and more than 10 megabytes of data being collected on a daily basis. The automated data processing procedures allow one to meet the challenges mentioned above and to devote resources to data interpretation and analysis.

EXPERIMENTAL DATA AND DATA MANAGEMENT

Patricia S. Hu
William R. Nelson
Oak Ridge National Laboratory

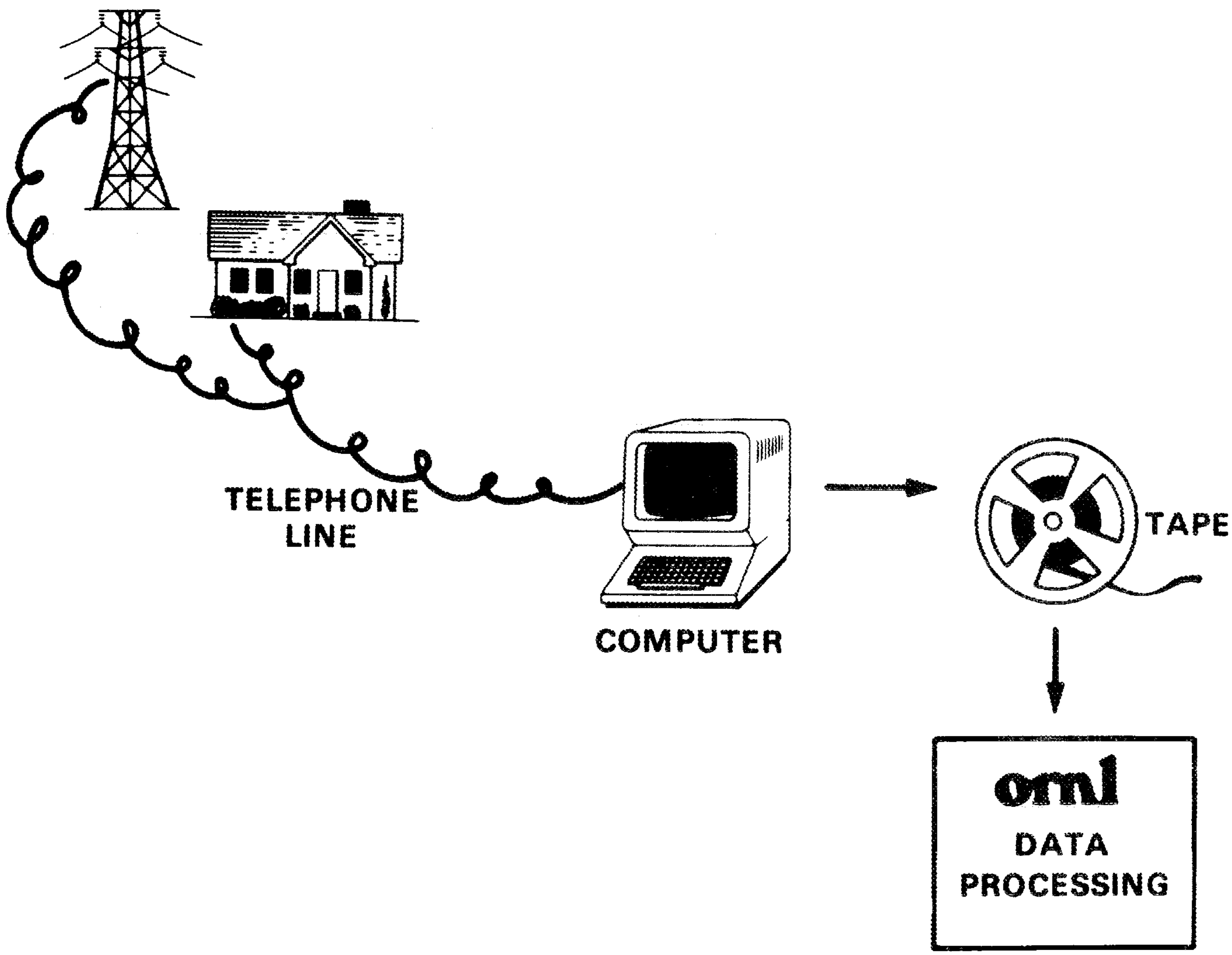
Athens Automation and Control Experiment Review Meeting
December 3, 1985
Knoxville, Tennessee

ATHENS AUTOMATION AND CONTROL EXPERIMENT PROVIDES A MAJOR DATA PROCESSING CHALLENGE

- DATA PROCESSING LOGISTICS
- DESCRIPTION OF DATA
- EFFICIENCY OF DATA PROCESSING

ORNL-DWG 85-18272

DATA FLOW CHART

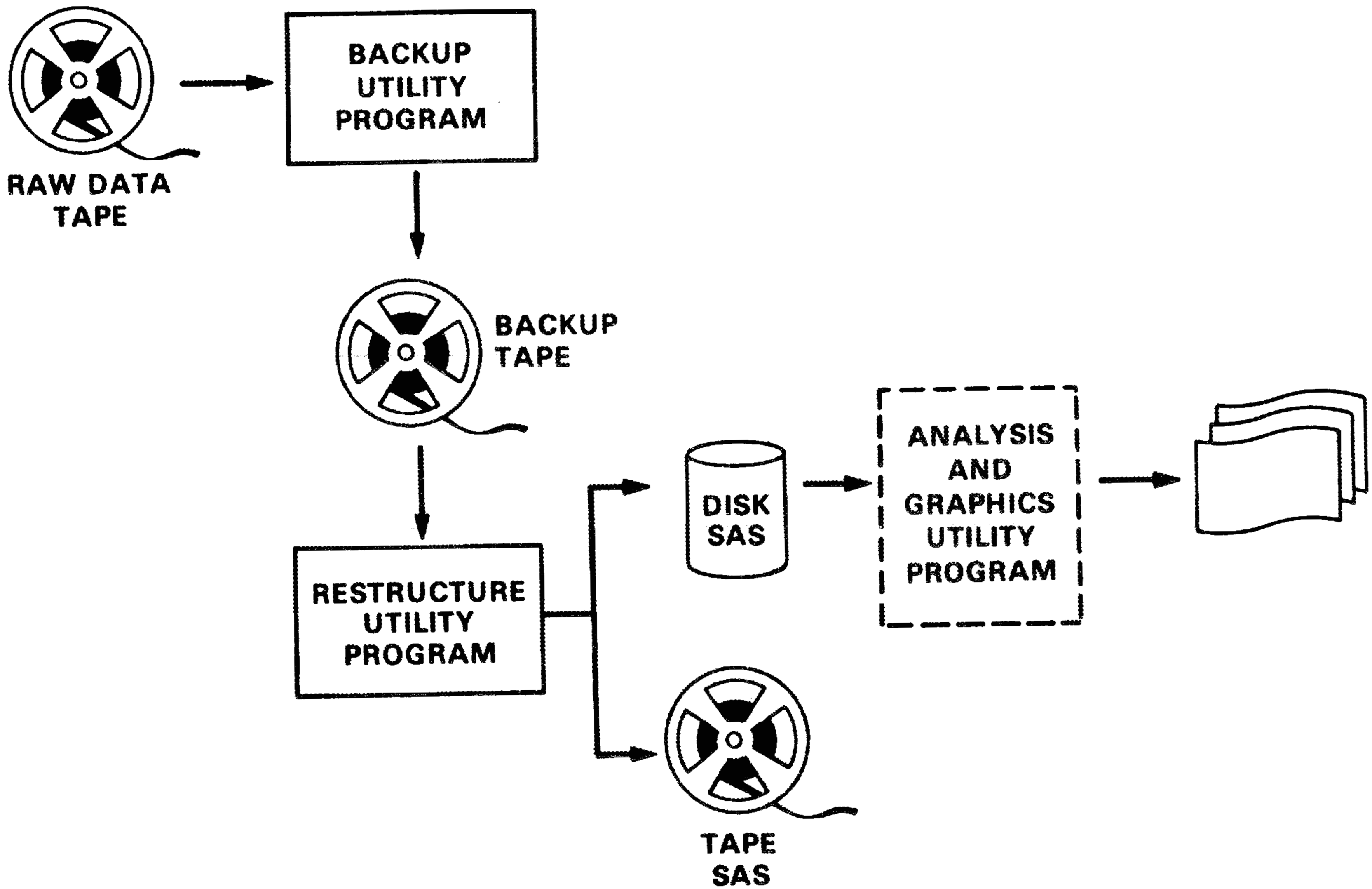


THERE ARE IMPORTANT REASONS FOR PROCESSING THE DATA

- BACKUP DATA FOR POSSIBLE SYSTEM CRASH
- REORGANIZE DATA STRUCTURE TO CONDENSE DATA
- ESTABLISH GROUNDWORK FOR
  FUTURE DATA ANALYSIS AND EXPERIMENTS

ORNL-DWG 85-18273

DATA PROCESSING LOGISTICS



DATA SETS PROVIDE COMPREHENSIVE INFORMATION ON INDIVIDUAL HOUSEHOLDS, LOAD CHARACTERISTICS AND WEATHER

- IDCS DATA
- APPLIANCE LOAD DATA
- AUDIT DATA
- PRE-EXPERIMENT SUBSTATION LOAD AND WEATHER, AND
- HISTORICAL DATA

IDCS DATA

- SUBSTATION LOAD DATA
- FEEDER DATA
  . SINGLE-PHASE PTU
  . THREE-PHASE PTU
  . DISTRIBUTION RTU
- HOUSEHOLD LOAD DATA

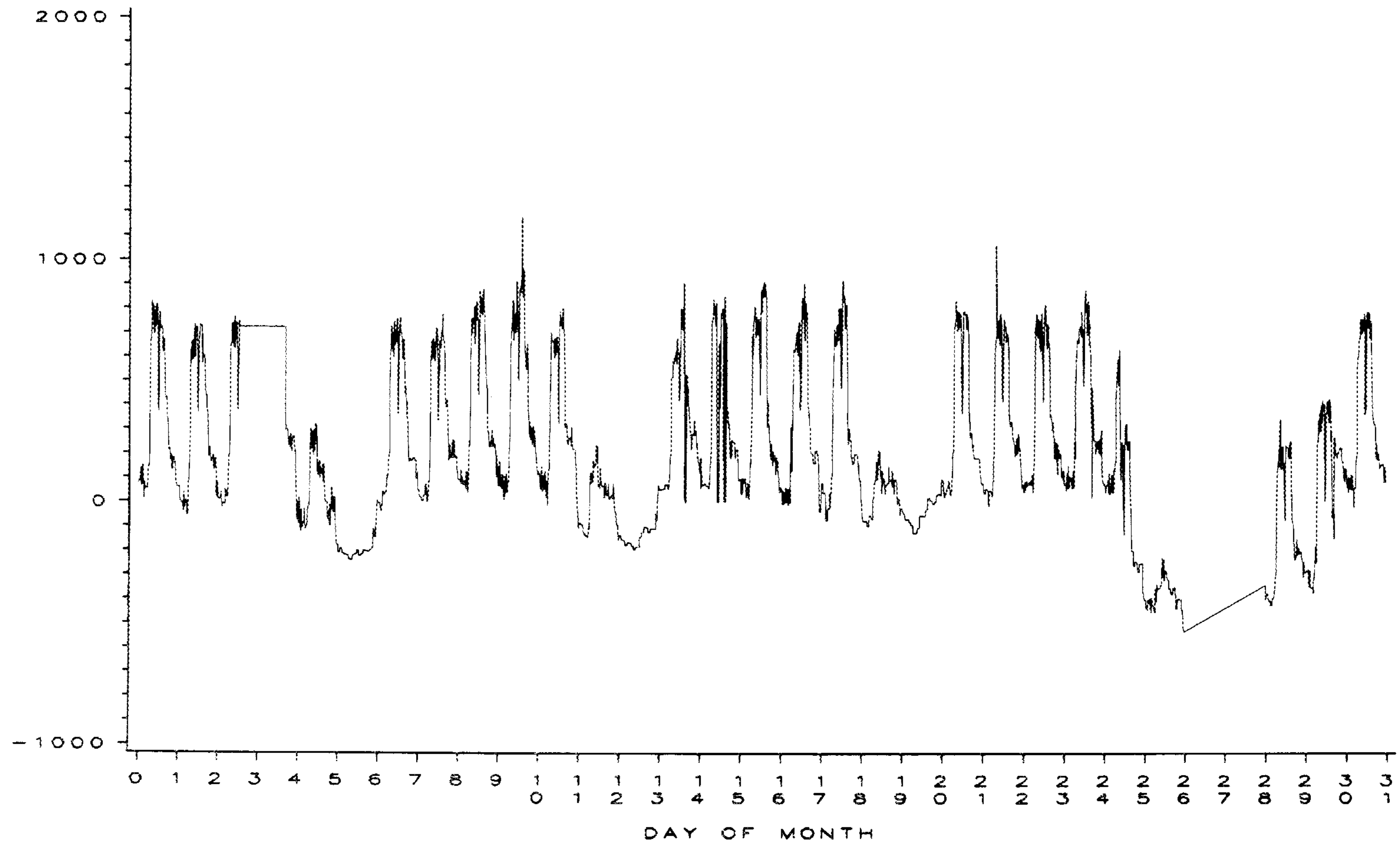
SUBSTATION LOAD AND WEATHER DATA

- INCLUDE TOTAL OF 12 FEEDERS
- COLLECT REAL AND REACTIVE POWER, VOLTAGE, AND OTHER VARIABLES ON A 15-MINUTE INTERVAL
- ALSO INCLUDE WEATHER DATA FROM EACH OF 3 SUBSTATIONS
- COVER THE PERIOD OF JULY 1985 - PRESENT

SUBSTATION DATA

MONTH OF OCTOBER, 1985

SUBSTATN=NORTH ATHENS BREAKER=224 PHASE=A



REACTIVE POWER IN KVAR

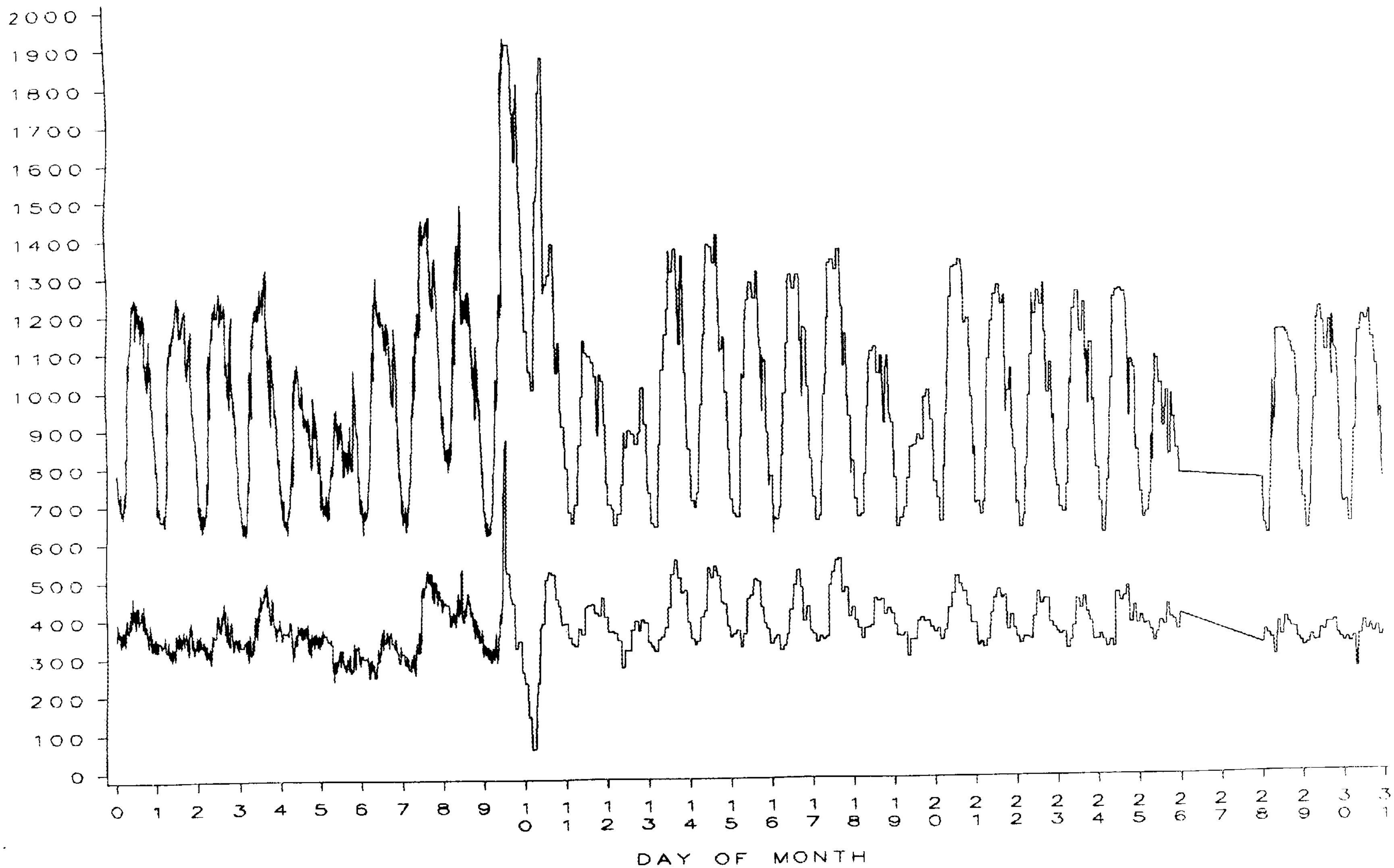
SINGLE-PHASE PTU DATA

- INCLUDE 28 SINGLE-PHASE POLE-TOP UNITS
- COLLECT REAL AND REACTIVE POWER, AND VOLTAGE DATA ON A 15-MINUTE INTERVAL
- COVER THE PERIOD OF JULY 1985 - PRESENT

1-PHASE PTU DATA

MONTH OF OCTOBER, 1985

POLE TOP UNIT=1



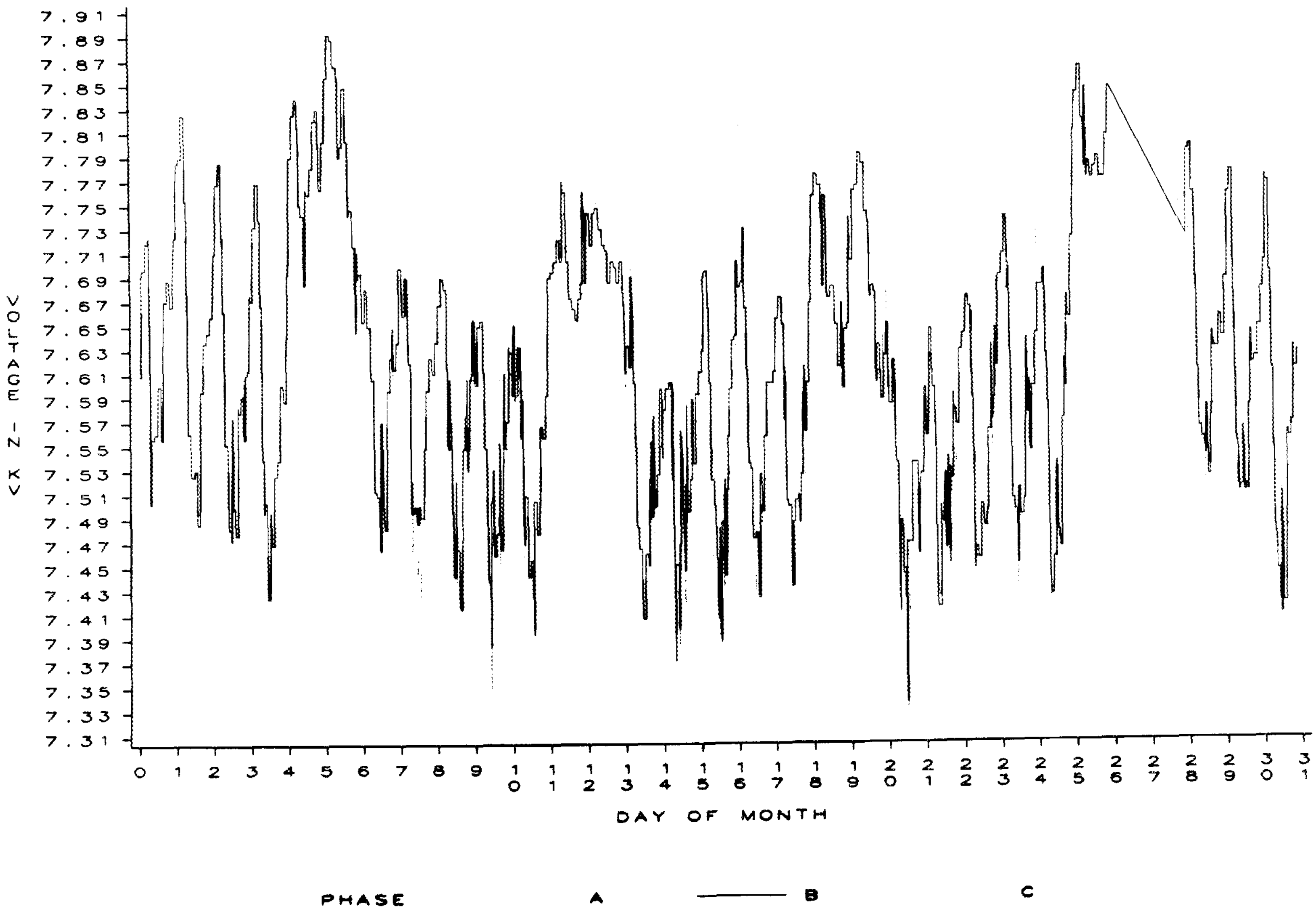
THREE-PHASE PTU DATA

- INCLUDE 10 THREE-PHASE POLE-TOP UNITS
- COLLECT REAL AND REACTIVE POWER, AND VOLTAGE DATA ON A 15-MINUTE INTERVAL
- COVER THE PERIOD OF JULY 1985 - PRESENT

3-PHASE PTU DATA

MONTH OF OCTOBER, 1985

POLE TOP UNIT ID=1



HOUSEHOLD LOAD DATA

- COLLECTED BY SMART METERS
- COVER 200 HOUSEHOLDS
- MONITOR TOTAL HOUSEHOLD LOAD ON A 15-MINUTE INTERVAL
- COVER THE PERIODS OF SUMMER AND FALL 1984, AND JULY 1985 - PRESENT

APPLIANCE LOAD DATA

- PROVIDE APPLIANCE-SPECIFIC INFORMATION FOR LOAD CONTROL EXPERIMENT
- COLLECTED BY ELECTRIC ARM'S
- COVER 200 HOUSEHOLDS
- COLLECT INFORMATION ON
  HEAT PUMP, SPACE HEATER,
  WATER HEATER, AIR CONDITIONING
  INTERIOR TEMPERATURE, AND
  TOTAL HOUSEHOLD LOAD
- COVER THE PERIOD OF JULY 1985 - PRESENT

AUDIT DATA GIVE INFORMATION ON HOUSEHOLDS

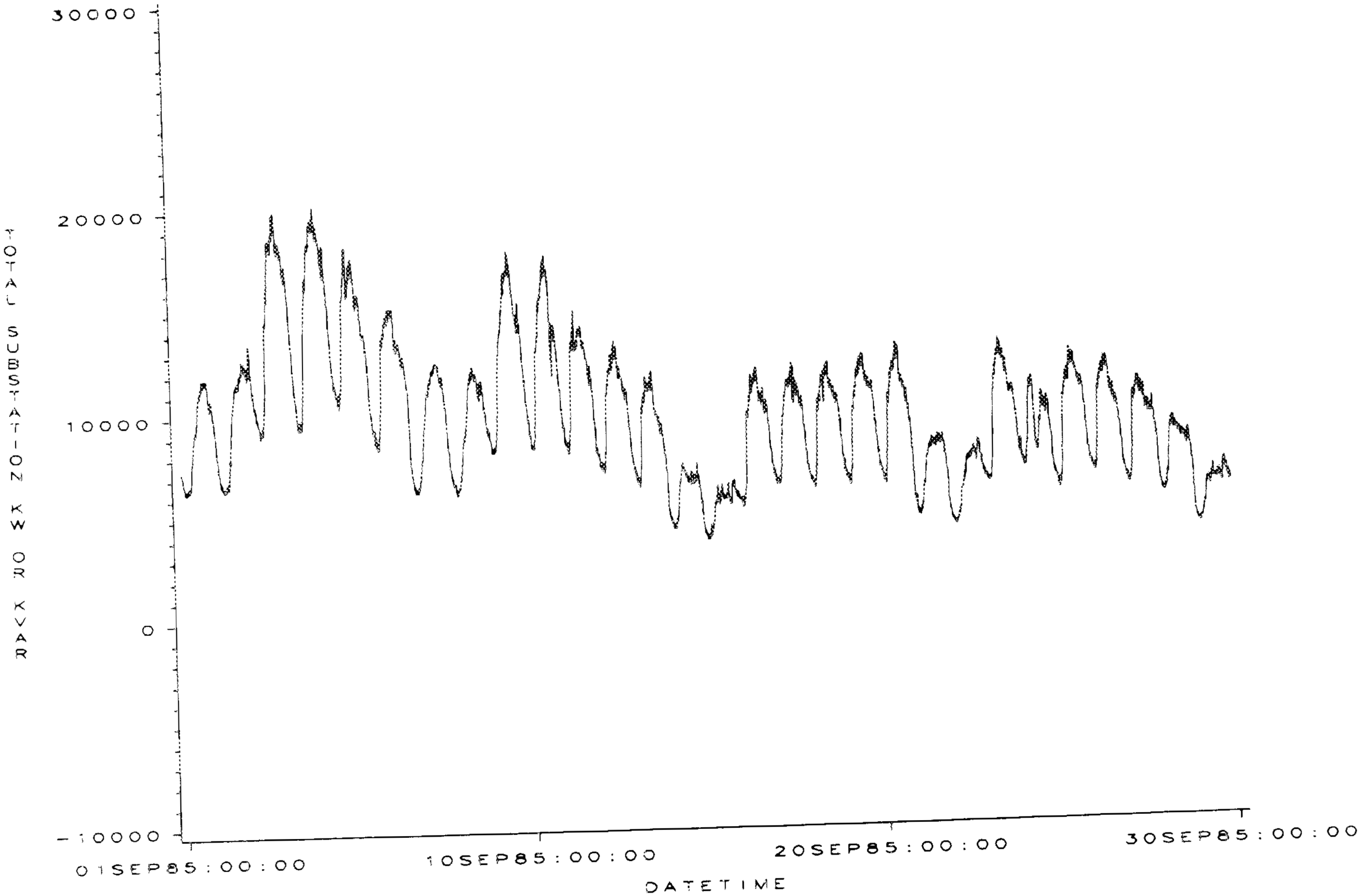
- WILL COVER 2,000 PARTICIPATING HOUSEHOLDS
- INCLUDE
  - . HOUSEHOLD ENERGY AUDIT
  - . HOUSEHOLD APPLIANCE AUDIT
  - . HOUSEHOLD DEMOGRAPHIC INFORMATION
- IMPORTANT INFORMATION FOR STUDYING LOAD CONTROL AND HOUSEHOLD BEHAVIOR

PRE-EXPERIMENT SUBSTATION LOAD AND WEATHER DATA

- USED FOR VOLT/VAR CONTROL AND SYSTEM RECONFIGURATION EXPERIMENTS
- INCLUDE SUBSTATIONS IN SOUTH ATHENS, NORTH ATHENS, AND ENGLEWOOD
- COLLECT REAL AND REACTIVE POWER, AND VOLTAGE DATA FROM 12 FEEDERS ON A 10-MINUTE INTERVAL
- INCLUDE WEATHER INFORMATION ON A 10-MINUTE INTERVAL
- COVER THE PERIOD OF NOVEMBER 1984 - PRESENT, FOR SOUTH ATHENS SUBSTATION

PRE-EXPERIMENT SUBSTATION DATA

SOUTH ATHENS – SEPTEMBER 1985



WHITE – REAL POWER
– REACTIVE POWER

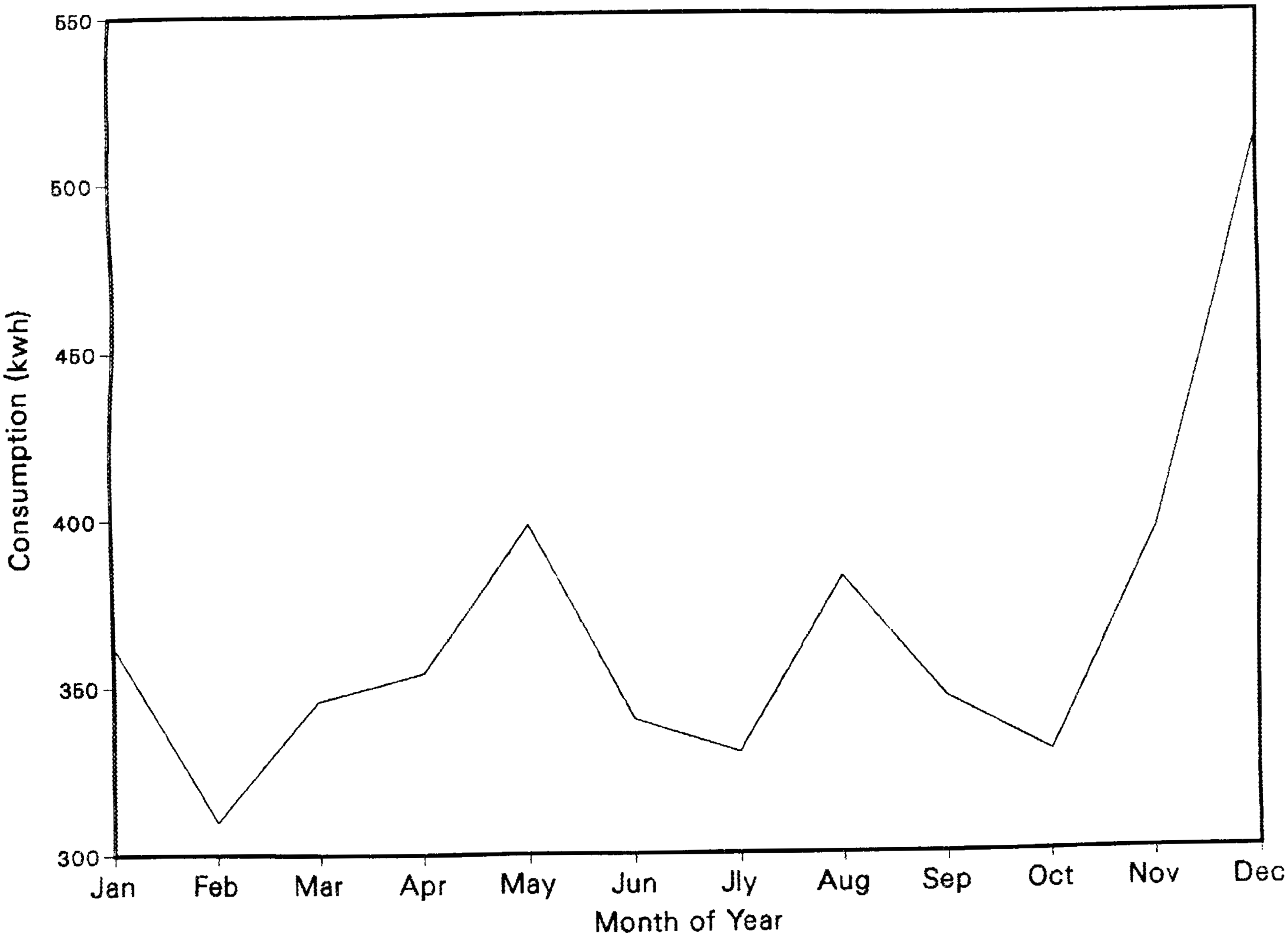
HISTORICAL DATA ALLOW PRE-EXPERIMENT FAMILIARITY

- BILLING DATA
- SUBSTATION LOAD DATA
- WEATHER DATA

HISTORICAL BILLING DATA ALLOW CLASSIFICATION OF ELECTRICITY USERS

- MONTHLY BILLING INFORMATION ON APPROXIMATELY 16,000 ACCOUNTS
- INCLUDED MONTHLY ELECTRICITY DEMAND AND COST
- COVERED THE PERIOD BETWEEN MARCH 1982-JUNE 1984

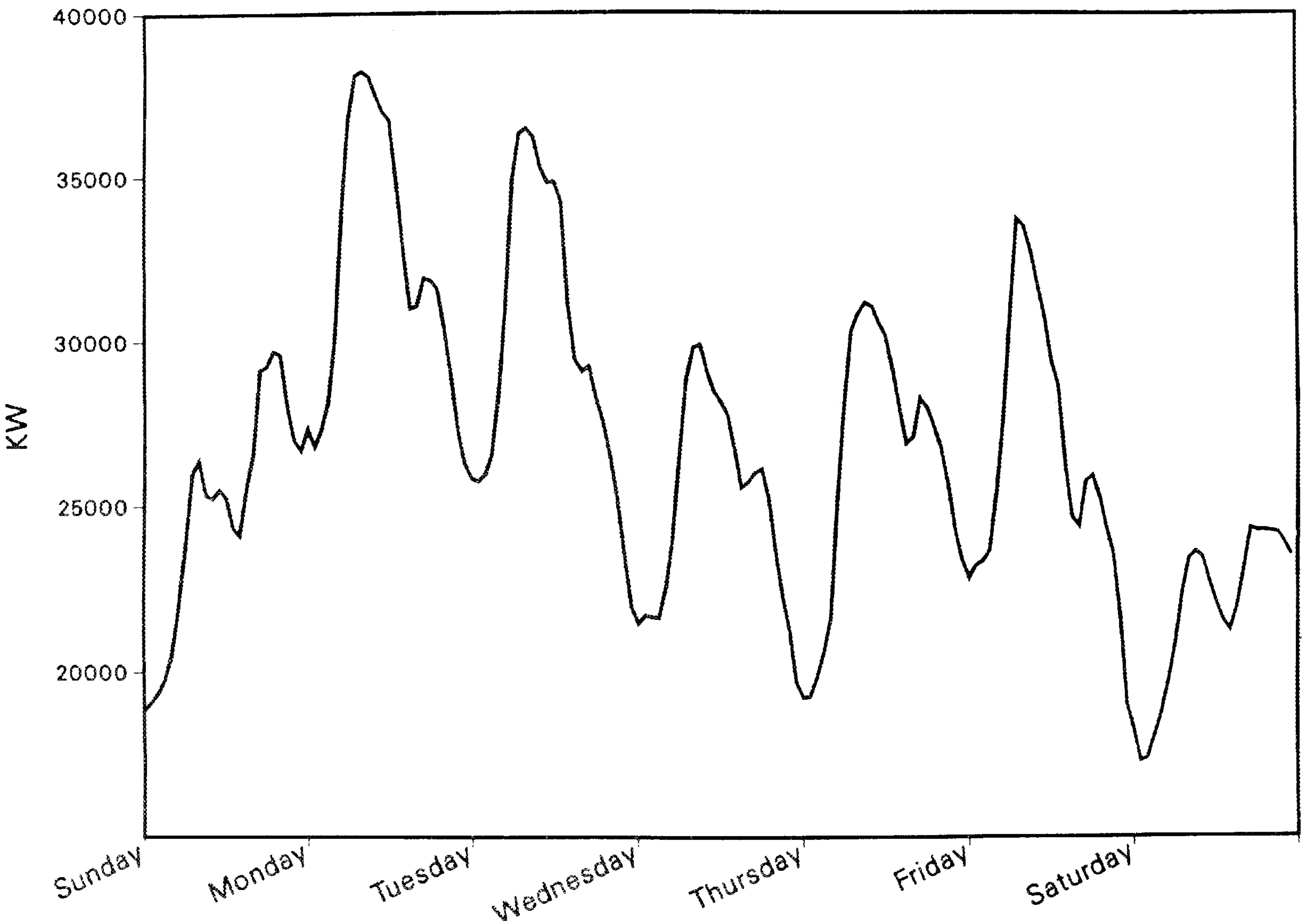
HISTORICAL BILLING DATA
ACCOUNT NO. 42640000
1983



HISTORICAL SUBSTATION LOAD DATA

- HOURLY DATA COLLECTED BY TVA
- COVERED THE PERIOD BETWEEN JUNE 1980 AND NOVEMBER 1983
- INCLUDED 3 OF THE ATHENS SUBSTATIONS

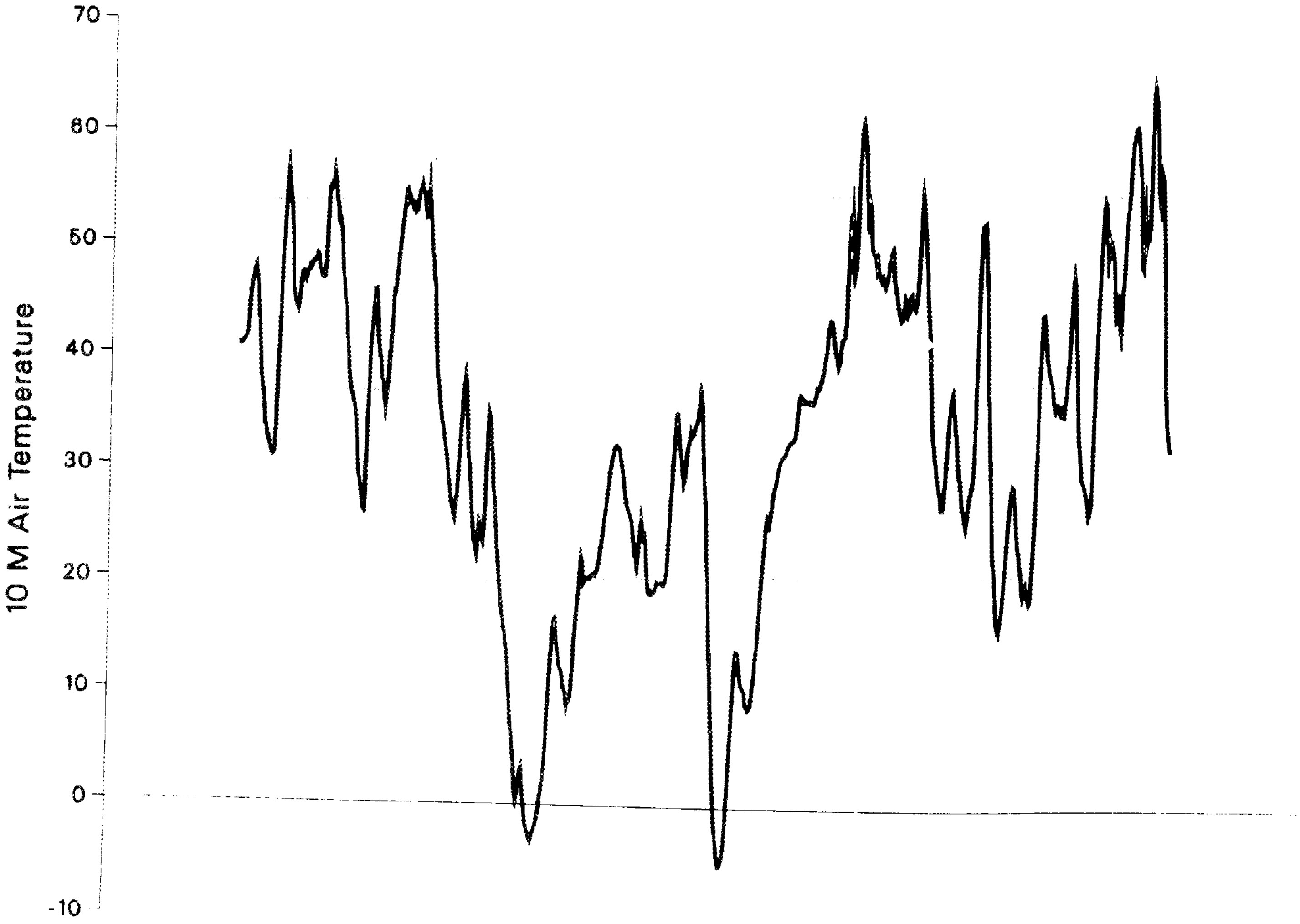
ACTUAL SUBSTATION LOADS
North Athens
January 10 - 16, 1982



HISTORICAL WEATHER DATA

- COLLECTED BY TVA AT WATTS BAR AREA
- COVERED THE PERIOD BETWEEN JANUARY 1980 AND MARCH 1984
- INCLUDED HOURLY WEATHER VARIABLES, SUCH AS AIR TEMPERATURE, WIND DIRECTION AND SPEED, DEW POINT, SOLAR RADIATION AND RAINFALL

HOURLY AIR TEMPERATURE
Watts Bar Area
January 1982



ORNL DATA PROCESSING PROCEDURES INCREASE EFFICIENCY

- LARGE VOLUME OF DATA IS CONDENSED
- PROCEDURES ARE AUTOMATED

DATA VOLUME IS CONDENSED ABOUT ONE-HUNDRED FOLD

- APPROXIMATELY 10 MEGABYTES OF DATA COLLECTED ON A DAILY BASIS
  - A HALF BOX OF COMPUTER OUTPUT PER DAY
- NO INFORMATION IS LOST
- DATA STRUCTURE IS CHANGED TO SUIT SUBSEQUENT ANALYSIS

AUTOMATION OF DATA PROCESSING PROCEDURES IS A HEAVY-FRONT PROGRAMMING EFFORT

- PROVIDES SKELETON SOFTWARE FOR BUILDING FILES
- STRINGS TOGETHER MANY INDIVIDUAL DATA PROCESSING STEPS
- AVOIDS REPETITIOUS PROGRAMMING
- USES STATISTICAL ANALYSIS SYSTEM - SAS, A POPULAR AND POWERFUL SOFTWARE SYSTEM
- SAS FACILITATES TRANSFER OF DATA TO OTHER USERS

ATHENS AUTOMATION AND CONTROL EXPERIMENT PROVIDES A MAJOR DATA PROCESSING CHALLENGE

- DATA PROCESSING LOGISTICS
- DESCRIPTION OF DATA
- EFFICIENT DATA MANAGEMENT
  - . AUTOMATED PROCESSING PROCEDURES
  - . CONDENSED DATA VOLUME
  - . DATA ANALYSIS GROUNDWORK

LOAD CONTROL

LOAD CONTROL

John H. Reed

This talk describes the objectives, the hardware, the structure of the experiments, and some preliminary data from the load control portion of the Athens Automation and Control Experiment.

The objectives include: (1) characterization and modeling for operations and for building an impact assessment model that is transferable to other utilities; (2) the evaluation of alternative control stategies; (3) the evaluation and identification of customer comfort constraints; (4) the evaluation of customer acceptance; and (5) evaluation of instrumentation requirements.

One to three residential appliances chosen from among water heaters, central air-conditioners, central electric heating units, or heat pumps will be independently controlled in 2000 customer homes. Energy use will be monitored at the appliance level in 200 homes, at the household level in approximately 350 homes, at 51 locations on the feeders, and at each of the feeder service points at the substation. In addition, information about appliances, characteristics of the thermal envelope, end customer lifestyle and demographics are being gathered for each household having a load control receiver. Weather information and some indoor temperature data are also being collected.

The design of the experiments is based on a model of residential electric load. Weather, human behavior, the thermal characteristics of buildings, and appliances combine to explain electric load. External control of appliances will alter load shapes and may result in changes to human behavior.

Five sets of experiments have been designed. There is one set of experiments for water heating, air-conditioning, and heating loads and additional experiments and analyses to evaluate customer acceptance, instrumentation needs, and reliability.

For each appliance, the conditions under which control actions are to be evaluated, the time of day at which control action is taken, the length of the control period, and the amount of time during the control period when the appliance is off have been systematically varied to provide comprehensive data. For example, one slide shows the summer load profile for the Athens system, the diversified demand for air-conditioning as estimated by TVA, and the control period noon to 10 p.m. The control period has been chosen to maximize load relief during peak load conditions. A second slide shows the temperature-day types and the various proportions of "off-time" per half hour that are of interest. For each proportion, the number of required customer days of control (i.e., the number of days households with monitoring will have to be sampled) have been calculated in order to obtain statistically significant results.

The Athens customer base has been divided into (1) those customers having very high summer and winter use, (2) those having high summer and high winter use, (3) those having high winter use, (4) those having high summer use, and (5) the remaining customers who have moderate to low usage the entire year. Customers who are to have appliance monitoring and/or whole household monitoring are being randomly recruited equally from the first four groups (50 to the group), if they have selected appliances. Customers who are to have whole household monitoring are being recruited equally from all five groups. Customers with load control devices are being selected from the first four groups.

The recruitment procedure is based on personal marketing and differs significantly from the incentive-based approaches used by many utilities. Based on the results of 344 customer contacts during the early phases of recruiting customers to be monitored and controlled, approximately 75%

of the customers contacted during this period agreed to participate. However, only half that number actually had the required appliances to make them eligible for installations in their home. Just 12 percent of those approached refused to participate. The remainder were excluded for a variety of reasons, such as health or the likelihood that they would move. This method has proven extremely effective especially when compared to typical industry practices which often result in low acceptance rates.

Several of the slides show preliminary results from early tests of the monitoring and control systems. There are several slides depicting the differences in water heating by day of the week. The demand during a one-hour water heater control action at 7:34 a.m. on November 5, 1985, is compared with the average kWh/hr (diversified demand, i.e., average kW) water heater usage for Tuesdays in October. This comparison was based on the monitoring for approximately 20 residential customers. The water heater curve for a typical Tuesday in October is bimodal with a major mode between 7:00 and 8:00 a.m. and a minor mode at approximately 8:00 p.m. A comparison of the two curves shows that the average comsumption was reduced by approximately 0.75 kWh/hr and that a new major mode of approximately 1.25 kWh/hr was produced upon release of the appliances from control.

These results are based on small samples and thus are not generalizable. However, when additional samples are taken and results are related to customer demographics, appliance holding, weather, and housing characteristics, it should be possible to build an impact model that other utilities can use to evaluate the impact of load control programs. Other analyses will focus on the level of metering required to understand the impacts of control, the willingness of customers to be controlled, and the retention of customers in the program.

To date, the Athens project has (1) developed methods for screening customers for participation based on billing data, (2) developed sampling techniques for identifying monitored customers, (3) implemented a practical method for achieving high rates of customer participation in the program, and (4) carried out control actions that demonstrate that appliances can be controlled and that the data from the control actions can be evaluated at the appliance level.

THE LOAD CONTROL EXPERIMENTS

ATHENS AUTOMATION AND CONTROL EXPERIMENT

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PRESENTATION TO

THE AACE ADVISORY COMMITTEE

KNOXVILLE, TENNESSEE
DECEMBER 3-5, 1985

THE PRESENTERS

JOHN H. REED
ORNL

STEVEN BRAITHWAIT
EPRI

BRIAN NEWTON
MINIMAX RESEARCH CORPORATION

PERSONS CONTRIBUTING TO THE ORNL EFFORT

JOHN H. REED
EVA BROADAWAY
PAT HU
WILLIAM NELSON
RANDALL WORTHINGTON
JULIE MCINTYRE
J. DOUGLAS BIRDWELL
JALEL ZRIDA
FRANK CHOW
NEAL THOMAS

PERSONS CONTRIBUTING TO THE MINIMAX EFFORT

BRIAN NEWTON
VICKI CLINE
GRACE JOHNS
TOM JOHNSTON
BRUCE SMITH
LOUISE WEILER

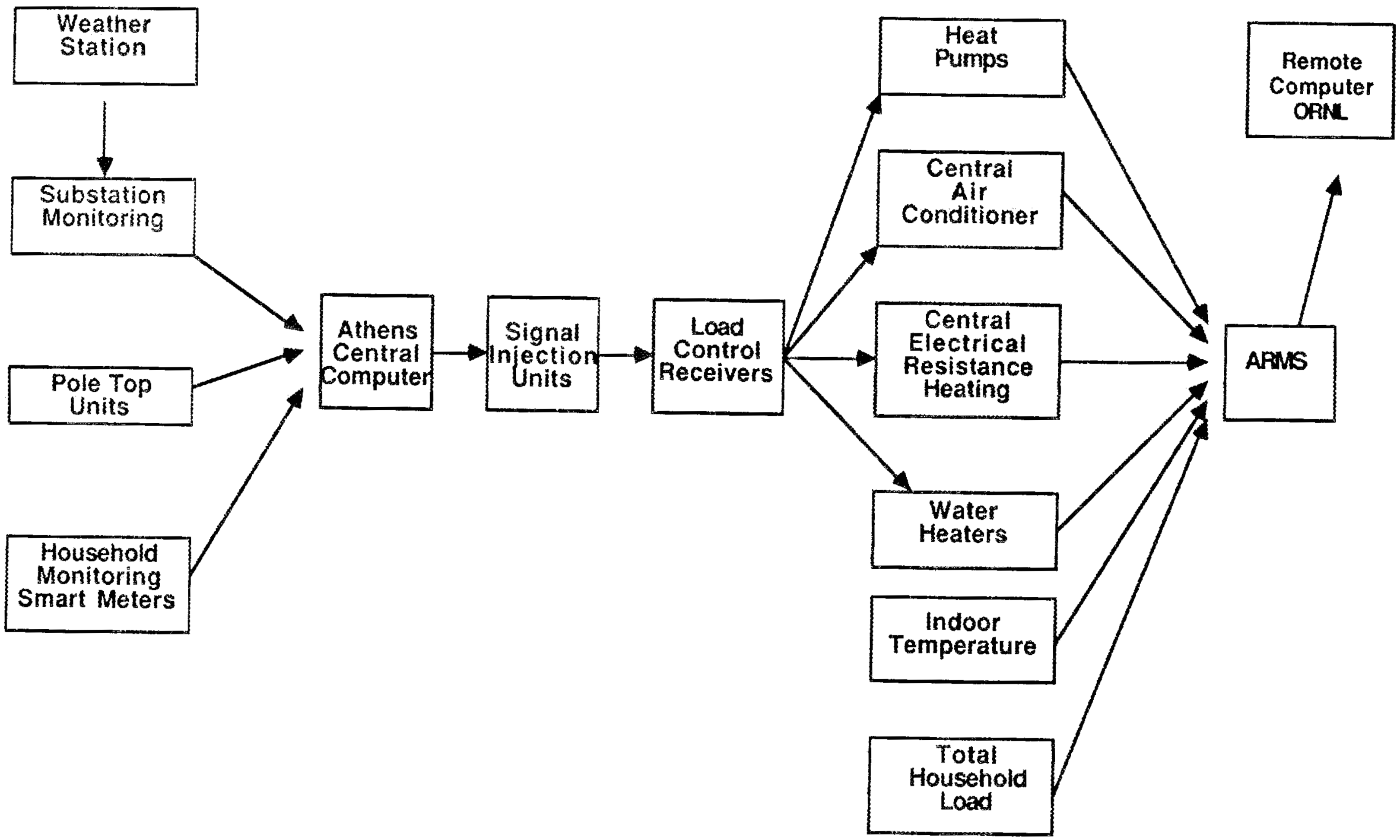
OVERVIEW OF THE PRESENTATION

- o OBJECTIVES
- o THE BASIC STRUCTURE OF THE EXPERIMENTS
- o EPRI'S OBJECTIVES
- o THE DUTY CYCLE MODEL
- o SOME PRELIMINARY EXPERIMENTAL DATA
- o CUSTOMER SELECTION
- o THE OPERATIONAL MODEL
- o CONCLUSIONS

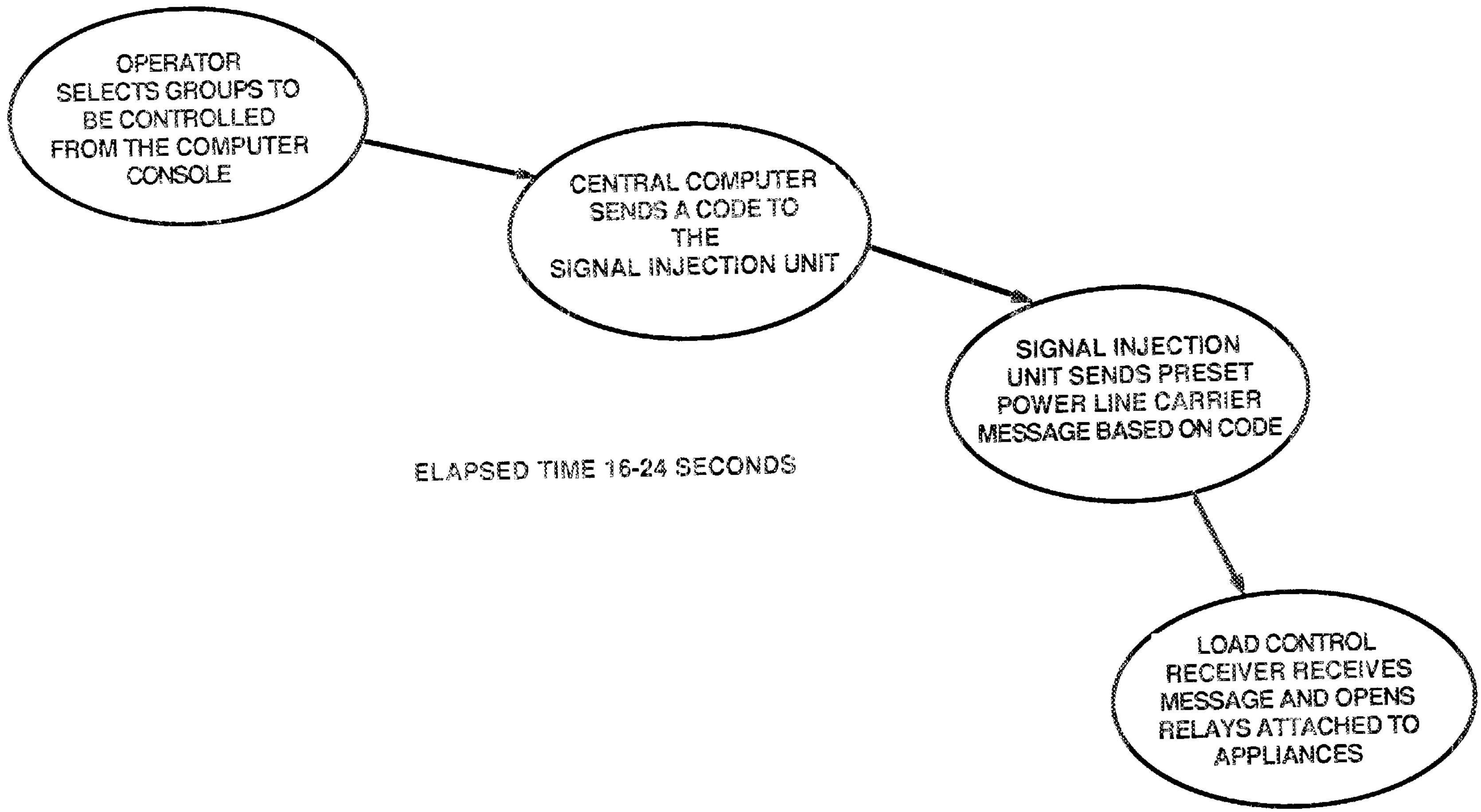
OBJECTIVES

- o CHARACTERIZATION AND MODELING
- o CONTROL STRATEGIES
- o CUSTOMER COMFORT CONSTRAINTS
- o INSTRUMENTATION REQUIREMENTS AND RELIABILITY
- o CUSTOMER ACCEPTANCE
- o TRANSFER TO THE UTILITY INDUSTRY

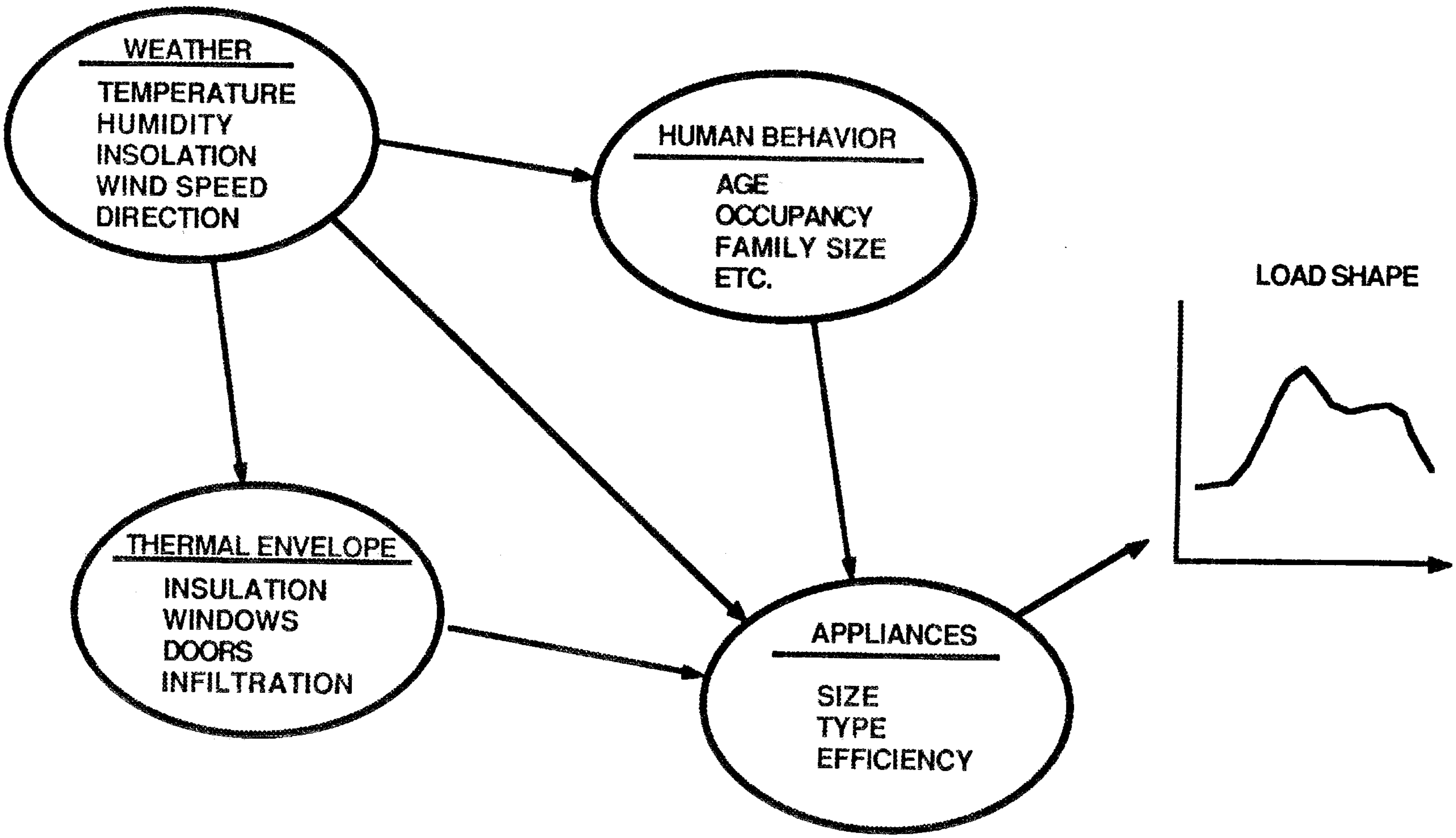
The Load Control Hardware



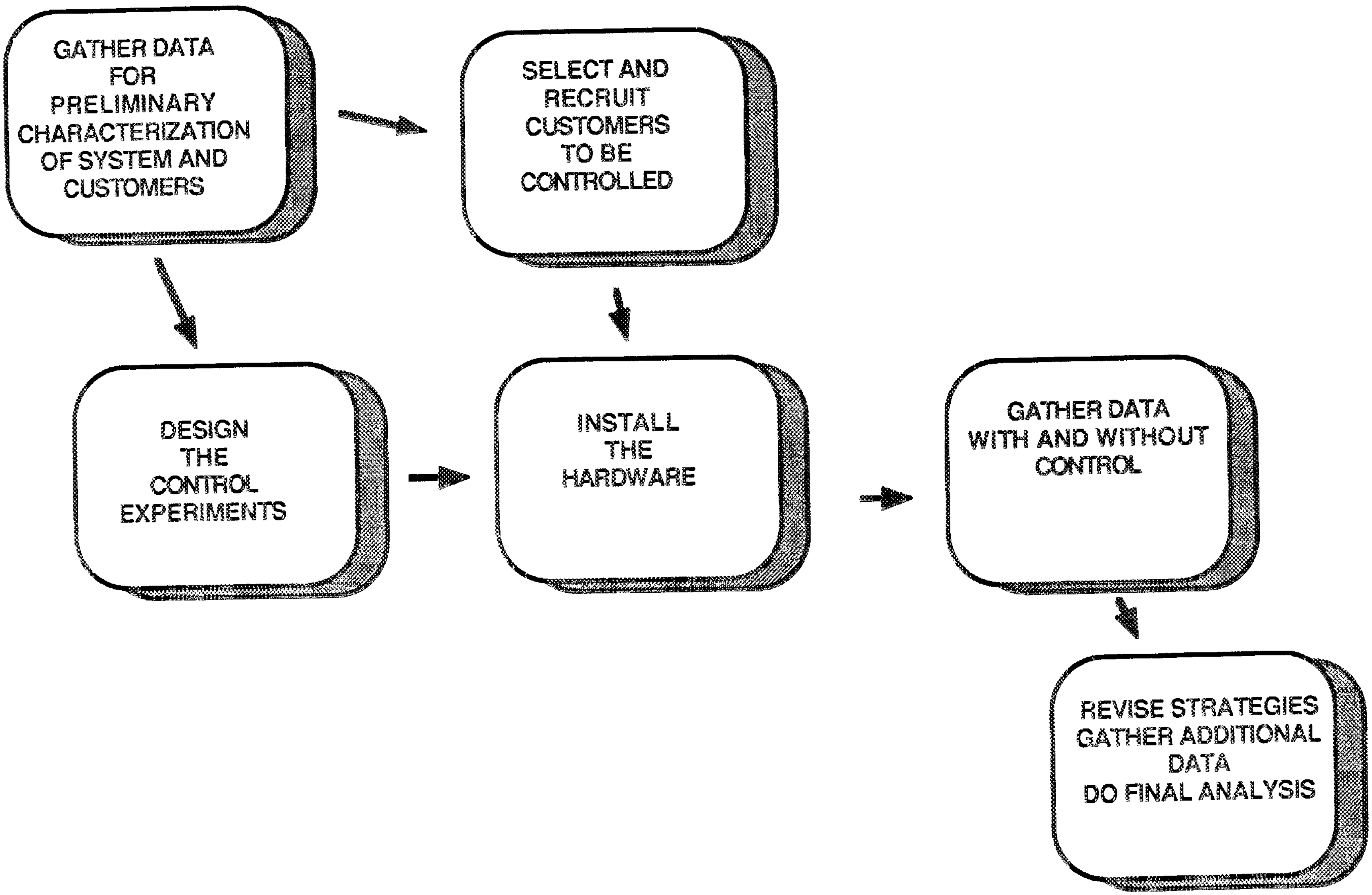
DOING LOAD CONTROL



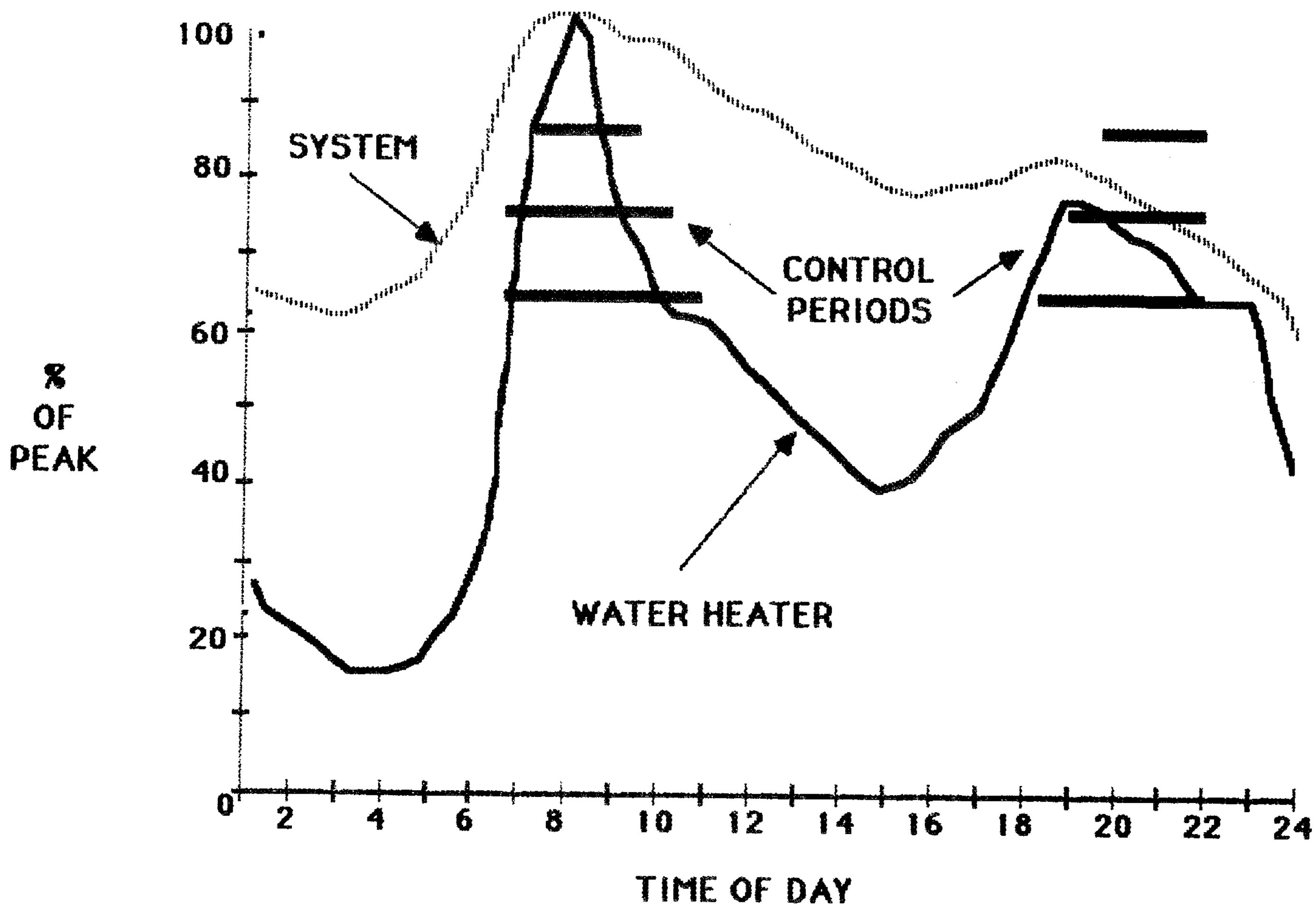
FACTORS CONTRIBUTING TO RESIDENTIAL ELECTRIC LOADS



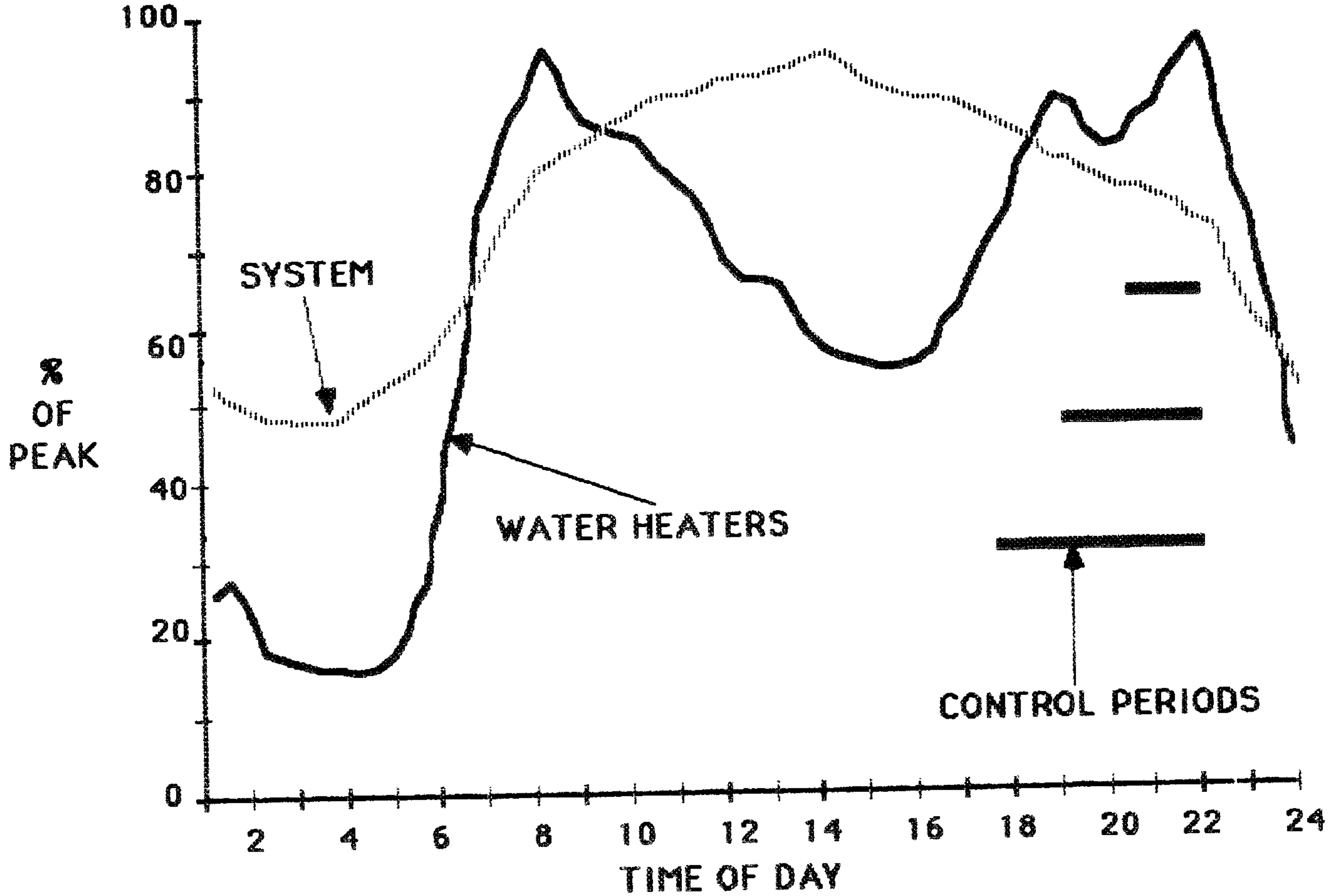
THE ATHENS LOAD CONTROL EXPERIMENT



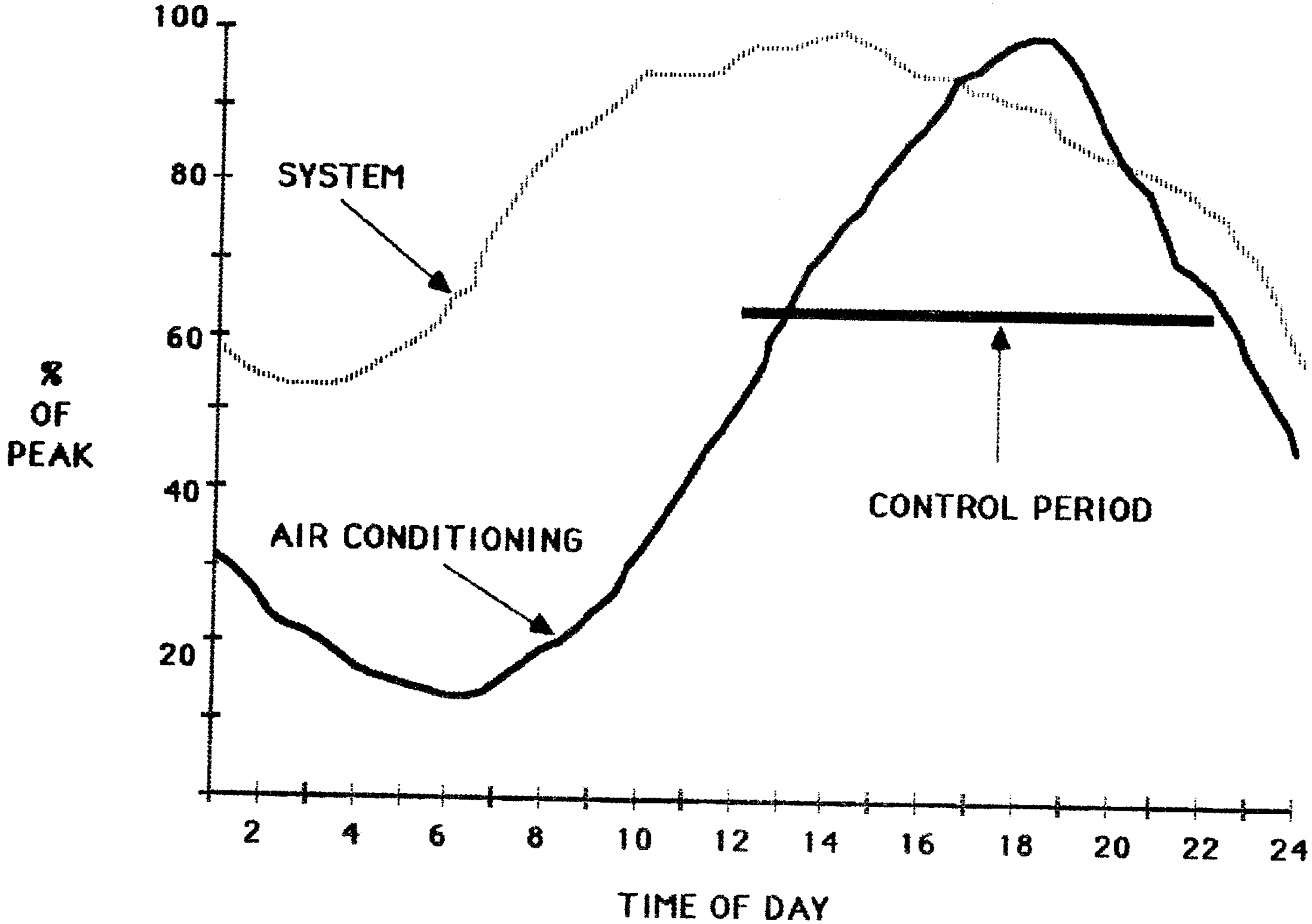
TIMING AND DURATION OF WINTER WATER HEATER CONTROL



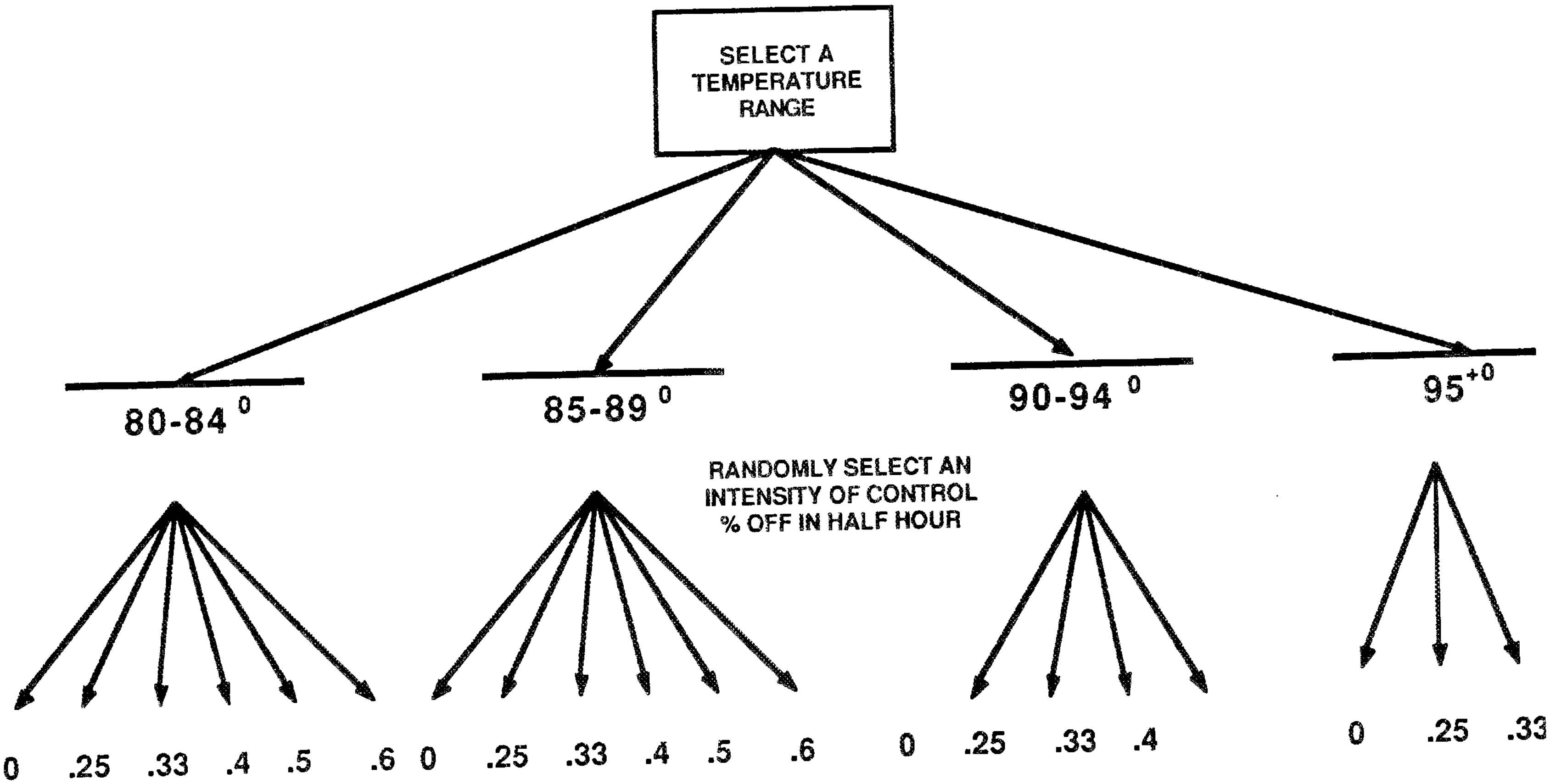
TIMING AND DURATION OF SUMMER WATER HEATER CONTROL



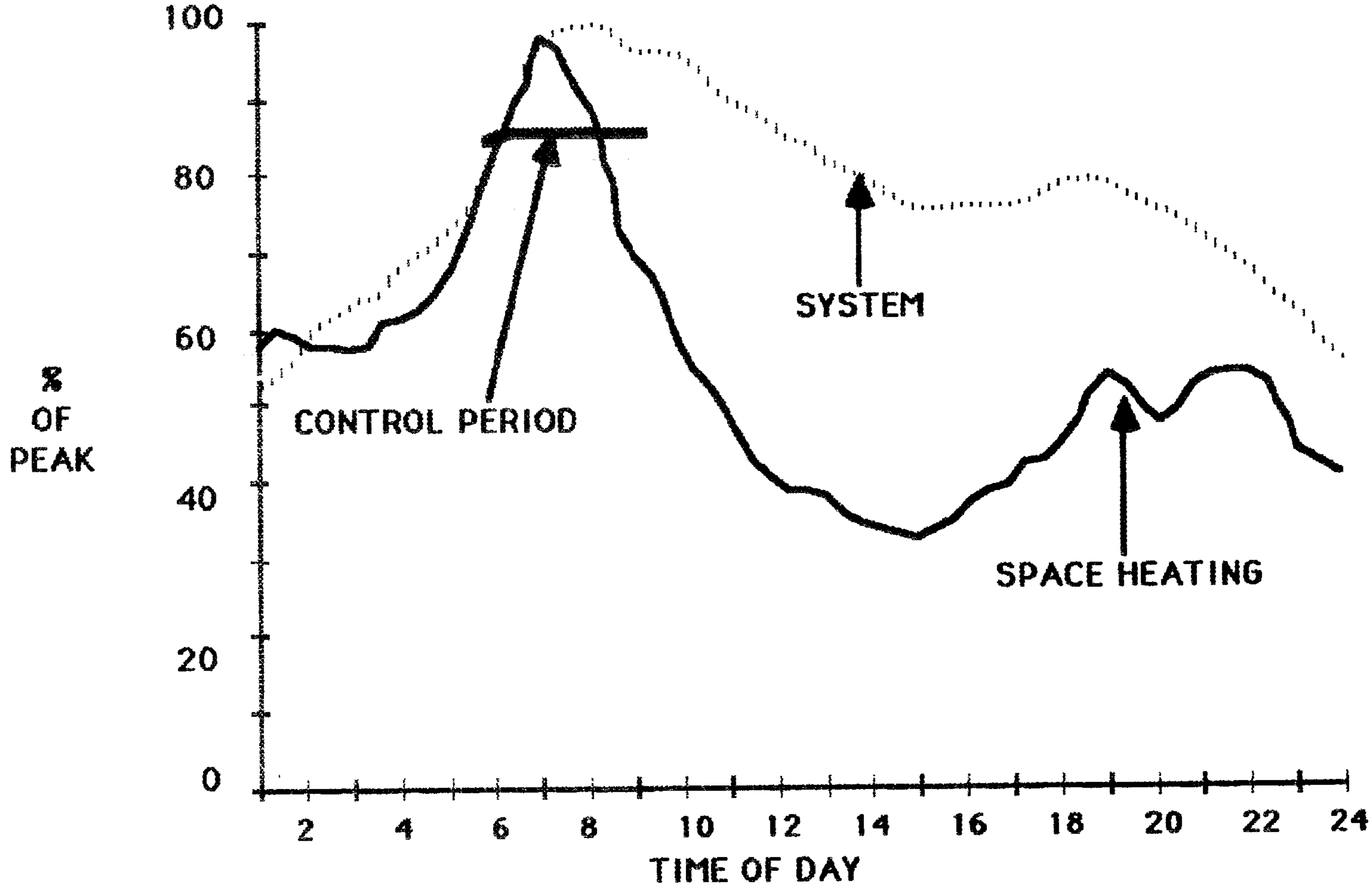
TIMING AND DURATION OF AIR CONDITIONING CONTROL



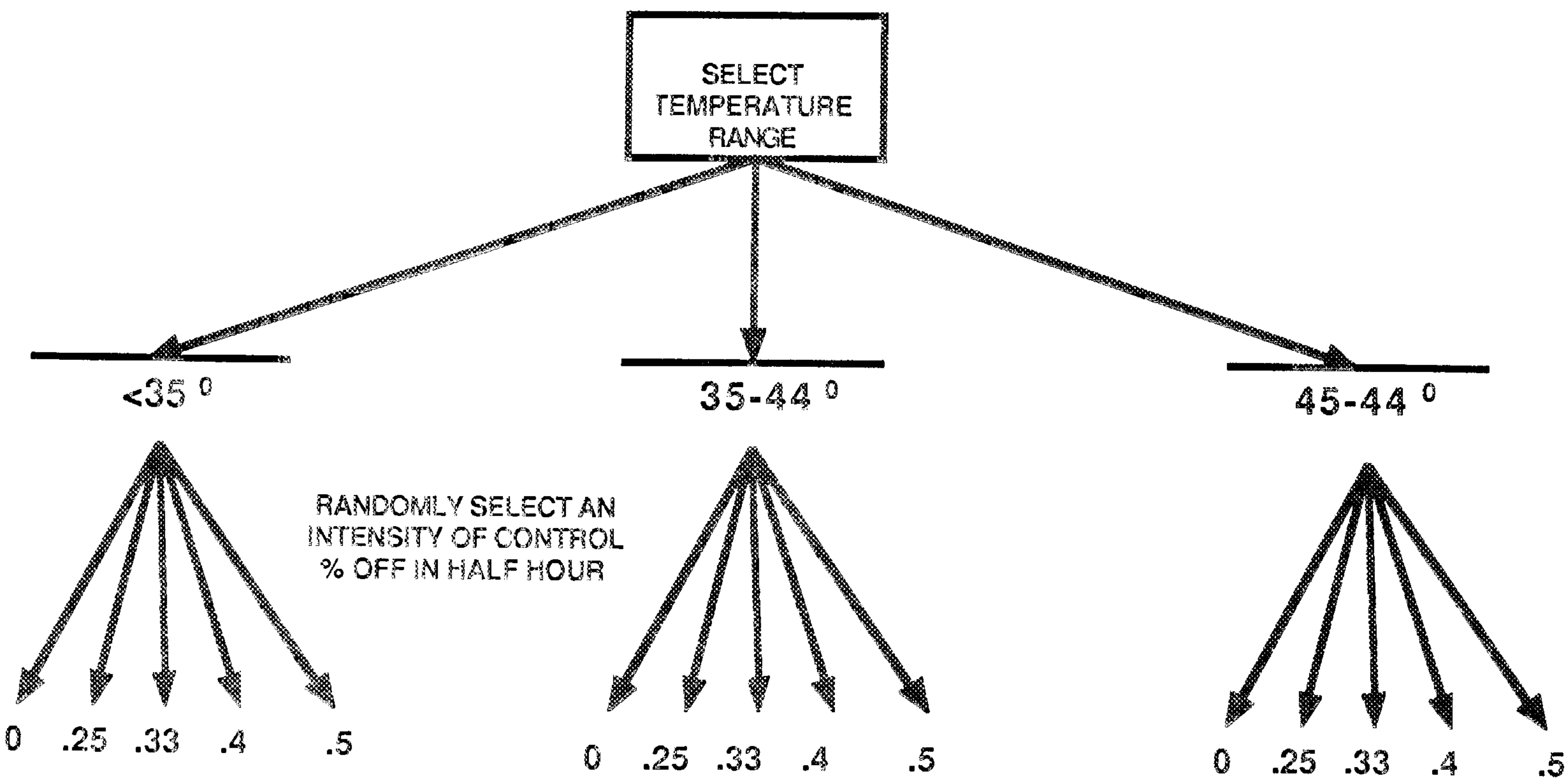
AIR CONDITIONING EXPERIMENTS



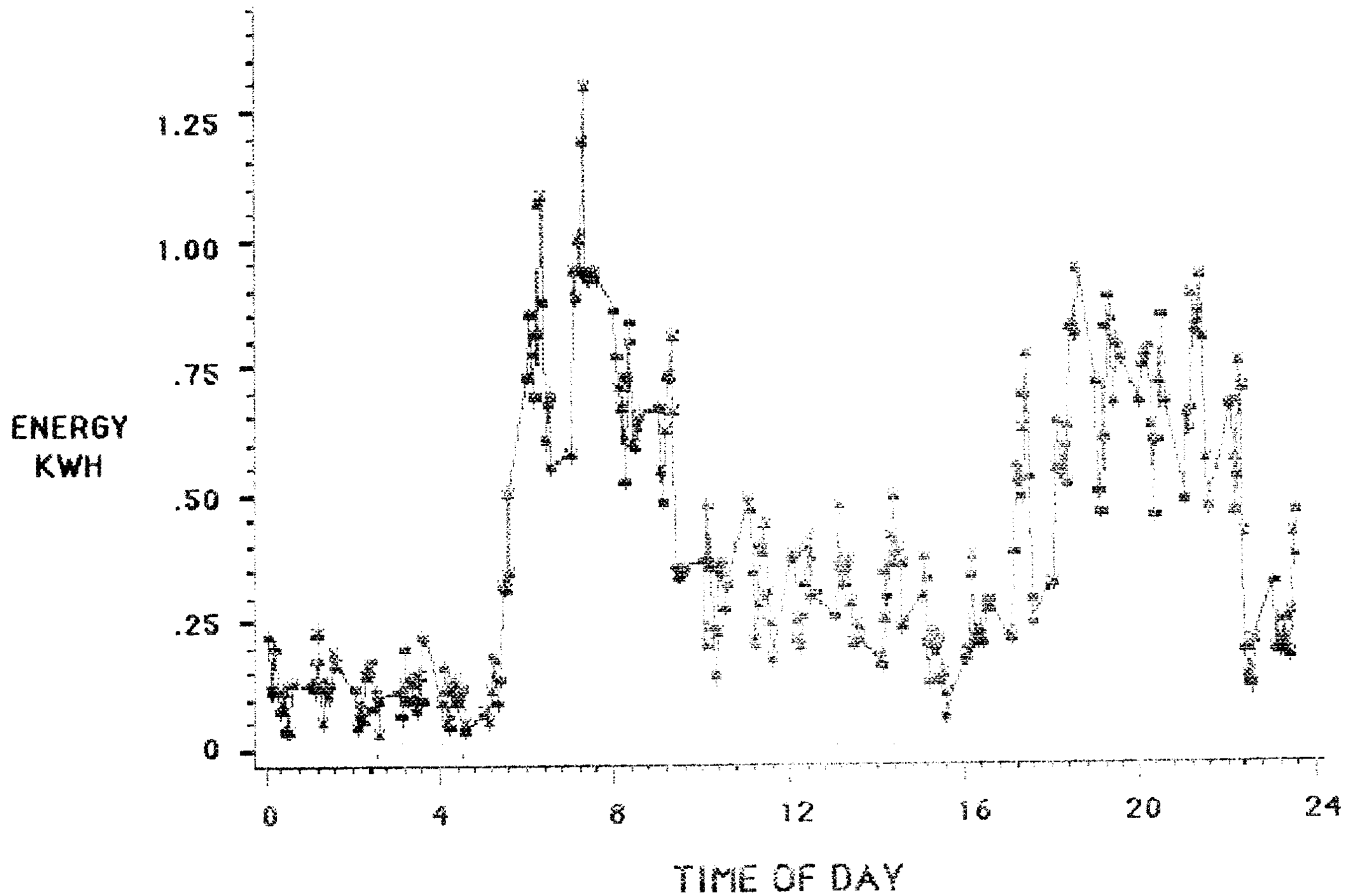
TIMING AND DURATION OF SPACE HEATNG CONTROL



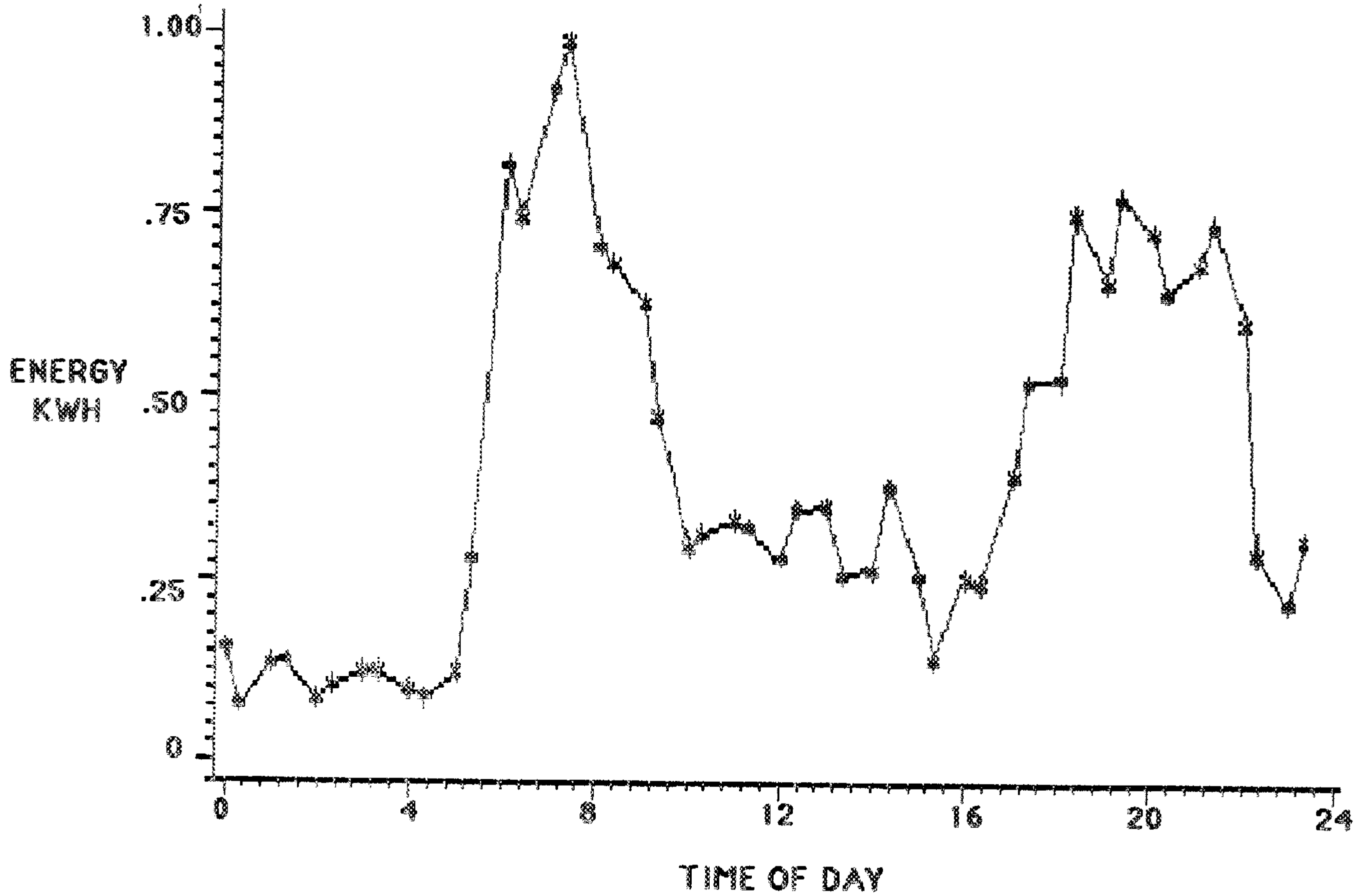
SPACE HEATING EXPERIMENTS



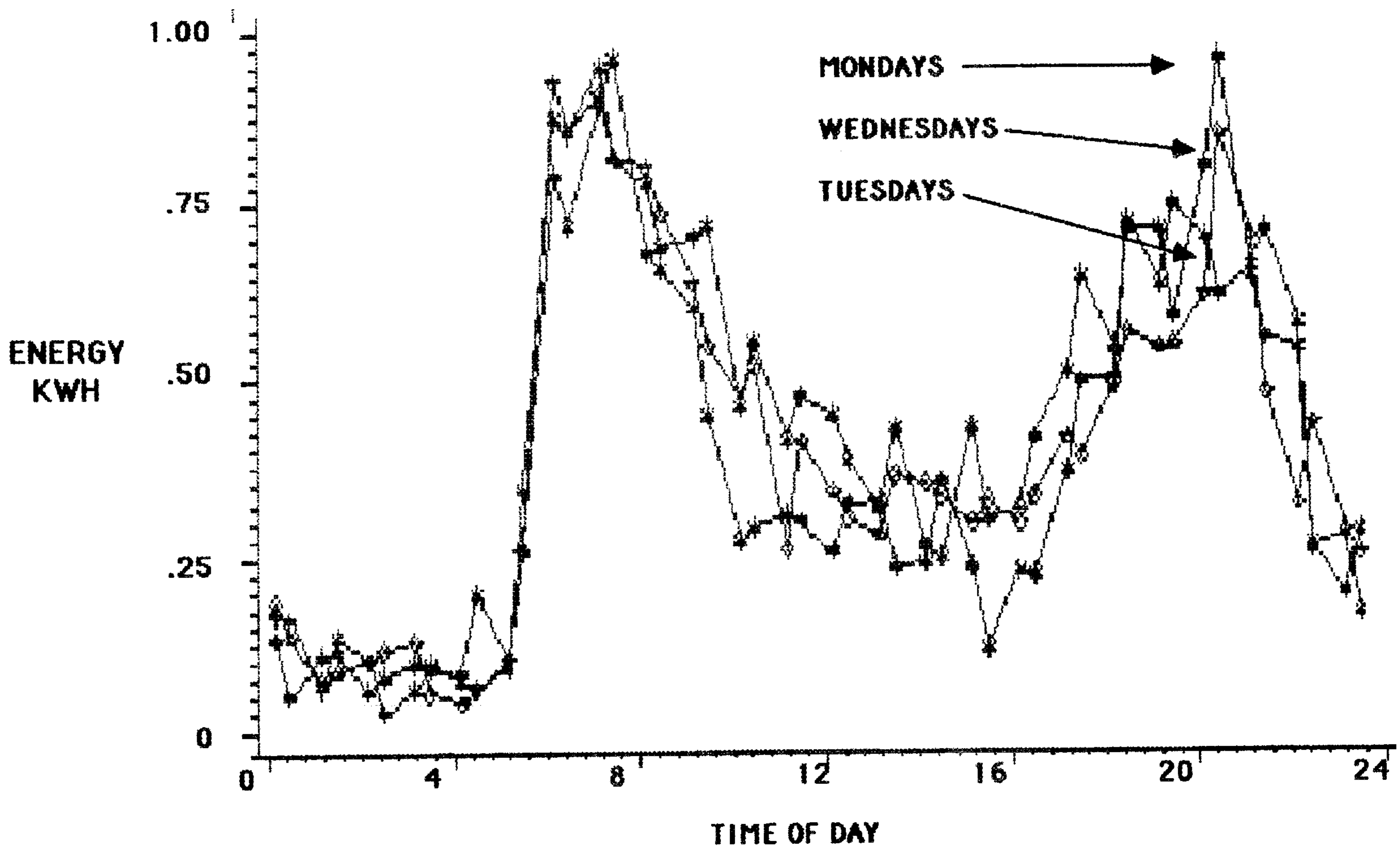
AVERAGE WATER HEATER CONSUMPTION (KWH)
20 HOUSEHOLDS BY TIME OF DAY
TUESDAYS IN OCTOBER 1985
ATHENS TENNESSEE
(5 MINUTE INTERVAL DATA)



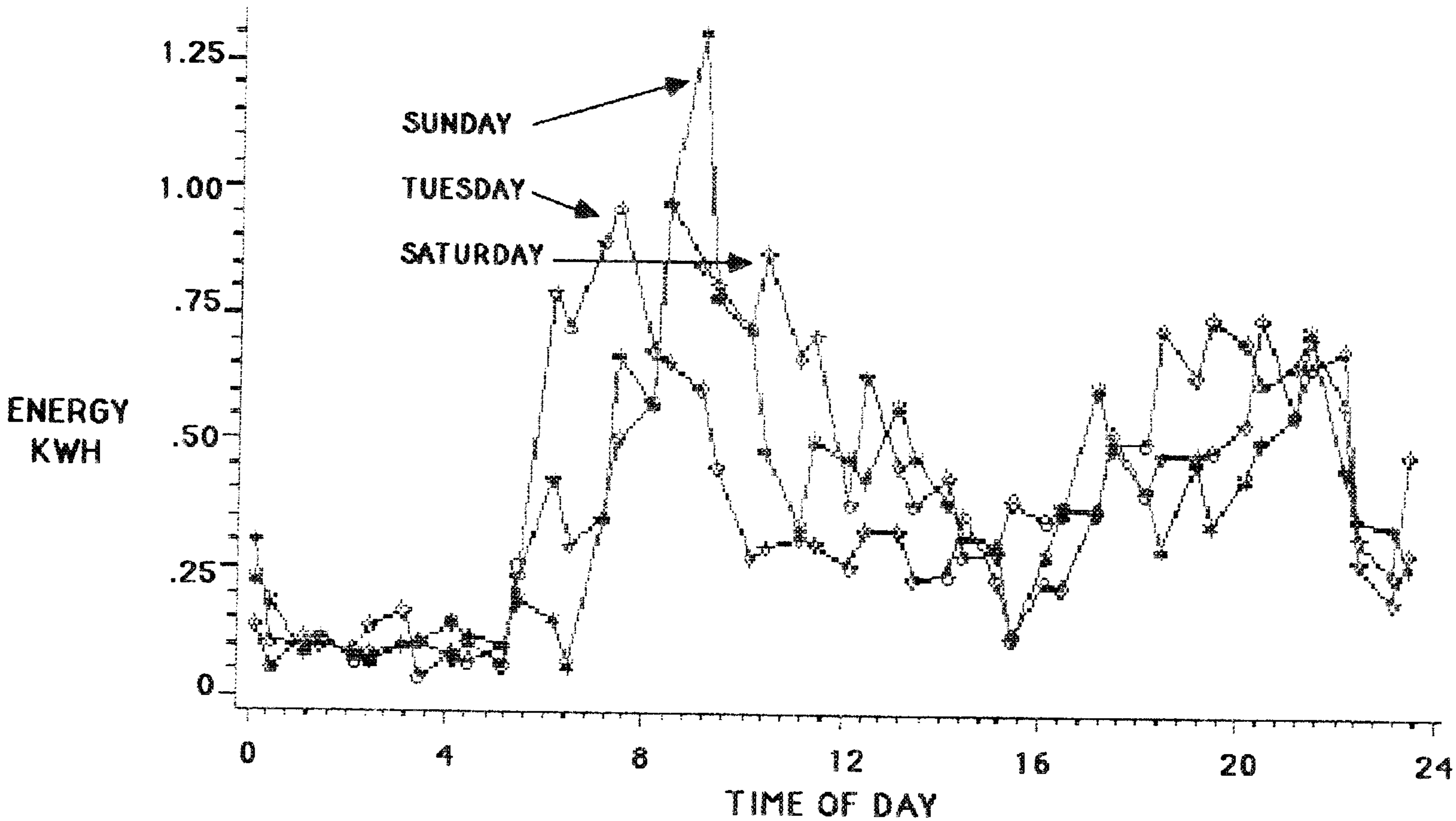
AVERAGE WATER HEATER CONSUMPTION (KWH)
20 HOUSEHOLDS BY TIME OF DAY
TUESDAYS IN OCTOBER 1985
ATHENS TENNESSEE
(30 MINUTE INTERVALS)



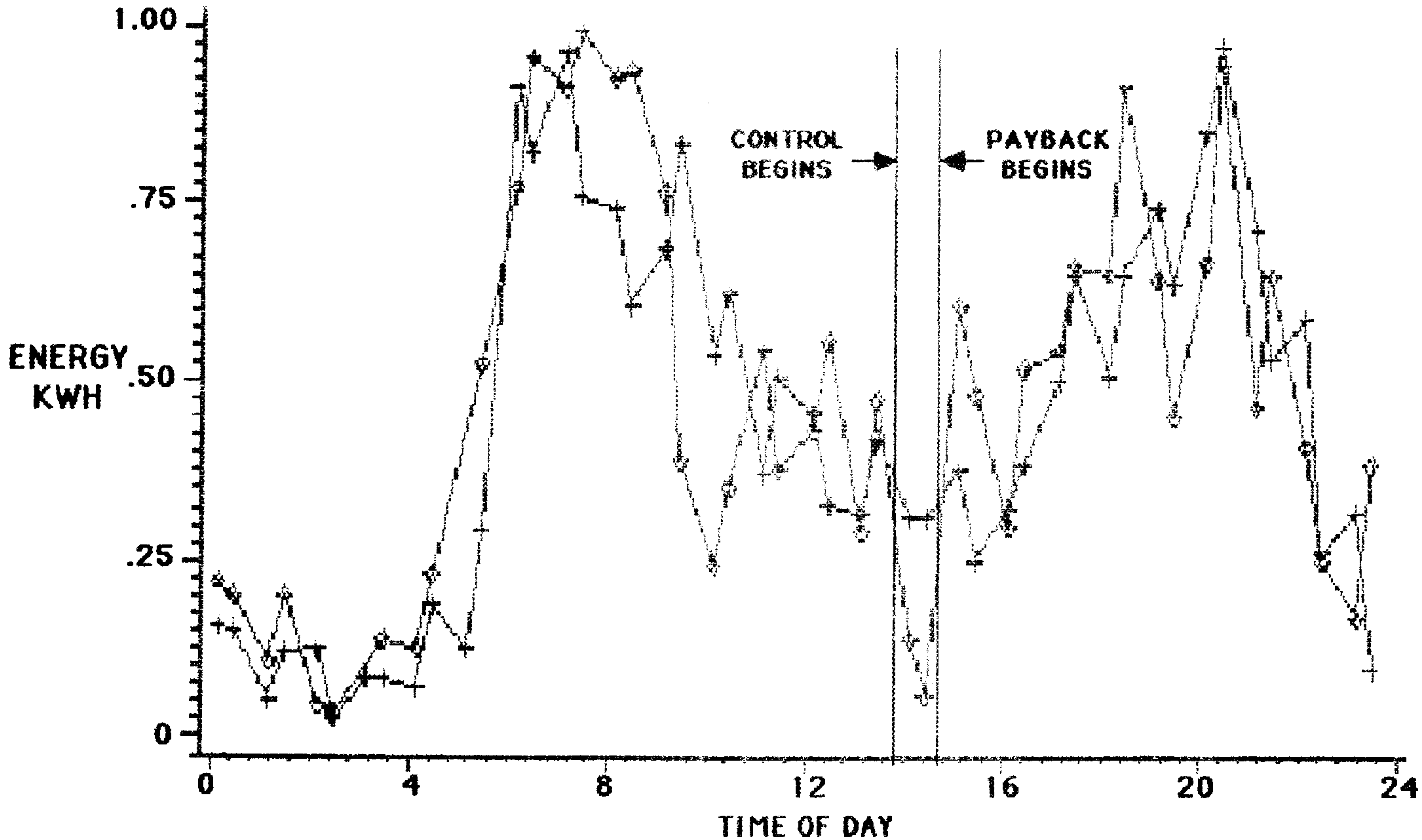
AVERAGE WATER HEATER CONSUMPTION (KWH)
20 HOUSEHOLDS BY TIME OF DAY
MONDAYS TUESDAYS AND WEDNESDAYS
OCTOBER 1985 ATHENS TENNESSEE



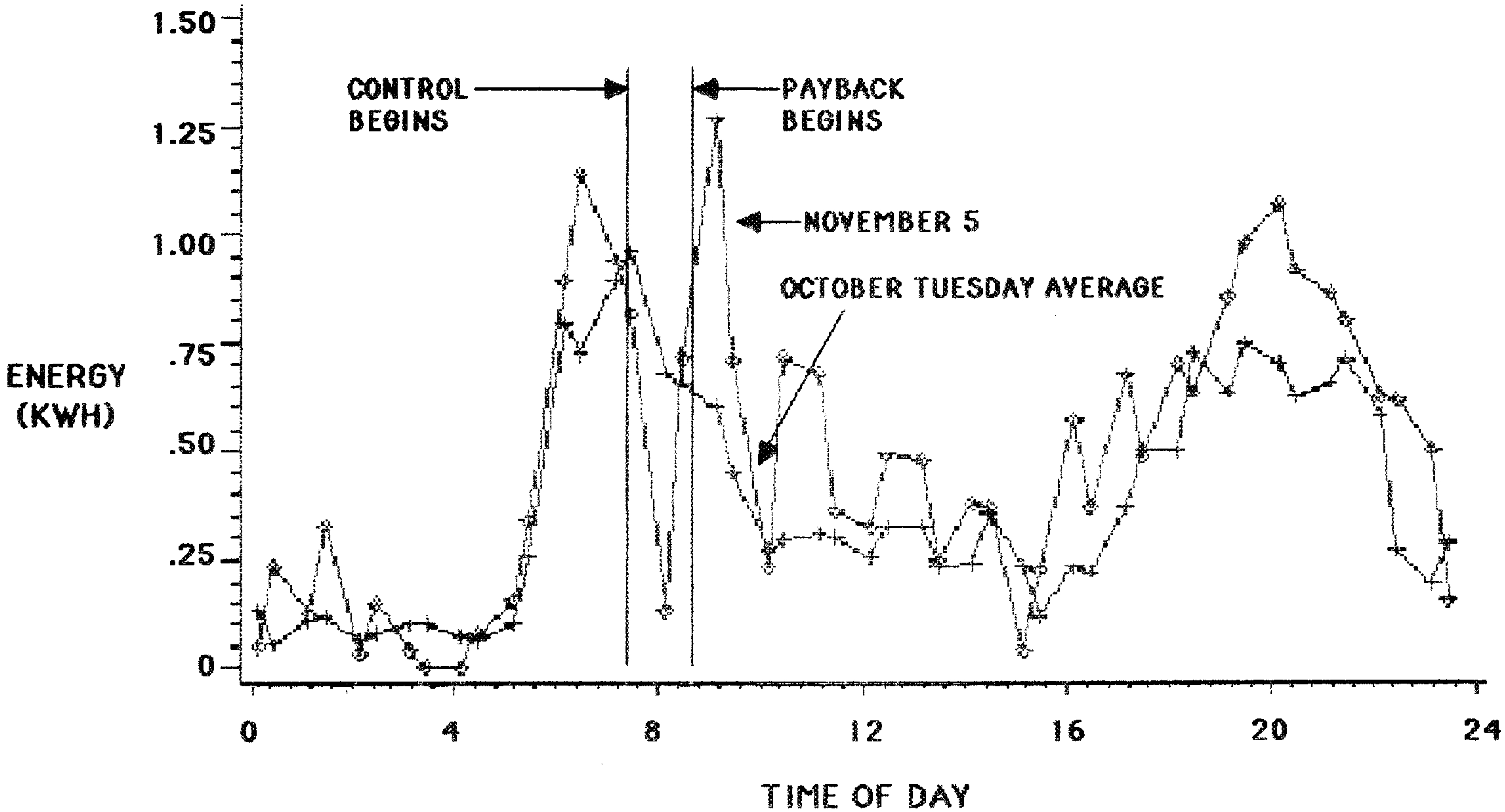
AVERAGE WATER HEATER CONSUMPTION (KWH)
20 HOUSEHOLDS BY TIME OF DAY
SUNDAYS TUESDAYS AND SATURDAYS
OCTOBER 1985 ATHENS TENNESSEE



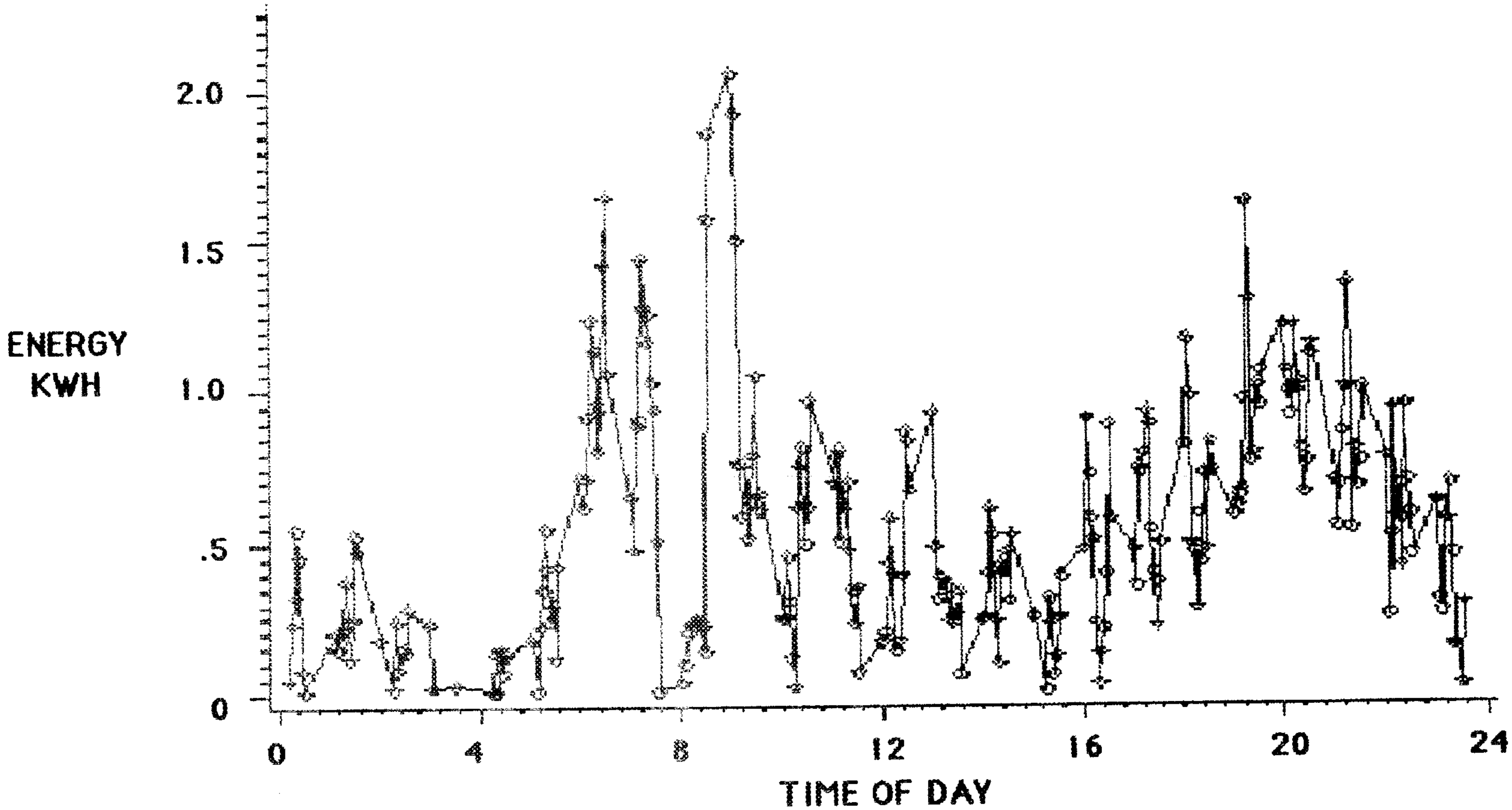
AVERAGE WATER HEATER CONSUMPTION (KWH)
FOR A MONDAY WITH LOAD CONTROL
OCTOBER 28 1985 AT 2:00 PM
COMPARED WITH 3 MONDAY AVERAGE FOR OCTOBER
ATHENS TENNESSEE



AVERAGE WATER HEATER CONSUMPTION (KWH) FOR A TUESDAY WITH LOAD CONTROL NOVEMBER 5 1985 AT 7:34 AM COMPARED WITH TUESDAY AVERAGE FOR OCTOBER ATHENS TENNESSEE

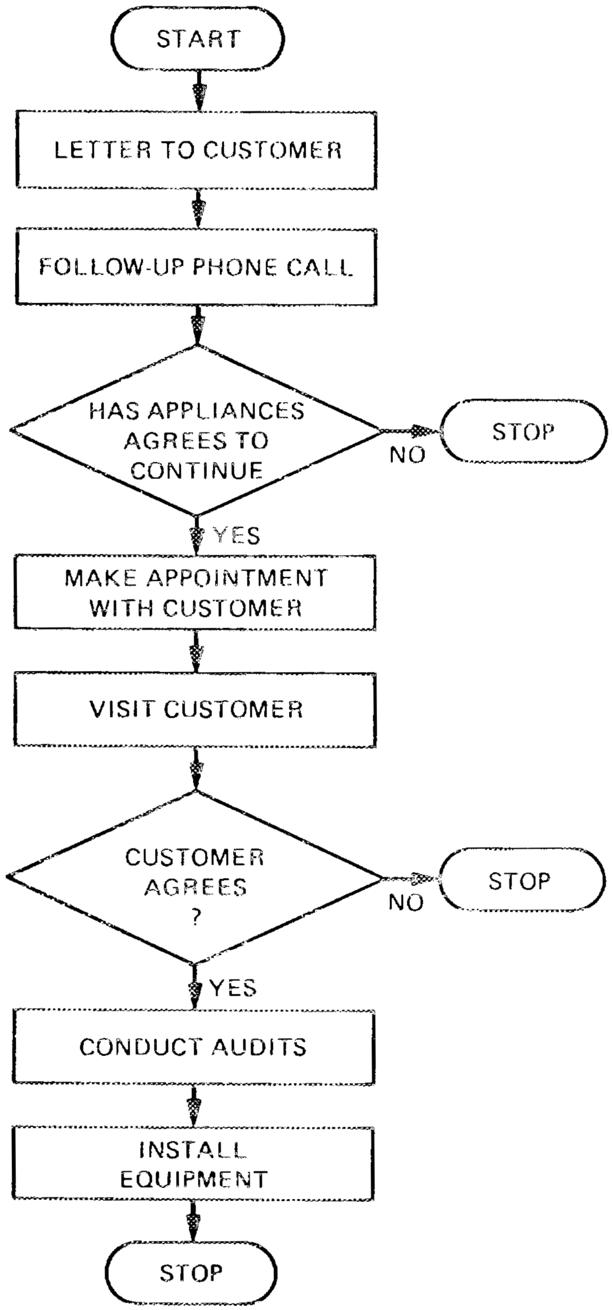


AVERAGE WATER HEATER CONSUMPTION (KWH)
WITH 1 HOUR LOAD CONTROL ACTION AT 7:34 AM
TUESDAY NOVEMBER 5 1985
ATHENS TENNESSEE
5 MINUTE DATA

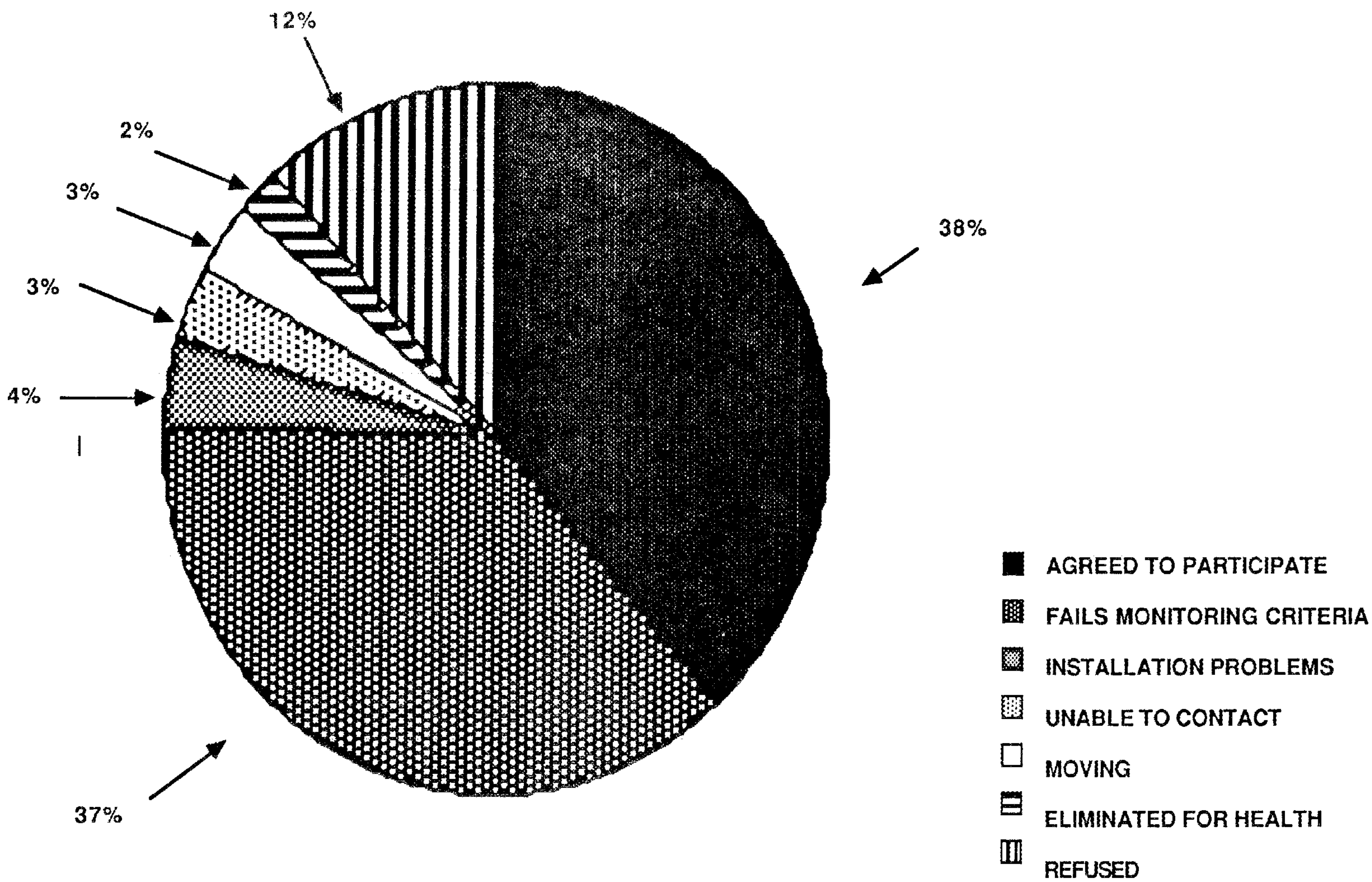


ORNL--DWG 84-17908

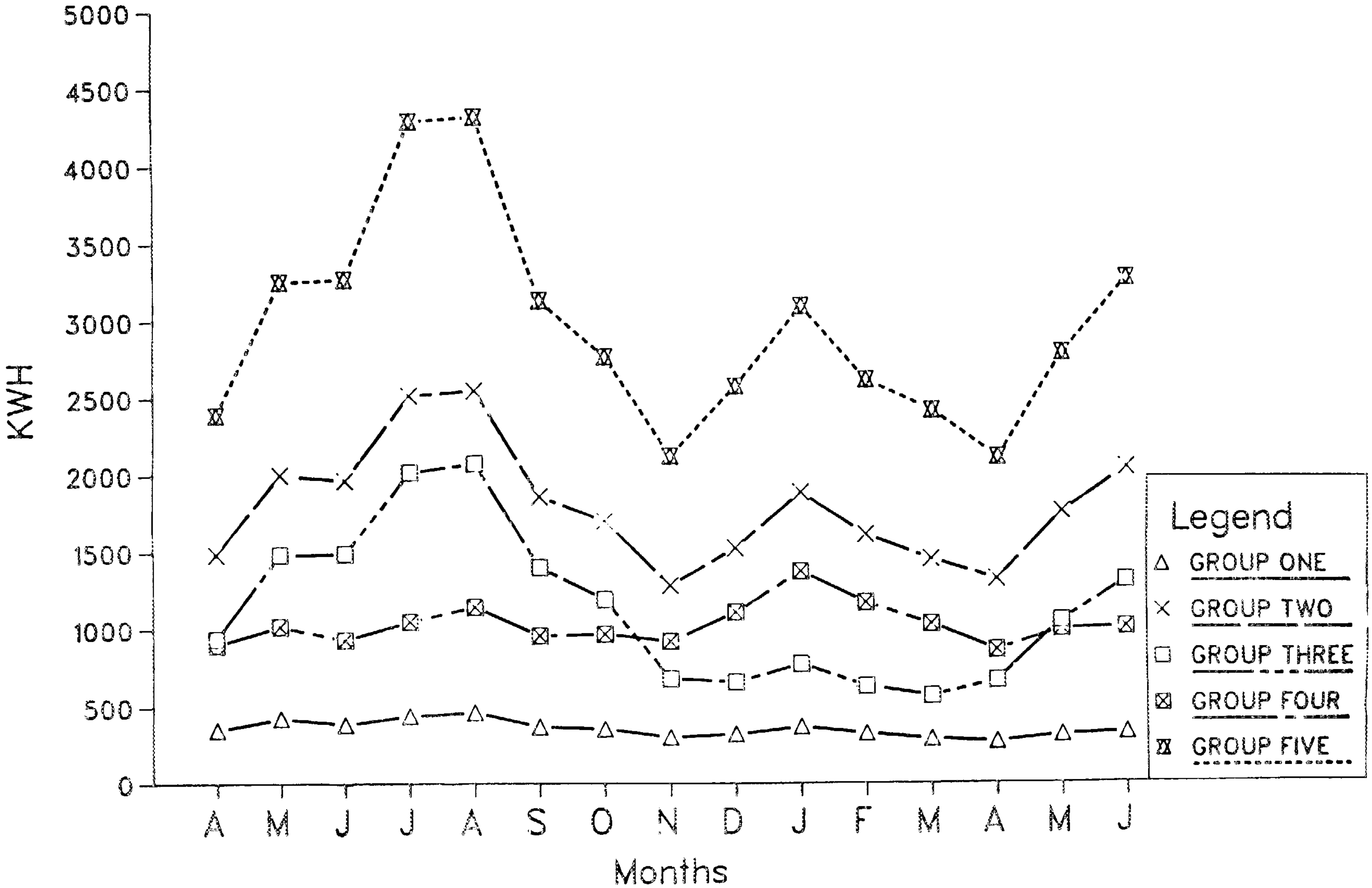
CUSTOMER RECRUITMENT PROCEDURE



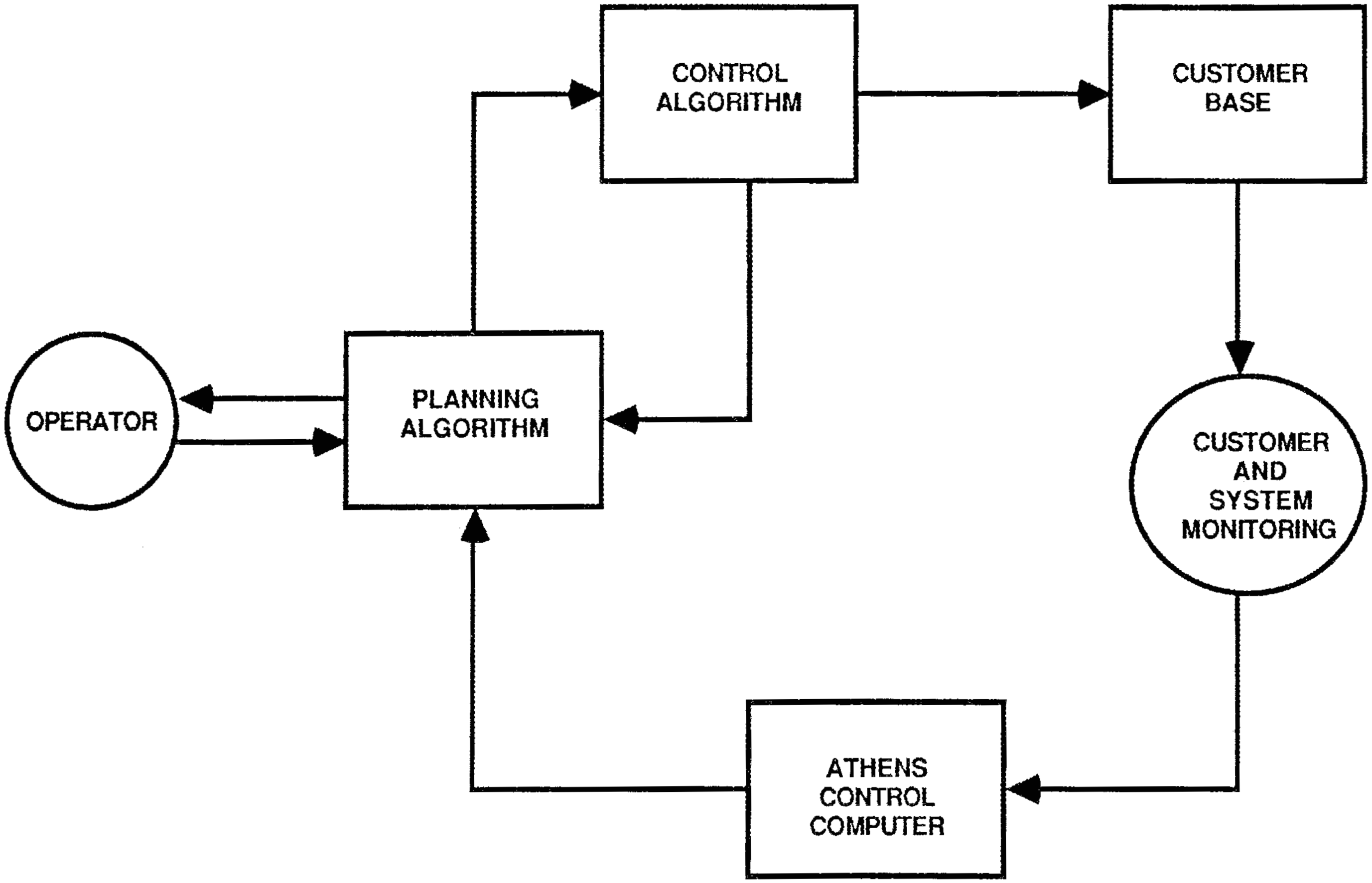
RESULTS OF CUSTOMER CONTACT FOR 344 CUSTOMERS



Average Monthly Consumption Patterns for Five Groups of Athens Customers



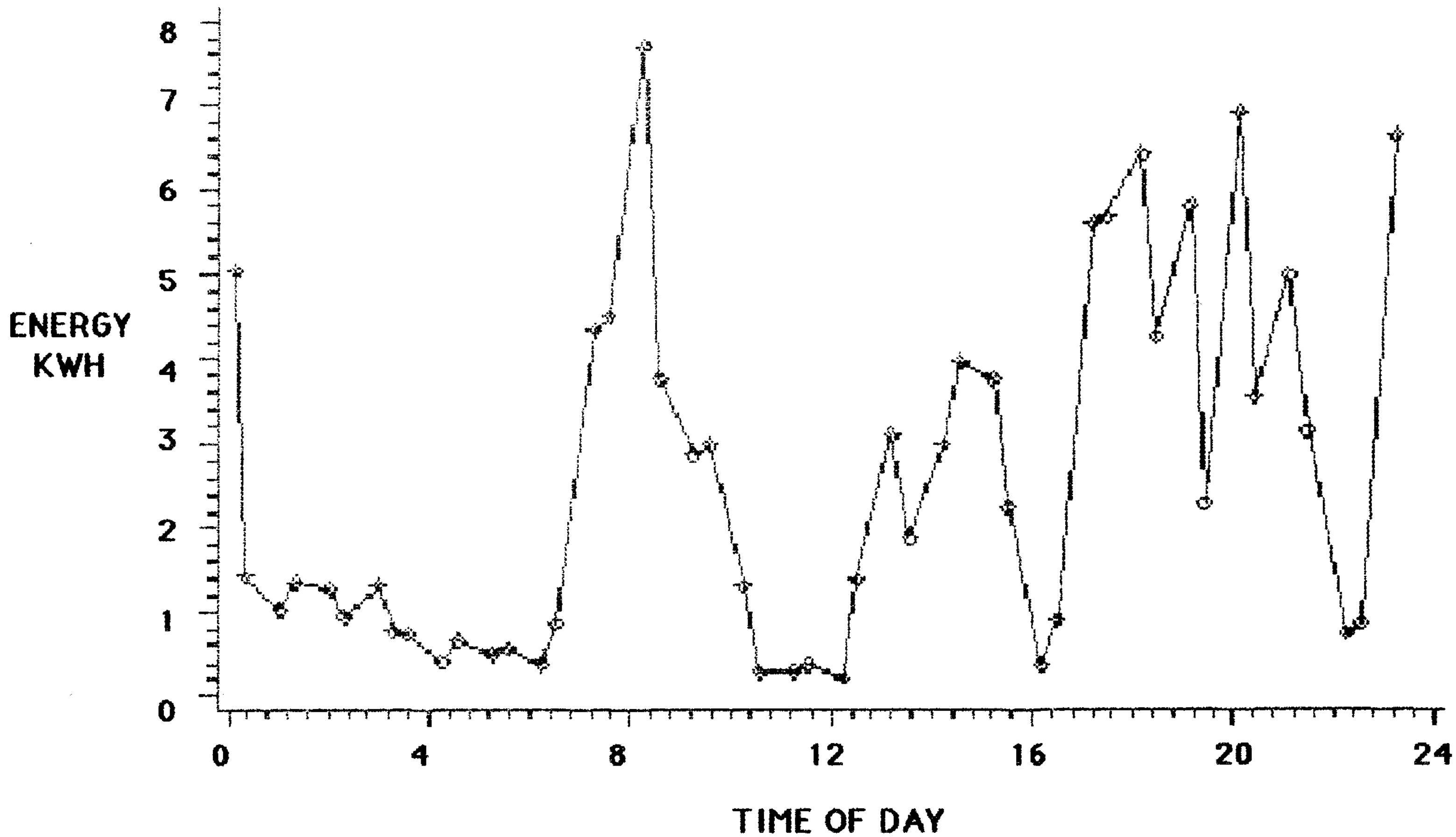
AUTOMATING LOAD CONTROL ON THE ATHENS TENNESSEE SYSTEM



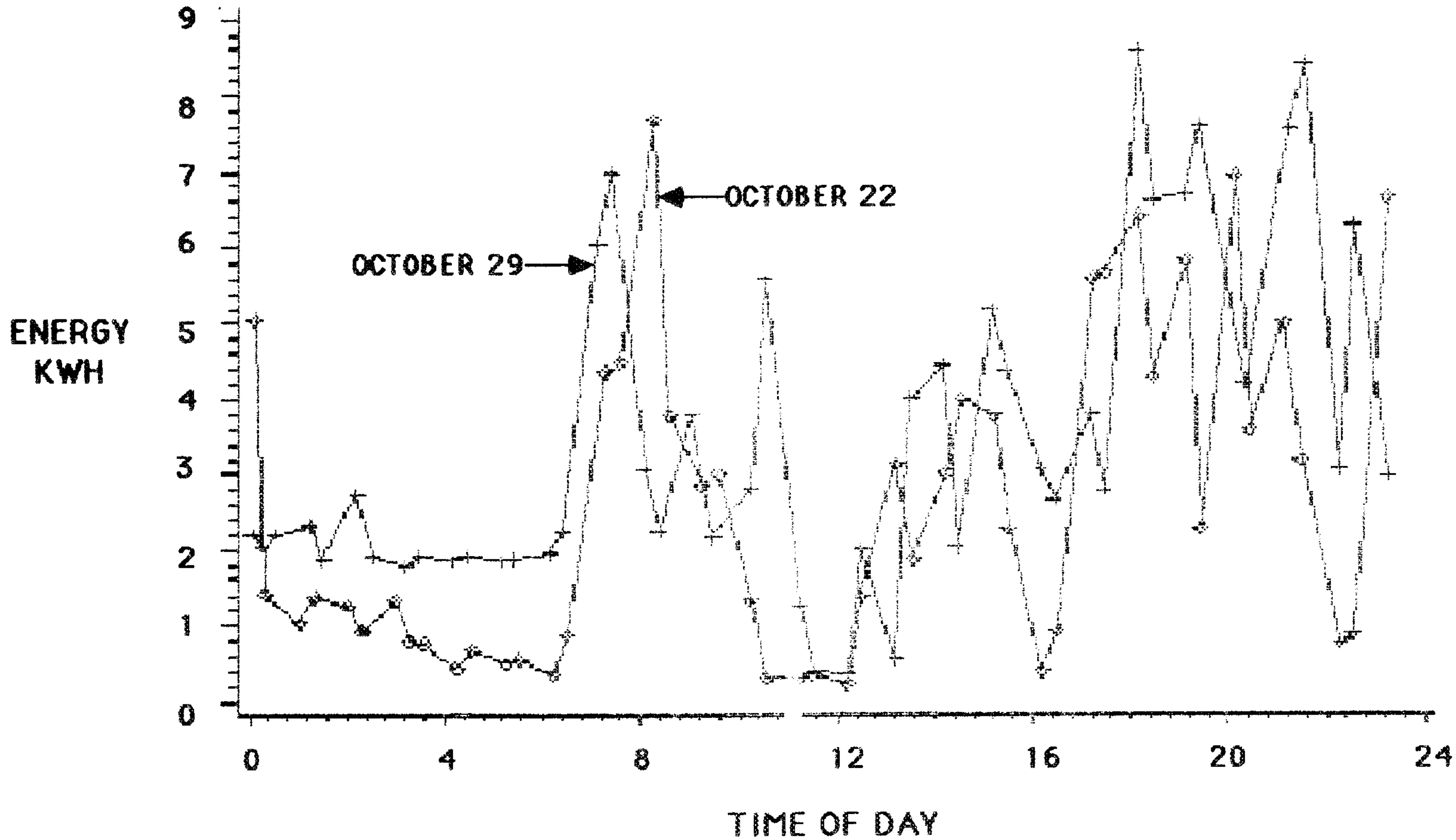
AUTOMATING LOAD CONTROL DEPENDS ON

- ESTIMATING SYSTEM LOADS
- ESTIMATING FEEDER LOADS
- ESTIMATING CUSTOMER CLASS BEHAVIOR FROM HOUSEHOLD DATA

CONSUMPTION (KWH) FOR A SINGLE HOUSEHOLD
FROM SMARTMETER DATA FOR
TUESDAY OCTOBER 22 1985 ATHENS TENNESSEE
APPROXIMATELY HALF HOUR INTERVALS



CONSUMPTION (KWH) FOR A SINGLE HOUSEHOLD
FROM SMARTMETER DATA FOR
TWO TUESDAYS OCTOBER 22 & 29 1985 ATHENS TENNESSEE
APPROXIMATELY HALF HOUR INTERVALS



SUMMARY

- O DATA REQUIREMENTS ARE DEPENDENT ON MODEL
- O TRANSFERABILITY REQUIRES ADEQUATE SAMPLING
- O MONITORED CUSTOMERS ARE RANDOMLY SELECTED
- O CONTROL DAYS RANDOMLY SELECTED WITHIN TEMPERATURE CATEGORIES
- O MONITORING EQUIPMENT IS IMPROVING BUT EQUIPMENT THAT IS EVEN EASIER TO USE AND INSTALL IS NEEDED

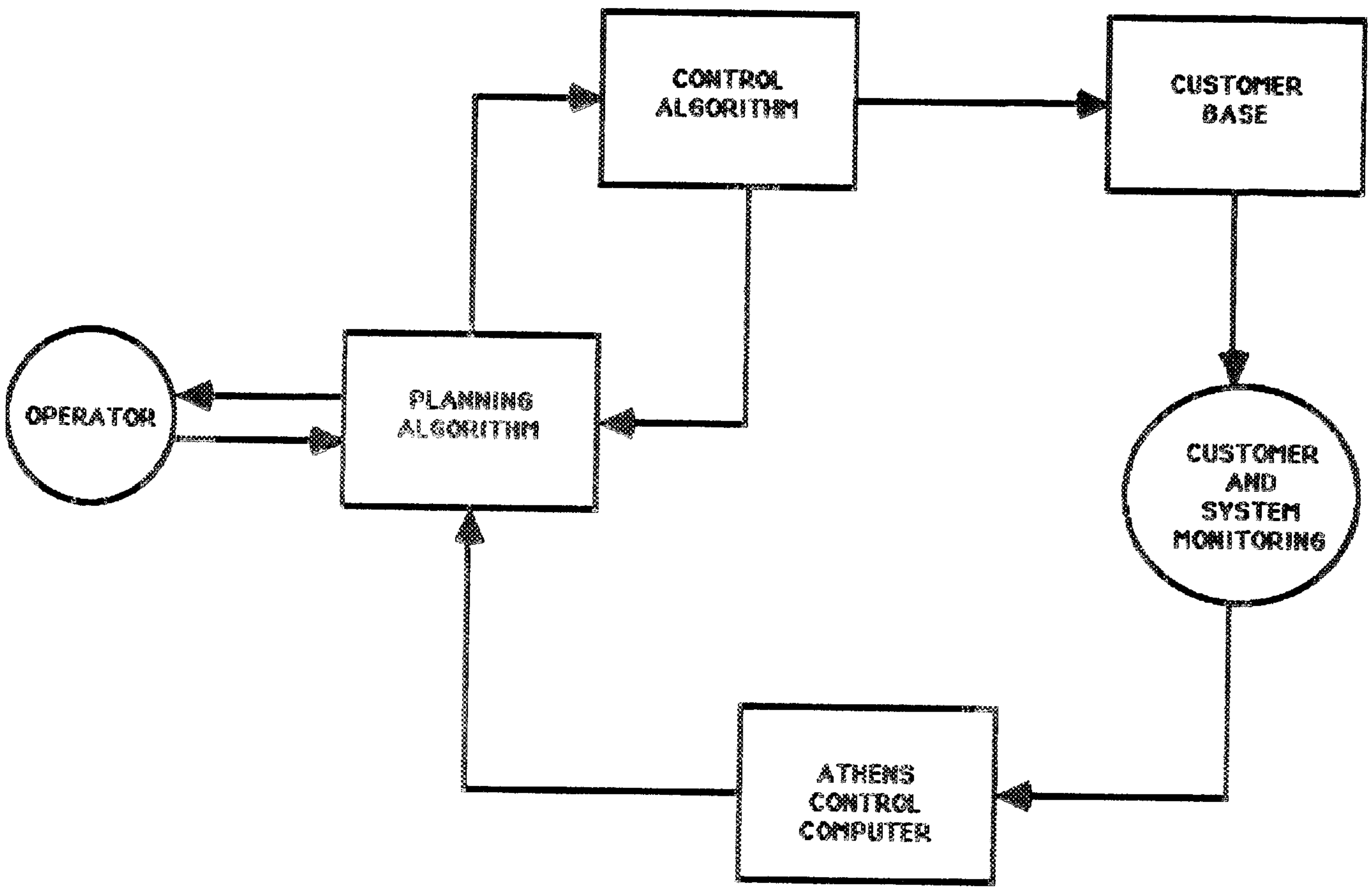
SUMMARY CONTINUED

- O VALIDATING DATA IS STILL A MAJOR PROBLEM
- O DATA HANDLING IS A MAJOR PROBLEM
- O MUCH OF THE PRELIMINARY ANALYSIS CAN BE AUTOMATED
- O PRELIMINARY WATER HEATER EXPERIMENTS WERE SUCCESSFUL
  - DEMONSTRATED CONTROL AND MONITORING
  - POINTS TO NEED TO CHECK RELIABILITY
  - REDUCED CONSUMPTION BY APPROXIMATELY .25 KWH AT 2:00 PM
  - REDUCED CONSUMPTION BY APPROXIMATELY .75 KWH AT 7:30 AM

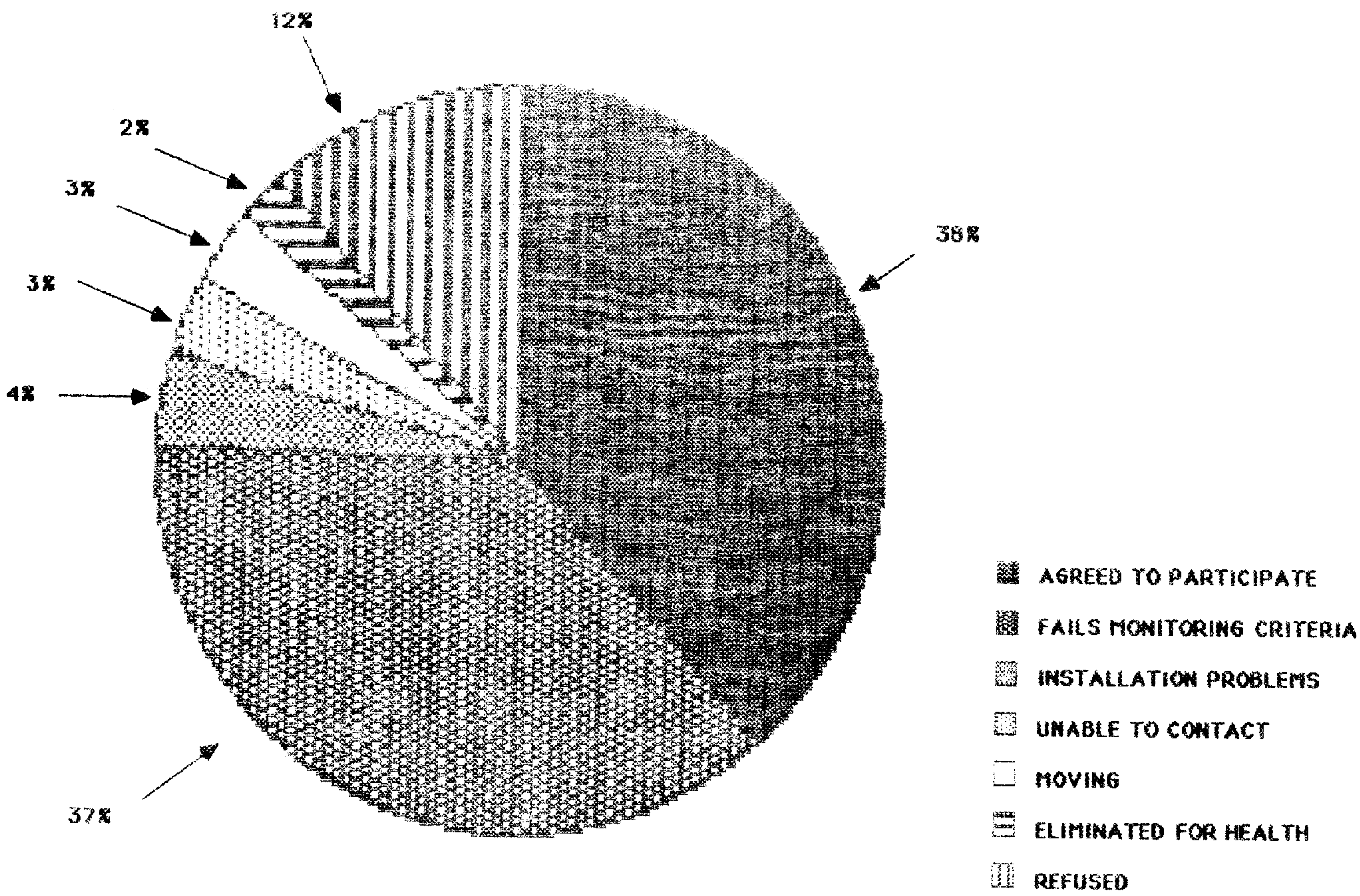
SUMMARY CONTINUED

- O WATER HEATER USAGE PATTERNS SIMILAR DURING THE WEEK
- O SATURDAYS AND SUNDAYS DIFFER FROM EACH OTHER AND FROM DAYS OF THE WEEK
- O SELECTION AND RECRUITMENT PROCEDURE HAS BEEN SUCCESSFUL (I.E. LOW REJECTION RATE)
- O USE OF BILLING DATA TO IDENTIFY APPLIANCE HOLDERS WORKS BUT THE TECHNIQUE COULD BE REFINED
- O CONTOUR PLOTS USEFUL FOR DATA SCREENING

AUTOMATING LOAD CONTROL ON THE ATHENS TENNESSEE SYSTEM



RESULTS OF CUSTOMER CONTACT FOR 344 CUSTOMERS



LOAD CONTROL EXPERIMENT BACKGROUND

Steven D. Braithwait

The AACE provides EPRI with the opportunity to pursue the goal of providing analysis tools and results to the utility industry in an efficient manner. By sharing the capabilities of the communications, load control, and data acquisition systems placed by DOE in Athens, EPRI will be better able to meet the project objectives of (1) developing transferable tools for program design and assessment, and (2) developing an analysis data base that accurately represents the residential DLC program.

Primary emphasis has thus far been directed in two areas: experimental design and analysis design. Experimental design focused on the development of an overall scheme that would ensure the highest probability of success in the experiments. A sample design based on available usage data and survey responses was constructed resulting in a plan calling for 50 customers in each of four strata to be sampled. End-use metering devices will be placed in these households to monitor a mix of water heater, space heater, air conditioner, and total household loads as well as indoor temperature. An experiment plan detailing the selection and sequencing of control strategies was also prepared. Historical weather information was used to define the set of feasible control strategies.

The analysis design included the development of a plan for analyzing the large amount of data to be collected during the load control experiments as well as specification of an impact assessment model. This model, known as the Duty Cycle Impact Model, will evaluate the impact of the various DLC strategies by assessing changes in the natural operation, or duty cycle, of the controlled appliances.

Deliverables in the project include the DESIGN Model, now in a research grade, pre-release version. This PC-based model provides the utility analyst with a valuable tool for use in evaluating DLC experiments before implementation, thus enhancing the likelihood of a successful experiment. Also to be produced are the Handbook on DSM Experimentation, which will serve as a guide for utility analysts in addressing issues relevant for utility experiments, and, most important, a transferable model of DLC impacts.

Transferability is the key to providing the industry with a broadly useful product. To achieve this goal, the impact model will evaluate the effects of several DLC strategies under varying environmental conditions and incorporate behavioral responses to appliance control. In this way, an integrated approach to modeling the factors that influence load will be carried out, yielding the desired transferable model, data base, and results.

EPRI PERSPECTIVE

ATHENS AUTOMATION AND CONTROL EXPERIMENT

Steven Braithwait, EPRI Project Manager

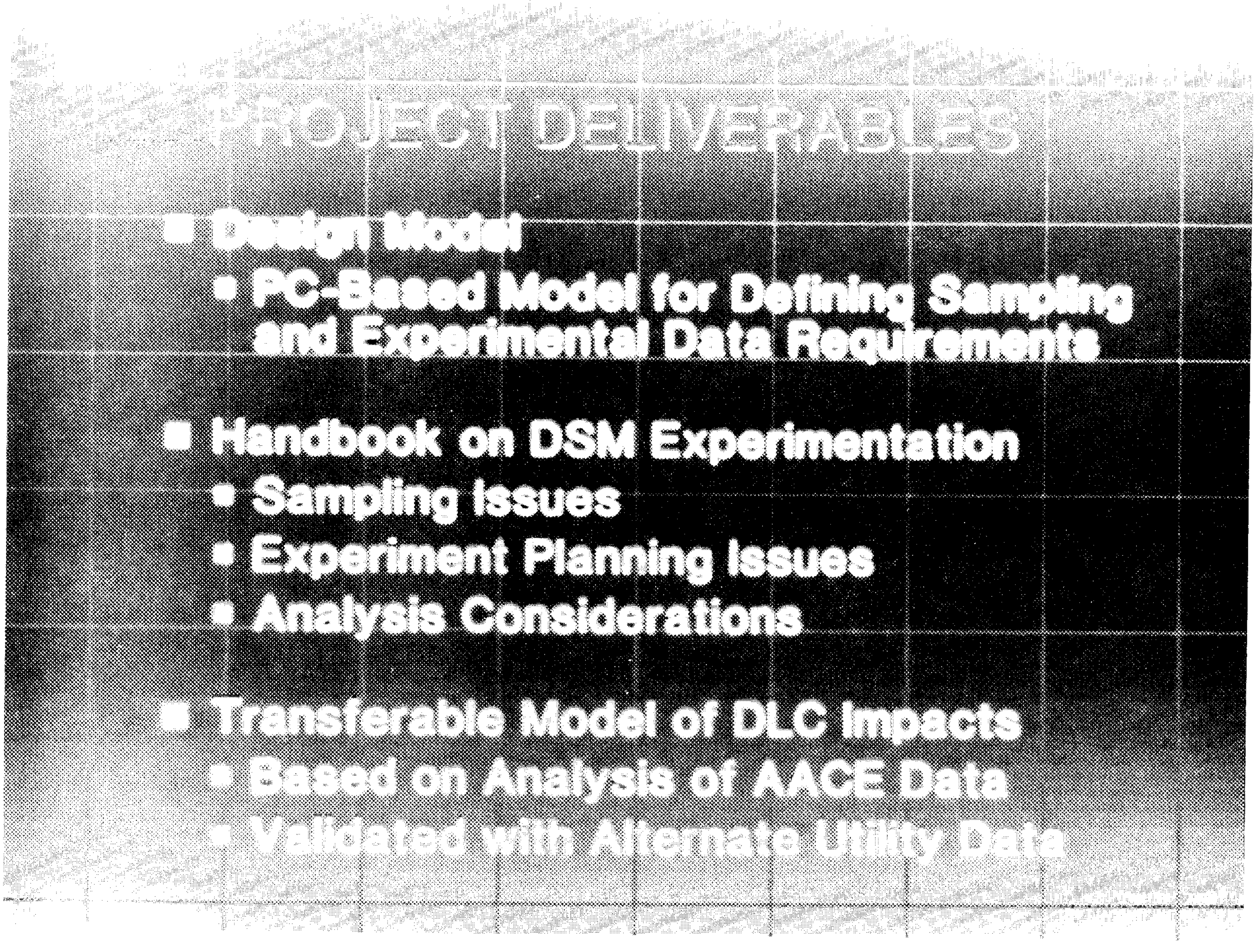
Brian Newton, Minimax Research Corporation

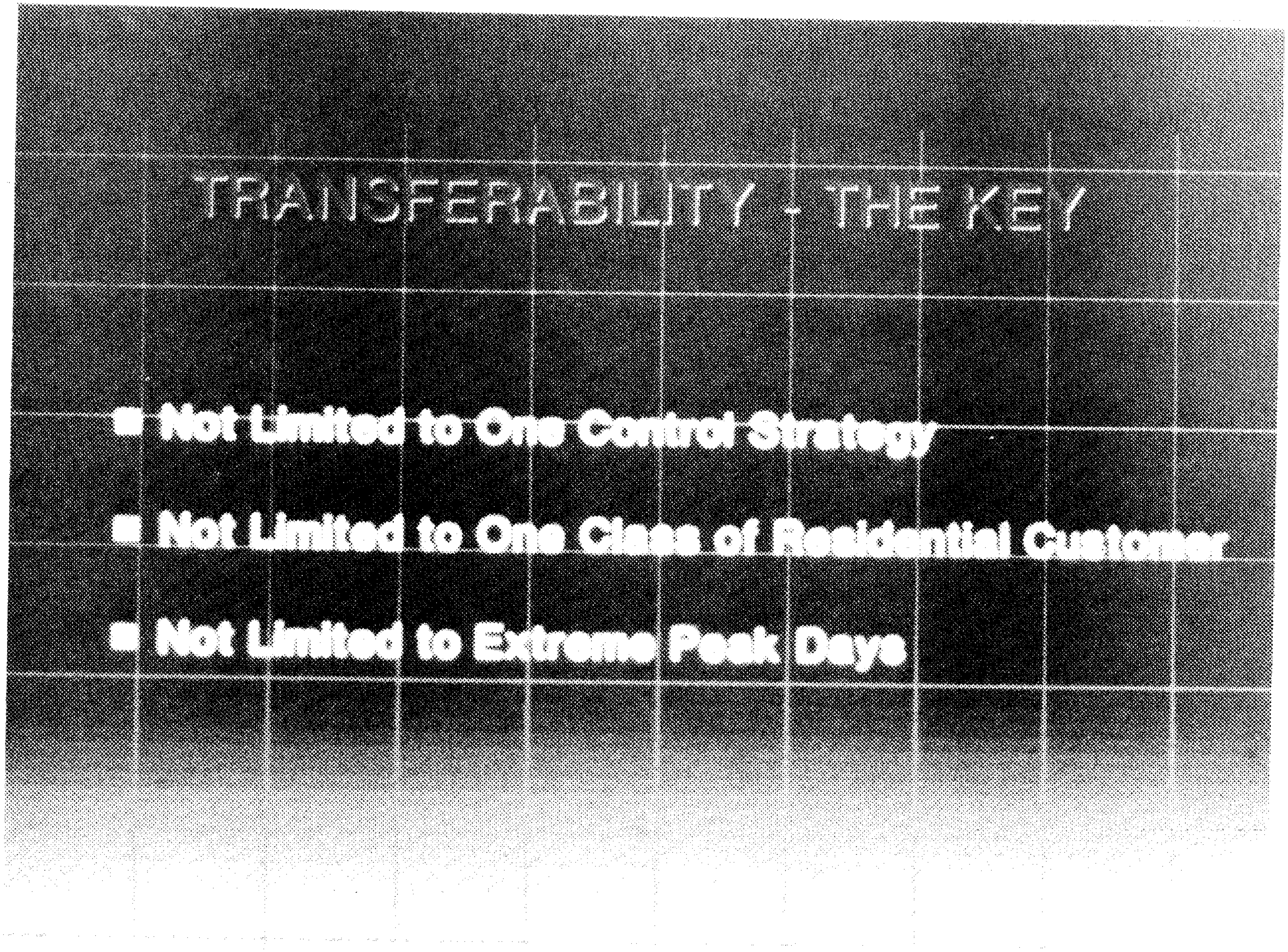
EPRI PROJECT OBJECTIVES

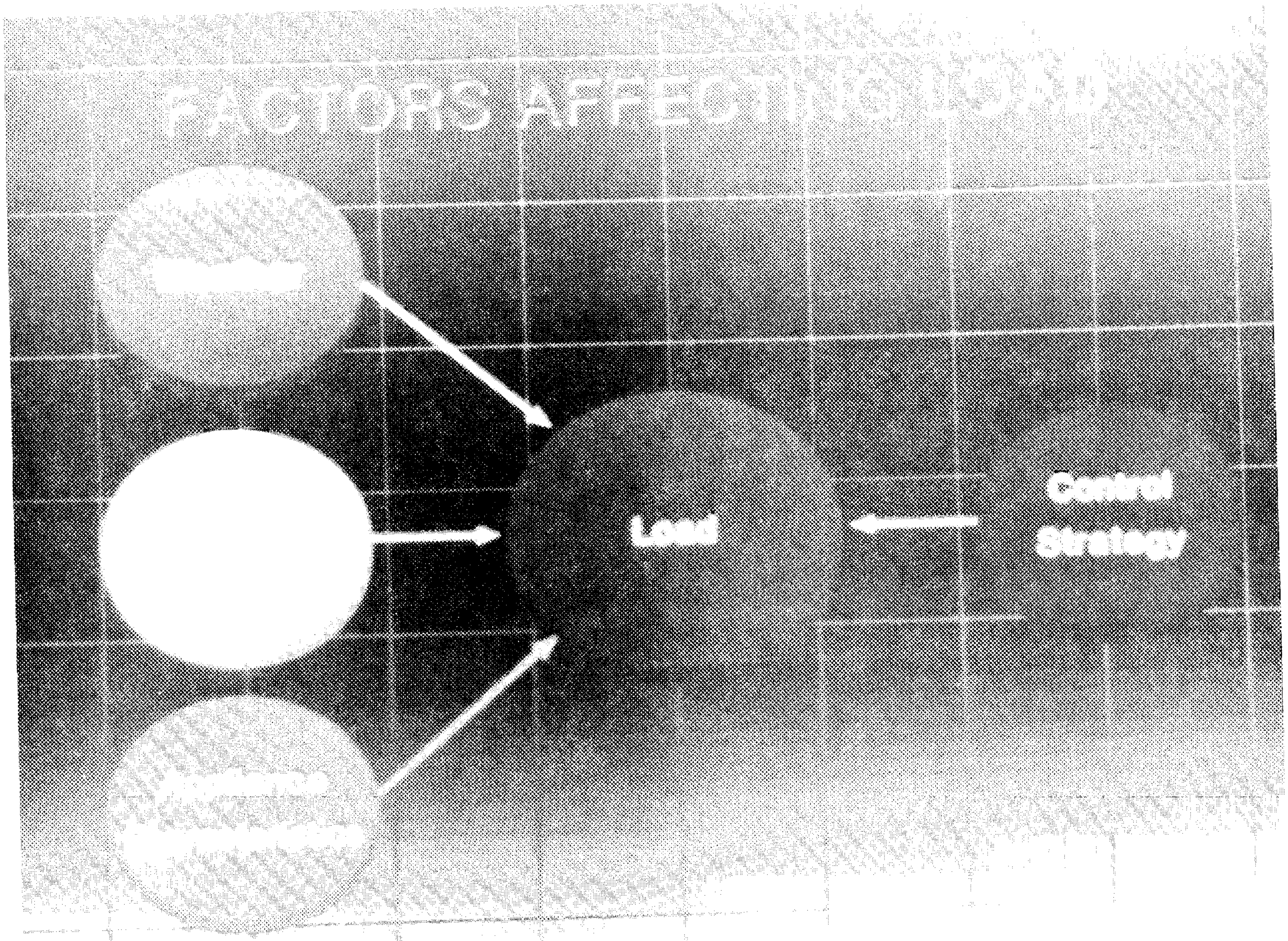
- Develop Transferable Tools for Program Design and Assessment
- Develop Analysis Data Base that Represents Residential DLC Programs

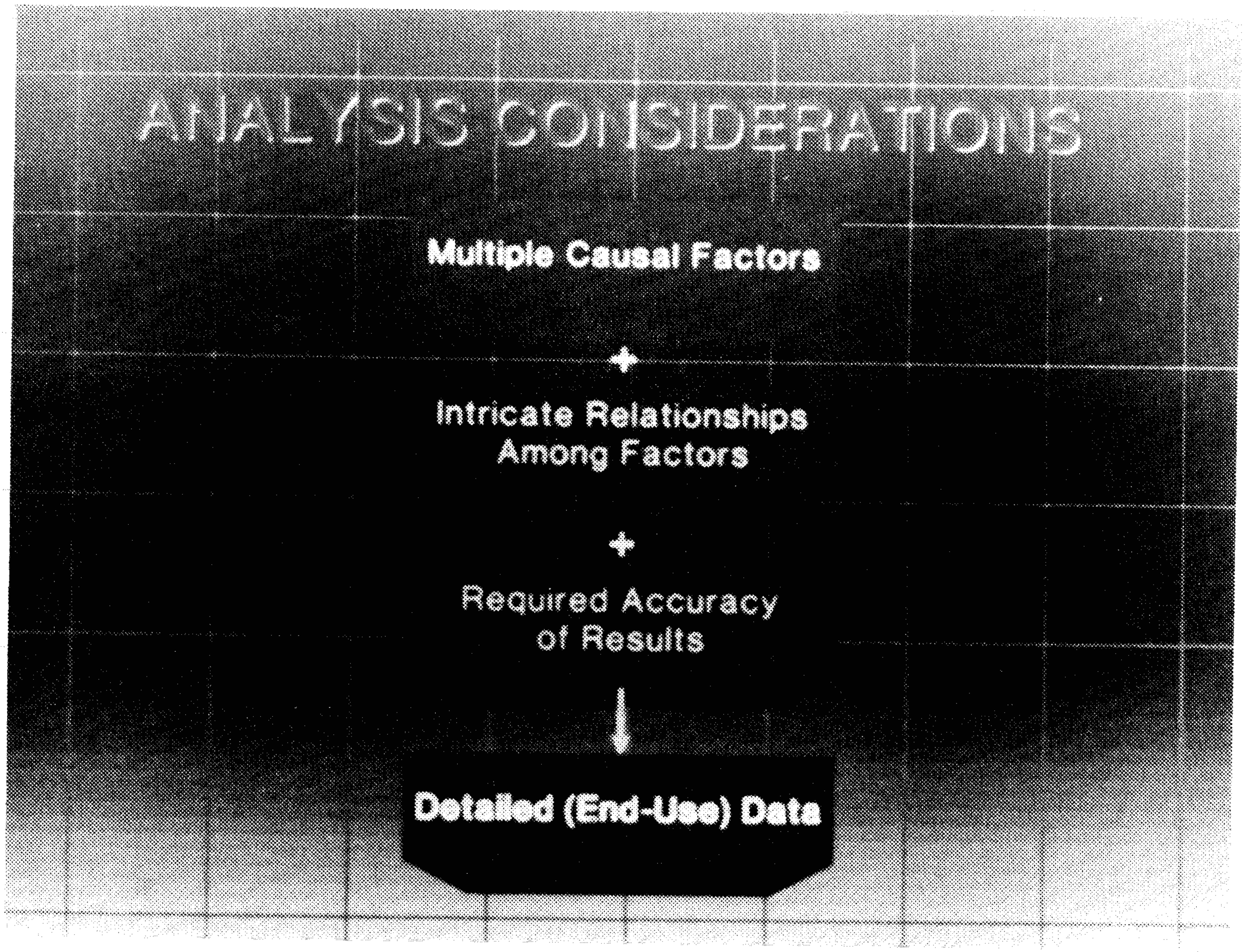
EPRI ACTIVITIES IN AACE

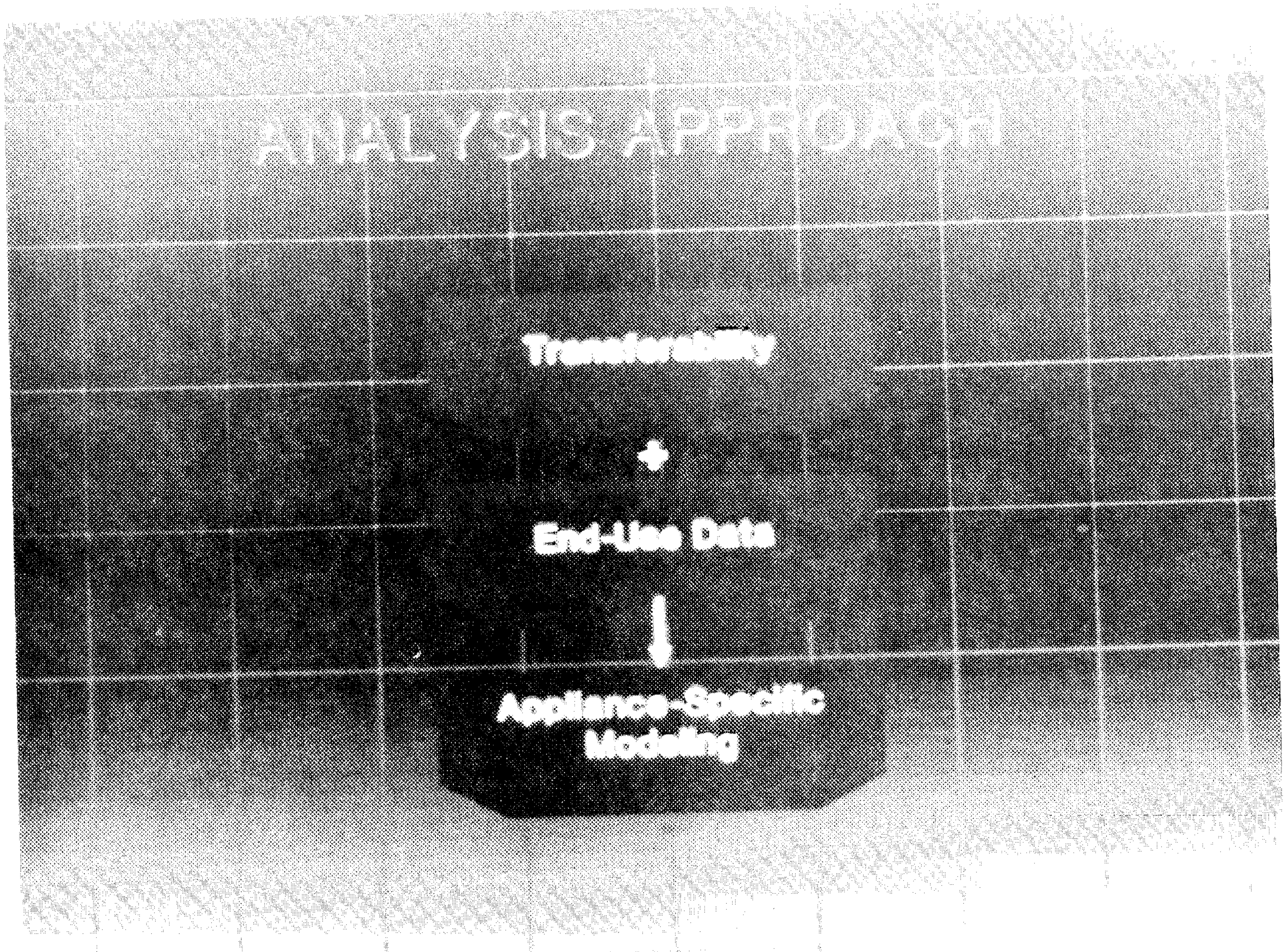
- Experimental Design
  - Sample Design
  - Experimental Plan
- Analysis Design
  - Analysis Plan
  - Impact Assessment Model


PROJECT DELIVERABLES
■ Design Model
▪ PC-Based Model for Defining Sampling and Experimental Data Requirements
■ Handbook on DSM Experimentation
▪ Sampling Issues
▪ Experiment Planning Issues
▪ Analysis Considerations
■ Transferable Model of DLC Impacts
▪ Based on Analysis of AACE Data
▪ Validated with Alternate Utility Data


TRANSFERABILITY - THE KEY
Not Limited to One Control Strategy
Not Limited to One Class of Residential Customer
Not Limited to Extreme Peak Days


FACTORS AFFECTING LOAD
Load
Control
Strategy


ANALYSIS CONSIDERATIONS
Multiple Causal Factors
+
Intricate Relationships
Among Factors
+
Required Accuracy
of Results
Detailed (End-Use) Data


ANALYSIS APPROACH
Transferability
+
End-Use Data
Appliance-Specific Modeling

ANALYSIS AND RESULTS

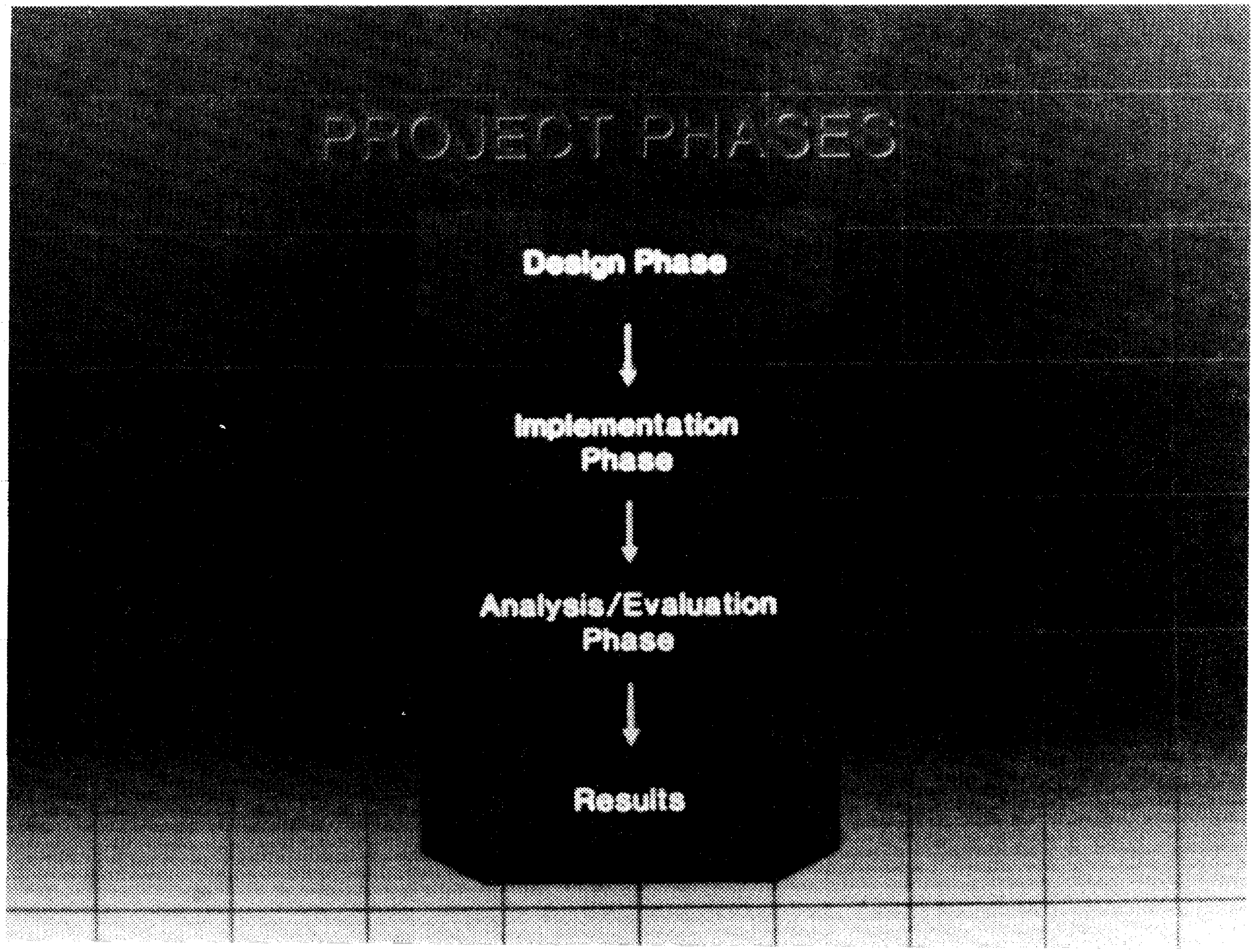
Brian K. Newton

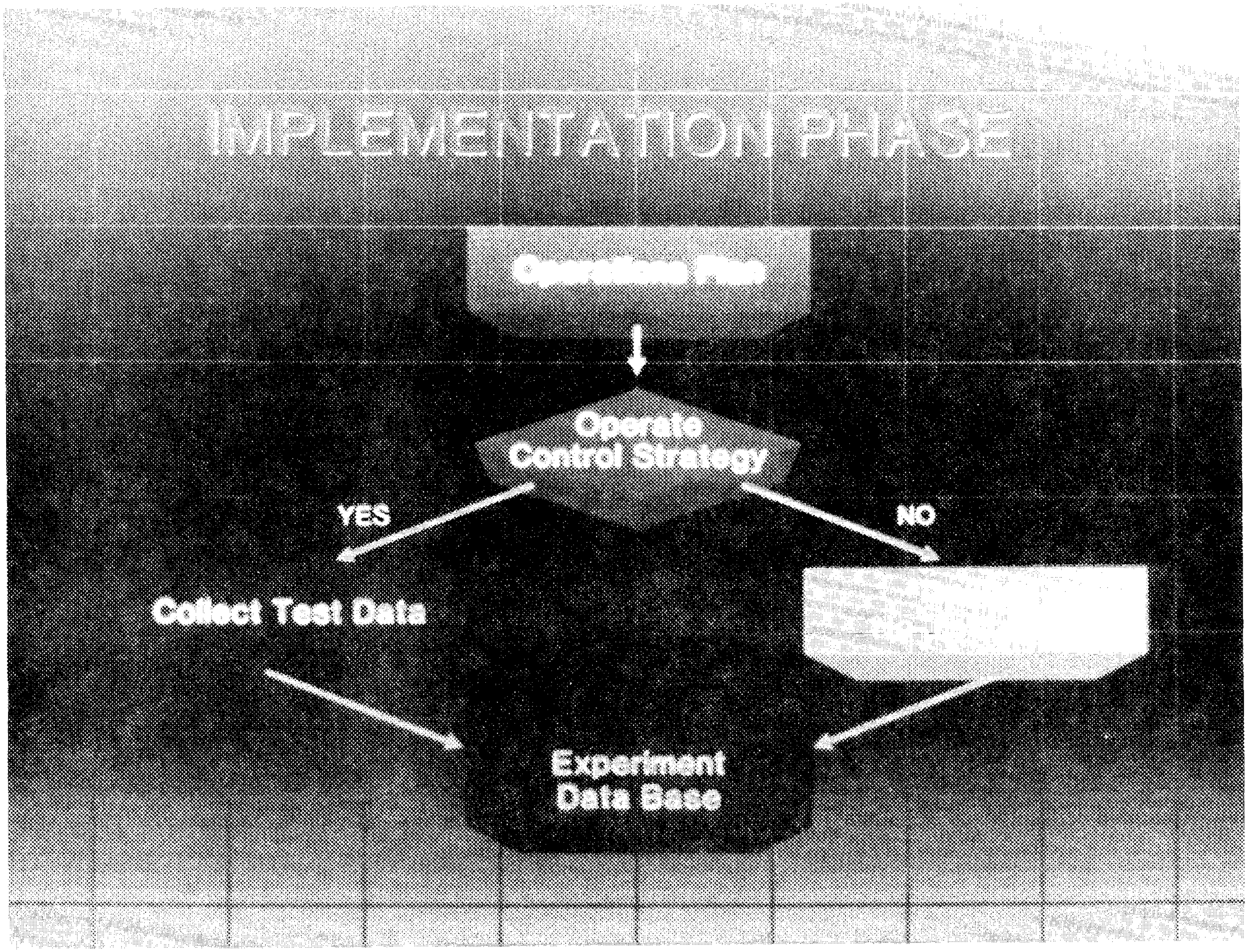
This presentation describes briefly the foundation for the analysis of the data now being collected from the EPRI ARMs submetering group in Athens, Tennessee. The emphasis of the presentation is placed on a detailed discussion of the modeling approach that has been developed for analyzing the Athens end-use data and the development of a transferable model for direct load control (DLC) impacts.

The EPRI portion of the AACE is conveniently partitioned into Design, Implementation, and Analysis/Evaluation phases all leading to desired Results. The Design phase encompassed initial specification of the model to be used in data analysis, careful preparation of a plan for sampling AUB customers based on seasonal usage and inferred appliance holdings, as well as specification of the end-use metering equipment necessary to monitor the experiments. Implementation activities included development of an indoor temperature-sensing device to provide a physical measure of DLC impacts as well as completion of an experiment plan that specifies which control actions will be implemented for each appliance under study. The Analysis phase is now beginning and will employ the Duty Cycle Impact Model for assessing baseline behavior, control impacts, and customer acceptance.

The Duty Cycle Impact Model focuses on the physical behavior of the appliance under control. For any time period, appliances such as space heaters and air conditioners have a natural cycle of operation. The proportion of time "on" is called the duty cycle of the appliance. Direct load control alters the natural duty cycle of an appliance in the case where the natural duty cycle exceeds that permitted by the control strategy. For example, an appliance that would normally operate at an 80% duty cycle would be restricted to 75% operation by a control strategy of 25%.

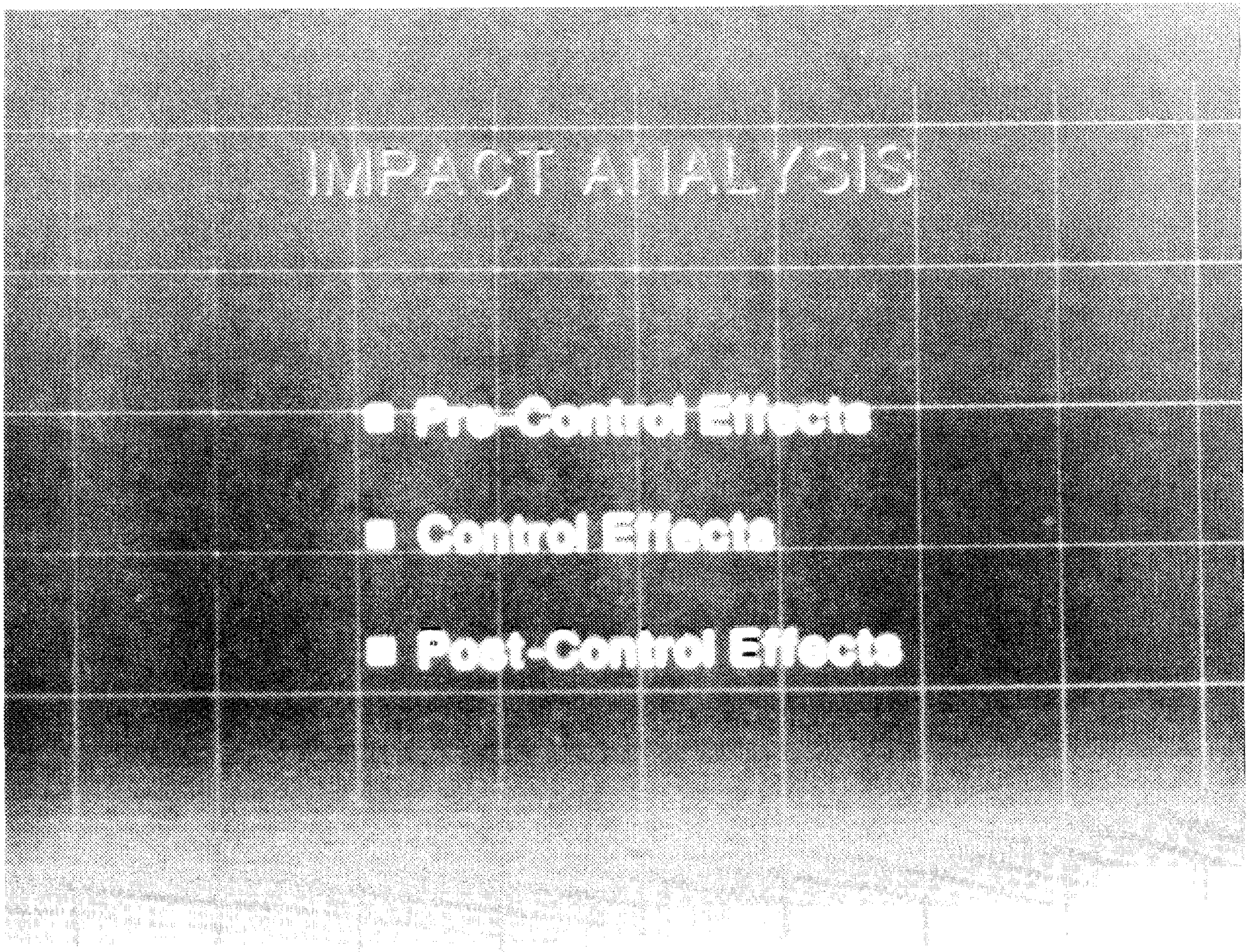
The Duty Cycle Impact Model will be used to estimate the distribution of duty cycles for each time period of the day. Since each appliance has a natural duty cycle for each time period, a collection of appliances will exhibit a distribution of duty cycles for each time period. Considering all of these distributions over a day, one for each time period, we obtain a duty cycle distribution surface that describes the behavior of the set of appliances over the entire day. The impacts, pre-control, control, and post-control will be evaluated by modeling the changes in the surface caused by various DLC strategies.

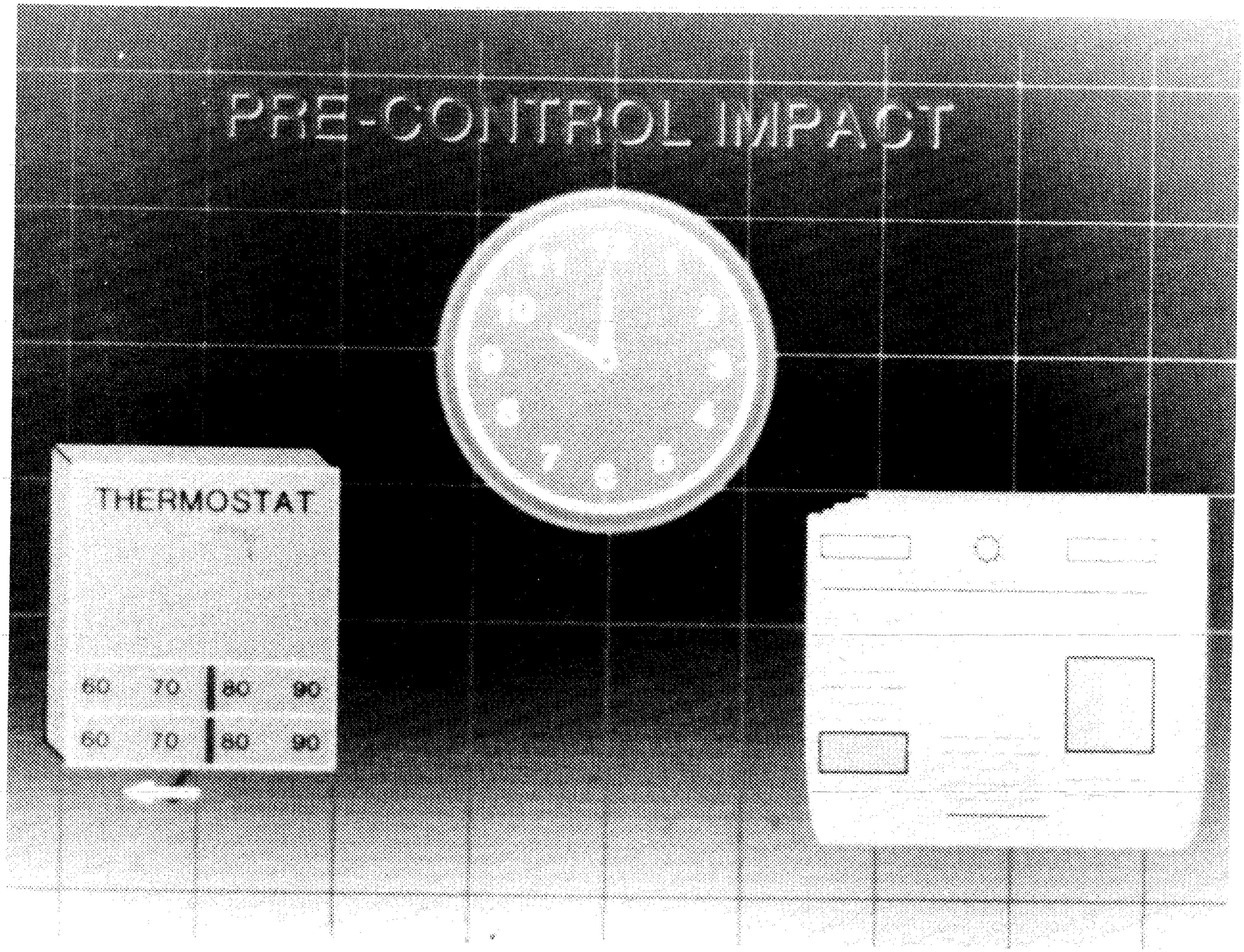

PROJECT PHASES
Design Phase
Implementation Phase
Analysis/Evaluation Phase
Results

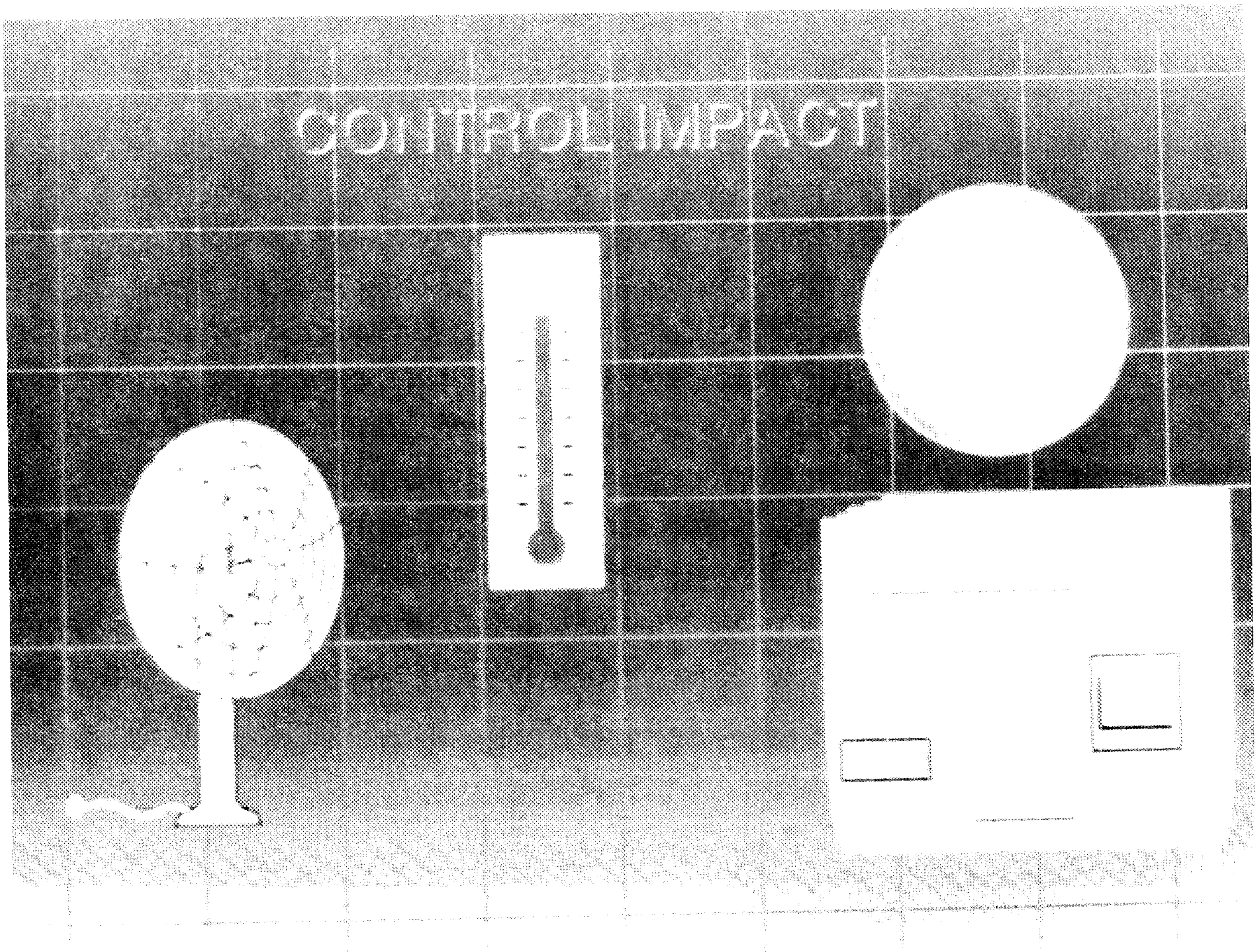

IMPLEMENTATION PHASE
Operate
Control Strategy
YES
NO
Collect Test Data
Experiment
Data Base

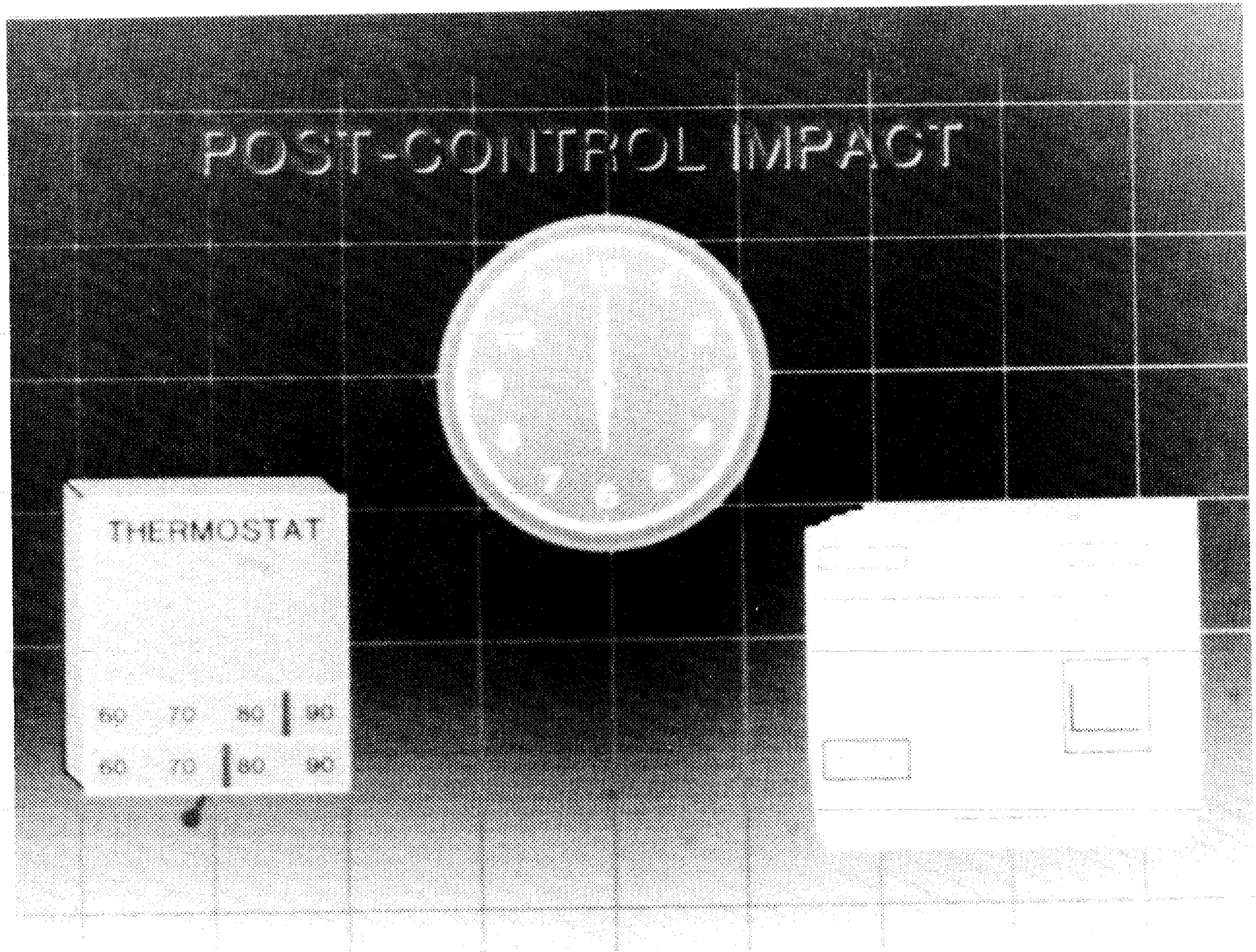
ANALYSIS PHASE

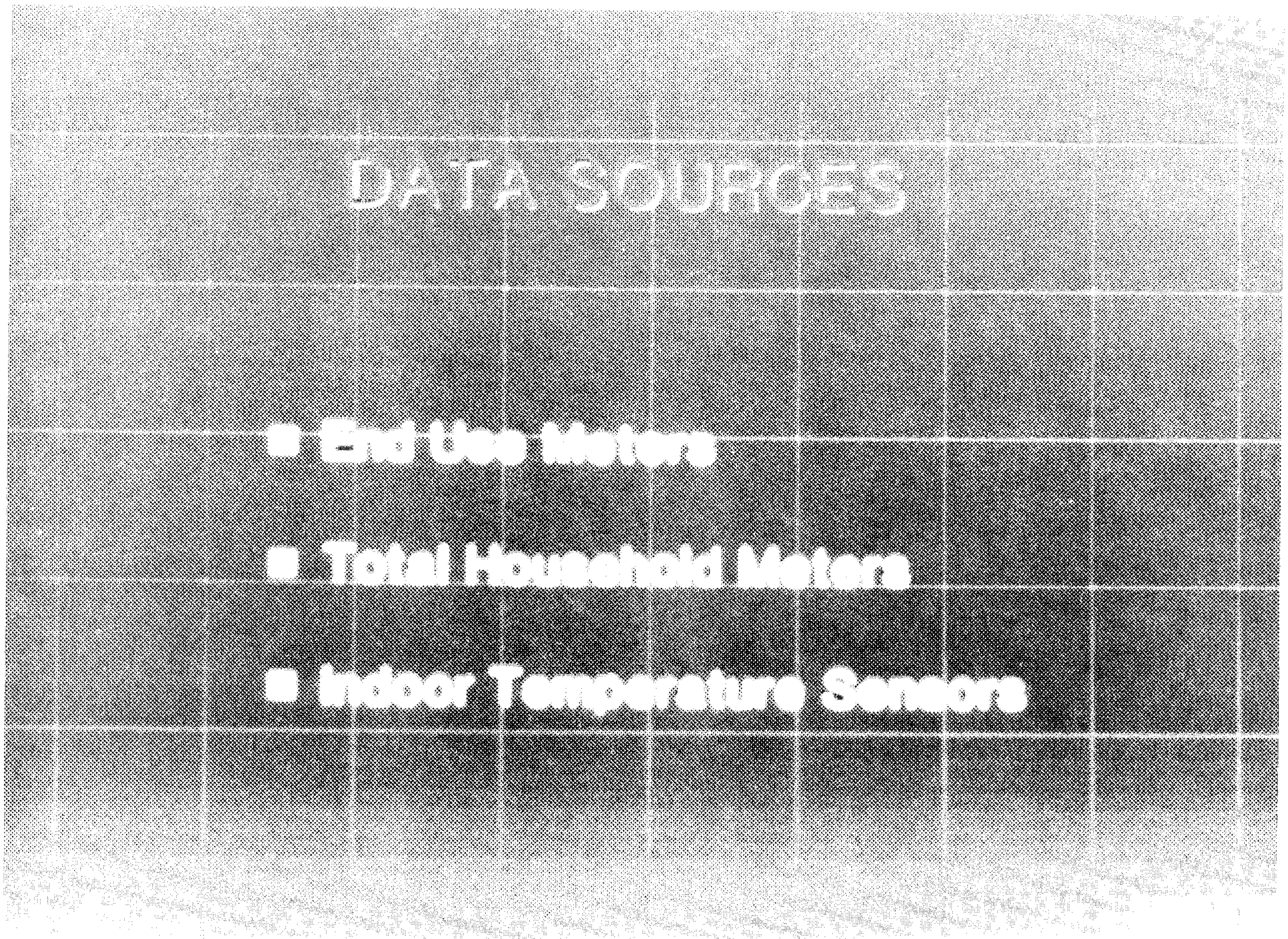
- Load and Energy Data Analysis
- Impact Analysis Through Appliance Duty Cycles
- Customer Acceptance Analysis


IMPACT ANALYSIS
Pre-Control Effects
Control Effects
Post-Control Effects


PRE-CONTROL IMPACT
THERMOSTAT
60 70 80 90
60 70 80 90

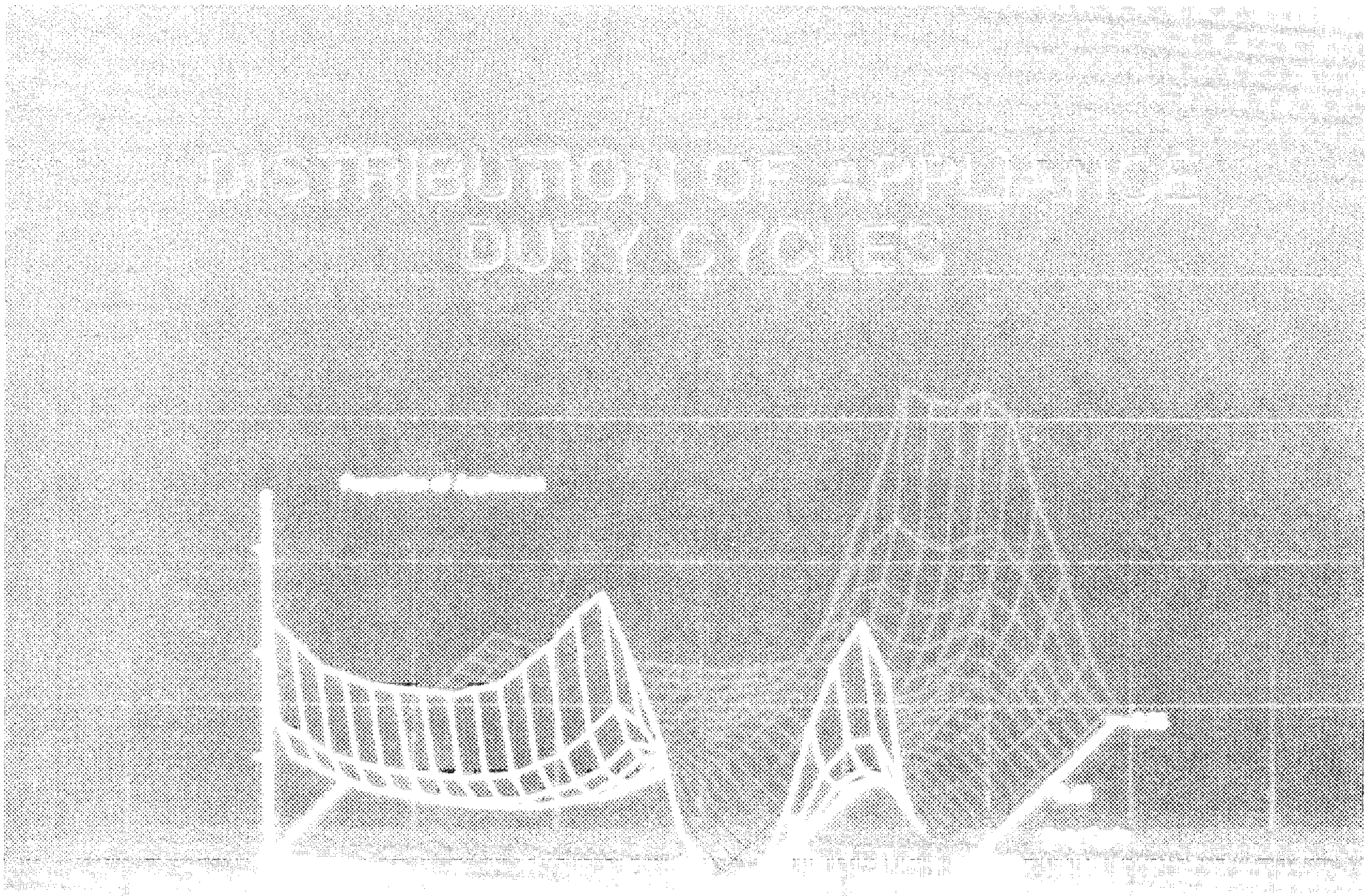

CONTROL IMPACT

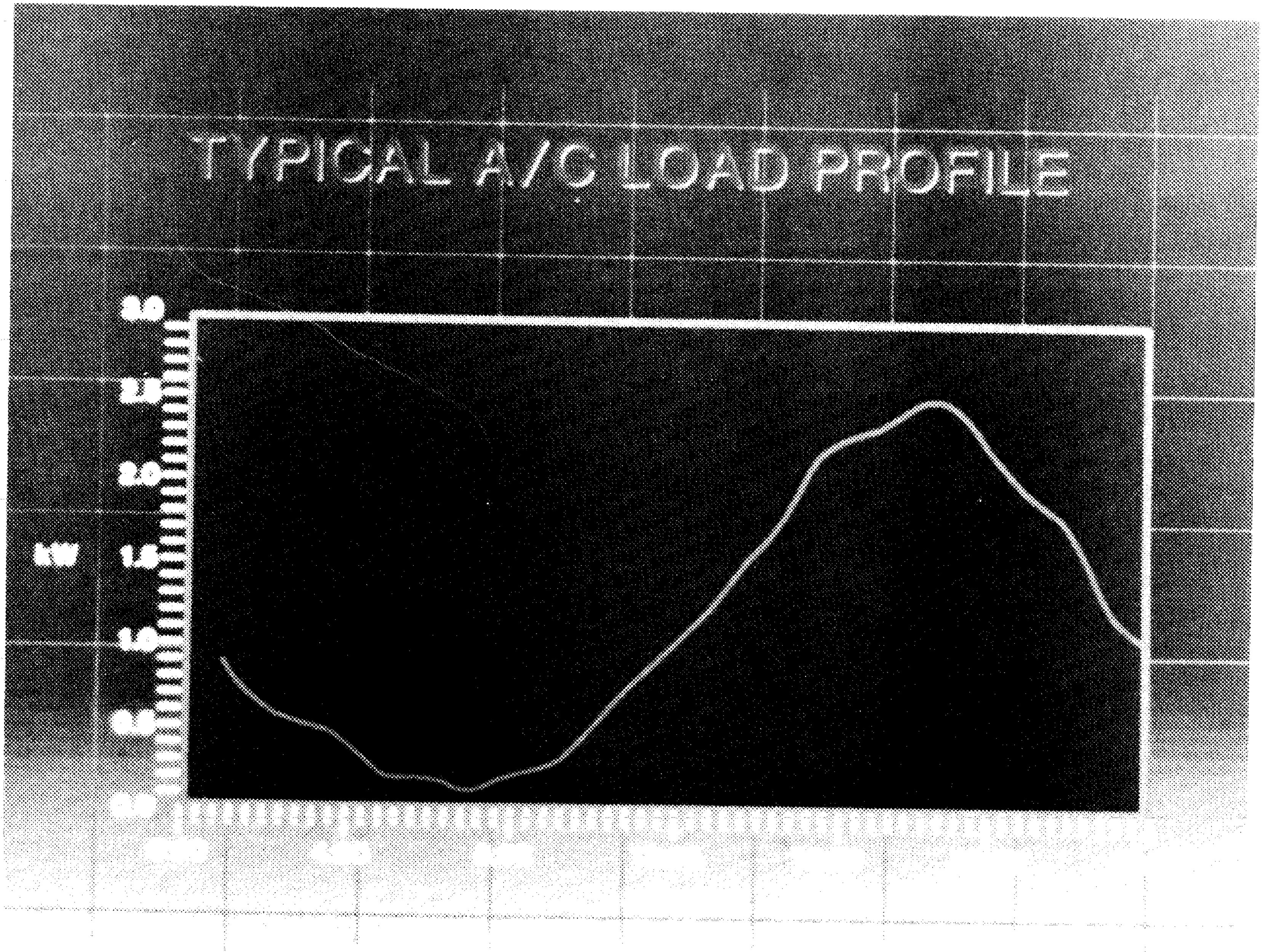

POST-CONTROL IMPACT
THERMOSTAT
60 70 80 90
60 70 80 90

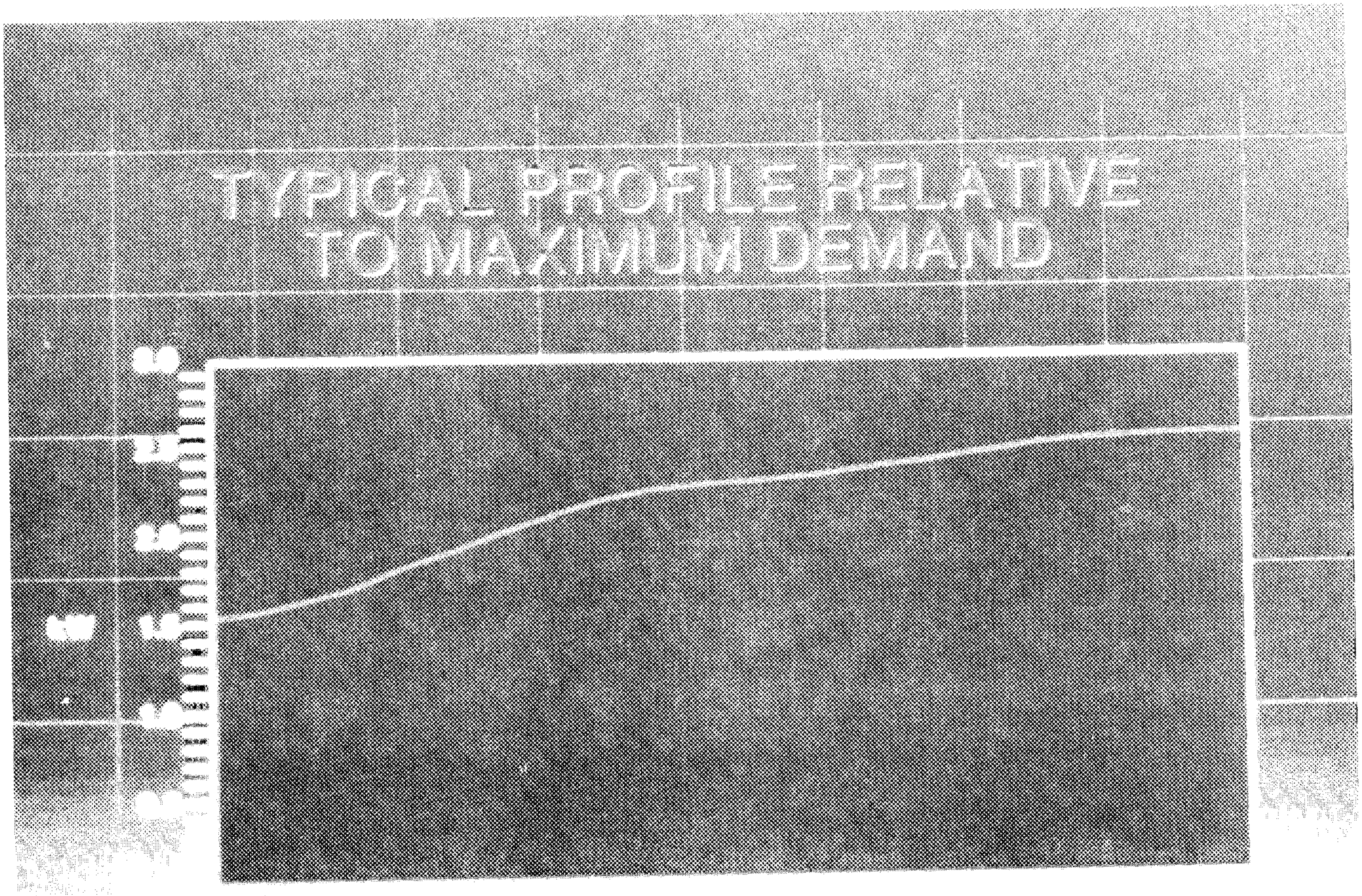

DATA SOURCES
End Use Meters
Total Household Meters
Indoor Temperature Sensors

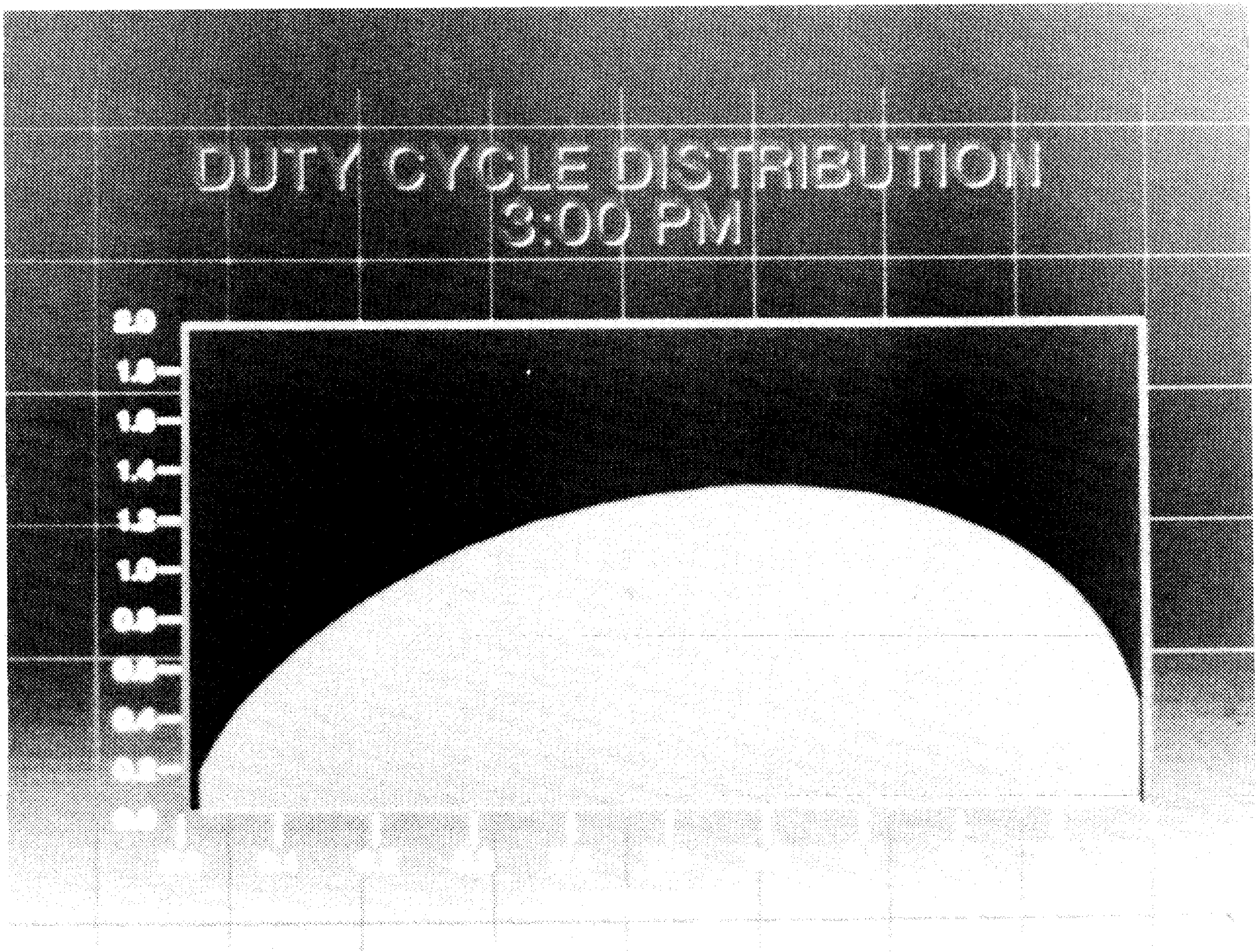
DUTY CYCLE IMPACT MODEL

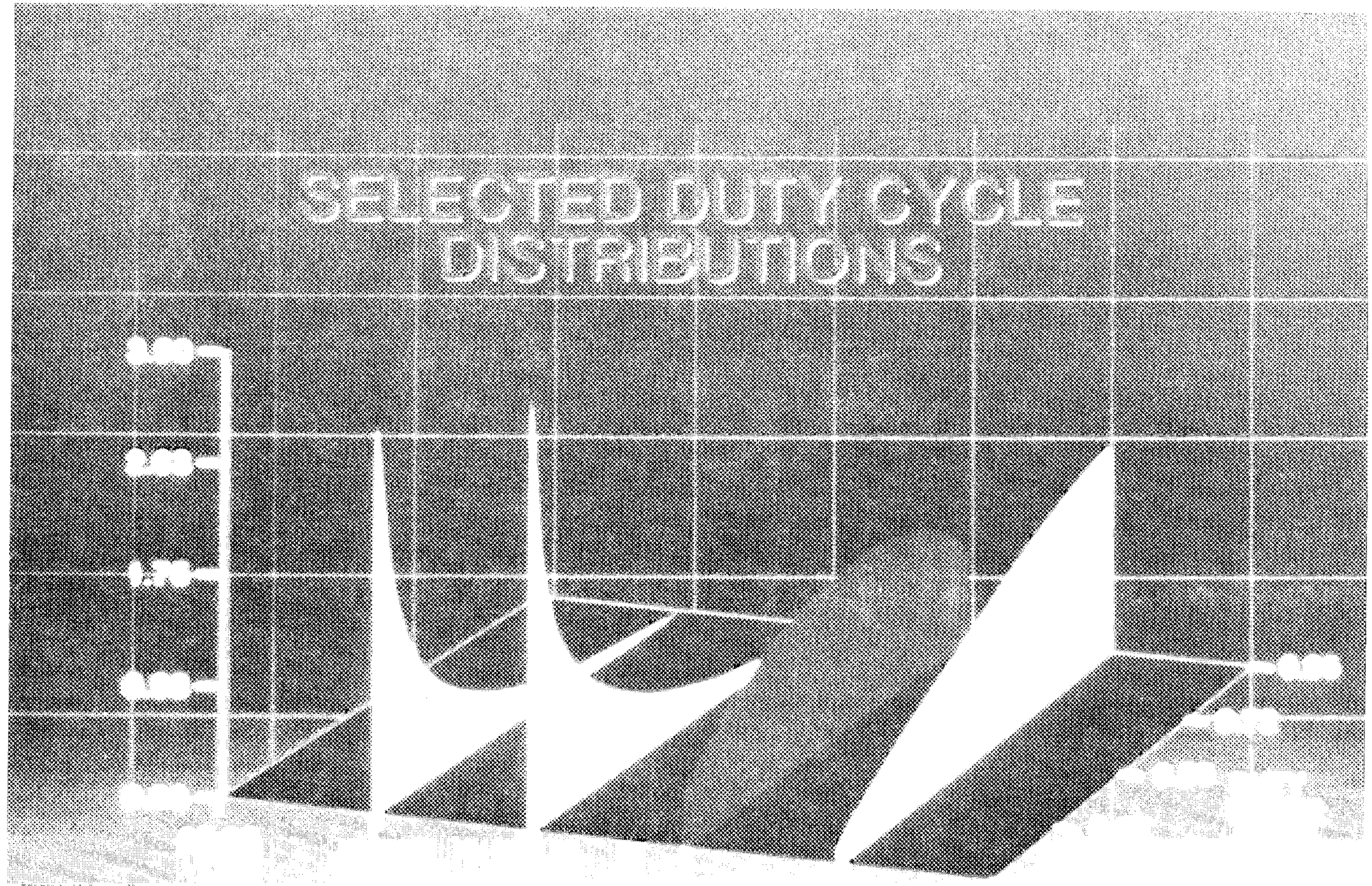
- Founded on Engineering Effects of Direct Load Control
- Based on Statistical Model of Appliance Duty Cycle Distributions
- Accounts for Behavioral, Physical, and Economic Effects

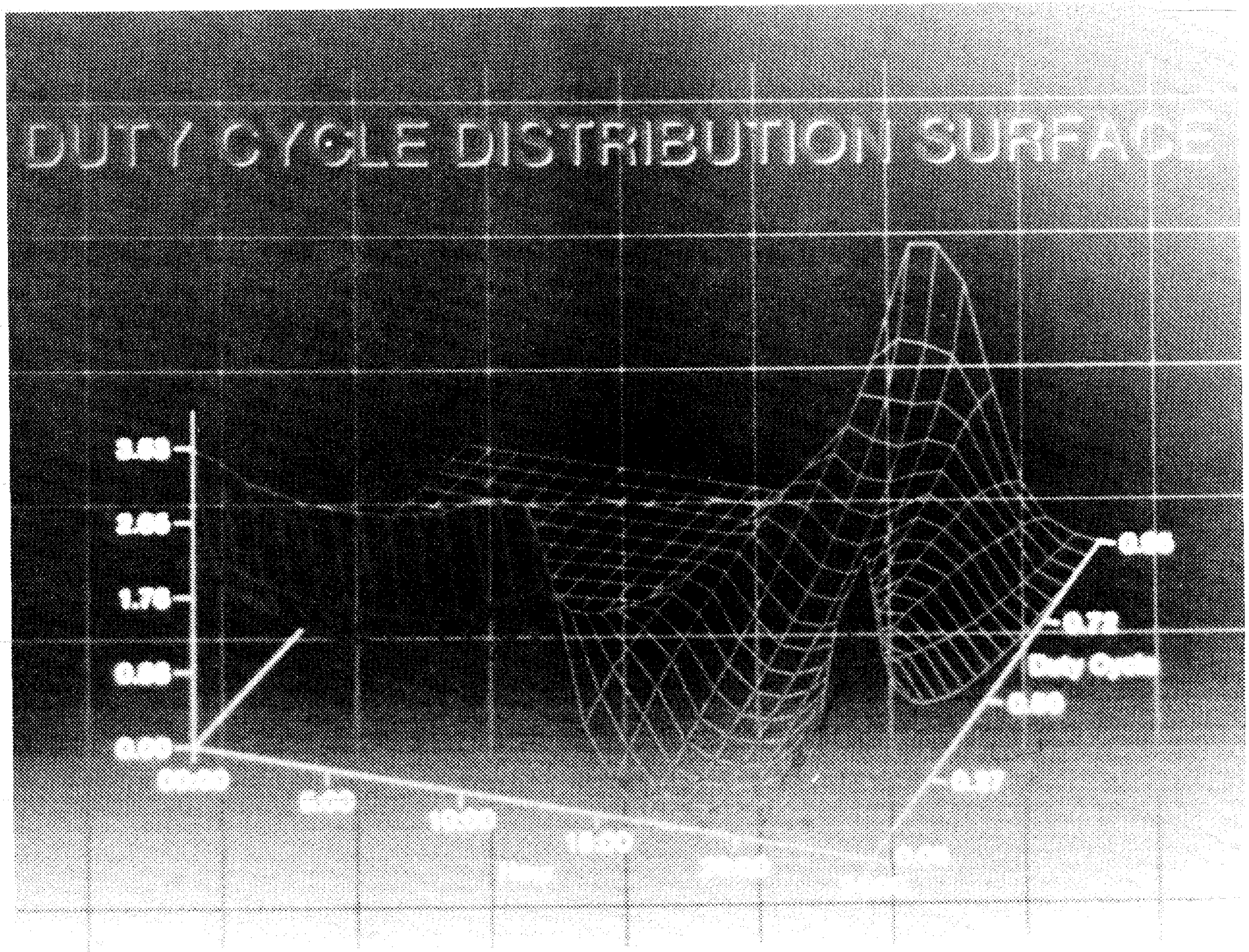

DISTRIBUTION OF APPLIANCE
DUTY CYCLES

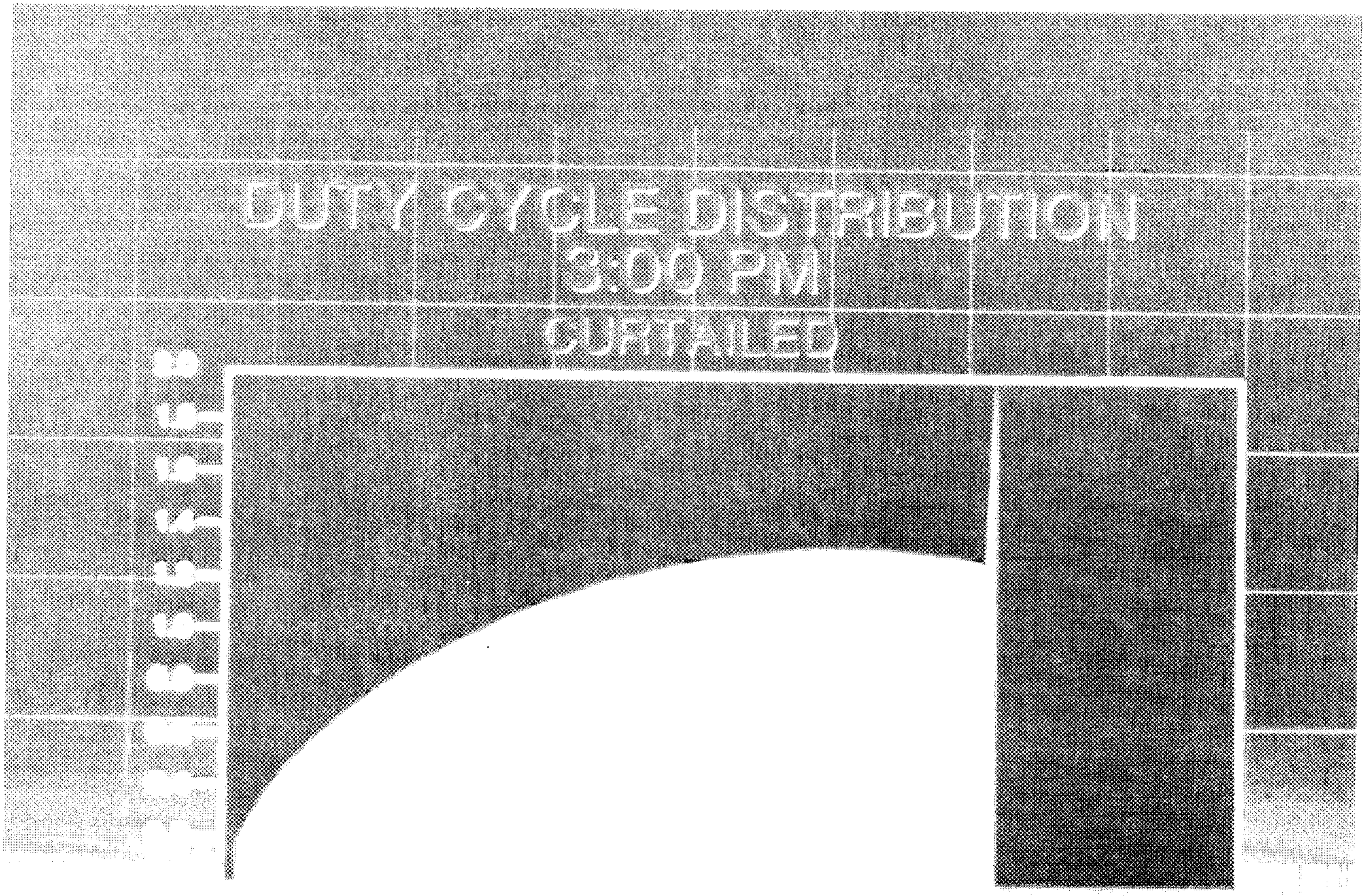

TYPICAL A/C LOAD PROFILE
kW
3.0
2.5
2.0
1.5
1.0
0.5
0.0

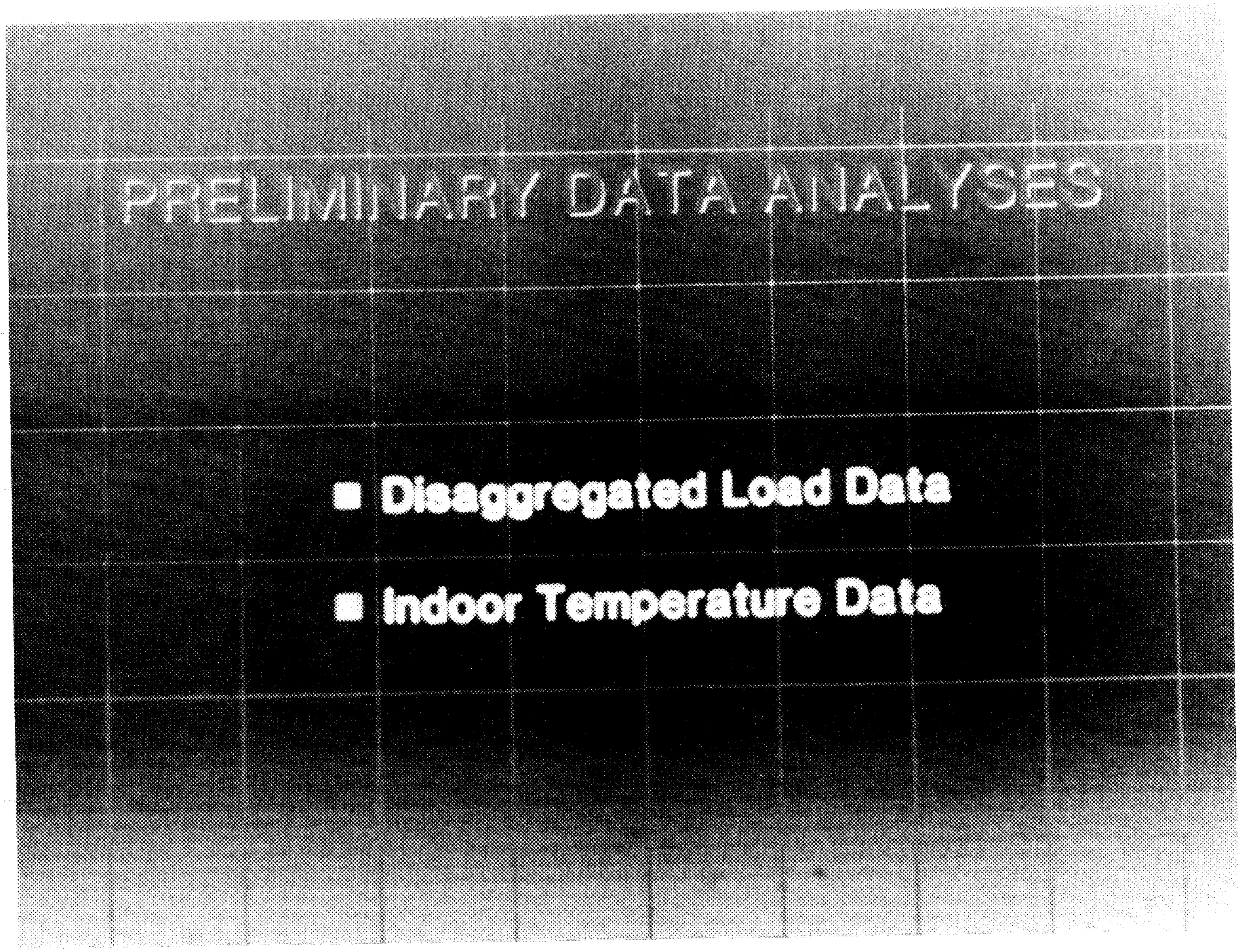

TYPICAL PROFILE RELATIVE
TO MAXIMUM DEMAND

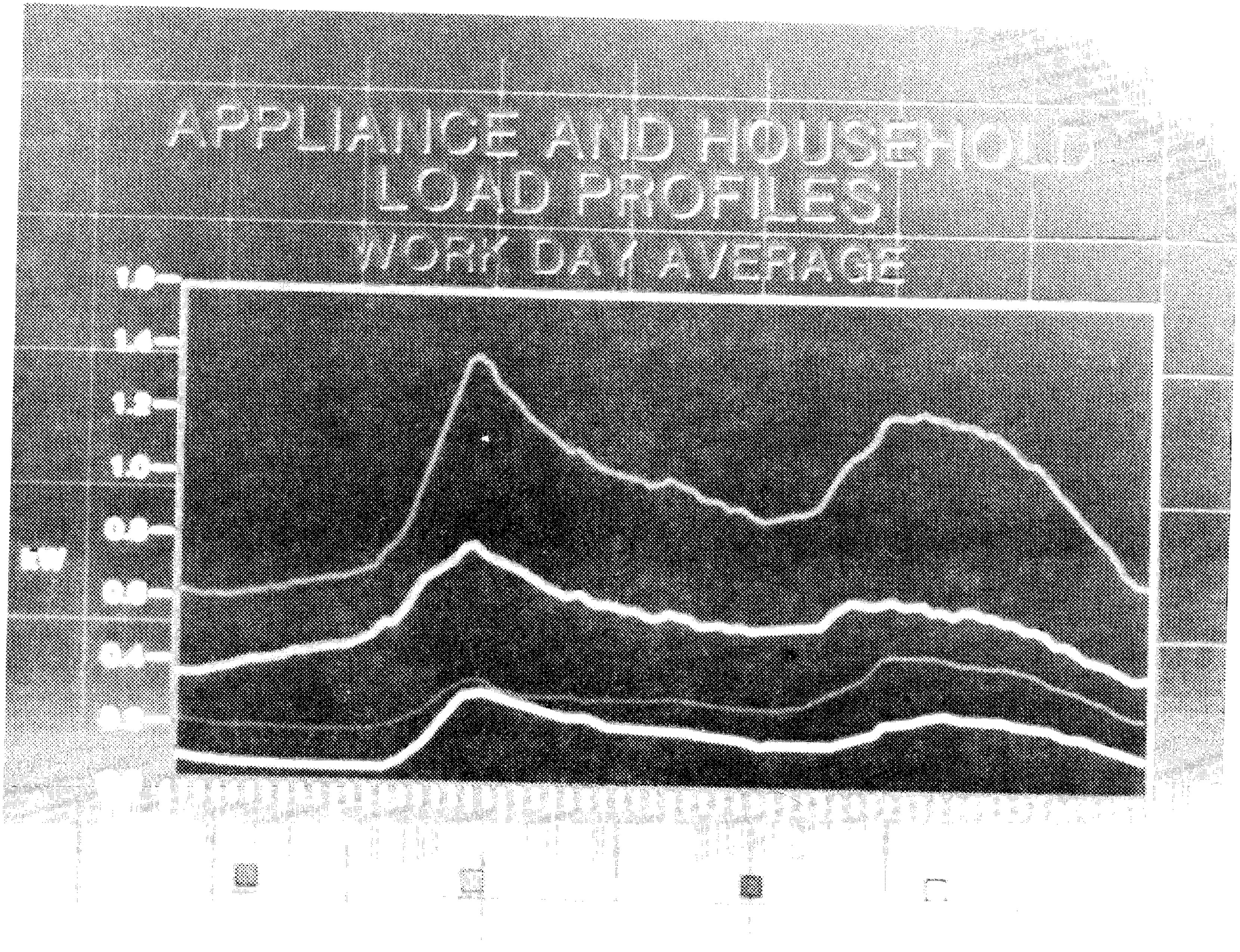

DUTY CYCLE DISTRIBUTION
3:00 PM

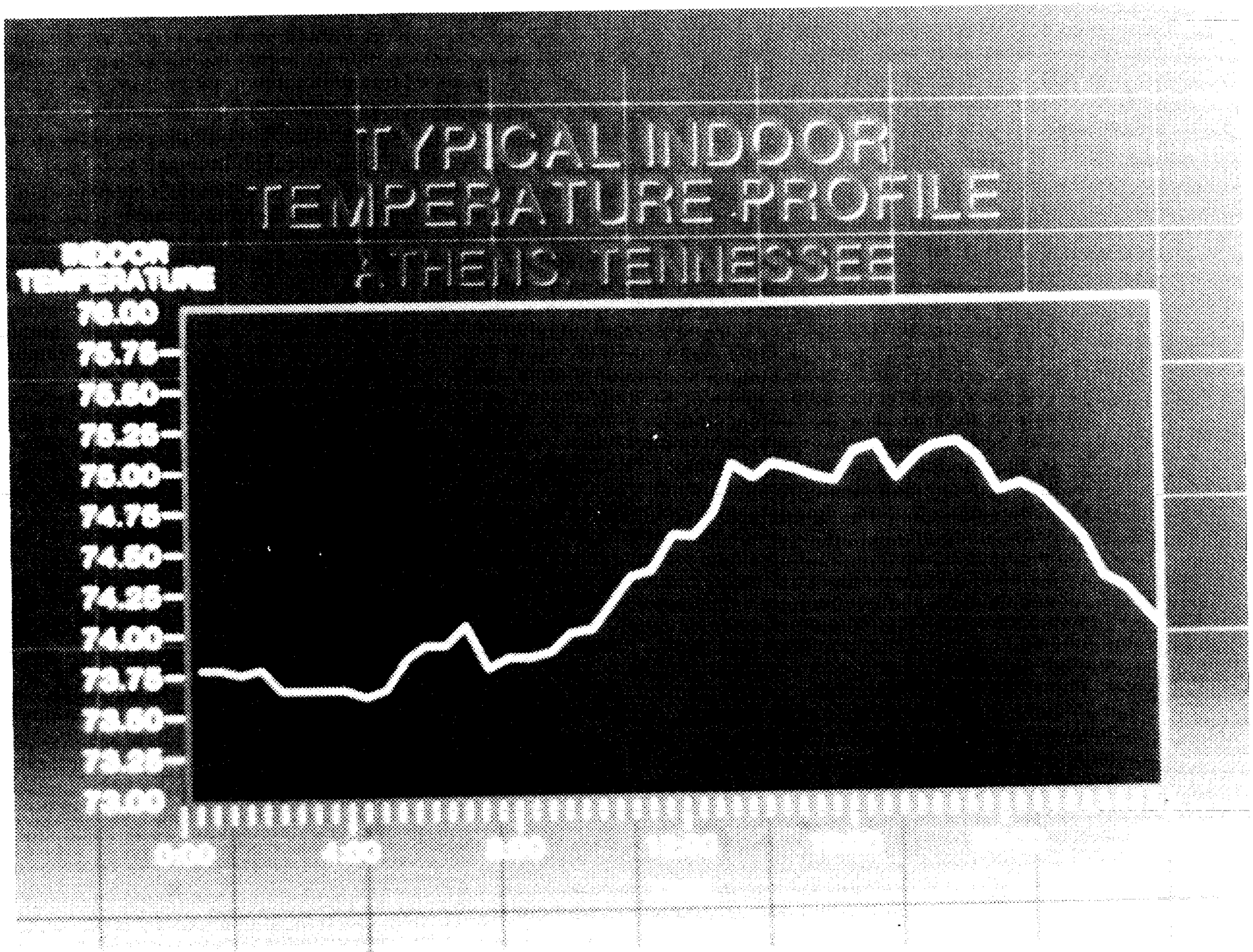

SELECTED DUTY CYCLE
DISTRIBUTIONS


DUTY CYCLE DISTRIBUTION SURFACE
Duty Cycle


DUTY CYCLE DISTRIBUTION
3:00 PM
CURTAILED


PRELIMINARY DATA ANALYSES
■ Disaggregated Load Data
■ Indoor Temperature Data


APPLIANCE AND HOUSEHOLD
LOAD PROFILES
WORK DAY AVERAGE
kW



TYPICAL INDOOR
TEMPERATURE PROFILE
ATHENS, TENNESSEE
INDOOR
TEMPERATURE
76.00
75.75
75.50
75.25
75.00
74.75
74.50
74.25
74.00
73.75
73.50
73.25
73.00

SOFTWARE TEST SYSTEM

THE ATHENS AUTOMATION AND CONTROL EXPERIMENT TEST SYSTEM (AACETS) AND ITS ROLE IN 1985

G. R. Wetherington, Jr.

The AACETS is a general purpose support tool that was developed by ORNL to support the activities of the Athens Automation and Control Experiment (AACE). The AACETS consists of two major subsystems. The first is a scaled-down copy of the Athens IDCS that features the same type of host computer, software, and database as the IDCS. The second subsystem is an electrical distribution system simulator called the smart test panel. The smart test panel is based on a commercially available automation device called a programmable controller and is used to generate electrical signals that are monitored by the control subsystem as KV, KW, KVAR, etc. Previously gathered distribution system data can be tabularized in the programmable controller's memory and sequentially accessed and transferred as electrical signals to the control subsystem such that they appear like those associated with the AUB electrical distribution system. As a productivity enhancer, the AACETS provides the facilities for software development, the capabilities for more thorough verification and validation of software prior to installation on the IDCS, and it also minimizes project dependency on system support. In addition, the AACETS has assisted in the procurement, installation, and shakedown of the IDCS. The AACETS provided support in three major areas during 1985. These areas are system management, data acquisition, and software development.

System management concerns computer systems planning, support, and features enhancement. The IDCS database, which consists of over 20,000 points, was built on the AACETS and involved approximately 9 man-months of effort. In addition, project personnel have acquired a detailed understanding of the MODSCAN software package—the software heart of the IDCS—that enables more effective system utilization for experimental applications.

Two data acquisition packages are supported on the AACETS. One package, which was developed at ORNL, is responsible for the acquisition of pre-experimental remote substation data. It allows the monitoring and storage of up to 60 points from each of the three main AUB substations on a 5- to 10-min repetitive basis, or high speed (7-sec) acquisition of the data from any one of the substations. The second data acquisition package supports the Electric ARM system, which was supplied by EPRI. This system allows monitoring of up to four selected appliances in each of 200 residences in Athens.

Software development on the AACETS can be categorized into two classifications. The first classification is referred to as support utilities (programs) which are of general benefit to all experimental areas. Examples include programs that interact with the IDCS history subsystem for the purpose of archiving system information over extended periods and a database reverse compiler that is used to capture any database modifications entered from the operator's consoles. The second classification of software that has been developed on the AACETS is referred to as software for experimental applications. This classification represents the programs that are developed to support the individual experimental needs of the load control, volt/var control, and system reconfiguration efforts. Examples include an experiment planner/implementer for the load control effort, a capacitor control program for the volt/var effort, and an integrated version of System Reconfiguration Analysis Package (SYSRAP) to support the system reconfiguration activities.

THE ATHENS AUTOMATION AND CONTROL EXPERIMENT TEST SYSTEM (AACETS), AND ITS ROLE IN 1985

G. R. WETHERINGTON JR.

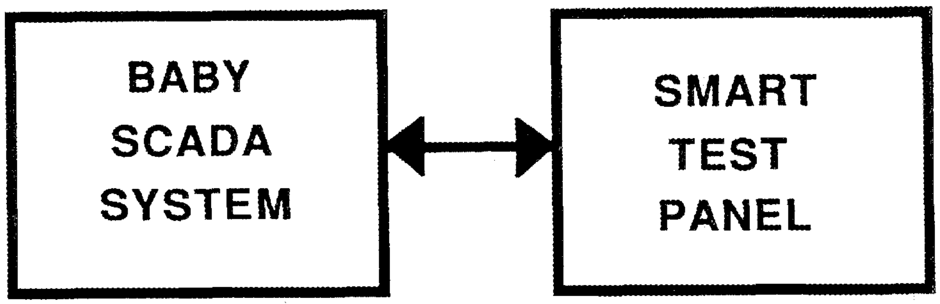
ORNL
INSTRUMENTATION AND CONTROLS DIVISION

DECEMBER 4, 1985

SYSTEM DESCRIPTION

SUMMARY OF 1985 ROLE

THE AACETS CONSISTS OF TWO SUBSYSTEMS

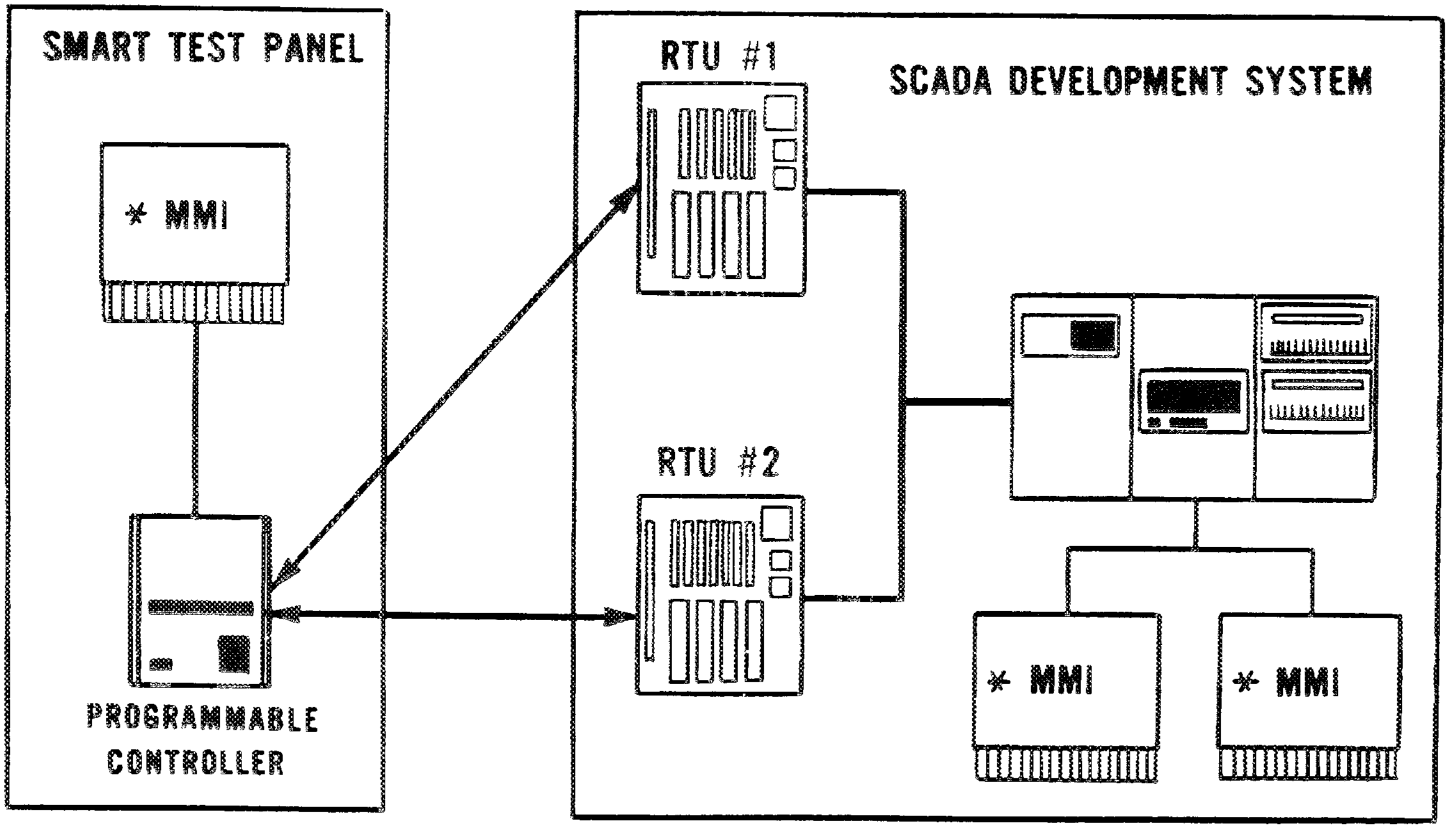


MODSCAN SUPPORT
DATABASE SUPPORT
OPERATOR DISPLAY DESIGN
DATA ACQUISITION
(EPRI / ORNL)

PROVIDES PROCESS
DATA & CONTROL
RESPONSES

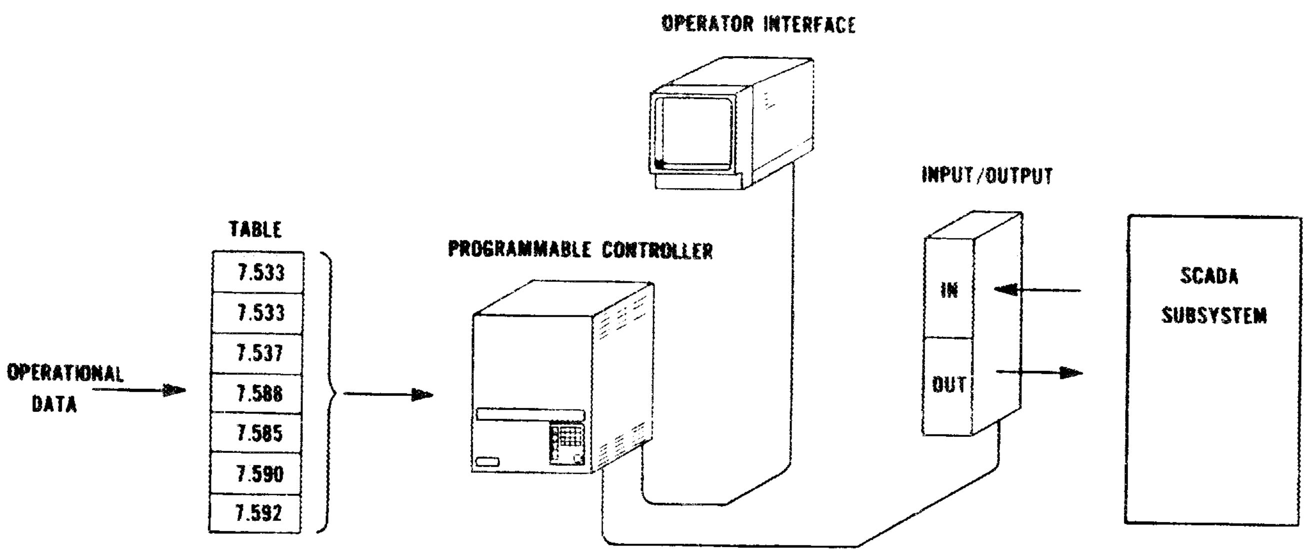
ORNL-DWG. 85-16106

AACETS



* MAN MACHINE INTERFACE (MMI)

ORNL-DWG 85-16104



THE AACETS IS DESIGNED TO IMPROVE PRODUCTIVITY

- FACILITATE SOFTWARE DEVELOPMENT
- PROVIDE FOR MORE THOROUGH SOFTWARE QUALITY ASSURANCE
- ASSIST IN THE PROCUREMENT, INSTALLATION, AND SHAKEDOWN OF THE IDCS
- MINIMIZE PROJECT DEPENDENCY ON SYSTEM SUPPORT
  - APPLICATIONS SOFTWARE
  - SYSTEM SOFTWARE AND SUPPORT
  - DEVELOPMENT ACTIVITIES ARE INDEPENDENT OF THE IDCS

MAJOR AREAS OF SUPPORT IN 1985

- SYSTEM MANAGEMENT
- DATA ACQUISITION
- SOFTWARE DEVELOPMENT
    - SUPPORT UTILITIES (PROGRAMS)
    - EXPERIMENTAL APPLICATIONS

SYSTEM MANAGEMENT CONCERNS COMPUTER SYSTEMS PLANNING, SUPPORT, AND FEATURES ENHANCEMENT

- DATABASE

  > 20,000 POINTS

  EACH POINT CONSISTS OF UP TO 38 ATTRIBUTES

  9 MONTH EFFORT

- MODSCAN

  USE / APPLICATION (SOLID FOUNDATION)

  FEATURES ENHANCEMENT

  MAINTENANCE

ATTRIBUTES ARE PIECES OF INFORMATION THAT MAKE UP A DATABASE POINT

ANALOG POINTS REQUIRE 38 ATTRIBUTES

- ALARM LIMITS
- ALARM STATE
- ALARM ACKNOWLEDGEMENT STATE
- ALARM DEADBAND
- POINT NAME
- ENGINEERING UNITS
- CONVERSION SCALING FACTOR
- CONVERSION OFFSET
- SENSITIVITY
- VALUE OVERRIDE INDICATION

THE AACETS SUPPORTS TWO MAJOR DATA ACQUISITION PACKAGES

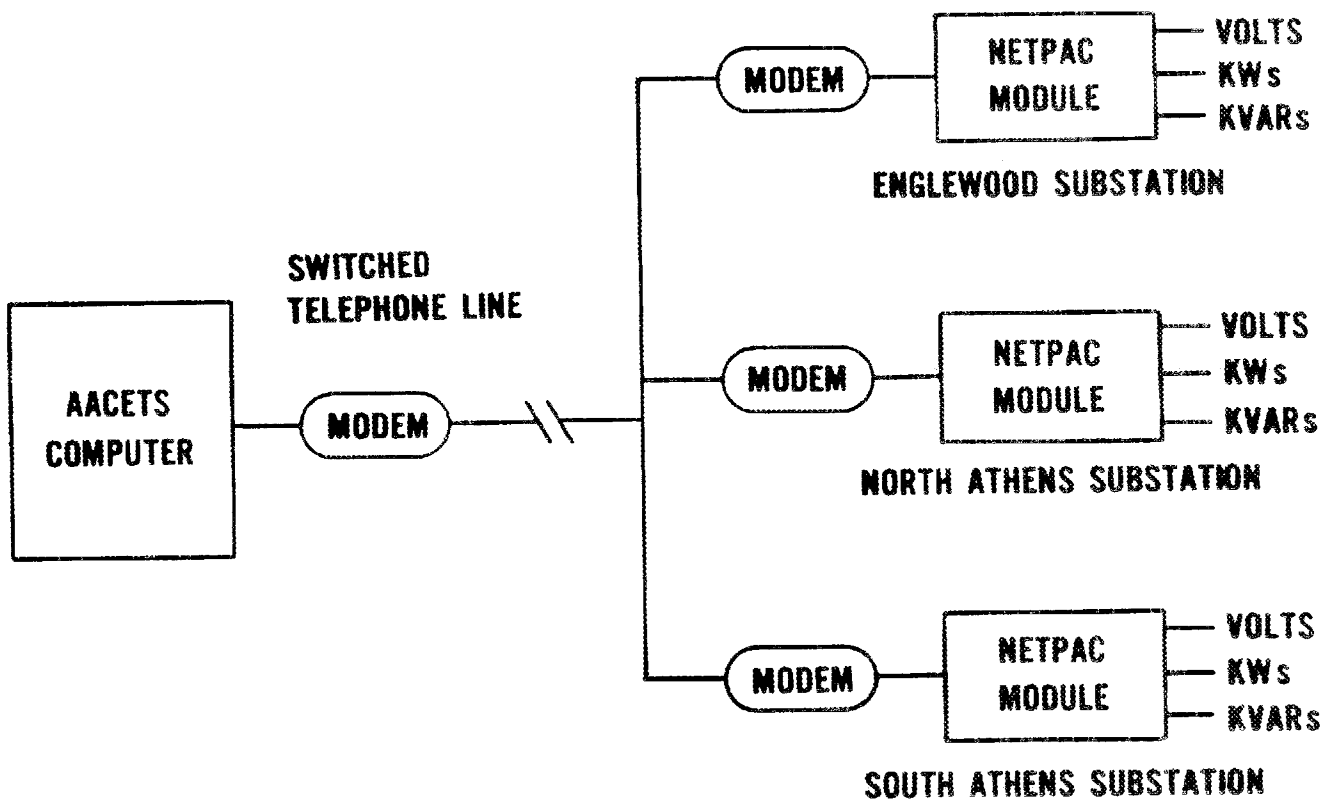
PRE-EXPERIMENTAL REMOTE SUBSTATION

- BUS VOLTAGES (3 ϕ)
- FEEDER KW, KVAR, (3 ϕ)
- WEATHER CONDITION
- 5 - 10 MINUTE RATE
- 7 SECOND RATE

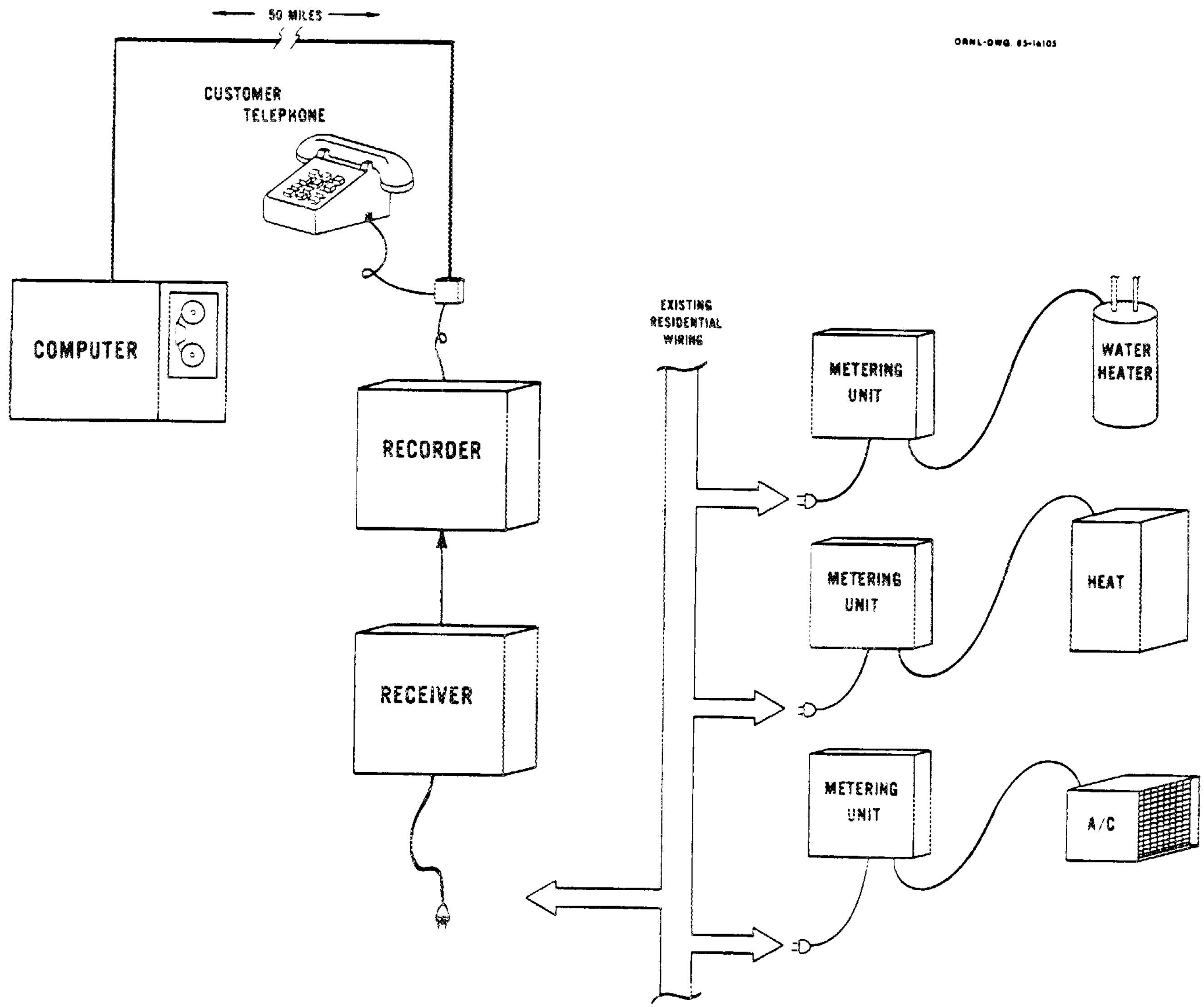
ELECTRIC ARM (SUPPLIED BY EPRI)

- 200 RESIDENCES MONITORED
- 4 POINTS AT EACH RESIDENCE
  - WATER HEATER
  - AIR CONDITIONER
  - SPACE HEATER
  - INTERIOR TEMPERATURE
  - WHOLE HOUSEHOLD LOAD

ORNL-DWG. 85-16101



ORNL-DWG 85-16105



SUPPORT UTILITIES ARE PROGRAMS THAT BENEFIT ALL 3 EXPERIMENTAL AREAS

- **MODSCAN DATA ACQUISITION**
  - 24 HOUR SNAP-SHOT RECORD
  - DATA CONVERSION TO IBM READABLE FORM
  - PERIODIC AUTOMATIC FILE MAINTENANCE PROCEDURES
- **DATABASE REVERSE COMPILER**
- **MESSAGE LOGGING OF SOFTWARE INITIATED ACTIONS**
- **PROGRAM TO COMPUTE OPERATIONAL INFORMATION**
- **SYSTEM COMMUNICATIONS TRAFFIC MANAGER**

SOFTWARE FOR EXPERIMENTAL APPLICATIONS

LOAD CONTROL

VOLT/VAR CONTROL

SYSTEM RECONFIGURATION

LOAD CONTROL EXPERIMENTAL APPLICATIONS SOFTWARE

AUTOMATED SCENARIO PLANNER / IMPLEMENTER

- OPERATOR GIVES THE PROJECTED WEATHER DATA
- PROGRAM DETERMINES EXPERIMENTAL SEQUENCE OF EVENTS
  - LOAD CONTROL CRITERIA
  - COMMUNICATIONS REQUIREMENTS
- IMPLEMENTS SCENARIO

CONCEPTUAL STAGE

VOLT/VAR CONTROL EXPERIMENTAL APPLICATIONS SOFTWARE

PROGRAM FOR AUTOMATIC CAPACITOR CONTROL

- INITIALLY TARGETED FOR SOUTH ATHENS CIRCUITS
- WILL INITIALLY RELY ON THE OPERATOR IN THE LOOP
- WILL AUTOMATE MANUAL CONTROL THAT WAS TESTED IN SEPT-OCT.

UNDER DEVELOPMENT

SYSTEM RECONFIGURATION EXPERIMENTAL APPLICATIONS SOFTWARE

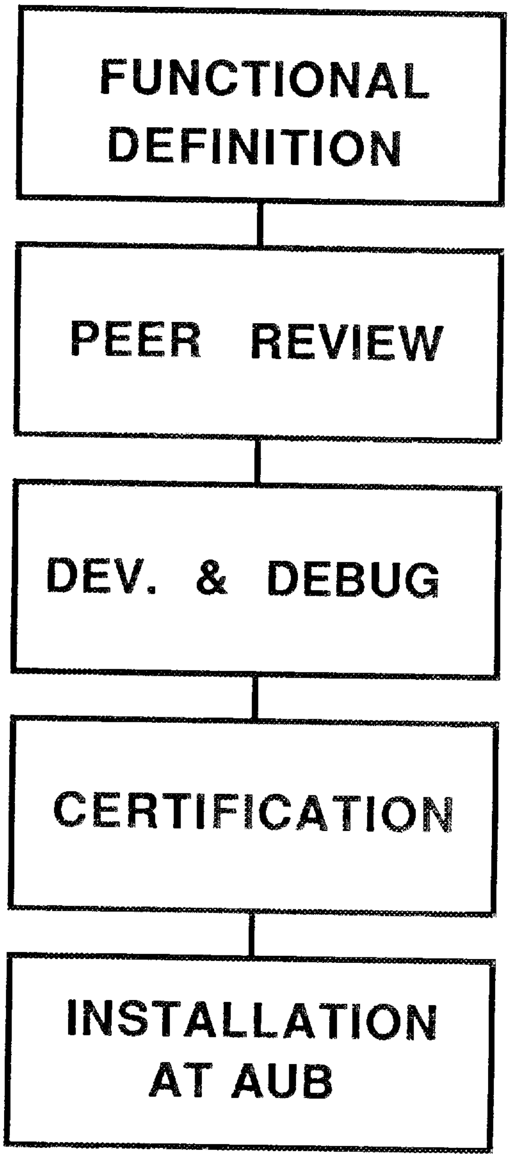
INTEGRATED (ON-LINE) VERSION OF SYSRAP

EMBEDDED IBM-PC EMULATOR

MODSCAN-RSX / IBM DATA TRANSFER

UNDER DEVELOPMENT

MAJOR STEPS IN AACE SOFTWARE DEVELOPMENT



ISSUES OF SOFTWARE CERTIFICATION

1. DOES IT MEET THE FUNCTIONAL REQUIREMENTS OF ITS INTENDED PURPOSE?

2. DOES IT MEET THE ELECTRICAL SYSTEM AND SAFETY REQUIREMENTS?

3. DOES IT OPERATE IN A HOMOGENEOUS MANNER WITH THE REST OF THE CONTROL SYSTEM'S ACTIVITIES?

4. DOES IT INTERFACE WITH THE OPERATOR AND/OR EXPERIMENTER IN AN EFFECTIVE WAY?

5. IS IT WRITTEN IN A STRUCTURED AND WELL DOCUMENTED MANNER?

THE AACETS IS SERVING AN IMPORTANT PROJECT SUPPORT ROLE

- SYSTEM MANAGEMENT
- DATA ACQUISITION
- SOFTWARE DEVELOPMENT
  - SUPPORT UTILITIES (PROGRAMS)
  - EXPERIMENTAL APPLICATIONS

VOLTAGE AND CAPACITOR CONTROL

SUMMARY OF VOLT/VAR PRESENTATIONS

D. T. Rizy and R. L. Sullivan

The purpose of the Volt/Var Experiments is to determine the benefits of real-time computer-automated capacitor and regulator control. The objectives for implementing real-time volt/var control on the Athens Utilities Board's (AUB) distribution system are to (1) determine whether or not real-time computer-automated capacitor control is effective in reducing line losses and in providing var support for the transmission system; (2) determine whether computer-automated regulator control is effective in reducing feeder voltage drops, ensuring acceptable voltage levels and providing a means of reducing load (via voltage reductions); (3) determine the type of application software needed to implement real-time volt/var control; (4) determine whether the type of computer, communications, and control equipment is adequate for collecting data and for implementing volt/var control actions; (5) determine the additional benefits of coordinating volt/var control with load control and system reconfiguration; and (6) identify the requirements for future-generation distribution automation systems that will employ volt/var control.

Volt/Var Experiments were conducted on the AUB system in September, October, and November 1985 on South Athens circuits No. 7, No. 8, and No. 9. The feeder response of the three circuits to capacitor switching and tap adjustments was tested in September, and substation analog data (real power, reactive power, and bus voltages) were collected every 30 seconds. The effectiveness of var control (control of capacitor banks through the real-time operating system at AUB) in reducing reactive power flows was tested against no var control (all the capacitors switched off) in October. Analog data were collected every 15 minutes during this month. In November, the response of the three South Athens circuits to capacitor switching was tested again using a higher speed monitoring system separate from AUB's system that sampled the analog data at the South Athens substation every 7 seconds. A higher sampling rate was used in November to reduce the time delay between the collection of real power data and the collection of reactive power data and bus voltage data.

Preliminary experimental results have been obtained on South Athens circuits No. 7, No. 8, and No. 9. As expected, monitored data indicated an easily observable reduction in reactive power and an increase in bus voltage when a capacitor is switched in. The reduction in reactive power, which is comparable to the size of the capacitor bank, varies depending on the voltage at which the capacitor bank is switched on or off and on other variables. The October experiments manually tested a procedure for controlling capacitor banks to reduce reactive power flows at monitored points. The procedure worked successfully and is being developed into a computer code. Oak Ridge National Laboratory (ORNL) was not able to observe a change in real power due to a capacitor action. This could be due either to the reduction in real power as a result of line loss reduction being overshadowed by the noise of the real power data, or to the voltage rise due to the capacitor being switched in causing an increase in real power consumption negating the reduction in line losses, or both. Further work will involve filtering of the monitored data, statistical analysis, and increased sampling rates to determine what effect capacitor switching has on real power.

A procedure has been developed by ORNL for implementing computer-automated capacitor control. This procedure is designed to reduce reactive power flows at monitored locations on the AUB feeders. The procedure was tested manually in October on three South Athens circuits.

ORNL is presently developing a FORTRAN computer code that will implement the computer-automated capacitor control procedure and will interface with the real-time operating software being used by AUB.

A simplified circuit model of South Athens circuit No. 7 has been developed based on the monitored locations. Real-time analog real power, reactive power, and voltage data have been used along with the simplified model to compare the simulation of capacitor switching actions with the actual results of capacitor switching. Preliminary model results appear to simulate the actual results of September experiments quite well. The model can be used to calculate parameters that are not monitored or cannot be directly calculated, such as line losses.

Future experiments will continue to test feeder response of the South Athens circuits and will be conducted on the North Athens and the Englewood circuits. The experiments will compare the effectiveness of computer-automated capacitor control versus local control (var controllers) of capacitor banks for reducing line losses. Also, computer-automated regulator control versus local control of regulators will be tested for reducing feeder voltage drops and for indirect load control. The specific experiments that will be conducted on the AUB system in the future are:

1. computer-automated capacitor control,
2. computer-automated regulator control,
3. combined computer-automated capacitor and regulator control,
4. voltage reduction for indirect load control, and
5. integrated volt/var control with load control and system reconfiguration.

ORNL WSC-83423

VOLTAGE AND CAPACITOR (VOLT/VAR) CONTROL EXPERIMENTS

Tom Rizy

WEDNESDAY
DECEMBER 4, 1985

ORNL WSC-43410

VOLT/VAR PROJECT TEAM

TOM RIZY - LEADER

BOB SULLIVAN - CONSULTANT/SUPPORT

BOB STEVENS - SOFTWARE DEVELOPMENT

LEO GRIGSBY - CONSULTANT/MODEL DEVELOPMENT

LARRY MONTEEN - AUB/HARDWARE INSTALLATION AND IMPLEMENTATION

MYRL VAUGHN - AUB SYSTEM OPERATOR

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OUTLINE OF VOLT/VAR PRESENTATION

1. OVERVIEW OF VOLT/VAR EXPERIMENTS - TOM

2. VOLT/VAR HARDWARE - TOM

3. IMPLEMENTATION ON THE AUB SYSTEM - LARRY

4. EXPERIMENTAL RESULTS - BOB
   - CAPACITOR CONTROL
   - REGULATOR CONTROL

5. SIMULATION RESULTS vs EXPERIMENTAL RESULTS - BOB

6. SUMMARY - TOM

ORNL WSC-43406

VOLTAGE CONTROL

- COMPUTER-AUTOMATED CONTROL OF REGULATORS
- LEVELIZE FEEDER VOLTAGE PROFILES
- REDUCE VOLTAGE TO TEST INDIRECT LOAD CONTROL
- LTC TRANSFORMERS (SOUTH ATHENS) AND SUBSTATION REGULATORS (ENGLEWOOD) CONTROLLED BY SUBSTATION RTUs
- FEEDER REGULATORS (NORTH ATHENS) CONTROLLED BY DISTRIBUTION RTUs

ORNL WSC-43405

VAR CONTROL

- COMPUTER-AUTOMATED CONTROL OF FEEDER CAPACITORS
- REDUCE REACTIVE POWER FLOWS ON FEEDER
  - TO REDUCE LINE LOSSES
  - TO IMPROVE POWER FACTOR
- SUPPLY OR ABSORB REACTIVE POWER FROM TRANSMISSION SYSTEM
- CAPACITORS CONTROLLED BY
  - POLE-TOP-UNITS (11),
  - DISTRIBUTION CONTROL RECEIVERS (18)
  - VAR CONTROLLERS (13)

ORNL WSC-43407

OBJECTIVES OF VOLT/VAR EXPERIMENTS

- DETERMINE IF EFFECTIVE IN REDUCING LINE LOSSES
- DETERMINE IF EFFECTIVE IN REDUCING VOLTAGE DROPS
- DETERMINE TYPE OF APPLICATION SOFTWARE NEEDED
- DETERMINE ADEQUACY OF COMPUTER, COMMUNICATIONS AND CONTROL EQUIPMENT
- DETERMINE BENEFITS OF COORDINATING WITH LOAD CONTROL AND SYSTEM RECONFIGURATION
- IDENTIFY REQUIREMENTS OF FUTURE SYSTEM

ORNL WSC-43408

EXPERIMENTS THAT HAVE BEEN CONDUCTED

- ON SOUTH ATHENS CURCUITS NO. 7, NO. 8 & NO. 9
- **SEPT 85** EXPERIMENTS
  - FEEDER RESPONSE TO CAPACITOR SWITCHING
  - FEEDER RESPONSE TO LTC TRANSFORMER TAP ADJUSTMENTS
- **OCT 85** EXPERIMENTS
  - MANUAL CONTROL OF CAPACITORS VIA CRT SCREENS
- **NOV 85** EXPERIMENTS
  - FEEDER RESPONSE TO CAPACITOR SWITCHING

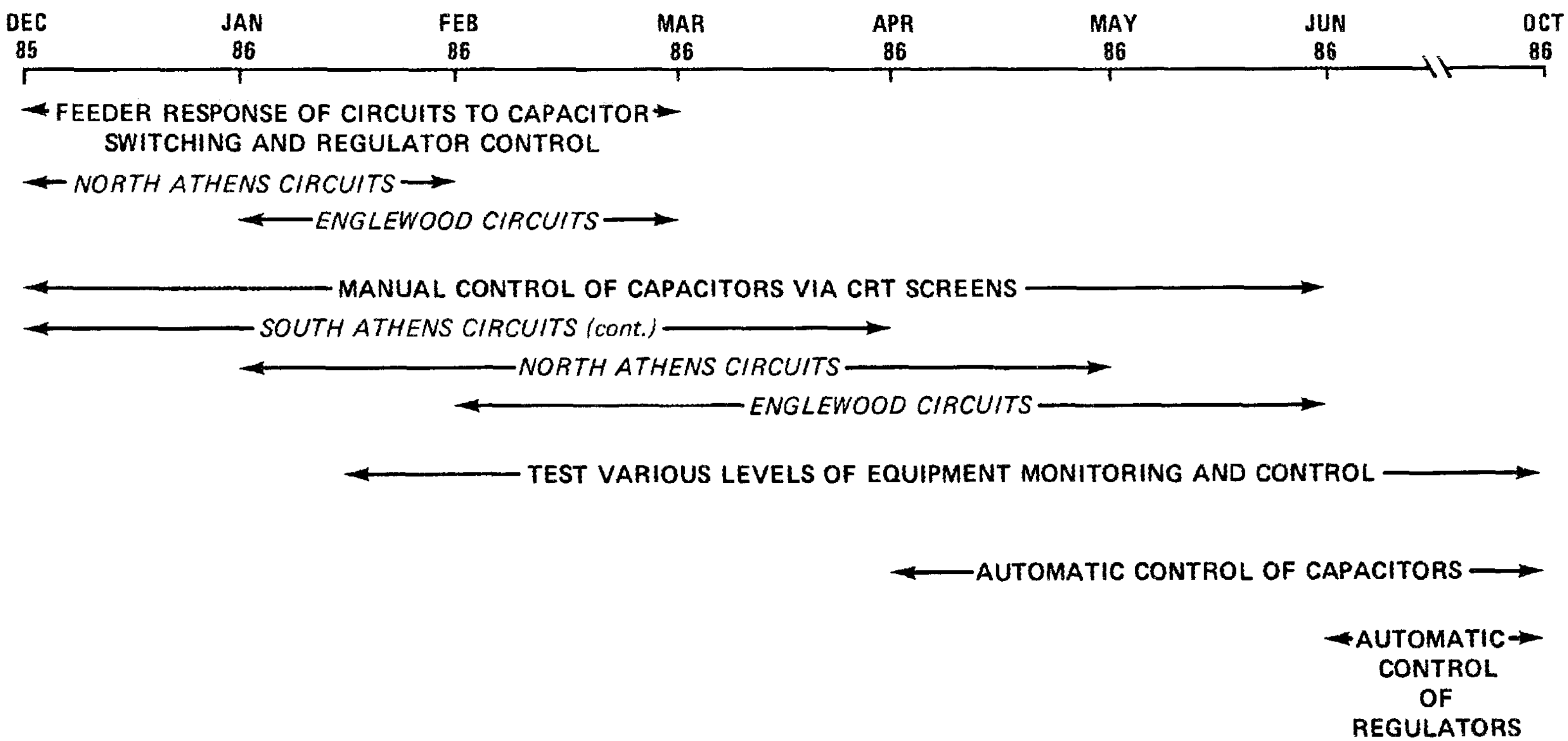
ORNL WSC-43409

FUTURE VOLT/VAR EXPERIMENTS

- COMBINE CAPACITOR & REGULATOR CONTROL
- INDIRECT LOAD CONTROL
- INTEGRATED CONTROL
- EQUIPMENT PENETRATION

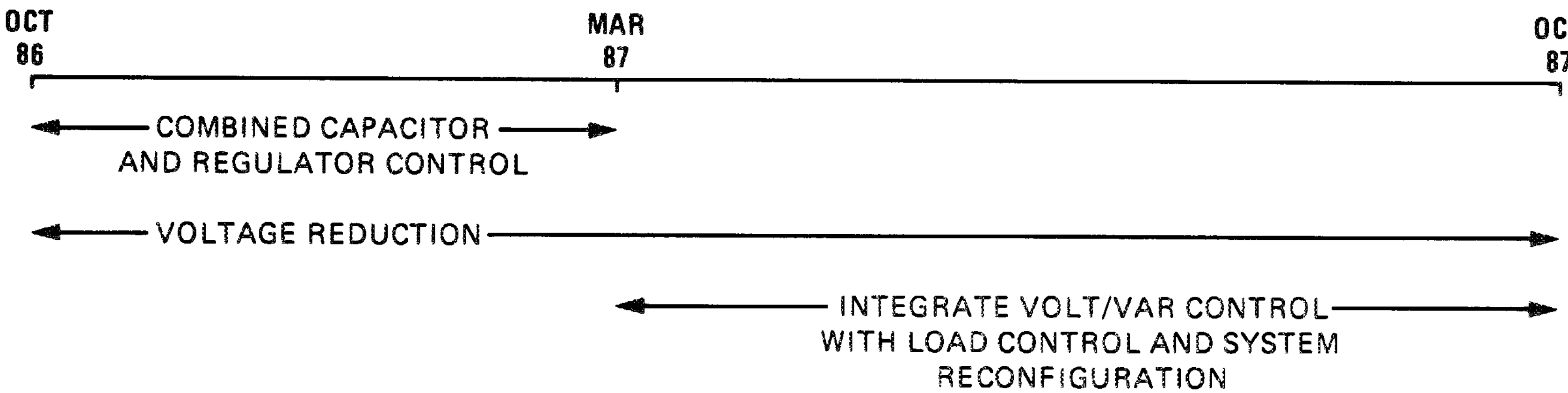
ORNL DWG 85-18275

VOLT/VAR EXPERIMENT SCHEDULE FOR 1986



ORNL DWG 85-18276

VOLT/VAR EXPERIMENT SCHEDULE FOR 1987



ORNL WSC-43424

VOLT/VAR HARDWARE

ORNL WSC-43426

SYSTEM-WIDE VOLTAGE CONTROL CAPABILITY

SUBSTATION NAME	CIRCUIT NO.	VOLTAGE REGULATION
NORTH ATHENS	0-5	NO SUBSTATION REGULATION
NORTH ATHENS	3	1 FEEDER REGULATOR
NORTH ATHENS	5	2 FEEDER REGULATORS
SOUTH ATHENS	7-9	2 LTC TRANSFORMERS
ENGLEWOOD	1-3	SUBSTATION REGULATOR
ENGLEWOOD	1	1 FEEDER REGULATOR

ORNL WSC-43425

SYSTEM-WIDE CAPACITOR CONTROL CAPABILITY

SUBSTATION NAME	CIRCUIT NO.	NUMBER AND SIZE OF CAPACITORS (kvar)
NORTH ATHENS	0	1-600
NORTH ATHENS	1	2-600, 2-1200
NORTH ATHENS	2	3-600*, 2-1200
NORTH ATHENS	3	1-900, 3-1200
NORTH ATHENS	4	NO CAPACITORS
NORTH ATHENS	5	2-600, 2-1200
SOUTH ATHENS	7	1-600, 1-900, 1-1200
SOUTH ATHENS	8	3-600
SOUTH ATHENS	9	3-600*, 2-1200
ENGLEWOOD	1	1-600
ENGLEWOOD	2	NO CAPACITORS
ENGLEWOOD	3	1-150*, 1-300

*ONE CAPACITOR IS FIXED (THERE ARE 29 SWITCHABLE CAPACITORS AND 3 FIXED CAPACITORS)

ORNL WSC-43427

SYSTEM-WIDE VOLT/VAR MONITORING AND CONTROL CAPABILITY

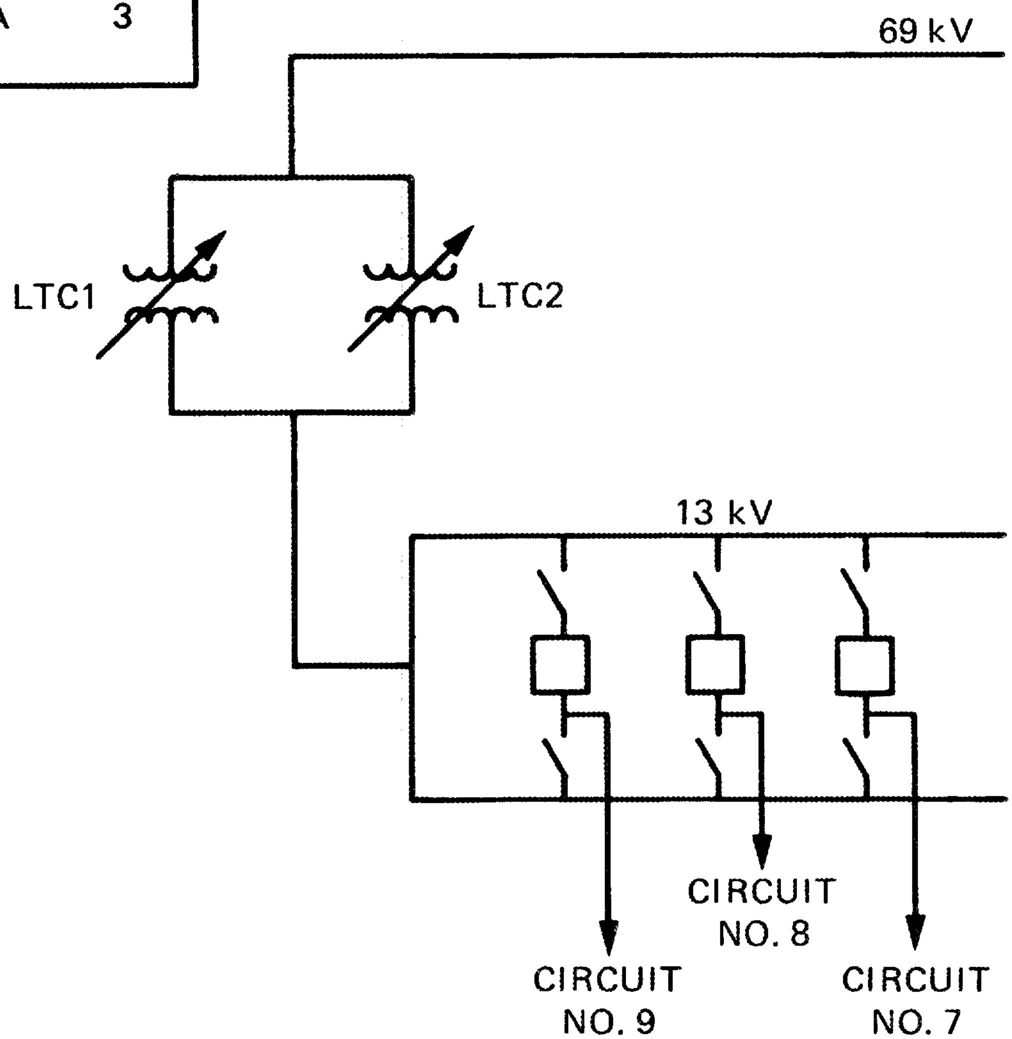
SUBSTATION	CIRCUIT NO.	DCRs	PTUs	VAR CONTROLLERS
NORTH ATHENS	0	1		
NORTH ATHENS	1	2	2	2
NORTH ATHENS	2	4		4
NORTH ATHENS	3	3	1	1
NORTH ATHENS	5	2	2	1
SOUTH ATHENS	7	2	1	1
SOUTH ATHENS	8		3	1
SOUTH ATHENS	9	2	2	1
ENGLEWOOD	1	1		1
ENGLEWOOD	3	1		1
TOTAL		18	11	13

ORNL DWG 85-18265

SUBSTATION RTUs CONTROL THE LTC TRANSFORMERS AND SUBSTATION REGULATORS

LTC TRANSFORMER TAP POSITIONS

	A/M	TAP
LTC 1	A	3
LTC 2	A	3



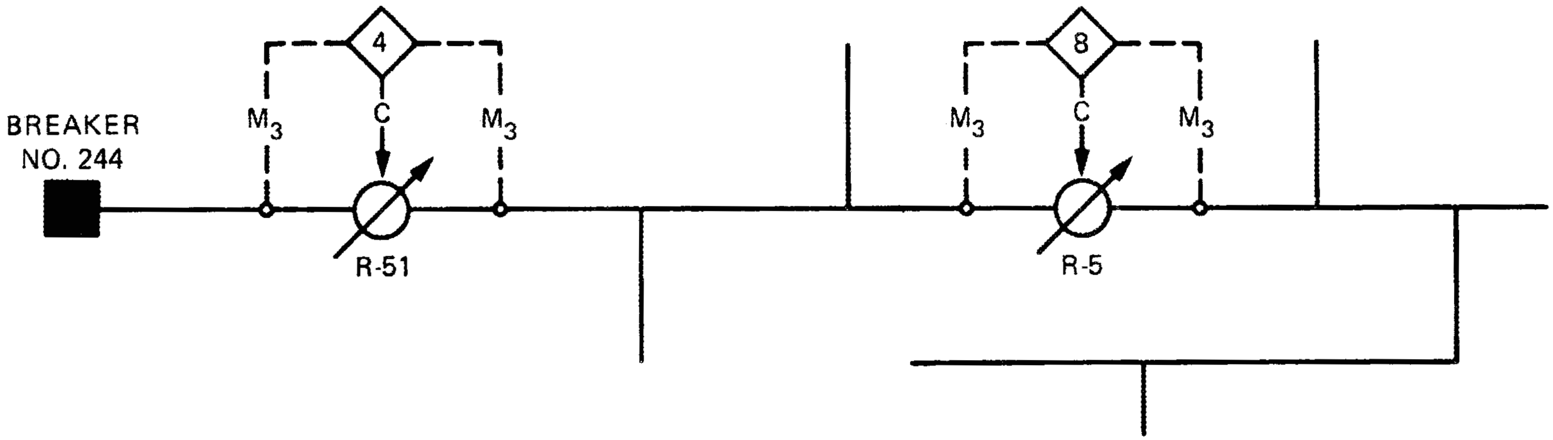
ORNL WSC-43433

LTC TRANSFORMER AND SUBSTATION REGULATOR MONITORING AND CONTROL BY A SUBSTATION REMOTE TERMINAL UNIT

- TWO-WAY COMMUNICATION (DEDICATED TELEPHONE)
  - RAISE OR LOWER TAP POSITION
  - REPORTS ANALOG AND STATUS DATA CHANGES
  - SUBSTATION RTU (INTERNAL) SCANS STATUS DATA EVERY 20 SEC AND ANALOG DATA EVERY 30 SEC
- ANALOG
  - REAL POWER (THREE 1ϕ FOR EACH CIRCUIT)
  - REACTIVE POWER (THREE 1ϕ FOR EACH CIRCUIT)
  - 13KV BUS VOLTAGES (THREE 1ϕ)
  - TAP POSITON OF LTC TRANSFORMERS OR REGULATOR

ORNL DWG 85-18264

DISTRIBUTION RTUs MONITOR AND CONTROL FEEDER REGULATORS



ORNL WSC-43432

FEEDER REGULATOR MONITORING AND CONTROL BY A DISTRIBUTION REMOTE TERMINAL UNIT

- TWO-WAY COMMUNICATION (DEDICATED TELEPHONE)
  - RAISE OR LOWER REGULATOR TAP POSITON (LOCAL LOGIC DISABLED)
  - REPORT ANALOG AND STATUS DATA CHANGES
  - DRTU (INTERNAL) SCANS STATUS DATA EVERY 20 SEC. AND ANALOG DATA EVERY 30 SEC.
- TWO DRTU CONTROL MODES
  - REMOTE (DRTU CAN READ AND CONTROL)
  - LOCAL (DRTU CAN READ AND CAN'T CONTROL)
- LOCAL LOGIC
  - VOLTAGE SENSING
  - LINE DROP COMPENSATION
  - REACTANCE
  - OR COMBINATION

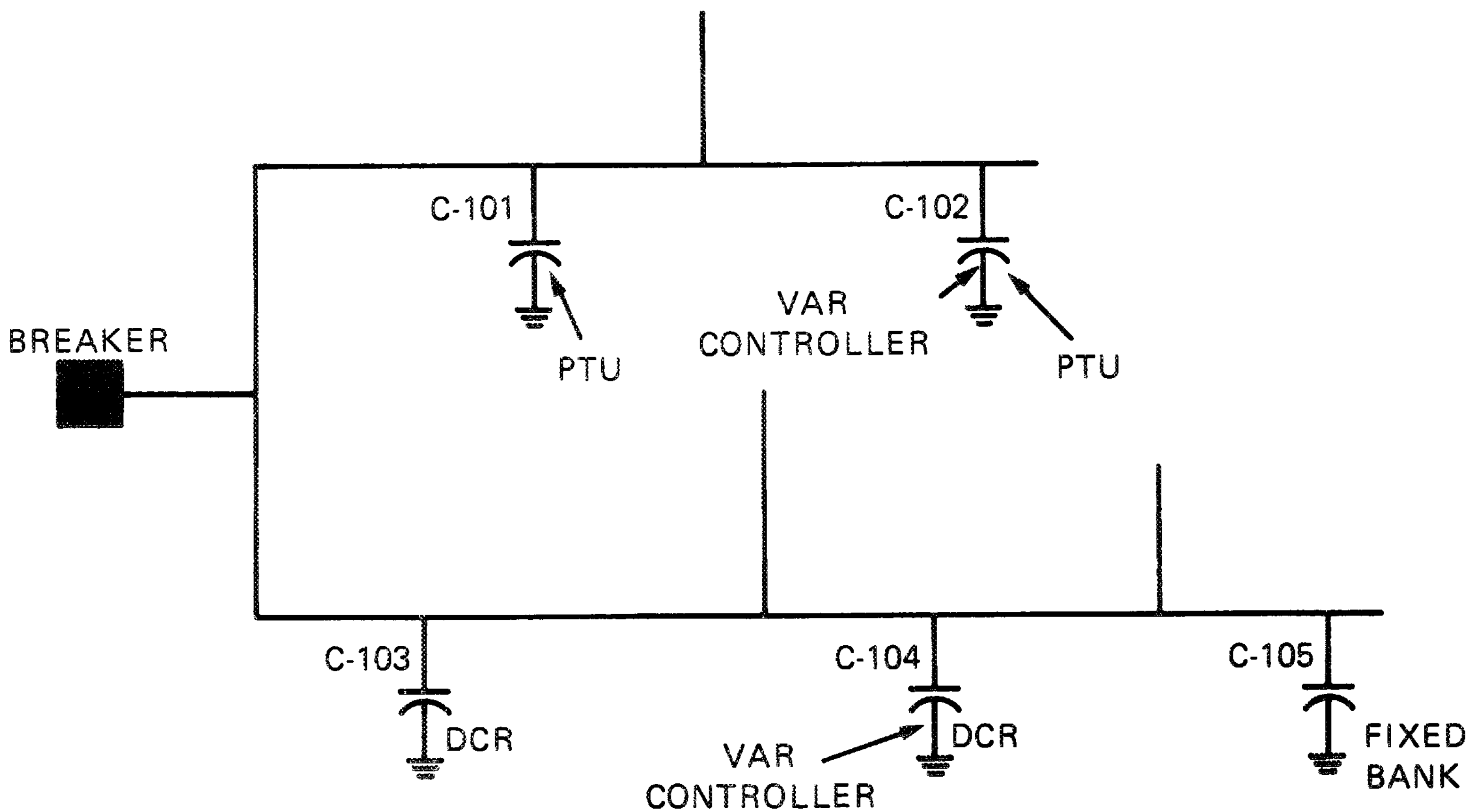
ORNL WSC-43431

DISTRIBUTION RTU REPORTS ANALOG AND STATUS DATA CHANGES

- ANALOG
  - REAL POWER (THREE 1ϕ)
  - REACTIVE POWER (THREE 1ϕ)
  - SOURCE-SIDE VOLTAGES (THREE 1ϕ)
  - LOAD-SIDE VOLTAGES (THREE 1ϕ)
  - TAP POSITION (TO BE COMPUTED)
- STATUS
  - REMOTE OR LOCAL CONTROL MODES
  - LOCAL LOGIC ENABLED
  - LOCAL LOGIC DISABLED

ORNL DWG 85-18266

FIVE TYPES OF CAPACITOR INSTALLATIONS



ORNL WSC-43428

CAPACITOR MONITORED AND CONTROLLED BY A POLE-TOP-UNIT

- TWO-WAY COMMUNICATION
  - CONTROL SIGNAL (POWER LINE CARRIER) OPENS/CLOSES CAPACITOR OIL SWITCH
  - PTU CALLS BACK (TELEPHONE) TO REPORT ANALOG AND STATUS DATA CHANGES
  - PTU HAS AN INTERNAL SCAN OF 12 SEC AND SHARES A PHONE LINE (DOES NOT CALL BACK AT A FIXED TIME, EXCEPT 116 MINUTES)
- TWO PTU CONTROL MODES
  - REMOTE (PTU CAN READ AND CONTROL)
  - LOCAL (PTU CAN READ BUT CAN'T CONTROL)
- LOCAL LOGIC CONTROL MODES
  - AUTOMATIC (VAR CONTROLLER ENABLED)
  - MANUAL (VAR CONTROLLER DISABLED)

ORNL WSC-43429

POLE-TOP-UNIT CALLS BACK ANALOG AND STATUS DATA

- ANALOG DATA
  - REAL POWER (ONE 1ϕ OR THREE 1ϕ)
  - REACTIVE POWER (ONE 1ϕ OR THREE 1ϕ)
  - BUS VOLTAGE (ONE 1ϕ OR THREE 1ϕ)

- STATUS DATA
  - CAPACITOR BANK SWITCHED ON OR OFF
  - VAR CONTROLLER ENABLED
  - VAR CONTROLLER DISABLED

ORNL WSC-43430

CAPACITOR CONTROLLED BY DISTRIBUTION CONTROL RECEIVER

- ONE-WAY COMMUNICATION
  - CONTROL SIGNAL (POWER LINE CARRIER) OPENS/ CLOSES CAPACITOR OIL SWITCH (VAR CONTROLLER DISABLED)
- NO MONITORED ANALOG OR STATUS DATA AT CAPACITOR INSTALLATION
- LOCAL LOGIC CONTROL MODES
  - AUTOMATIC MODE (VAR CONTROLLER ENABLED)
  - MANUAL MODE (VAR CONTROLLER DISABLED)

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IMPLEMENTATION OF VOLT/VAR CONTROL

PRESENTED BY

Larry Monteen

ORNL WSC-43440

CONTROL OF LTC TRANSFORMER TAPS AT SOUTH ATHENS SUBSTATION

ORNL WSC-43439

CONTROL OF SHUNT CAPACITORS ON SOUTH ATHENS CIRCUITS

ORNL WSC-43412

PRELIMINARY EXPERIMENTAL RESULTS

Presented by Bob Sullivan

CONSULTANT

ORNL WSC-43421

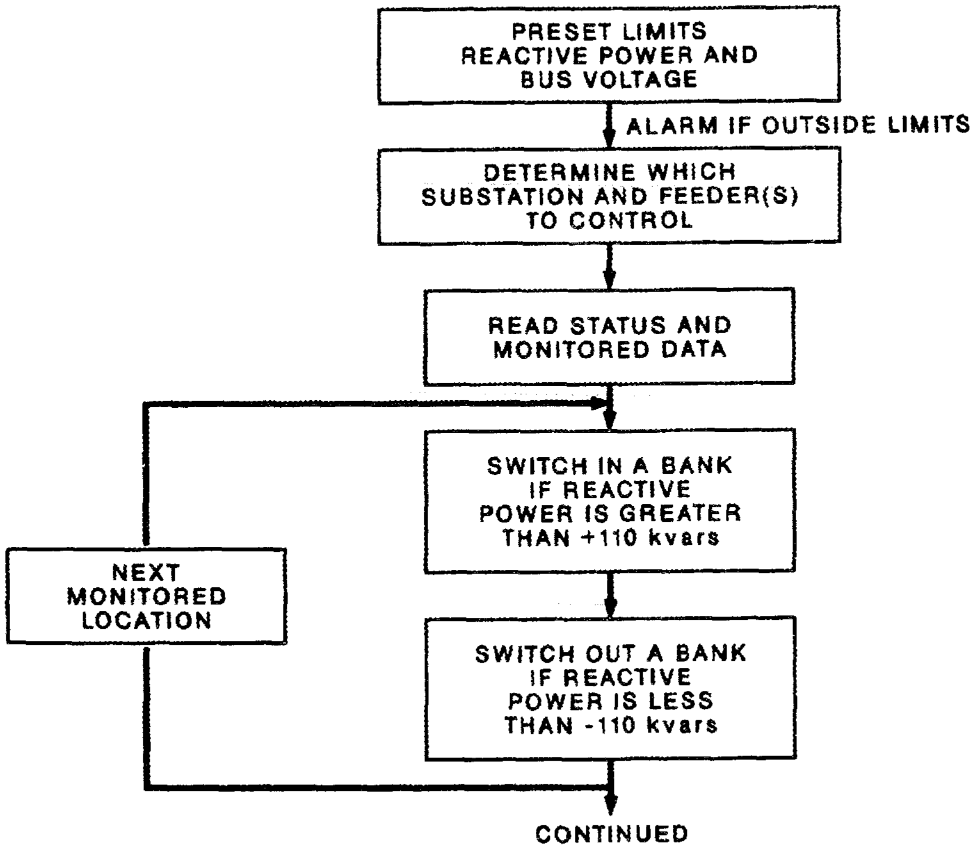
CAPACITOR CONTROL EXPERIMENT SUMMARY

SEPTEMBER: CONDUCTED FEEDER RESPONSE STUDIES AND MANUAL CONTROL STUDIES (CRT PRINTOUTS)

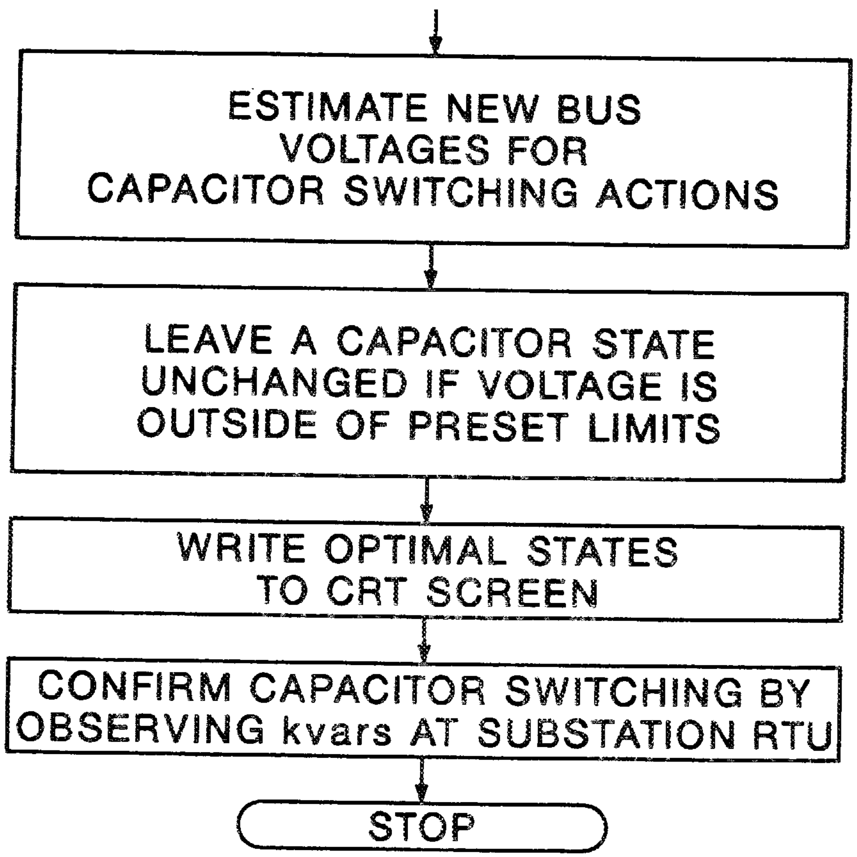
OCTOBER: CONDUCTED MANUAL CONTROL STUDIES ON CIRCUITS NO. 7, NO. 8, NO. 9, RESULTS WILL BE DESCRIBED IN NEXT SLIDE. SCAN RATES (15 MINUTE)

NOVEMBER: CONDUCTED FEEDER RESPONSE STUDIES AND CAPACITOR CONTROL STUDIES WITH FASTER SCAN RATES (7 SEC)

CAPACITOR SWITCHING PROCEDURE (IMPLEMENTED MANUALLY IN OCTOBER 1985)



ORNL-DWG 85C-18262



ORNL WSC-43420

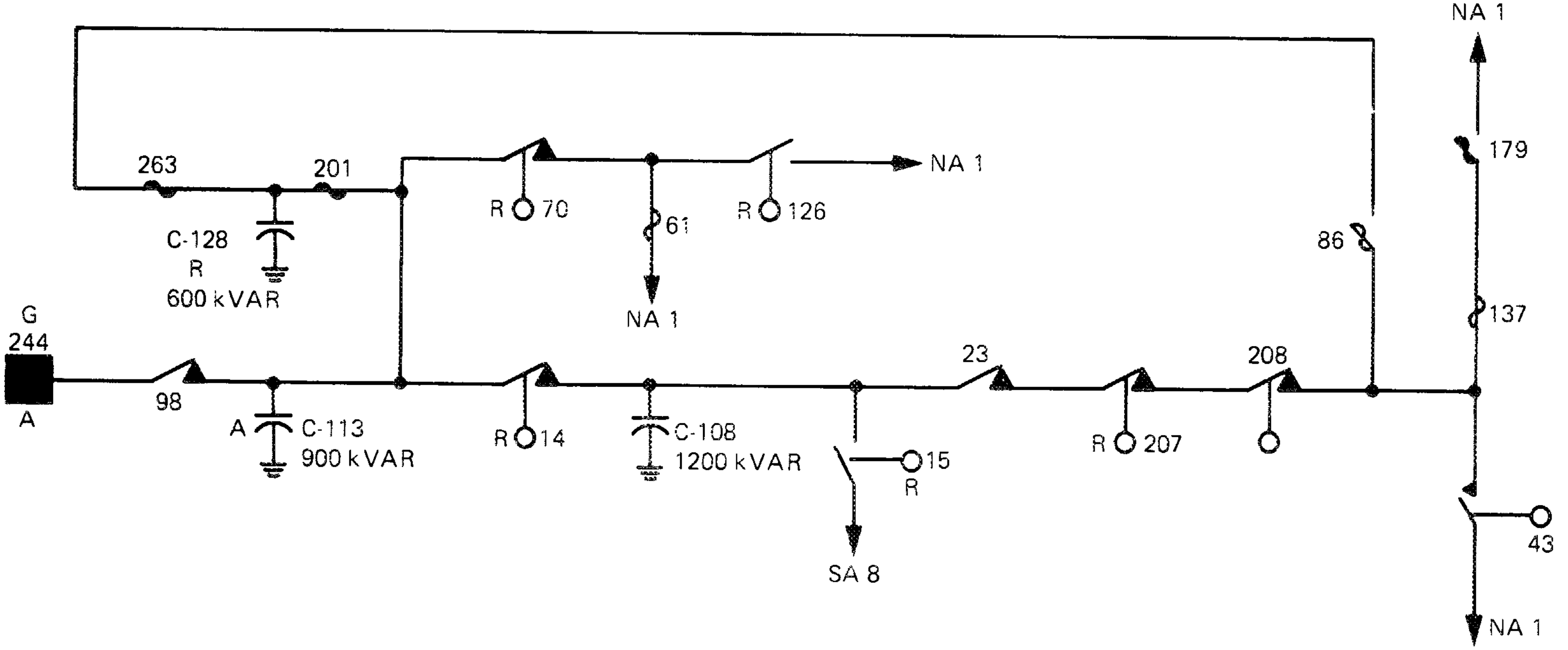
CIRCUIT NO. 7
VOLT/VAR EXPERIMENTS

SEPT 26	13:53-14:09	FEEDER RESPONSE TO CAPACITOR SWITCHING
OCT 15	13:00-16:00	VAR CONTROL
OCT 16	9:00-16:00	NO VAR CONTROL
OCT 17	9:00-16:00	VAR CONTROL
NOV 7	10:50-11:12	FEEDER RESPONSE TO CAPACITOR SWITCHING

ORNL DWG 85-18269

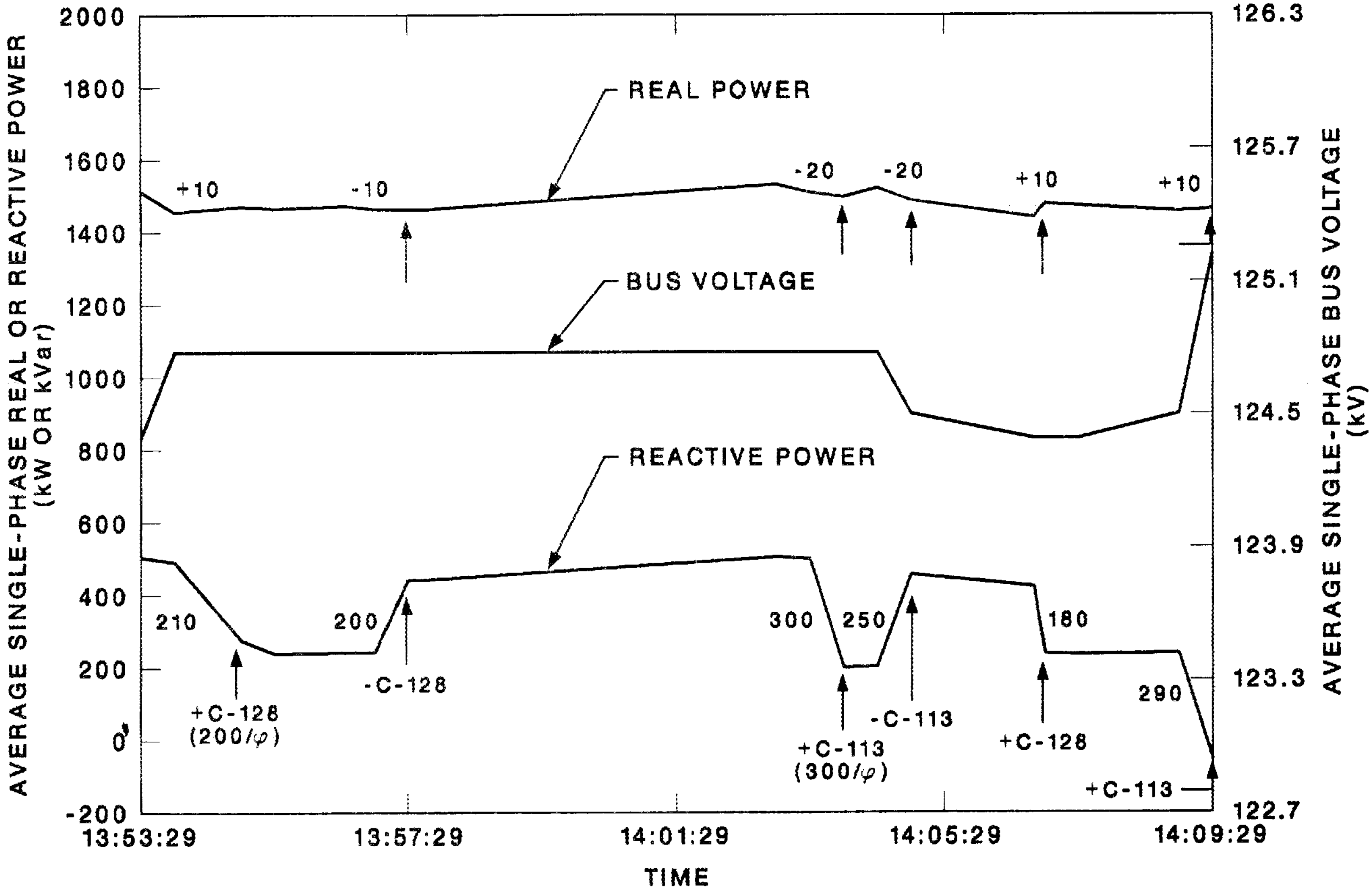
CONTROL POINTS ON CIRCUIT NO. 7

50% RESIDENTIAL/50% COMMERCIAL



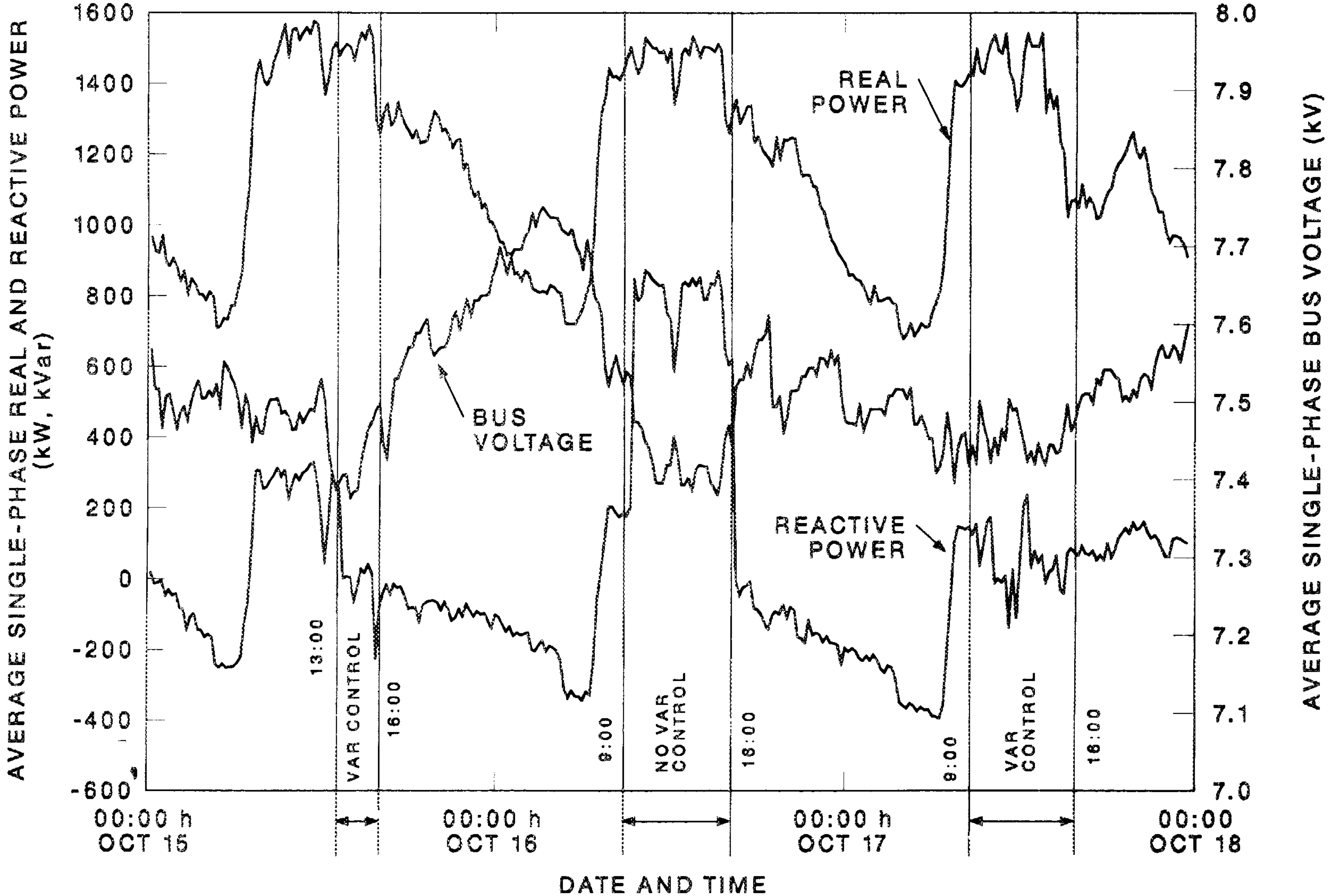
ORNL-DWG 85C-18402

FEEDER RESPONSE TO CAPACITOR SWITCHING (9/85) CIRCUIT NO. 7, AVERAGE SINGLE-PHASE DATA



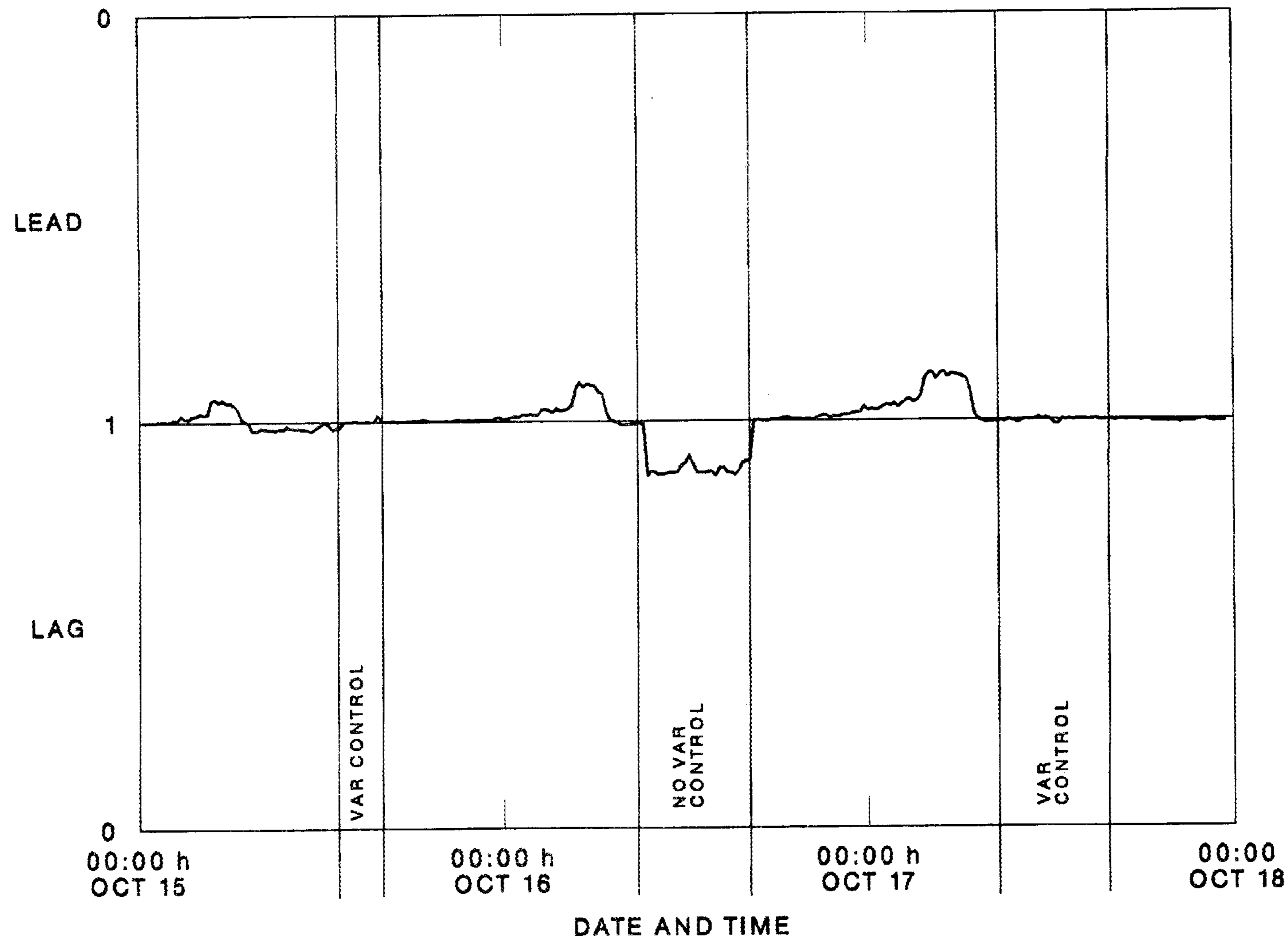
ORNL-DWG 85C-18388

VAR CONTROL VERSUS NO VAR CONTROL (10/85)
CIRCUIT NO. 7, AVERAGE BREAKER DATA



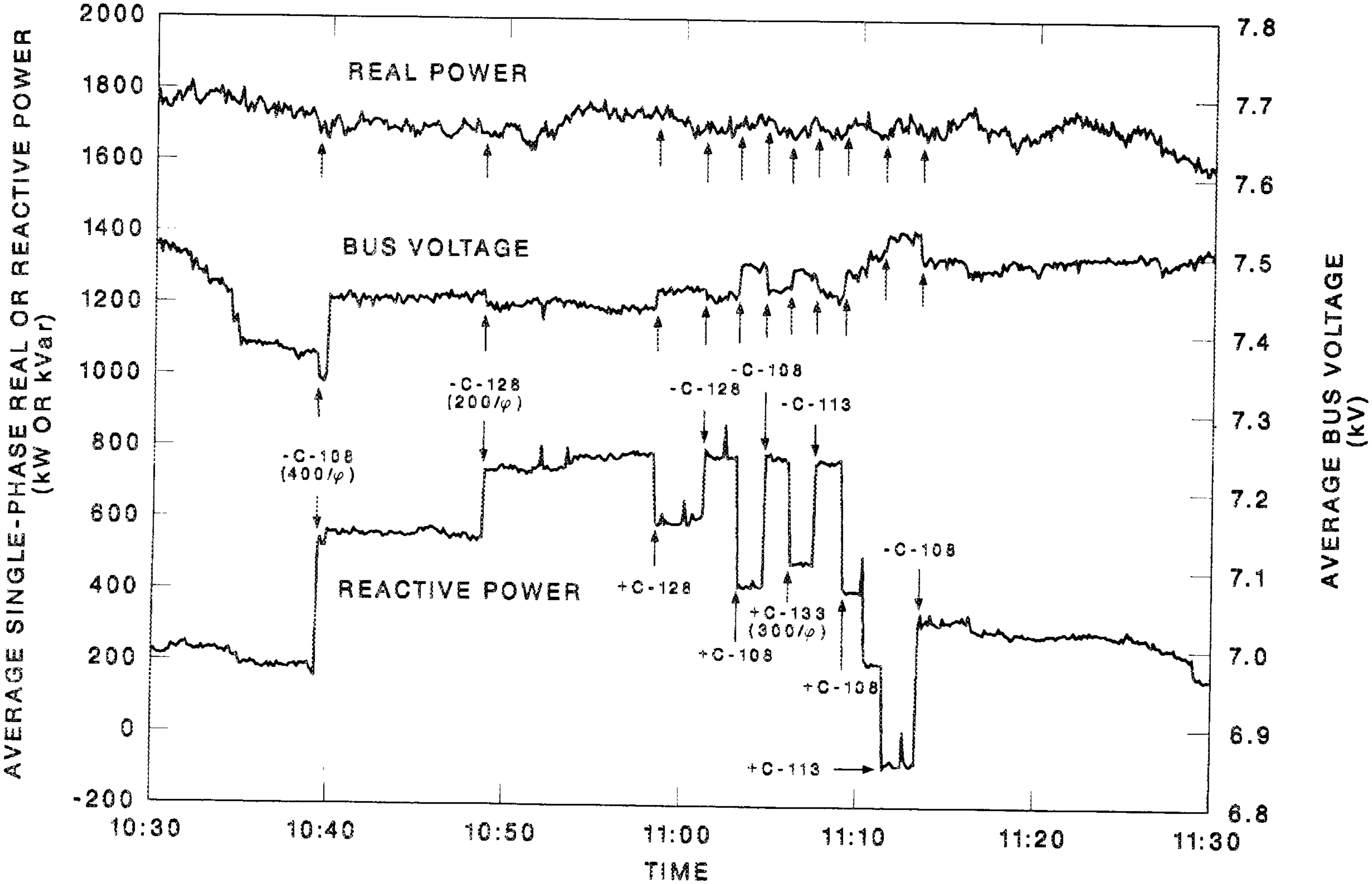
ORNL-DWG 85C-18392

VAR CONTROL VERSUS NO VAR CONTROL (10/85) CIRCUIT NO. 7, AVERAGE POWER FACTOR



ORNL-DWG 85C-18373

FEEDER RESPONSE TO CAPACITOR SWITCHING (11/85) CIRCUIT NO. 7, AVERAGE SINGLE-PHASE DATA



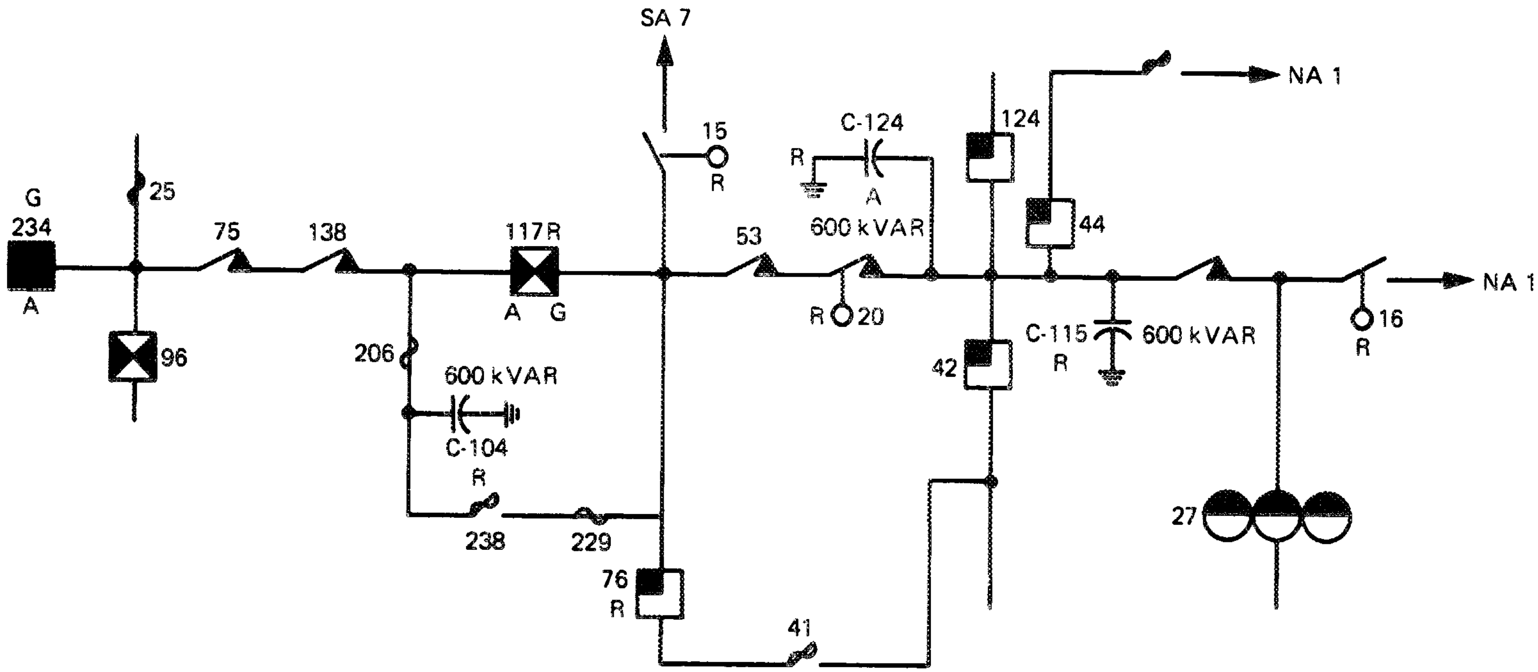
ORNL WSC-43413

CIRCUIT NO. 8
VOLT/VAR EXPERIMENTS

SEPT 26	15:48-16:00	FEEDER RESPONSE TO CAPACITOR SWITCHING
OCT 15	13:00-16:00	NO VAR CONTROL
OCT 16	9:00-16:00	VAR CONTROL
OCT 17	9:00-16:00	VAR CONTROL
NOV 7	11:16-11:40	FEEDER RESPONSE TO CAPACITOR SWITCHING

ORNL DWG 85-18268

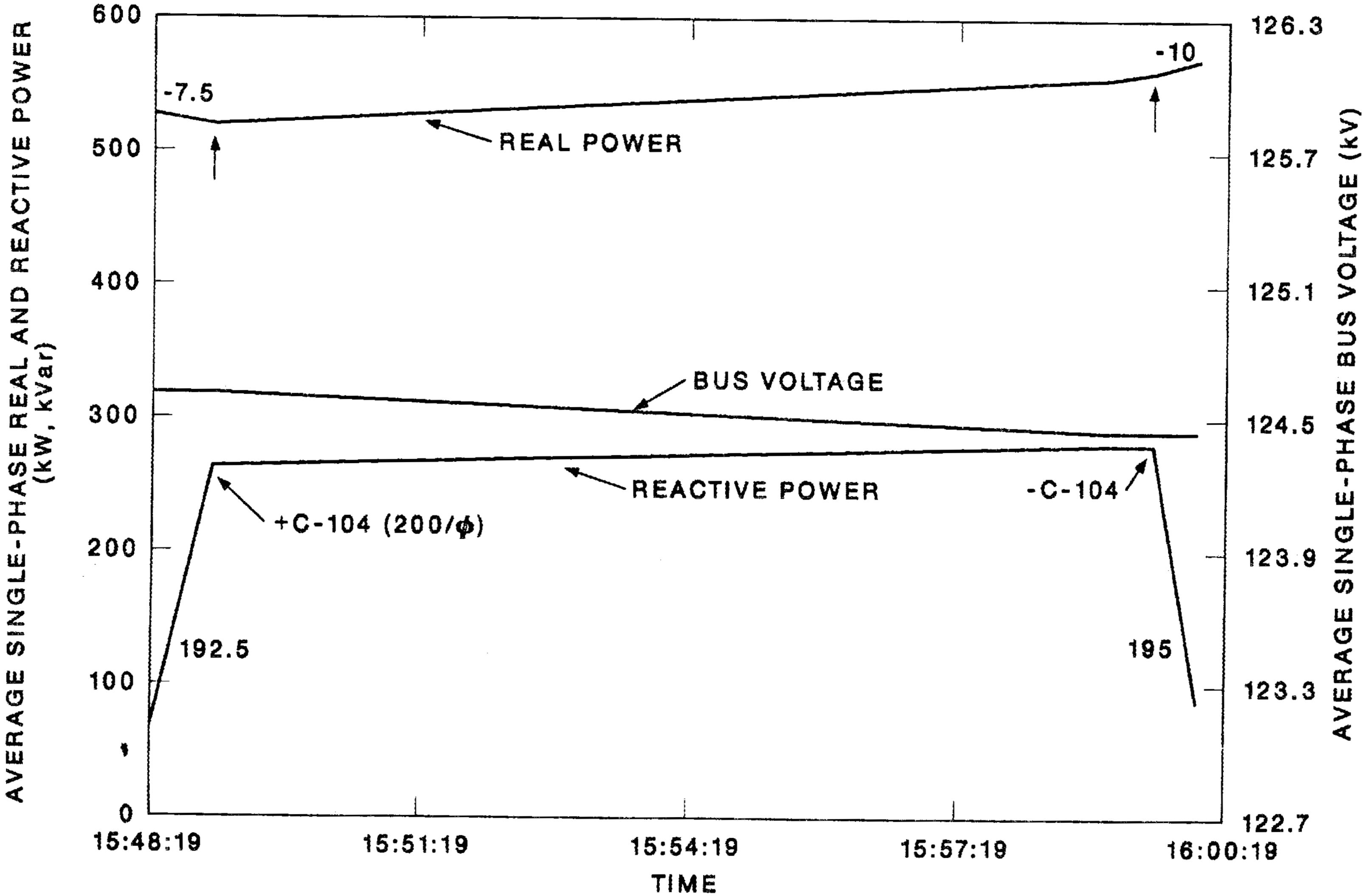
CONTROL POINTS ON CIRCUIT NO. 8
PRIMARILY RESIDENTIAL



(NOTE: C-124 TO BE ADDED)

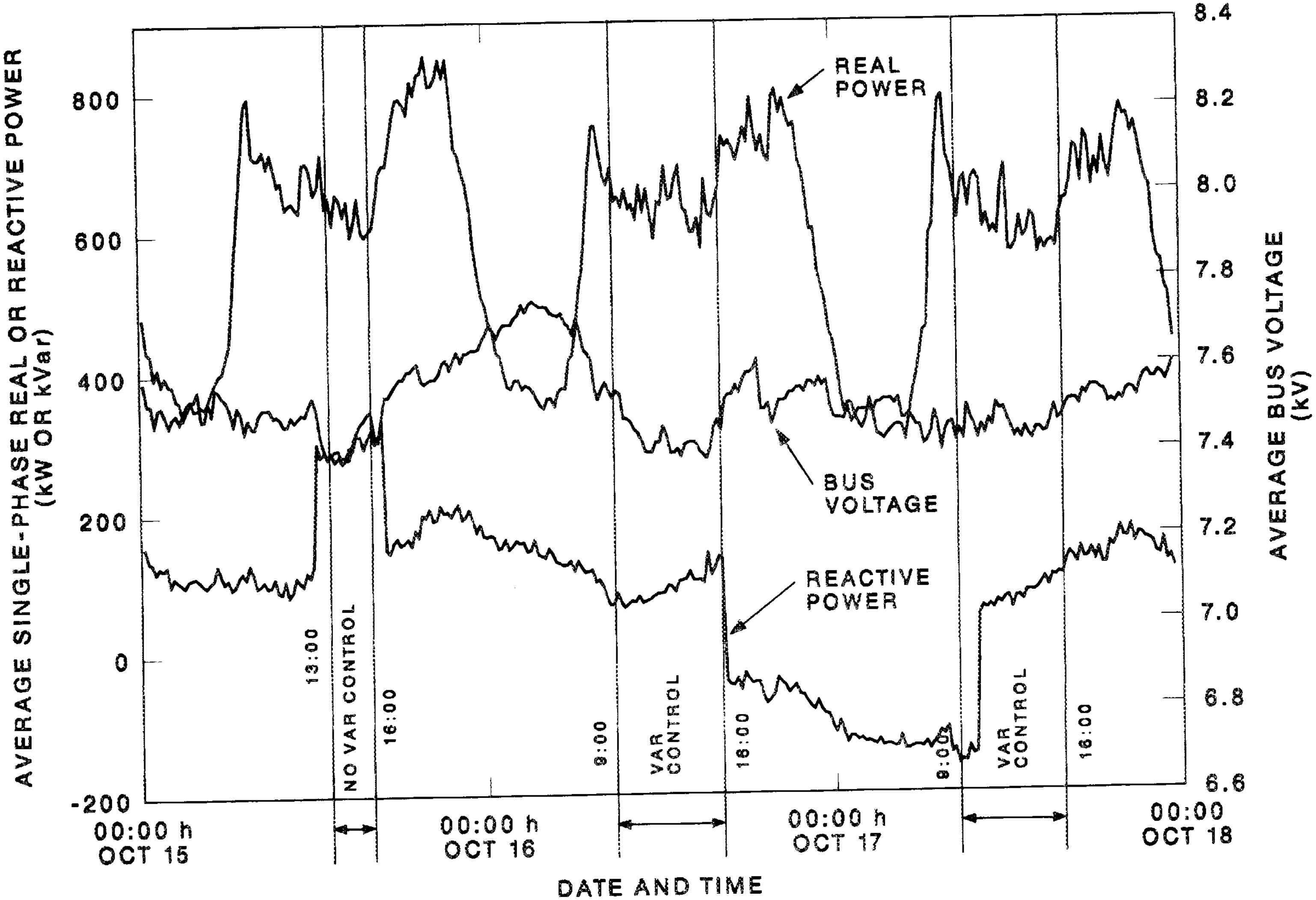
ORNL-DWG 85C-18406

FEEDER RESPONSE TO CAPACITOR SWITCHING (9/85) CIRCUIT NO. 8, AVERAGE SINGLE-PHASE DATA



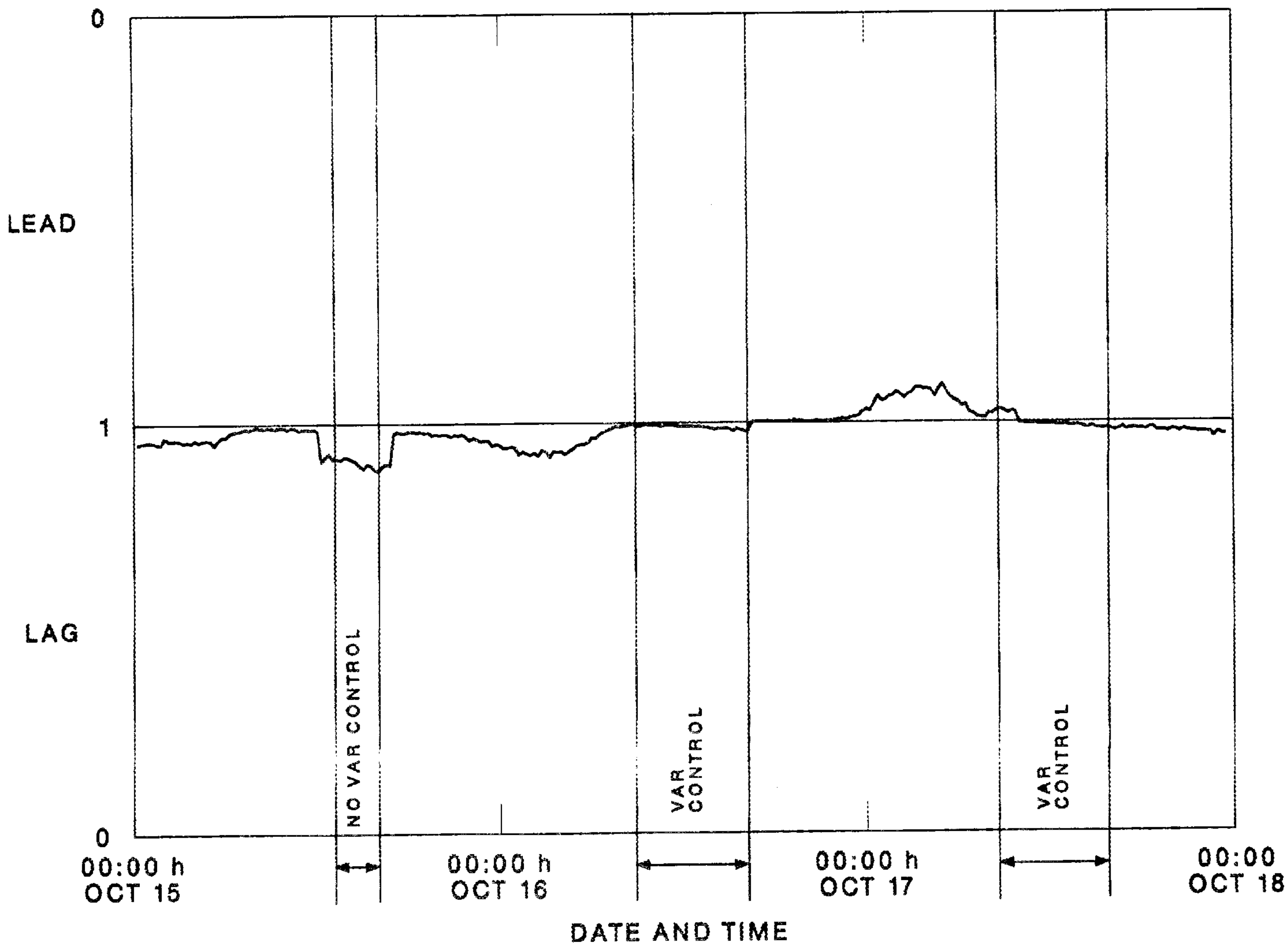
ORNL-DWG 85C-18394

FEEDER RESPONSE TO CAPACITOR SWITCHING (10/85)
CIRCUIT NO. 8, AVERAGE BREAKER DATA



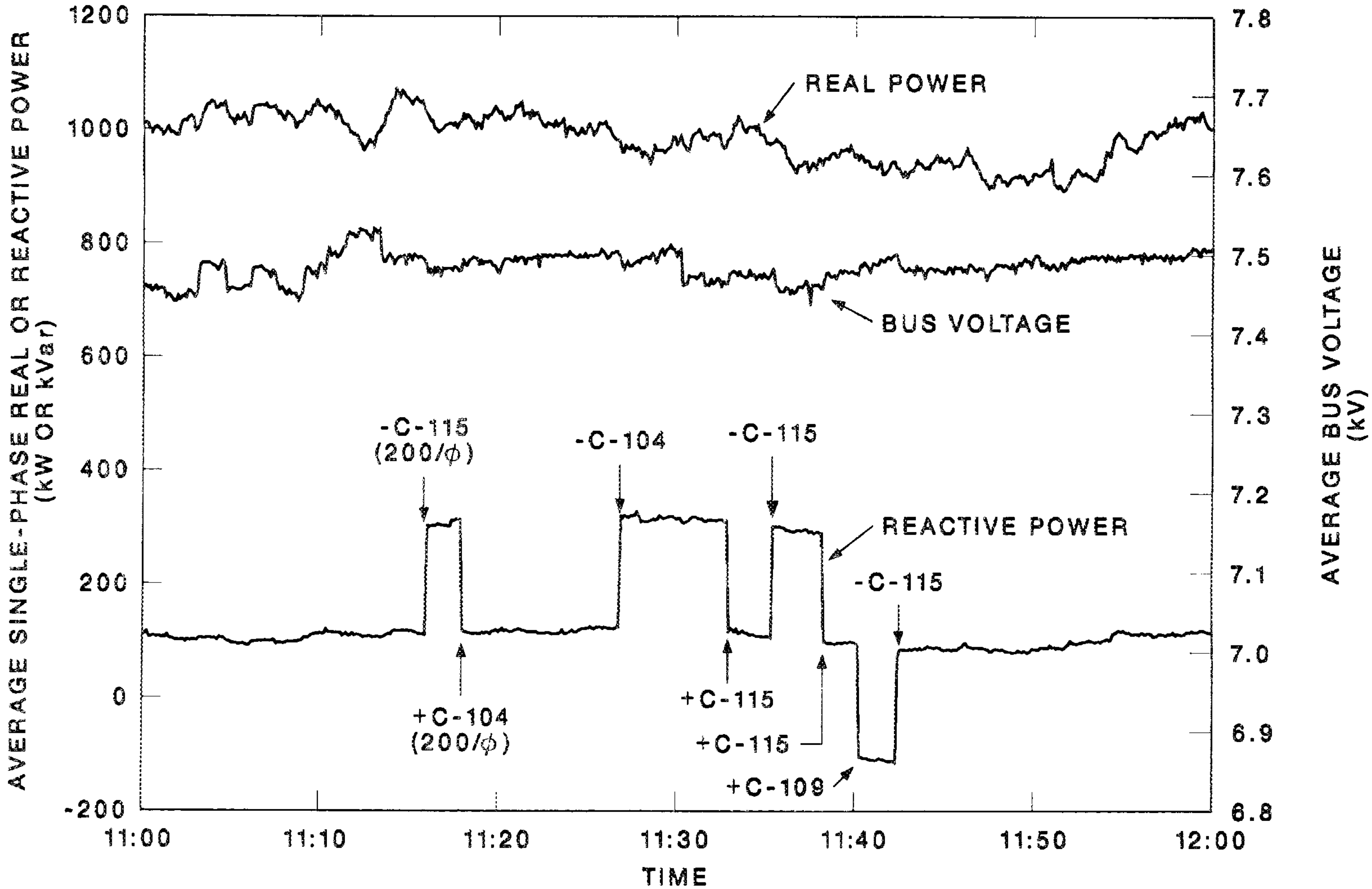
ORNL-DWG 85C-18396

VAR CONTROL VERSUS NO VAR CONTROL (10/85)
CIRCUIT NO. 8, AVERAGE POWER FACTOR



ORNL-DWG 85C-18378

FEEDER RESPONSE TO CAPACITOR SWITCHING (11/85)
CIRCUIT NO. 8, AVERAGE SINGLE-PHASE DATA



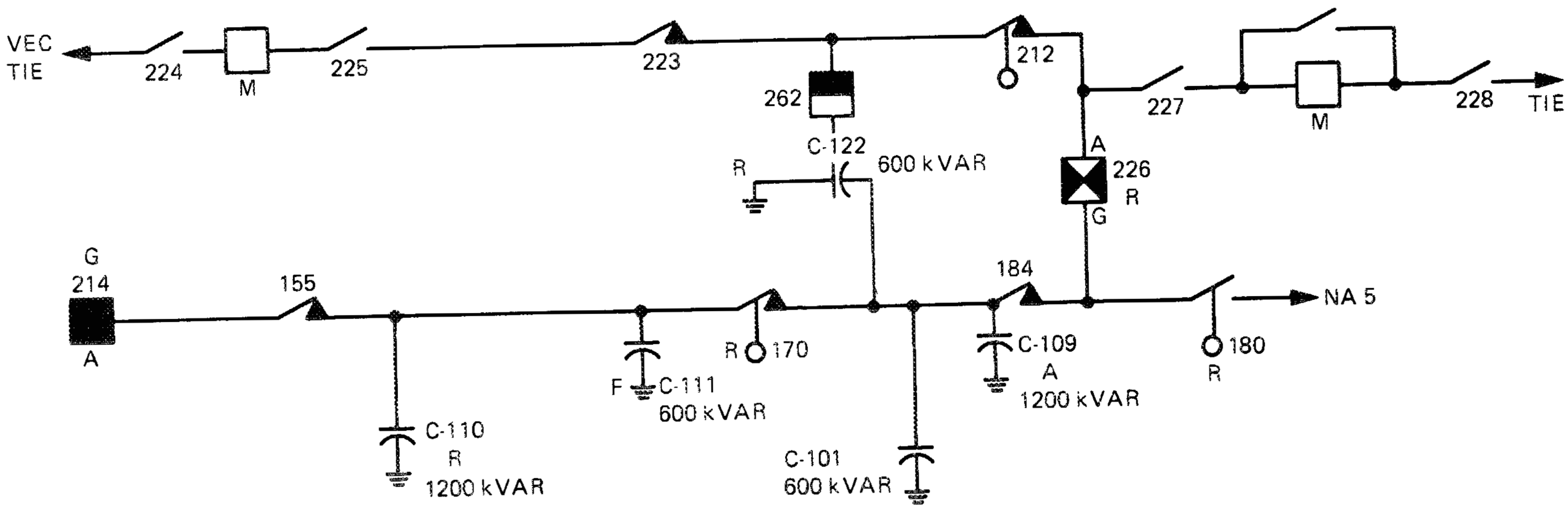
ORNL WSC-43414

CIRCUIT NO. 9
VOLT/VAR EXPERIMENTS

SEPT 26	10:06-10:53	FEEDER RESPONSE TO CAPACITOR SWITCHING
SEPT 27	10:16-11:56	FEEDER RESPONSE TO TRANSFORMER TAP ADJUSTMENTS
OCT 15	13:00-16:00	NO VAR CONTROL
OCT 16	9:00-16:00	VAR CONTROL
OCT 17	9:00-16:00	NO VAR CONTROL
NOV 7	13:24-13:44	FEEDER RESPONSE TO CAPACITOR SWITCHING

ORNL DWG 85-18267

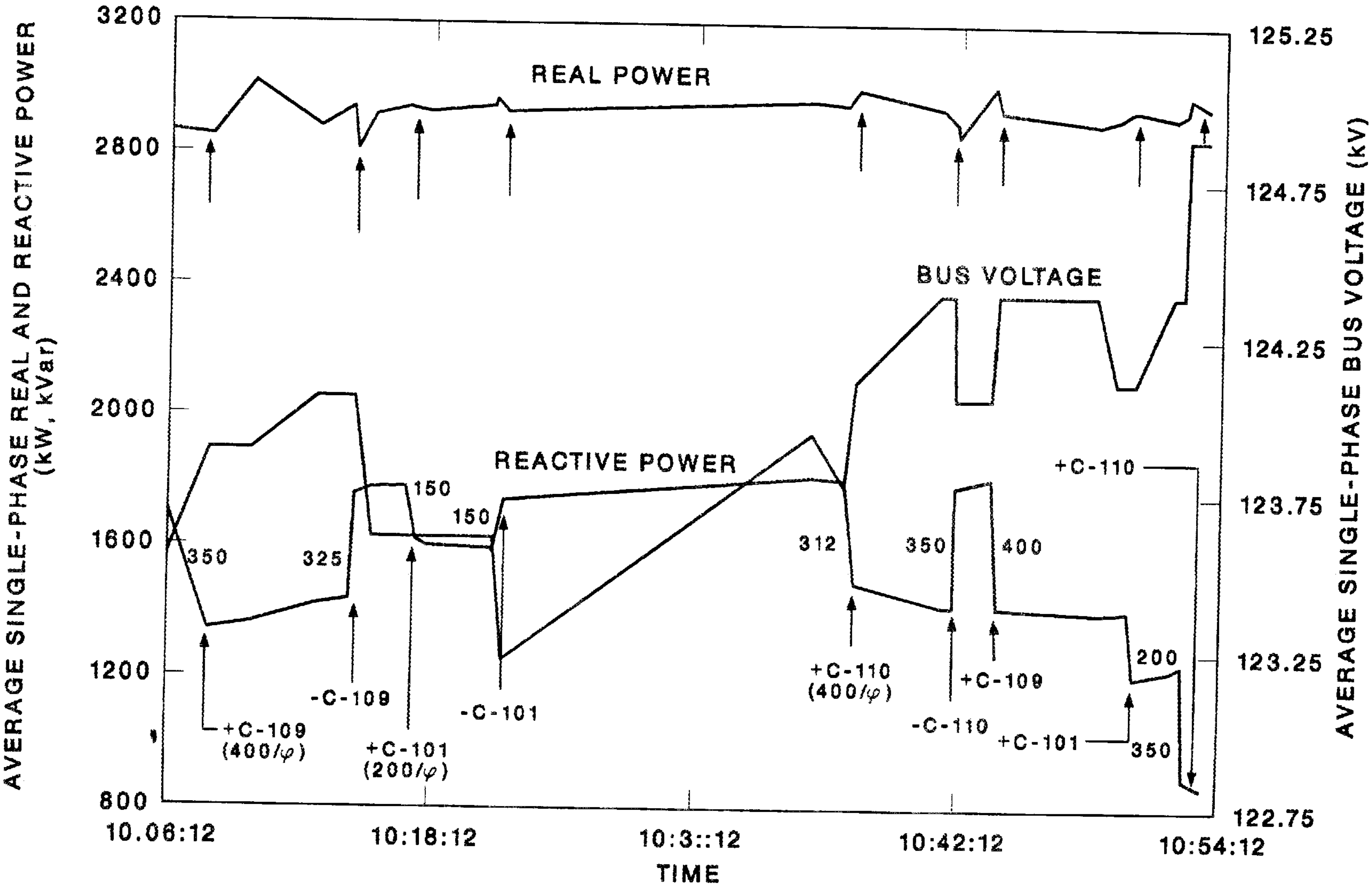
CONTROL POINTS ON CIRCUIT NO. 9
PRIMARILY INDUSTRIAL



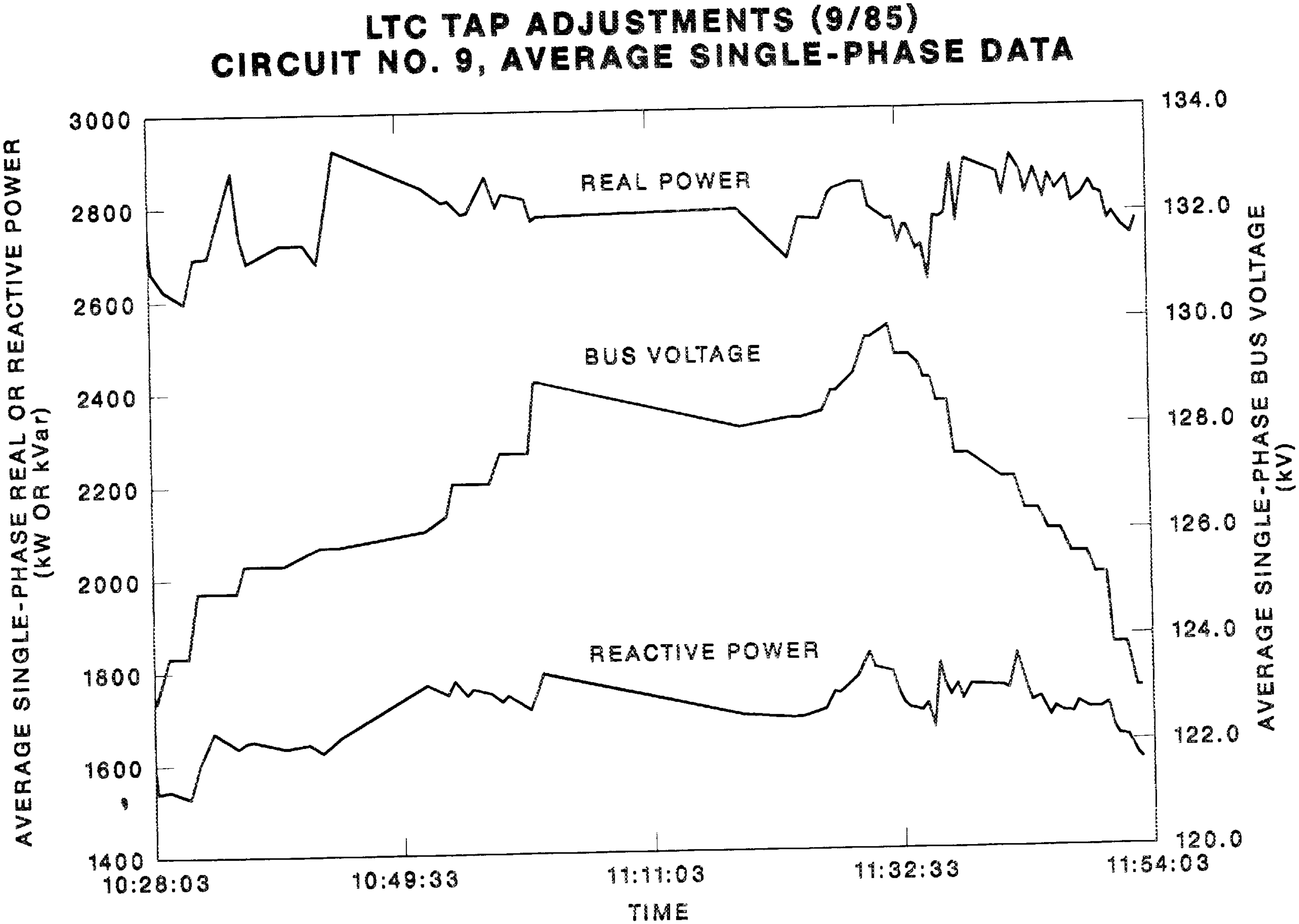
(NOTE: C-122 TO BE ADDED)

ORNL-DWG 85C-18408

FEEDER RESPONSE TO CAPACITOR SWITCHING (9/85) CIRCUIT NO. 9, AVERAGE SINGLE-PHASE DATA

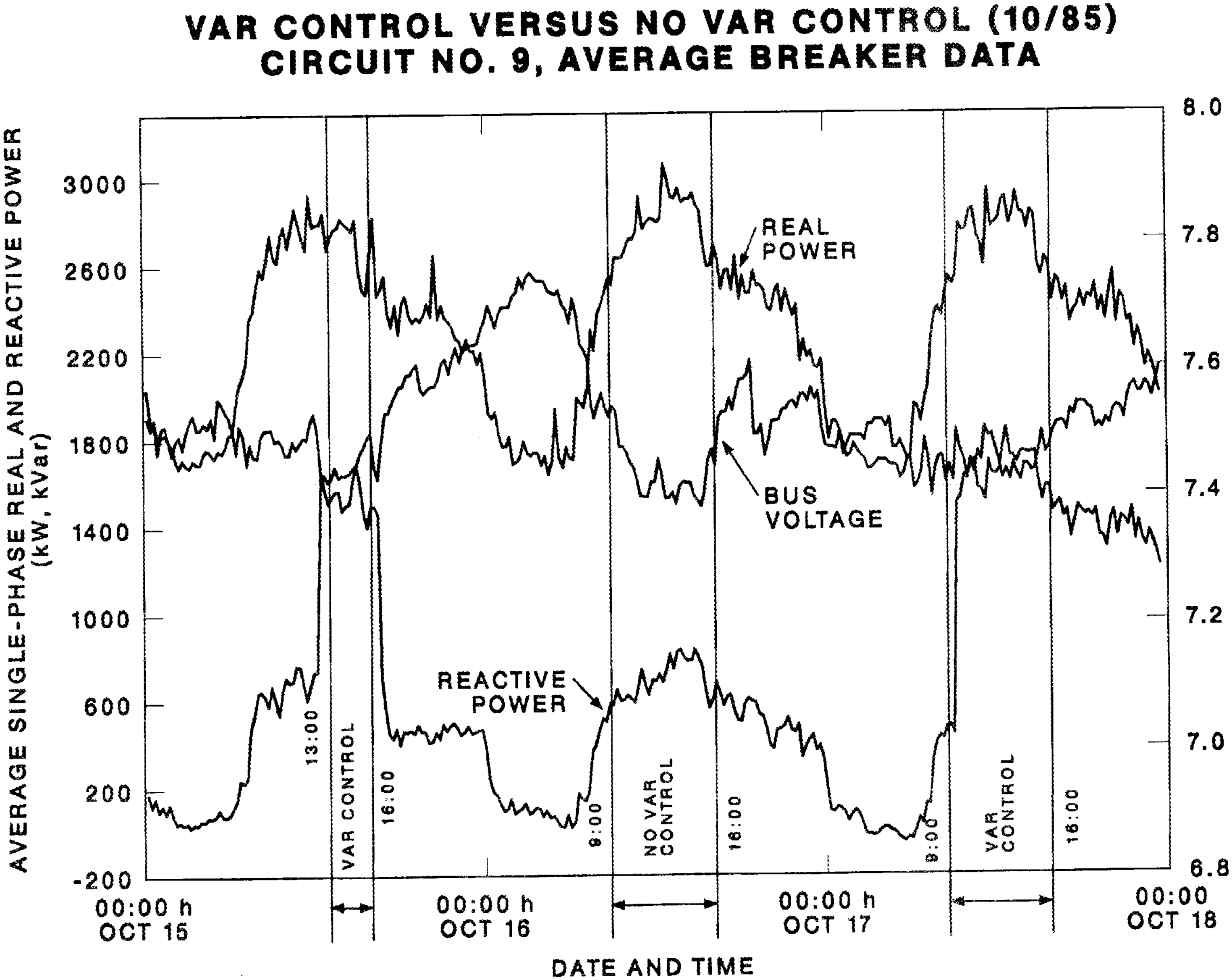


ORNL-DWG 85C-18412



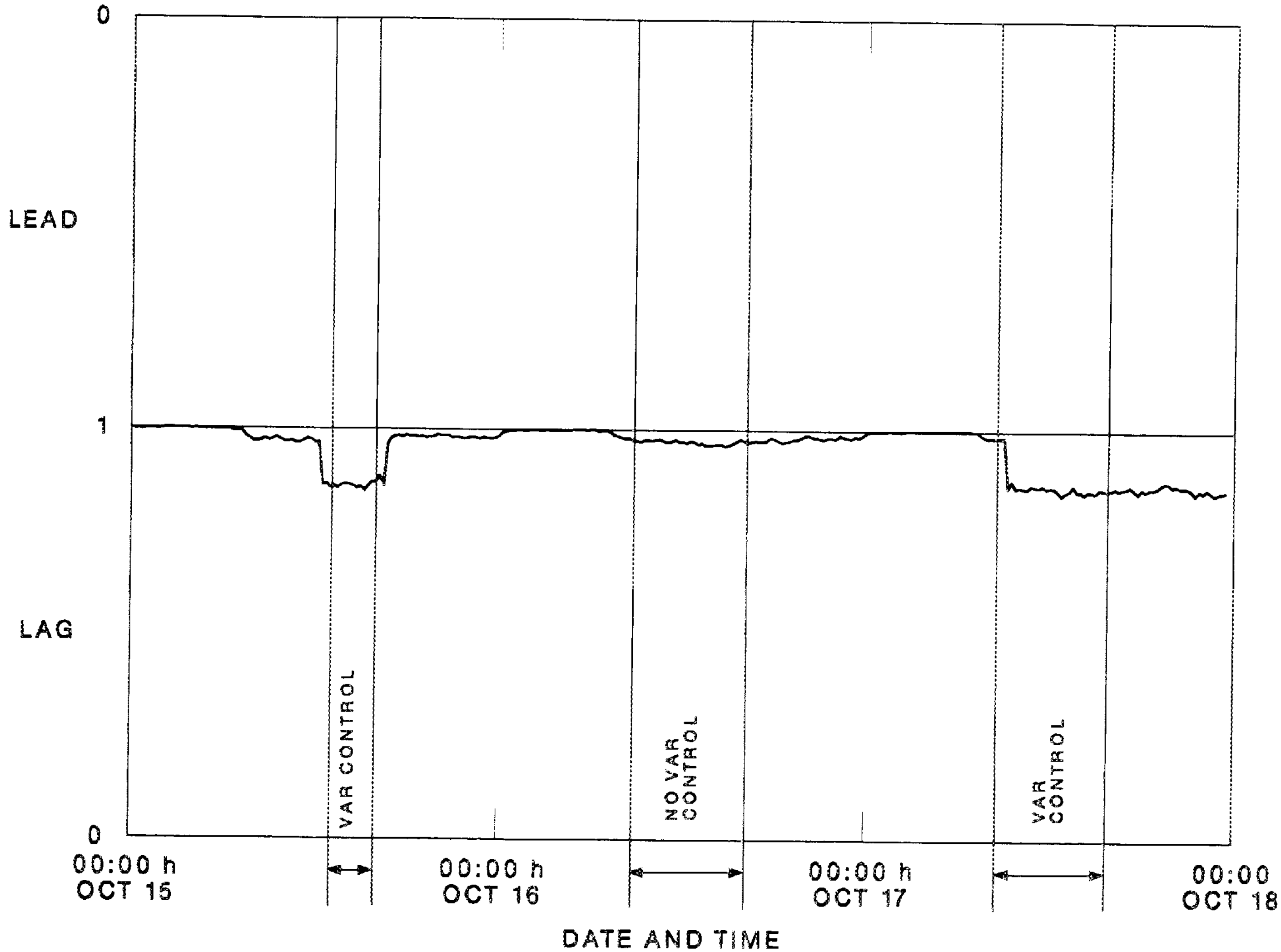
310

ORNL-DWG 85C-18398



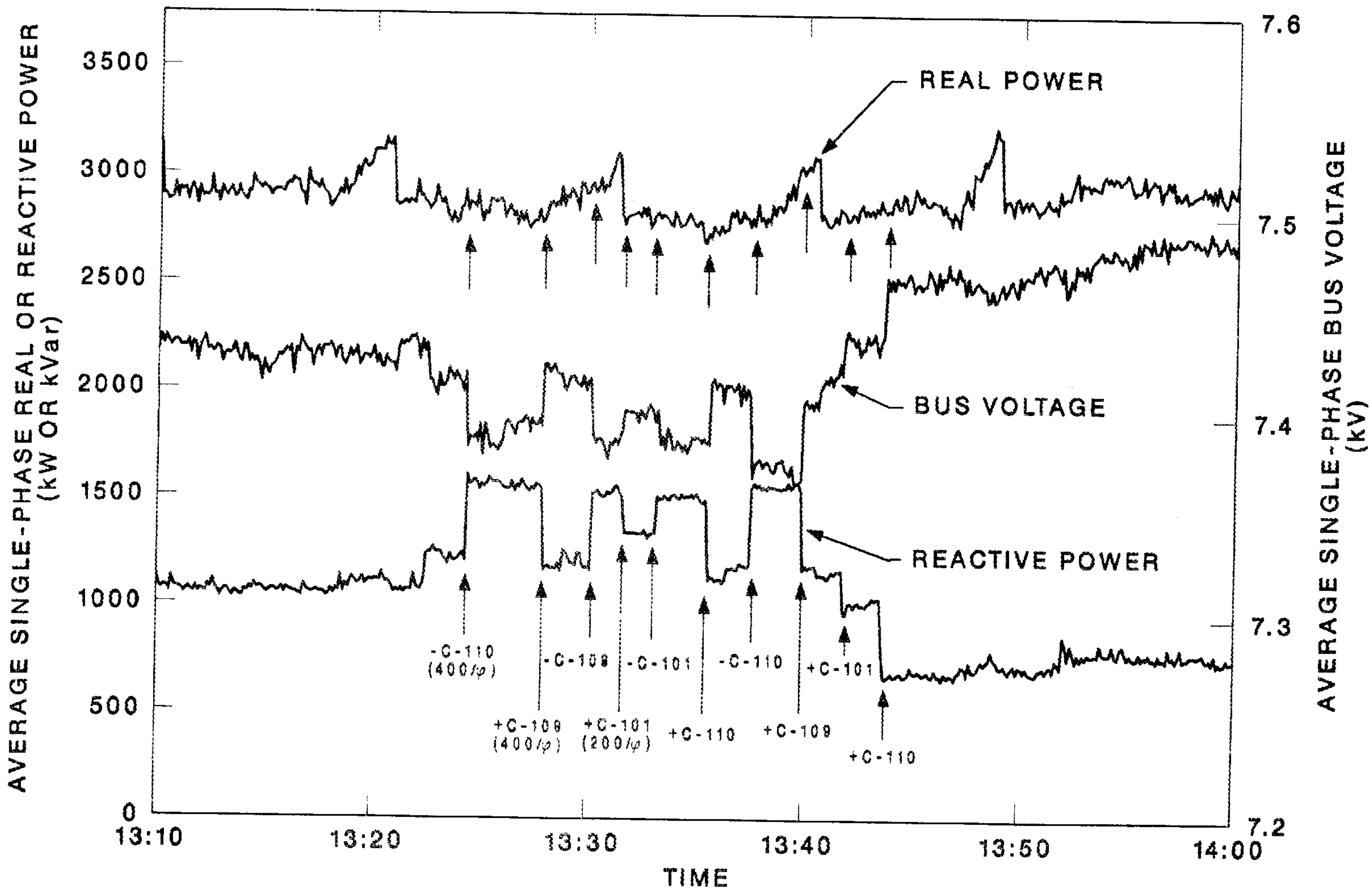
ORNL-DWG 85C-18400

VAR CONTROL VERSUS NO VAR CONTROL (10/85) CIRCUIT NO. 9, AVERAGE POWER FACTOR



ORNL-DWG 85C-18383

FEEDER RESPONSE TO CAPACITOR SWITCHING (11/85)
CIRCUIT NO. 9, AVERAGE SINGLE-PHASE DATA



ORNL WSC-43416

MOTIVATIONS FOR MODEL DEVELOPMENT

- DEVELOP MODEL FOR DETERMINING RESPONSE OF FEEDERS TO CAPACITOR CONTROL
- USE MODEL TO CALCULATE PARAMETERS THAT ARE NOT MONITORED (i.e., LINE LOSSES)
- INTEGRATE WITH AUTOMATIC CONTROL

ORNL WSC-43419

MONITORING BENEFITS

- DIAGNOSTIC CHECKING OF CAPACITOR PERFORMANCE
- DETECTION OF FEEDER LOAD IMBALANCES
- IDENTIFICATION OF FEEDER PERFORMANCE TO CONTROL ACTIONS

ORNL WSC-43418

OBSERVED HARDWARE LIMITATIONS

- PTU CALLBACK TOO LONG AND UNCERTAIN
- MODSCAN DATA FILE CONTAINS 15 MINUTE DATA
- ONLY THREE PHONE LINES FOR SOUTH ATHENS

ORNL WSC-43415

SIMULATION RESULTS VERSUS EXPERIMENTAL RESULTS

PRESENTED BY

Bob Sullivan

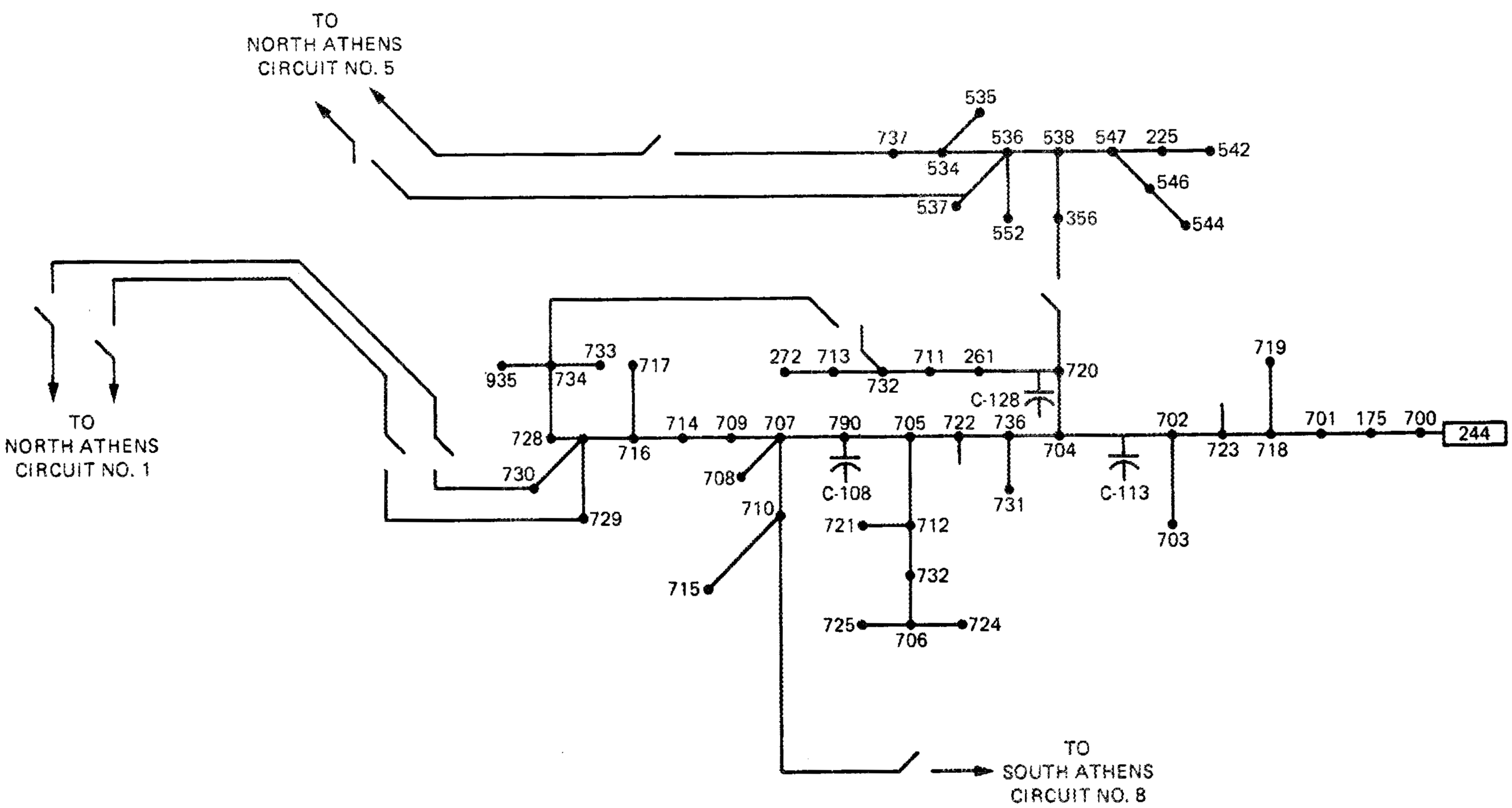
ORNL WSC-43417

SIMULATION ACTIVITIES

- PERFORMED FOR SOUTH ATHENS CIRCUIT NO. 7
- USED SEPT 26, 1985 MONITORED DATA
- IDENTIFIED MONITORED LOAD POINTS
- REDUCED FEEDER TO INCLUDE ONLY MONITORED BUSSES
- CALCULATED FEEDER PERFORMANCE USING MONITORED BUS DATA & POWER FLOW ANALYSIS

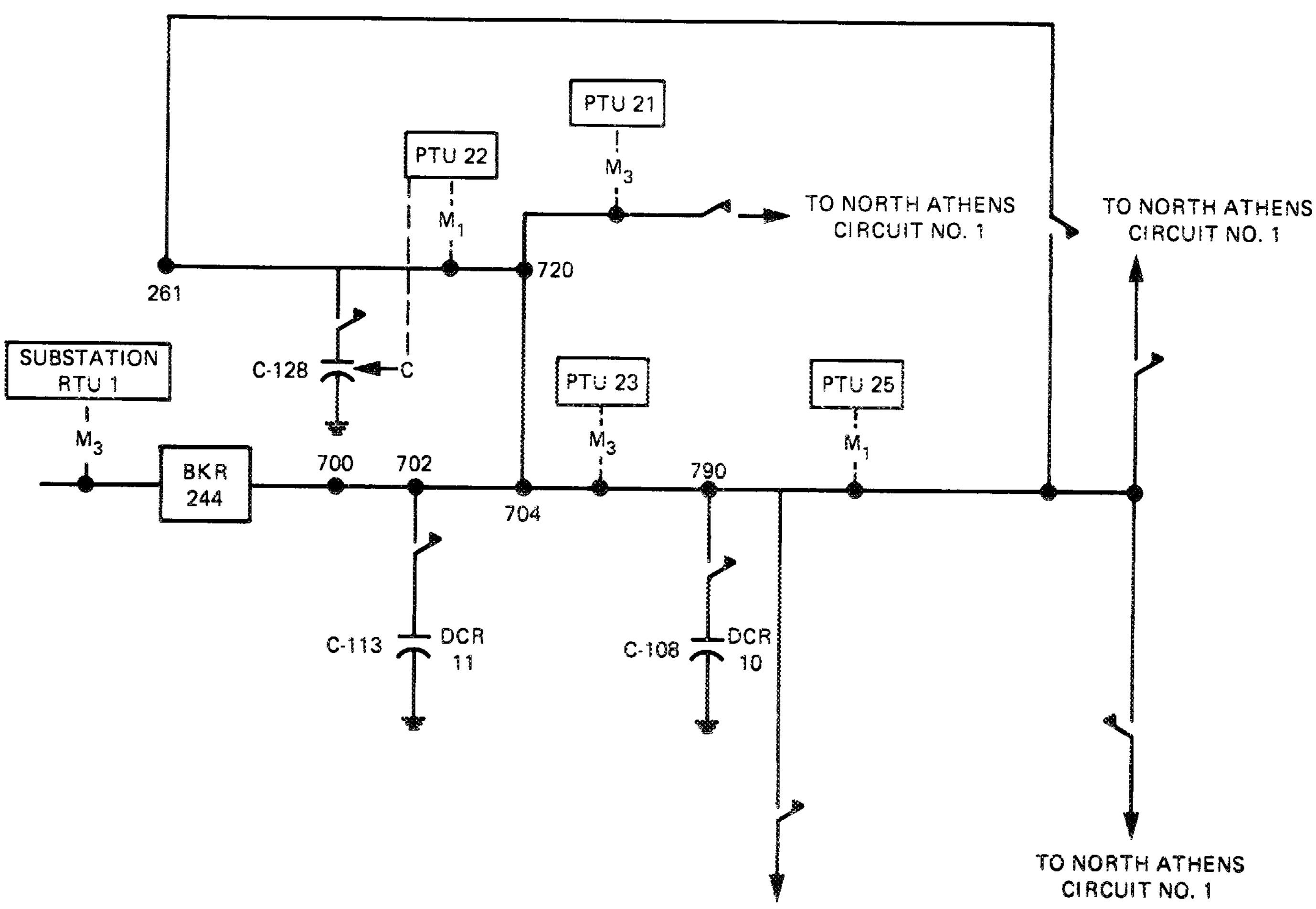
ORNL DWG 85-18277

DETAILED ONE-LINE DIAGRAM OF SOUTH ATHENS CIRCUIT NO. 7



ORNL DWG 85-18271

MONITORED LOCATIONS ON SOUTH ATHENS CIRCUIT NO. 7



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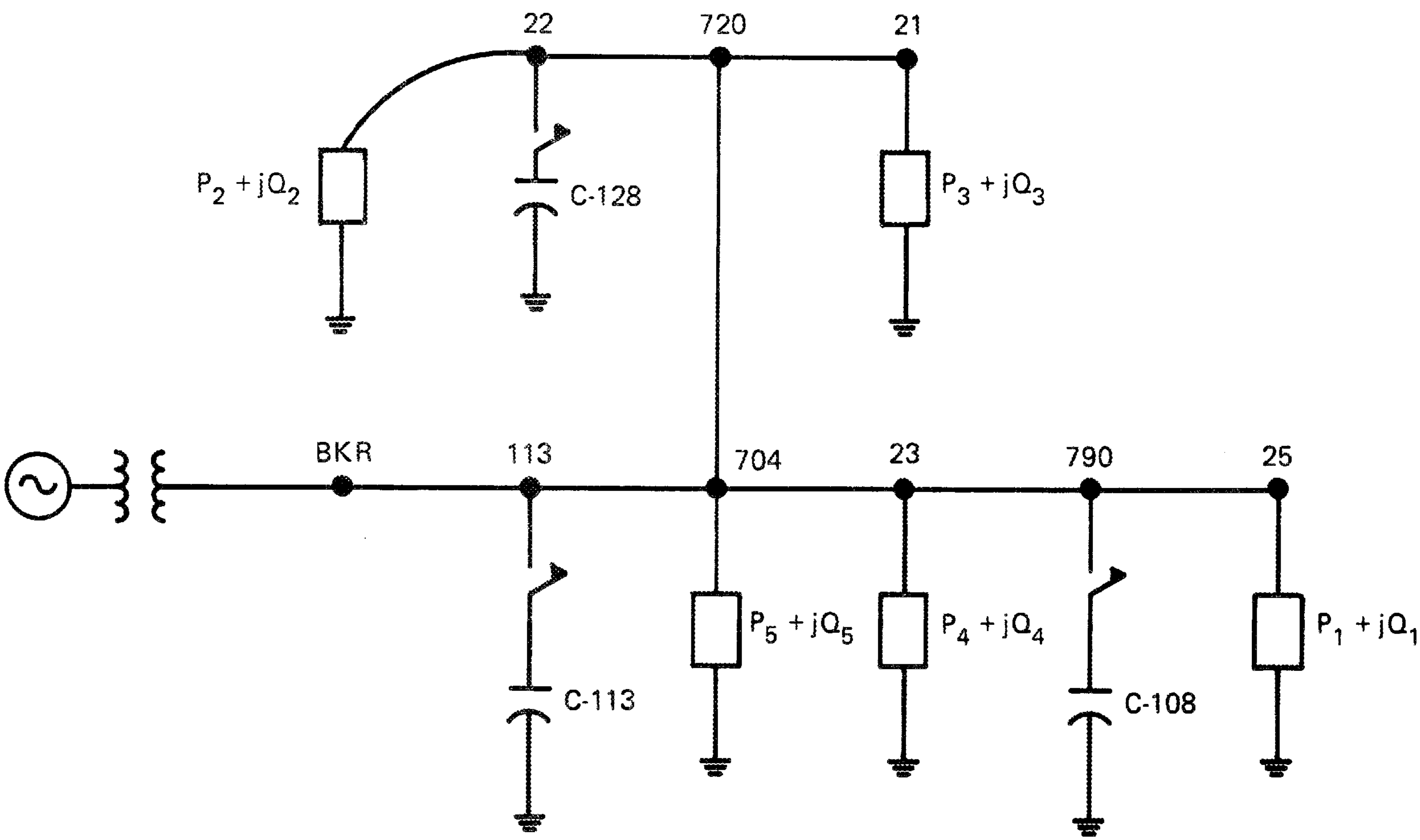
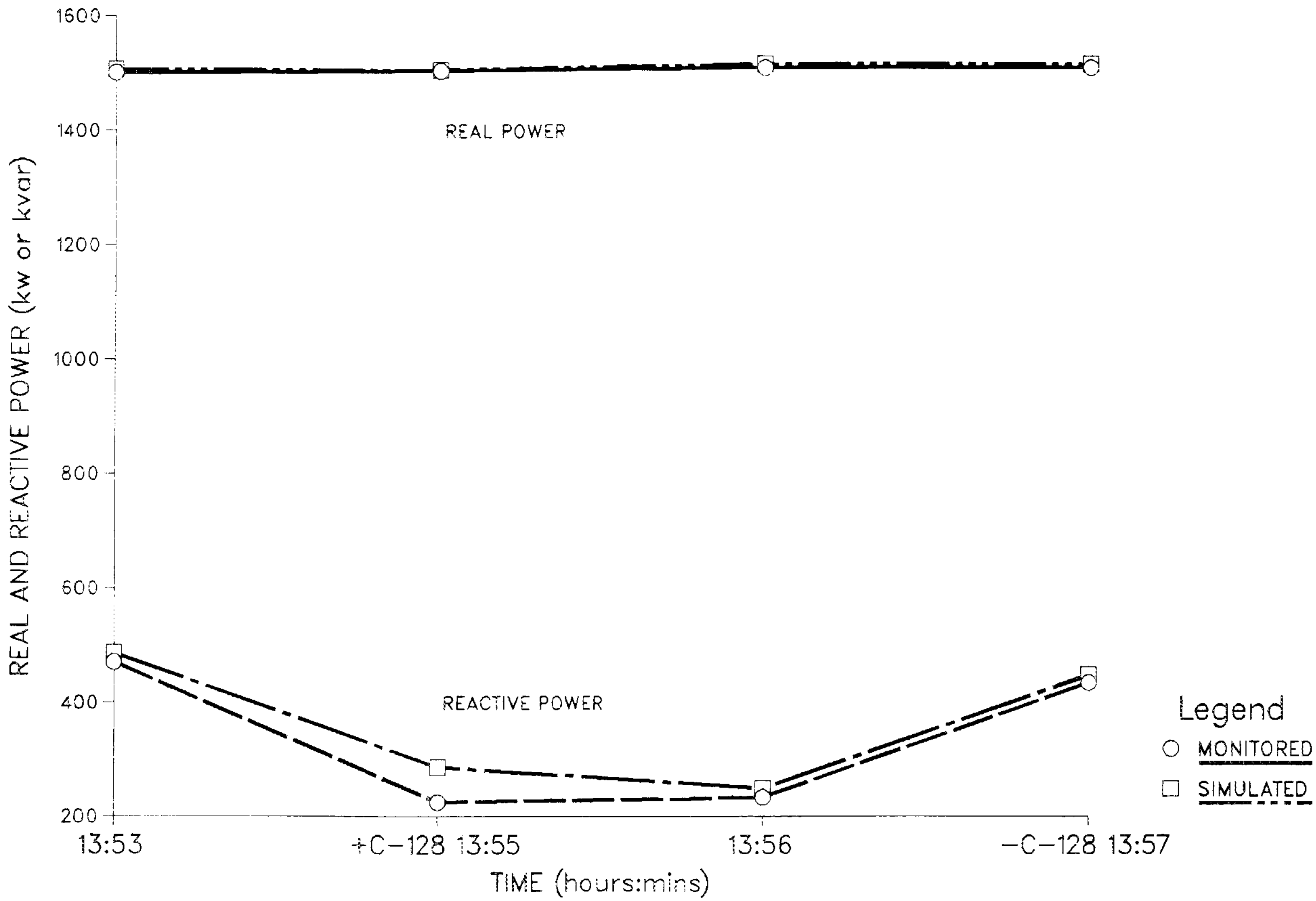
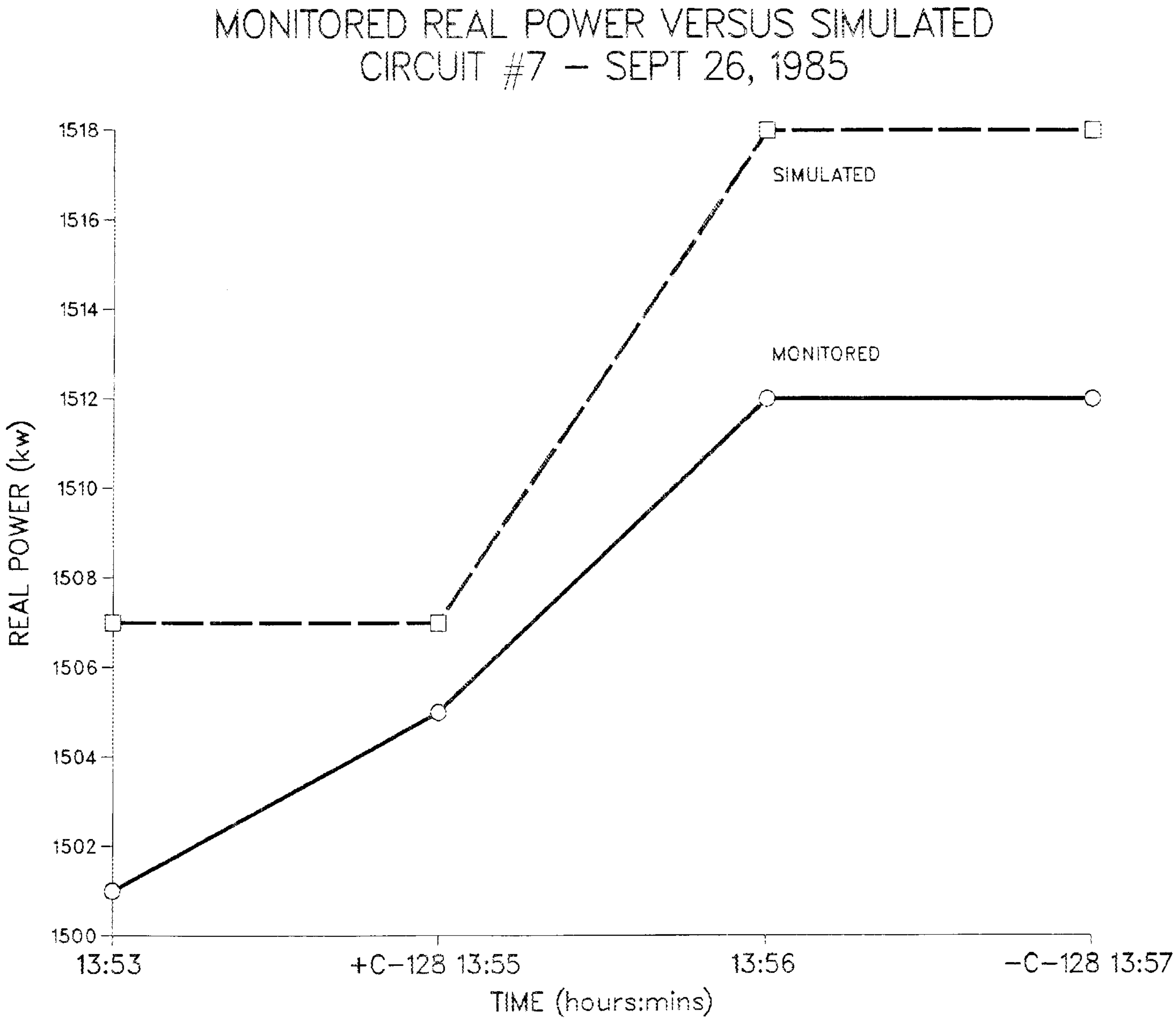
REDUCED MODEL OF SOUTH ATHENS CIRCUIT NO. 7

Q5



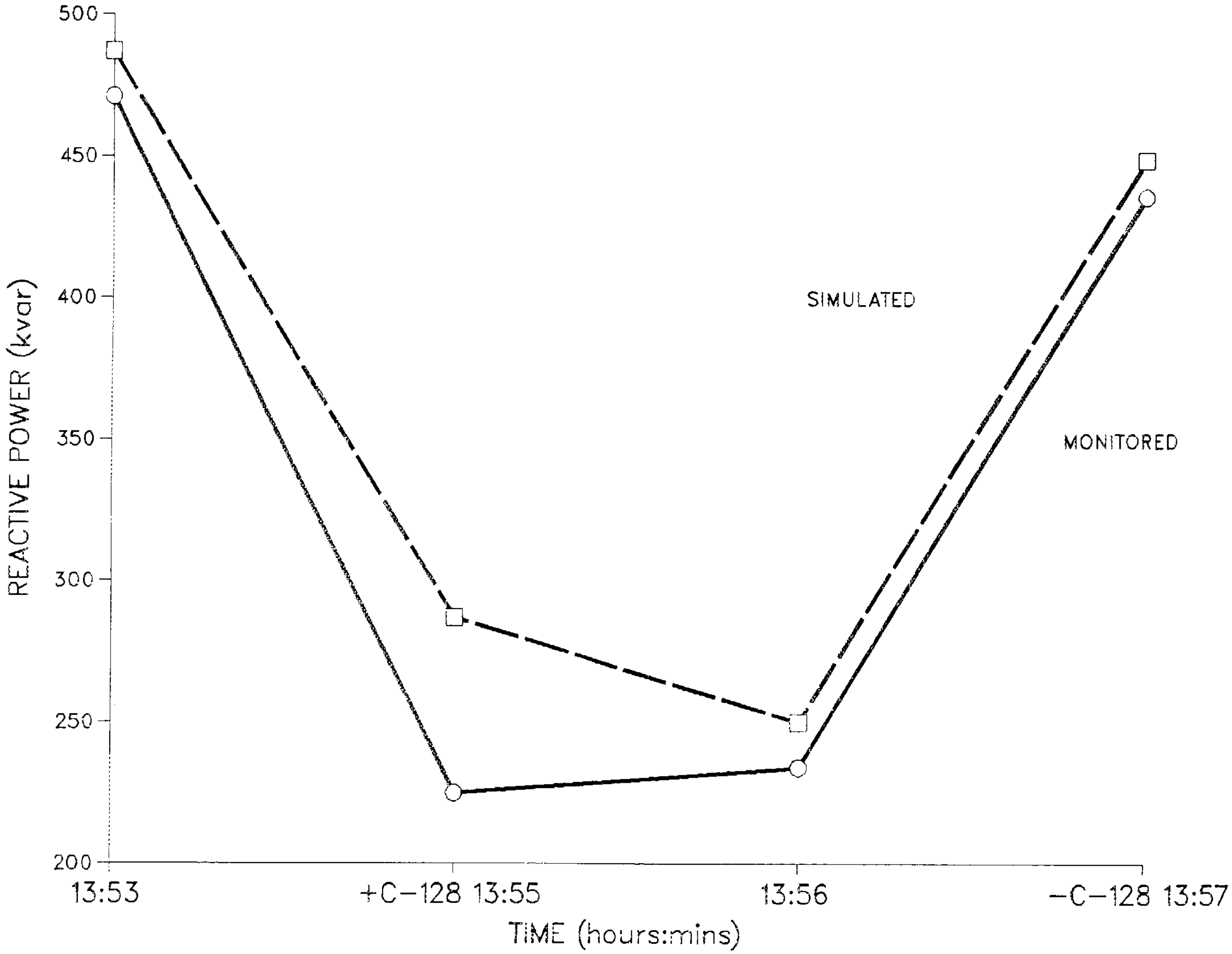
FEEDER RESPONSE TO CAPACITOR SWITCHING
CIRCUIT #7 – SEPT 26, 1985
MONITORED VERSUS SIMULATED DATA



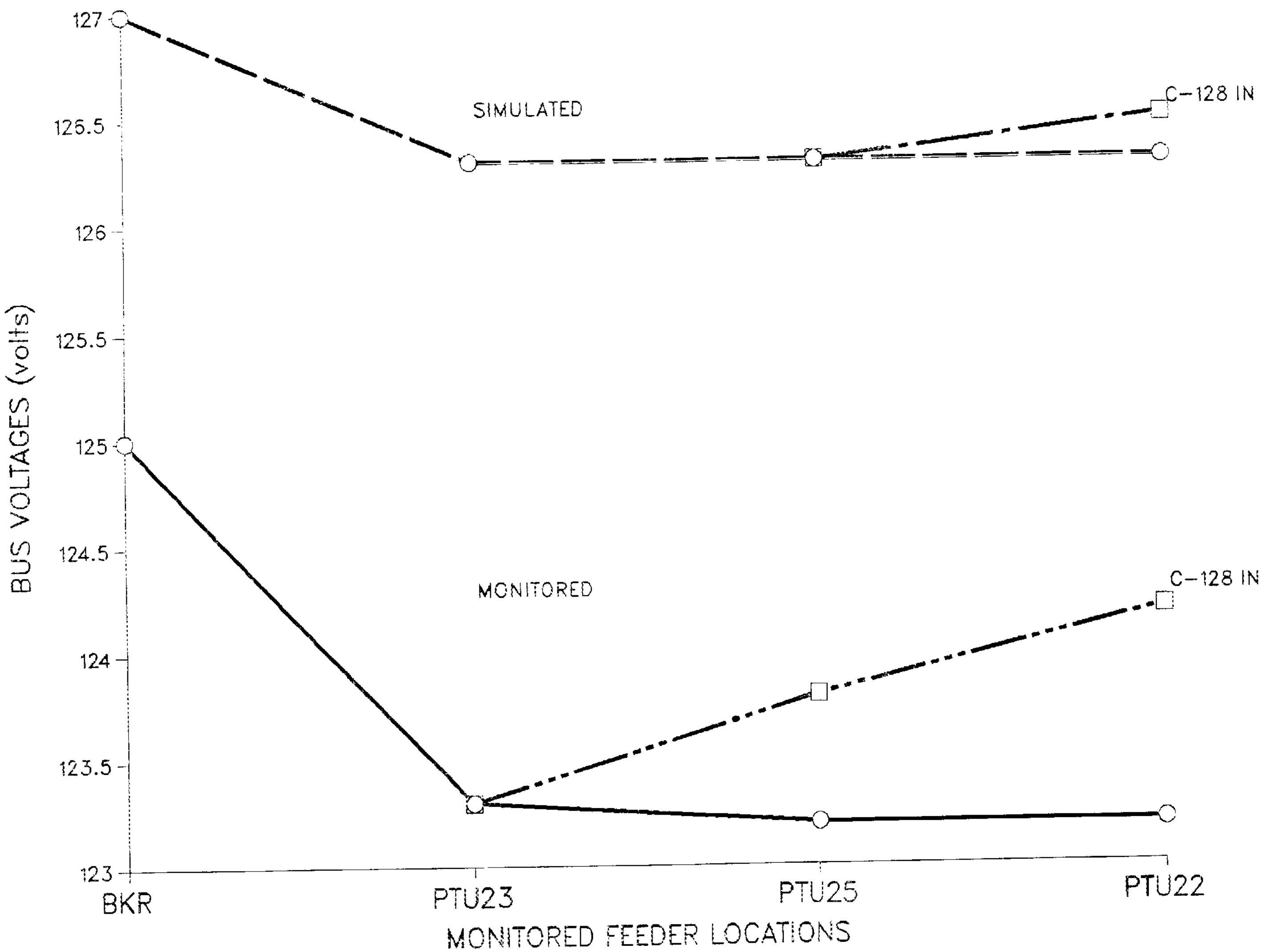


MONITORED REAL POWER VERSUS SIMULATED
CIRCUIT #7 - SEPT 26, 1985
SIMULATED
MONITORED
REAL POWER (kw)
1518
1516
1514
1512
1510
1508
1506
1504
1502
1500
13:53
+C-128 13:55
13:56
-C-128 13:57
TIME (hours:mins)

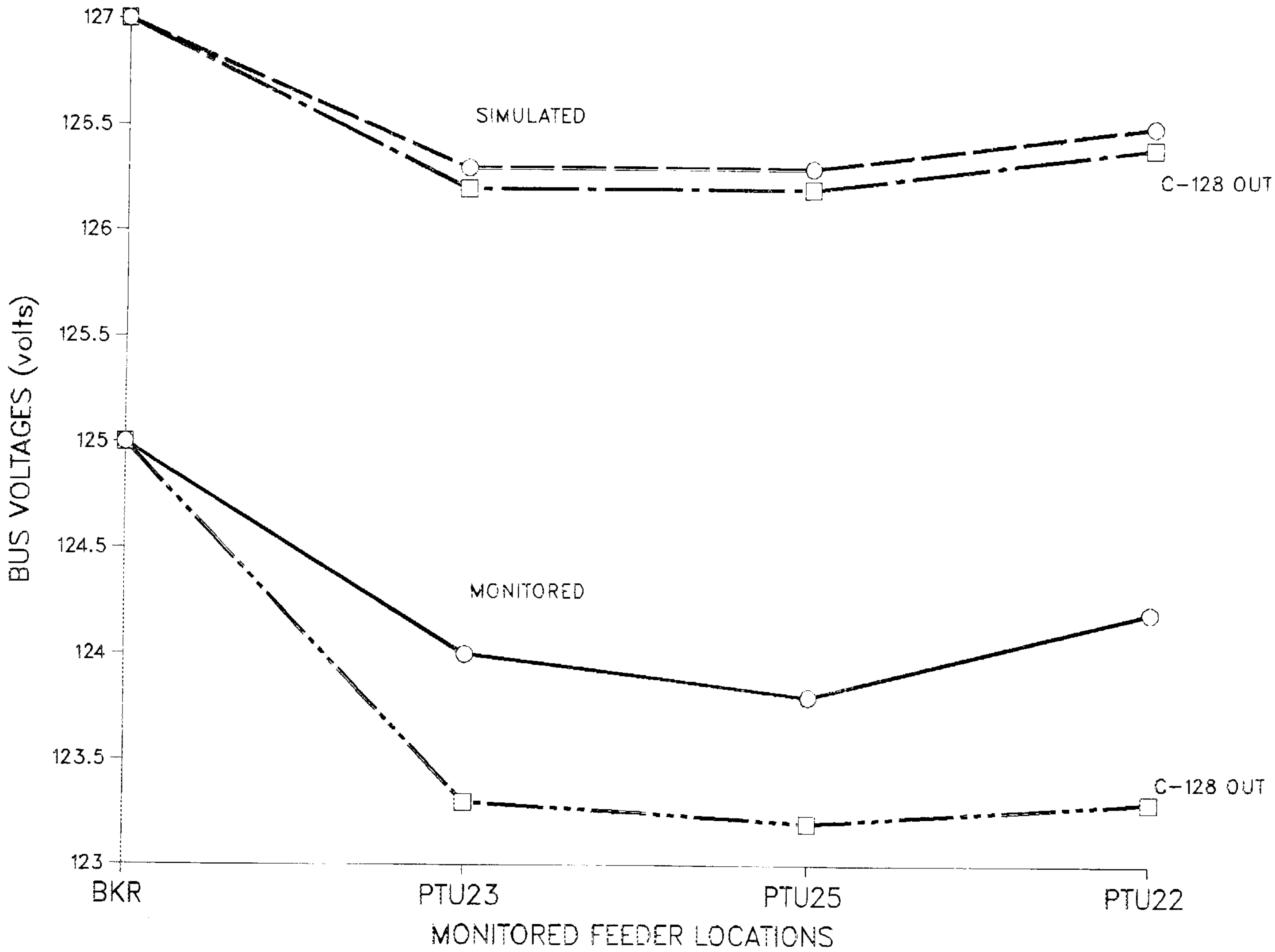
MONITORED REACTIVE POWER VERSUS SIMULATED
CIRCUIT #7 – SEPT 26, 1985



VOLTAGE PROFILE FOR 13:53 TO 13:55
CIRCUIT #7 –SEPT 26



VOLTAGE PROFILE FOR 13:56 TO 13:57
CIRCUIT #7 – SEPT 26, 1985



ORNL WSC-43449

SUMMARY

- DEVELOPED A PROCEDURE FOR AUTOMATING THE CONTROL OF CAPACTOR SWITCHING TO REDUCE REACTIVE POWER FLOWS
- REAL-TIME MODELING APPEARS TO GIVE A GOOD SIMULATION OF VAR CONTROL

  SIMPLIFIED MODEL PRODUCES FAST RESULTS
  MODEL USES MONITORED DATA

- PRELIMINARY EXPERIMENTAL RESULTS HAVE BEEN OBTAINED ON SOUTH ATHENS CIRCUITS

  AS EXPECTED DATA INDICATES A REDUCTION IN REACTIVE POWER (COMPARABLE TO CAPACITOR BANK SIZE) AND AN IMPROVEMENT IN POWER FACTOR WHEN VAR CONTROL IS IMPLEMENTED

  HOWEVER, PRELIMINARY DATA DOES NOT SHOW AN OBSERVABLE CHANGE IN REAL POWER DUE TO CAPACITOR SWITCHING

  TOO EARLY TO CONCLUDE HOW MUCH REAL POWER IS REDUCED BY VOLTAGE REDUCTION

ORNL WSC-43450

SUMMARY
(continued)

- FUTURE EXPERIMENTS WILL CONTINUE TO TEST FEEDER RESPONSE OF SOUTH ATHENS CIRCUITS AND WILL BE CONDUCTED ON NORTH ATHENS AND ENGLEWOOD
  - VAR CONTROL ON ALL CIRCUITS
  - VOLTAGE CONTROL
  - VOLTAGE REDUCTION
  - VAR CONTROL VERSUS LOCAL CONTROLLERS
  - VOLTAGE CONTROL VERSUS LOCAL CONTROLLERS

SYSTEM RECONFIGURATION

SYSTEM RECONFIGURATION

Jack Lawler and J. B. Patton

System reconfiguration involves the automated monitoring of the distribution system operating conditions and the remote control of distribution switching elements. Automated monitoring allows abnormal or undesirable network conditions, such as permanent faults or imminent component overloads, to be recognized at the distribution system control center. Remote control of switches allows the system operator to reconfigure the network in order to avoid such problems or minimize their effect on system operation. Potential benefits of automated system reconfiguration include system reliability and enhanced capacity utilization.

The objectives of the system reconfiguration experiments are to (1) quantify the reliability and capacity utilization benefits; (2) determine the trade-off between the amount of automation hardware and level of benefit; (3) determine if adaptive protection is required to support automated reconfiguration; (4) determine the added benefits of integrating system reconfiguration with volt/var and customer load control; and (5) transfer the experimental findings to the electric utility industry. During the past year, significant progress has been made towards meeting these objectives. In particular, the experiment team has developed a detailed test plan for the experiments to be conducted during the first year of operation. The focus of this presentation is on the computer software that has been developed to support experiment design and analysis and on the results of the initial round of experimentation.

ATHENS AUTOMATION AND CONTROL EXPERIMENT

SYSTEM RECONFIGURATION

Jack Lawler

Jim Patton

Bob Stevens

Kevin McKinley

Larry Monteen

PRESENTATION OUTLINE

I. Introduction

II. The First Year Experiments

III. System Reconfiguration Analysis Program

IV. Preliminary Experience with Automated Load Transfers

V. Preliminary Experience with Automation Assisted Response to Faults

VI. Conclusions

I. Introduction

- Definition of System Reconfiguration
- System Reconfiguration Hardware
- System Reconfiguration Functions
- Control Diagram
- Experiment Objectives

Definition

System reconfiguration is the automatic monitoring of the distribution network operating condition and the remote control of distribution switching elements.

System Reconfiguration Hardware

Controllable Switching Elements:

- Feeder Breakers
- Power Reclosers
- Motor Operated Load Break Switches

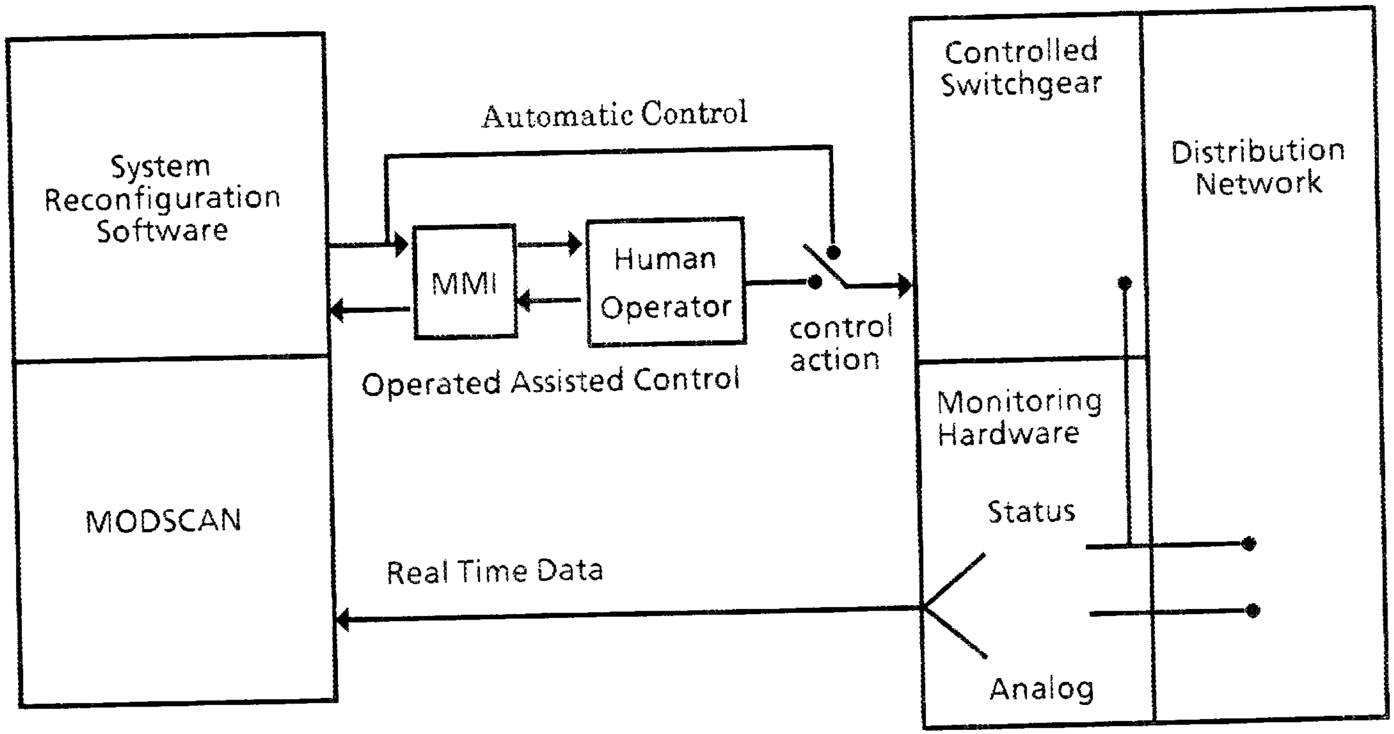
Monitoring Hardware:

- PTs and CTs for analog values
- Switching element status
- Relay status
- Fault detectors

System Reconfiguration Functions

1. Fault Detection
2. Fault Location
3. Fault Isolation and Service Restoration
4. Feeder Monitoring
5. Feeder Load Transfers
6. Substation Load Transfers
7. Adaptive Protection

CONTROL DIAGRAM



Experimental Objectives

I. Determine the improvement in distribution system service reliability that can be achieved by automating the detection, location and isolation of faults and subsequent service restoration.

II. Determine the improvement in distribution system capacity utilization with automated feeder monitoring, feeder load transfer and substation load transfer functions.

III. Determine whether or not adaptive protection is necessary to support on-line system reconfiguration.

Experimental Objectives

IV. Study the amount of automation hardware required to improve distribution system service reliability and capacity utilization.

V. Determine the additional benefits of system reconfiguration when integrated with volt/var and customer load control.

VI. Transfer the experimental results to the electric utility industry.

II. The First Year Experiments

RELIABILITY ENHANCEMENT EXPERIMENTS

SR-1 Fault Detection

SR-2 Fault Location

SR-3 Fault Isolation and Service Restoration

AUTOMATED MONITORING EXPERIMENT

SR-4 Feeder Monitoring

CAPACITY UTILIZATION ENHANCEMENT EXPERIMENTS

SR-5 Feeder Load Transfers

SR-6 Substation Load Transfers

Reliability Enhancement Experiments

SR-1 Fault Detection

SR-2 Fault Location

SR-3 Fault Isolation & Service Restoration

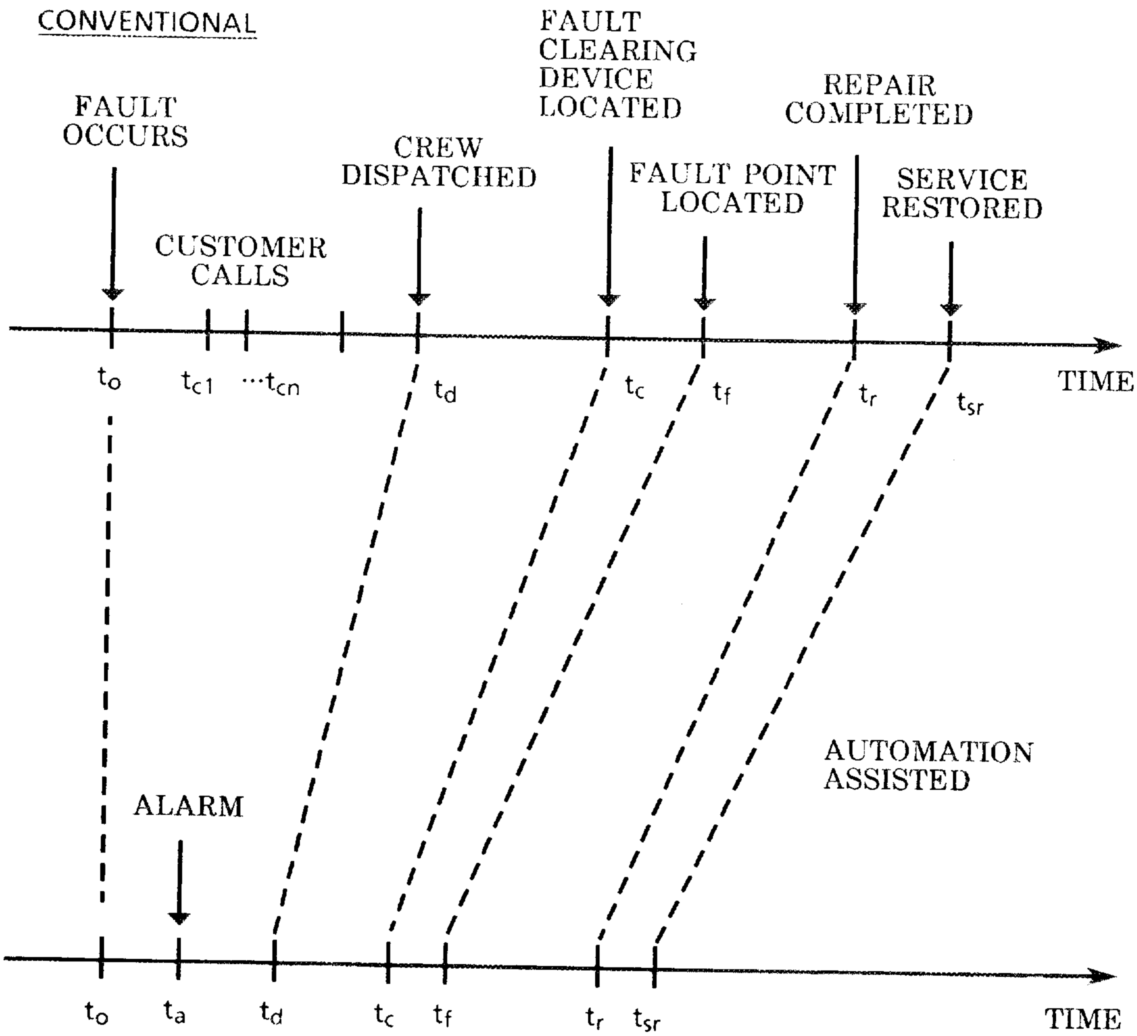
GOALS:

1. Determine the reduction in customer outage hours and unserved energy due to each automated fault response function.
2. Determine the reliability of the automated fault response system and its individual components.

PROCEDURE;

Document AUB response to naturally - occuring faults.

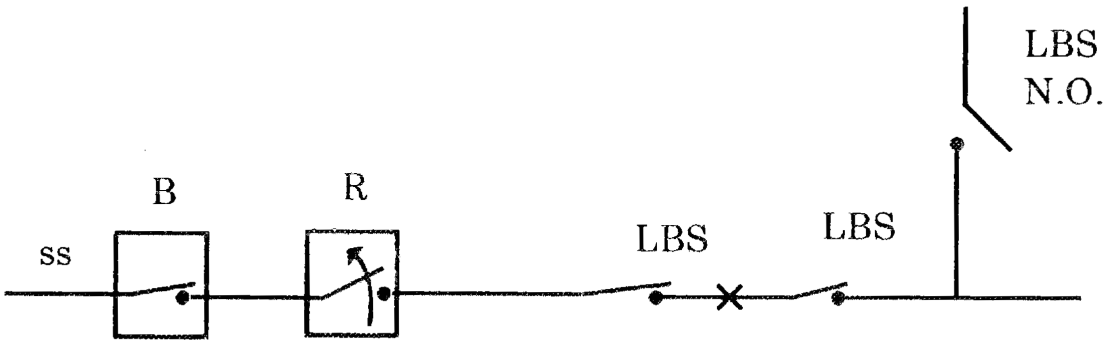
FAULT RESPONSE: EVENT/TIME-LINE



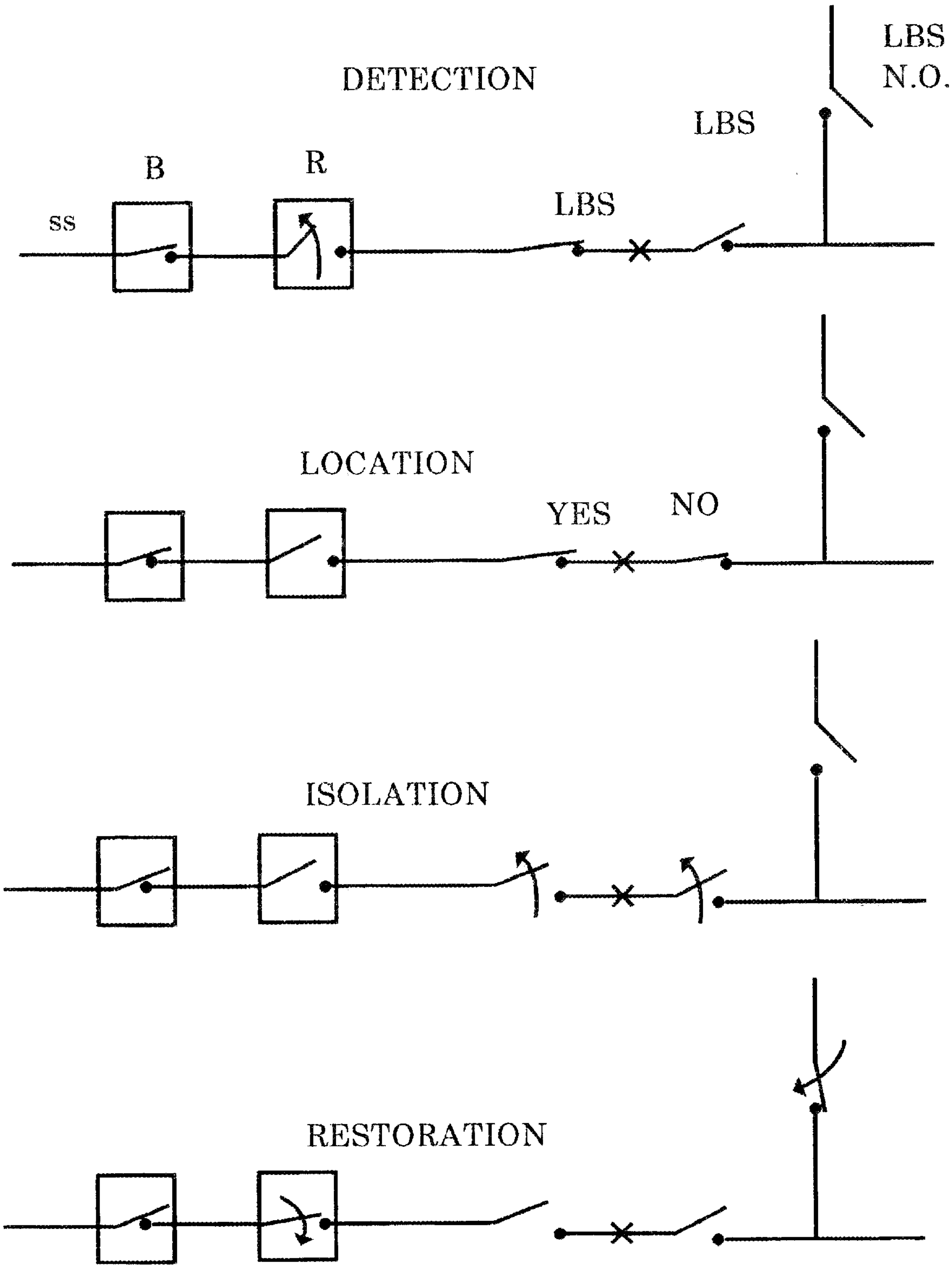
RELIABILITY EXPERIMENT DATA SOURCES

- MODSCAN Data Logs
- AUB Trouble Forms
- Voice-Actuated Recorder

UTILITY RESPONSE TO FAULTS
CONVENTIONAL PRACTICE



UTILITY RESPONSE TO FAULTS: AUTOMATION ASSISTED



FEEDER MONITORING EXPERIMENT

SR-4 Feeder Monitoring

GOAL:

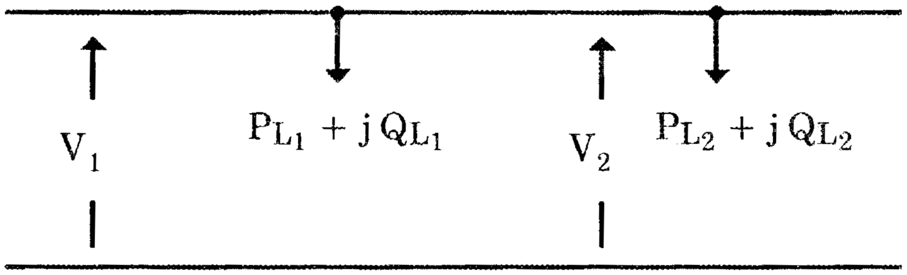
Develop a load model which is sufficiently accurate to support on-line load transfer decisions at AUB.

PROCEDURE:

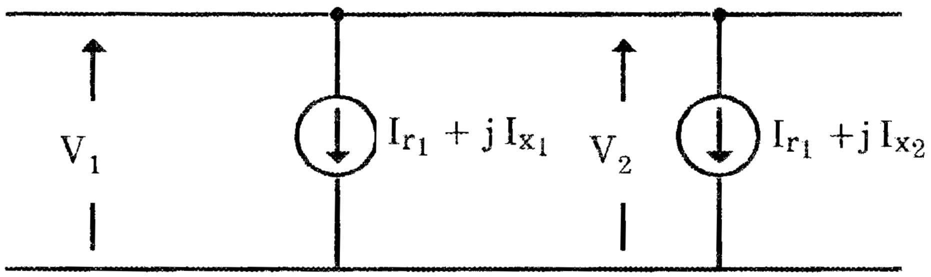
Investigate simple load models consisting of constant power, constant current and constant impedance components that can be scaled to fit measured conditions.

Possible Load Models

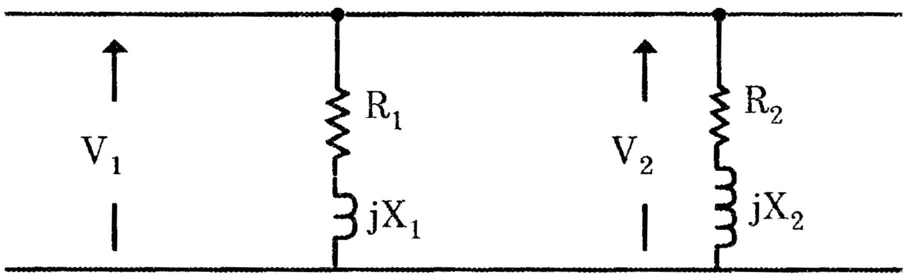
Constant Power



Constant Current



Constant Impedance



Capacity Utilization Enhancement Experiments

SR-4 Feeder Monitoring

SR-5 Feeder Load Transfer

SR-6 Substation Load Transfer

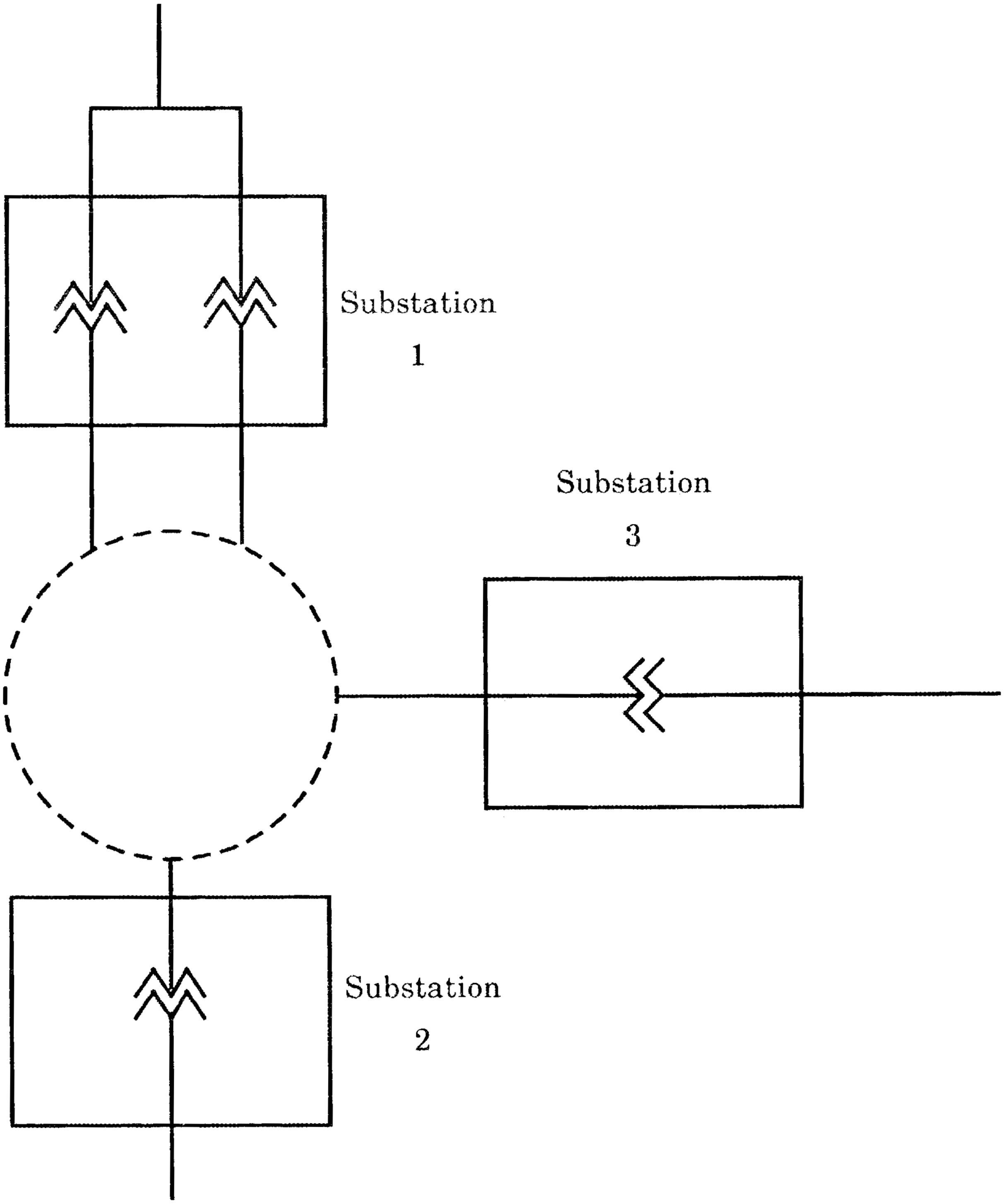
GOALS:

1. Establish the data base required to support feeder and substation load transfers.
2. Determine the practical constraints and procedural details necessary to execute automated load transfers.

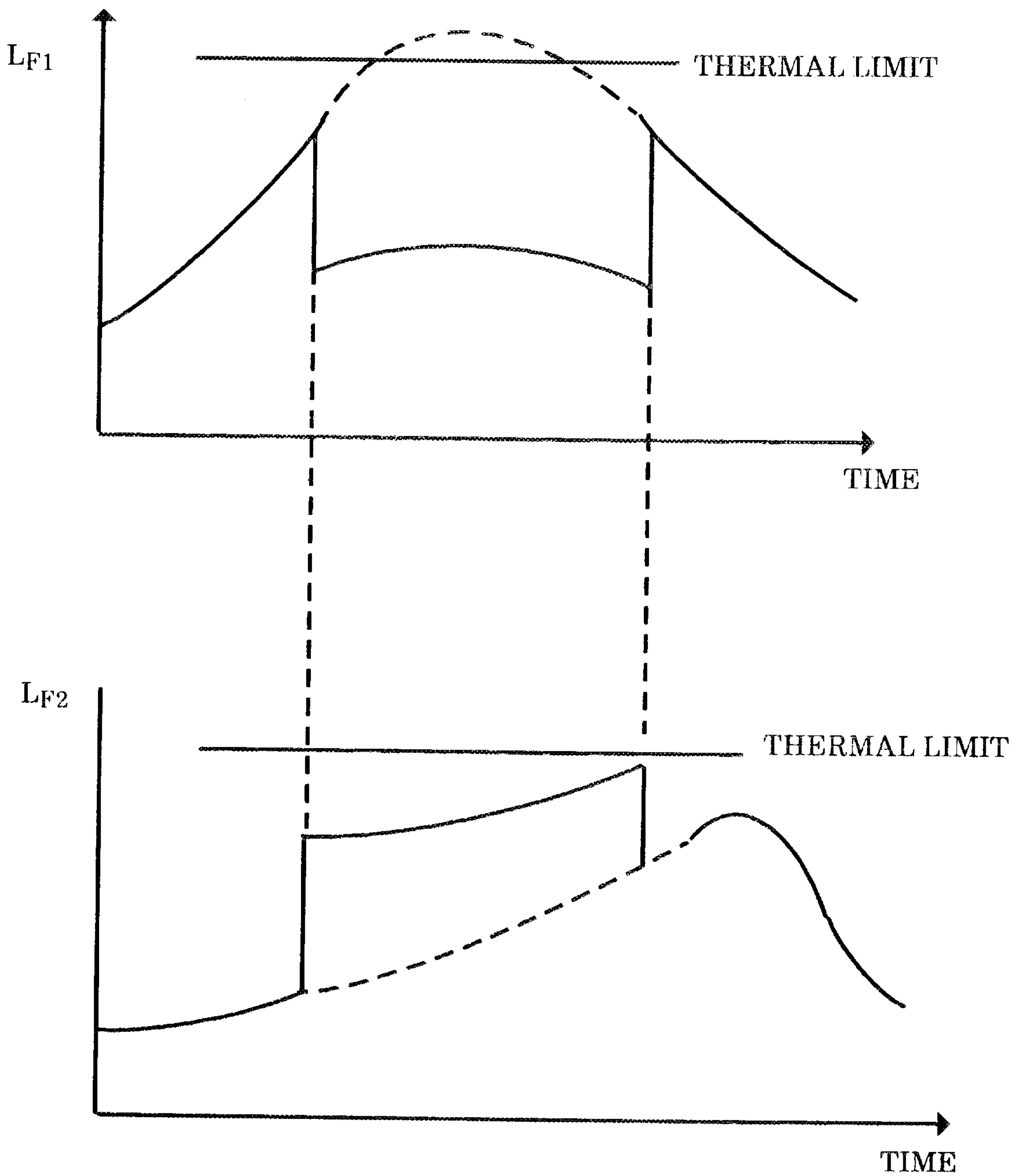
PROCEDURE:

Document several load transfers which are safe even under peak load conditions.

FIRM AREA CONCEPT



FEEDER LOAD TRANSFER TO EXPLOIT LOAD DIVERSITY



III. System Reconfiguration Analysis Package

SYSRAP is an interactive personal computer program which was developed to support the design and analysis of load transfer experiments at AUB.

Concerns in Reconfiguration

- How much load lies in the section to be transferred?
- Is the reconfiguration acceptable from a capacity perspective?
- Is the reconfiguration accceptable from a voltage and loss profile perspective?
- Is the reconfiguration acceptable from a protection coordination perspective?

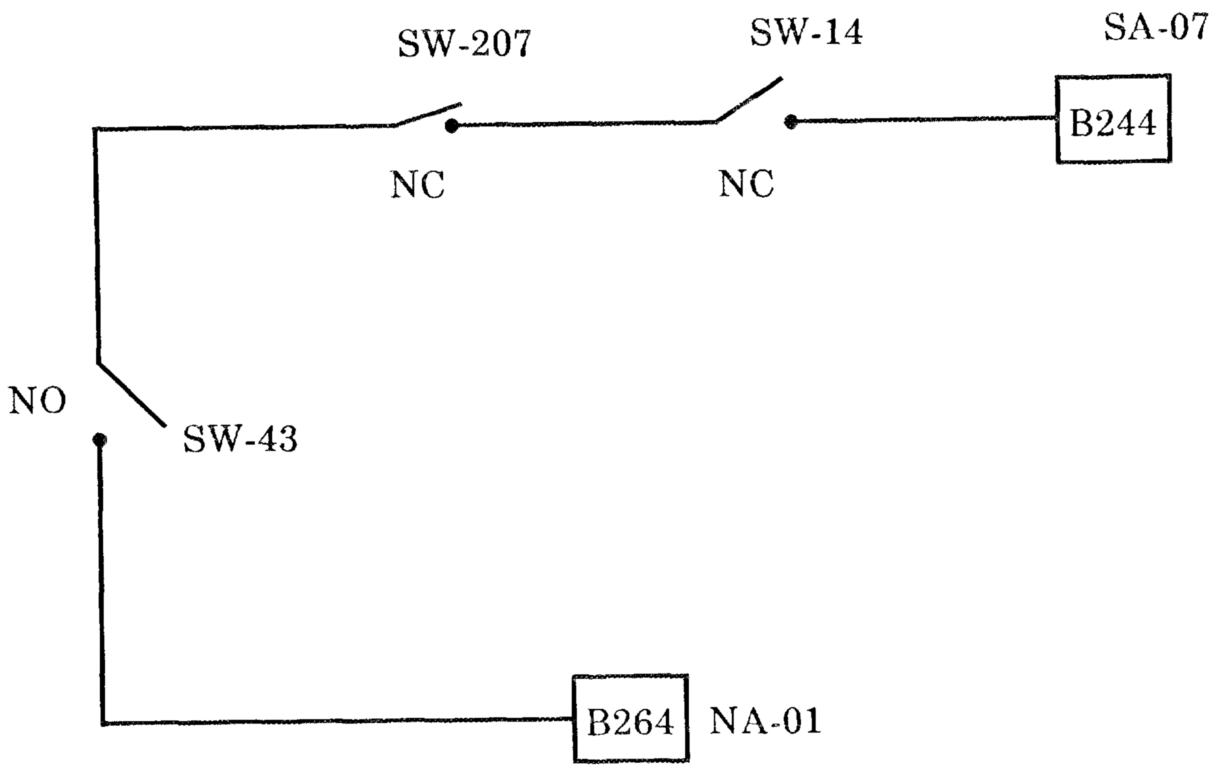
IV. Preliminary Experience with Automated Load Transfers

A. 0.75 MW transfer from SA-07 to NA-01

B. 1.5 MW transfer from SA-07 to NA-01

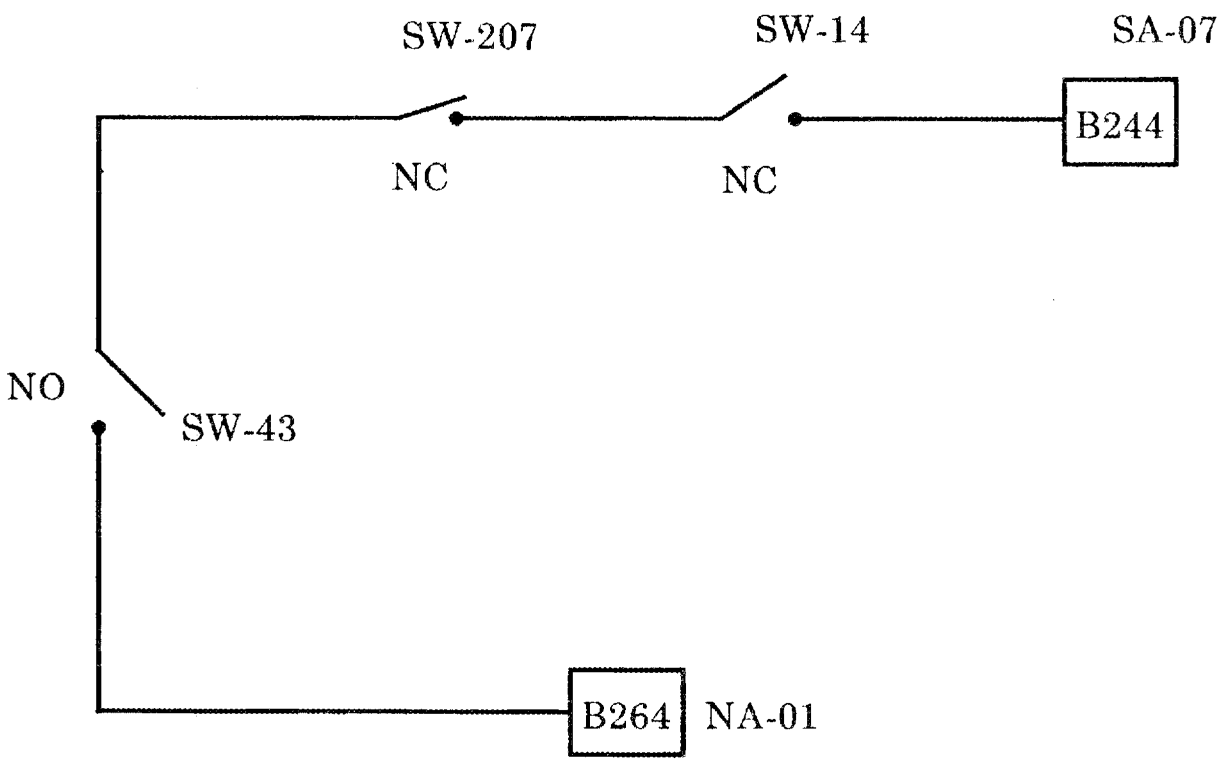
C. 4.0 MW transfer from SA-09 to NA-05

A. 0.75 MW Transfer From SA-07 to NA-01



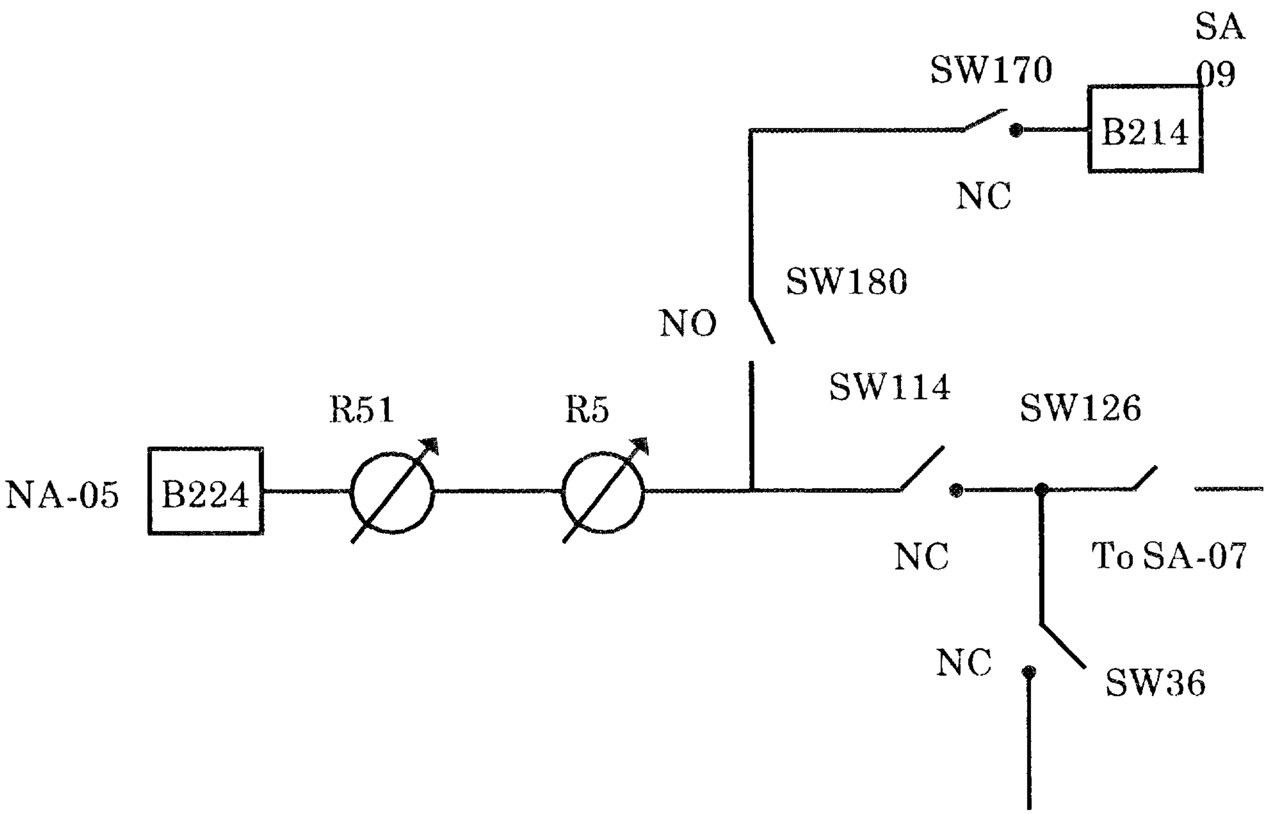
Can the load bounded by SW 207 and SW 43 be transferred from SA 07 to NA-01?

B. 1.5 MW Transfer From SA-07 to NA-01



Can the load bounded by SW14 and SW 43 be transferred from SA-07 to NA-01?

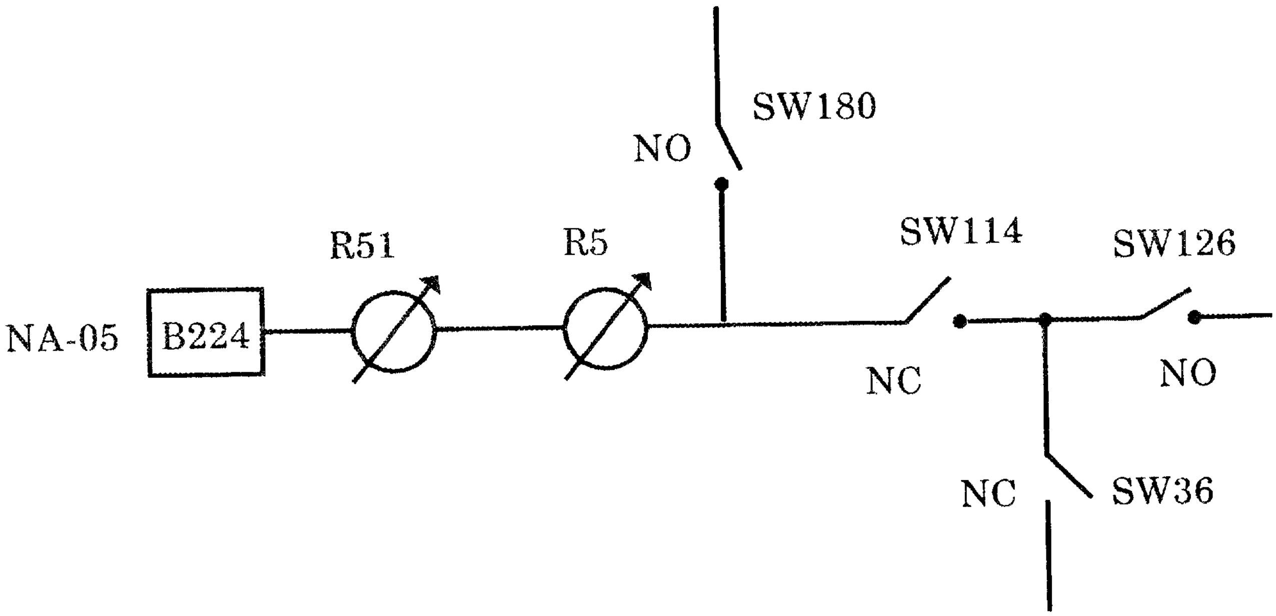
C. 4.0 MW Transfer From SA-09 to NA-05



R5 is set for 2.5% boost
R51 is set for 2.5% boost

Both regulators must be "ZEROED" prior to load transfer.

Impact of Regulator Zeroing on NA-05 Voltage Profile



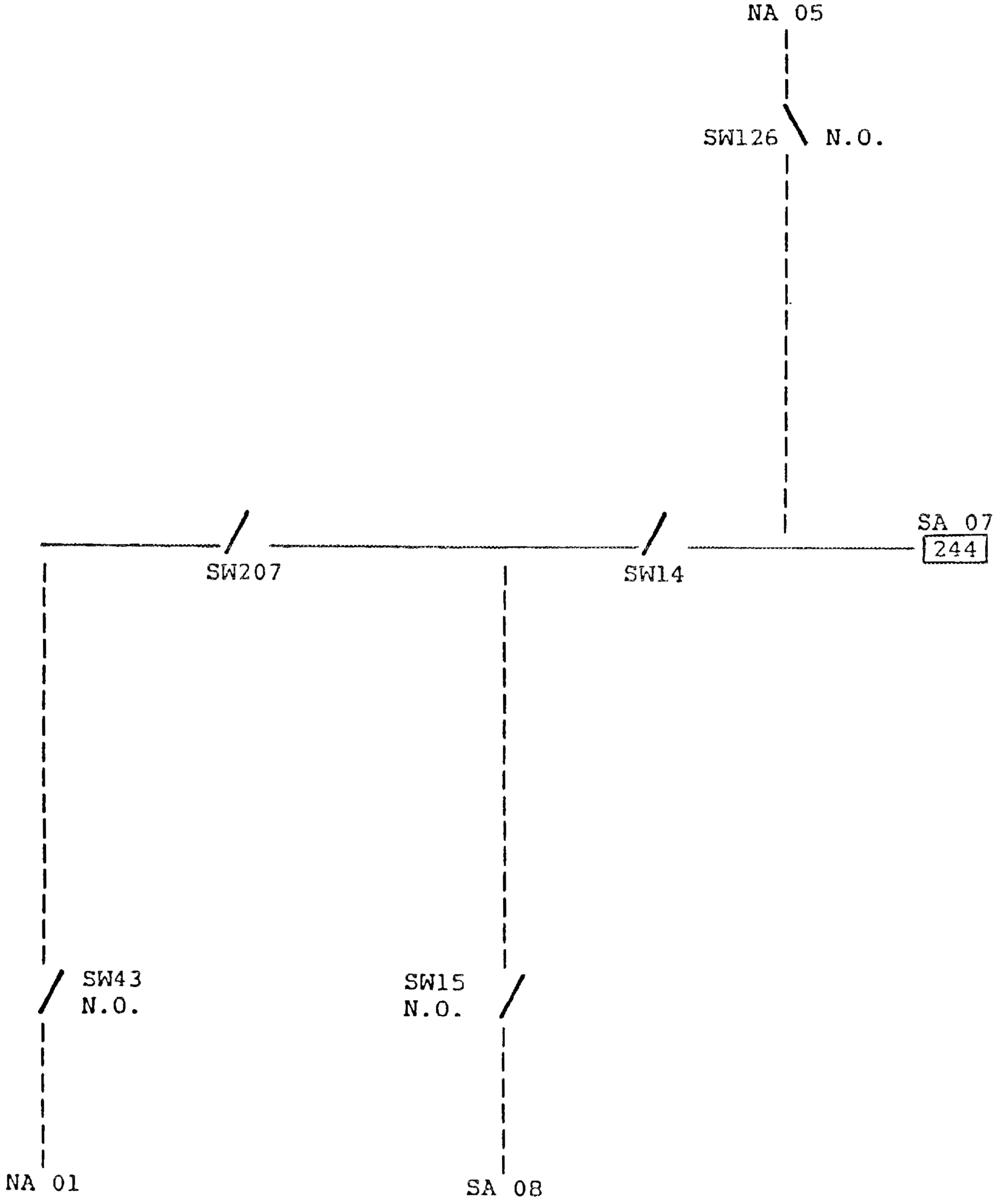
Secondary B Phase voltage

	Pre-regulator zeroing	Post-regulator zeroing
R5	123.8	120.0
SW-180	124.9	122.6
SW-114	123.5	120.6
SW-36	124.4	118.5
SW-126	122.4	122.7
	2:35 PM	3:04 PM

Load Transfer Example

Fault Analysis Example

Load Transfer Example


NA 05
SW126
N.O.
SA 07
244
SW207
SW14
SW43
N.O.
SW15
N.O.
NA 01
SA 08

```
--------------------------------------------------------------------------
SYSRAP
--------------------------------------------------------------------------

                             SYSRAP MAIN MENU

                   1> Load or Customer Information Study
                   2> Short Circuit Study
                   3> Load Transfer Study
                   4> Fault Transfer Study
                   5> Voltage Study


                   6> Reports

                   7> Edit Data Base
                   8> Re-organize Data Base after Load Transfer


--------------------------------------------------------------------------
Your choice?
--------------------------------------------------------------------------
```

```
------------------------------------------------------------------------
SYSRAP
------------------------------------------------------------------------

                  LOAD/CUSTOMER STUDY MENU

                  Load Area Identifier



                  1> Whole Feeder
                  2> Zone
                  3> At a particular Line Section
                  4> Below a Line Section

                  5> Update the feeder data base



------------------------------------------------------------------------
Your choice?
------------------------------------------------------------------------
```

SYSRAP

Load Report on feeder, SA07

	kW	kVAR	kW Losses	kVAR Losses	Customer #
A phase	260.2	203.7	0.3	0.4	
B phase	306.1	213.0	0.4	0.6	
C phase	253.3	183.3	0.2	0.3	
TOTAL			1.0	1.3	257

Reporting load below Edp = SW207

Input monitored values?

SYSRAP

Load Report on feeder, SA07

	kW	kVAR	kW Losses	kVAR Losses	Customer #
A phase	260.2	203.7	0.3	0.4	
	250	200			
B phase	306.1	213.0	0.4	0.6	
	300	200			
C phase	253.3	183.3	0.2	0.3	
	250	180			
TOTAL			1.0	1.3	257

Reporting load below Edp = SW207

Input monitored values? Y

```
------------------------------------------------------------------------
SYSRAP
------------------------------------------------------------------------


        Updating feeder SA07




------------------------------------------------------------------------
 Calculation method - constant P)ower, C)urrent, or Z) ?
------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------
SYSRAP
-----------------------------------------------------------------------

                         SYSRAP MAIN MENU

                 1> Load or Customer Information Study
                 2> Short Circuit Study
                 3> Load Transfer Study
                 4> Fault Transfer Study
                 5> Voltage Study


                 6> Reports

                 7> Edit Data Base
                 8> Re-organize Data Base after Load Transfer


-----------------------------------------------------------------------
Your choice?
-----------------------------------------------------------------------
```

```
--------------------------------------------------------------------------
SYSRAP
--------------------------------------------------------------------------


              Ambient Temperature (degrees f)

                          1> 32
                          2> 50
                          3> 68
                          4> 77
                          5> 86
                          6> 95


--------------------------------------------------------------------------
Ambient temperature selection  (Note: <CR> = default temp = 77)?
--------------------------------------------------------------------------
```

SYSRAP

Ampere load below candidate main-line switches to be opened

	A	B	C
BR244	184.3	188.5	189.6
SW70	56.3	60.7	43.2
SW14	70.8	72.0	74.3
SW207	45.9	51.8	43.4

Position cursor with <CR> and press "O" to open element ...

Load Transfer Study

SYSRAP

Ampere load below candidate main-line switches to be opened

		A	B	C
	BR244	184.3	188.5	189.6
	SW70	56.3	60.7	43.2
	SW14	70.8	72.0	74.3
0	SW207	45.9	51.8	43.4

Data on candidate ties to be closed

	Minimum Capacity (Location)			Tie	Minimum margin (Location)		
	A	B	C	Fdr	A	B	C
SW43	360(707)	360(707)	360(707)	NA01	300(100)	295(100)	289(100)

Continue?

```
--------------------------------------------------------------------------
SYSRAP
--------------------------------------------------------------------------

                             SYSRAP MAIN MENU

                   1> Load or Customer Information Study
                   2> Short Circuit Study
                   3> Load Transfer Study
                   4> Fault Transfer Study
                   5> Voltage Study


                   6> Reports

                   7> Edit Data Base
                   8> Re-organize Data Base after Load Transfer


--------------------------------------------------------------------------
Your choice?
--------------------------------------------------------------------------
```

SYSRAP

VOLTAGE STUDY MENU

PROFILES FROM THE SUBSTATION
A> Voltage profile
B> Loss profile

PROFILES ABOVE AN INTERTIE
C> Voltage profile
D> Loss profile

PROFILES ABOVE AN OPEN ELEMENT
E> Voltage profile
F> Loss profile

PLOT PARAMETER MODIFICATIONS
G> Adjust x or y plot scale
H> Change phase being studied

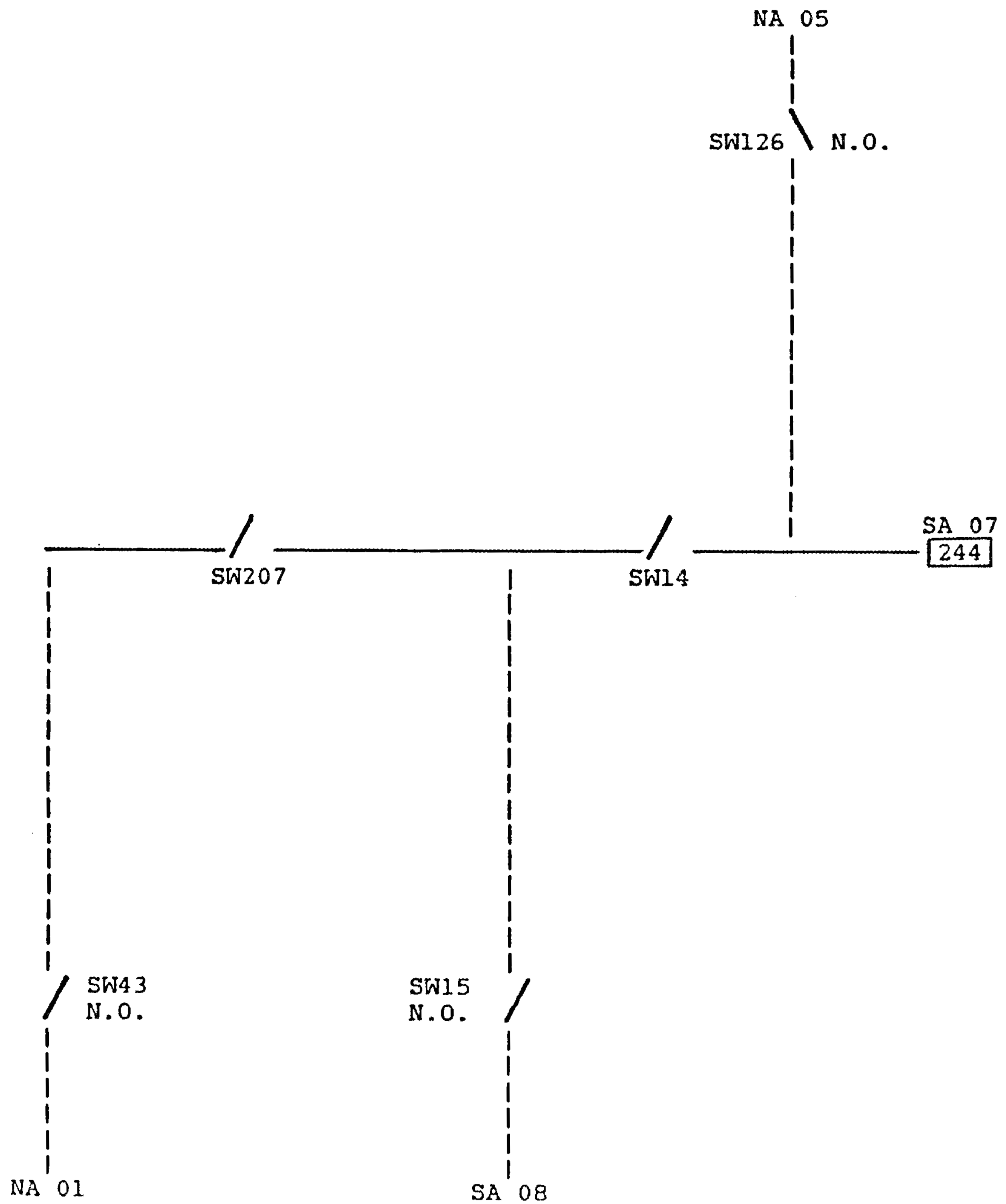
EXIT OPTIONS
I> Exit w/o modifying data base
J> Exit and modify data base

Your choice?

```
-----------------------------------------------------------------------------
SYSRAP                  Voltage Profile          Phase A
-----------------------------------------------------------------------------
  127.0
  126.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  125.0
  124.0
  123.0
V 122.0 -            -
O 121.0                      -        -       -
L 120.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
T 119.0
S 118.0
  117.0
  116.0
  115.0
  114.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  113.0
        BR244        CA113    SW14     CA108   SW207

-----------------------------------------------------------------------------
Adjust:  R)egulator    C)apacitor    P)hase?
-----------------------------------------------------------------------------
```

```
----------------------------------------------------------------------------
SYSRAP                   Loss Profile         Phase A
----------------------------------------------------------------------------
   24.5
k  22.7
W  21.0
   19.2
L  17.5
O  15.7
S  14.0
S  12.2
E  10.5
S   8.8
    7.0 -(   7)
    5.3
    3.5            -
    1.8                    -
    0.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~_~~~~~~_~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
        BR244       CA113   SW14    CA108  SW207

----------------------------------------------------------------------------
Adjust:  R)egulator    C)apacitor    P)hase?
----------------------------------------------------------------------------
```

```
------------------------------------------------------------------------------
SYSRAP
------------------------------------------------------------------------------

                           VOLTAGE STUDY MENU

  PROFILES FROM THE SUBSTATION          PLOT PARAMETER MODIFICATIONS
          A> Voltage profile                    G> Adjust x or y plot scale
          B> Loss profile                       H> Change phase being studied

  PROFILES ABOVE AN INTERTIE            EXIT OPTIONS
          C> Voltage profile                    I> Exit w/o modifying data base
          D> Loss profile                       J> Exit and modify data base

  PROFILES ABOVE AN OPEN ELEMENT
          E> Voltage profile
          F> Loss profile


------------------------------------------------------------------------------
Your choice?
------------------------------------------------------------------------------
```


NA 05
SW126
N.O.
SA 07
244
SW207
SW14
SW43
N.O.
SW15
N.O.
NA 01
SA 08

```
---------------------------------------------------------------------------
SYSRAP                  Voltage Profile         Phase A
---------------------------------------------------------------------------
  127.0
  126.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  125.0
  124.0
  123.0
V 122.0 -
O 121.0
L 120.0 ~~~~~~~~~~~~~~__~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
T 119.0                          -         -
S 118.0
  117.0
  116.0
  115.0
  114.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  113.0
        BR264         SW1        CA105     SW207
                       CA117     SW43

---------------------------------------------------------------------------
View loss profile?
---------------------------------------------------------------------------
```

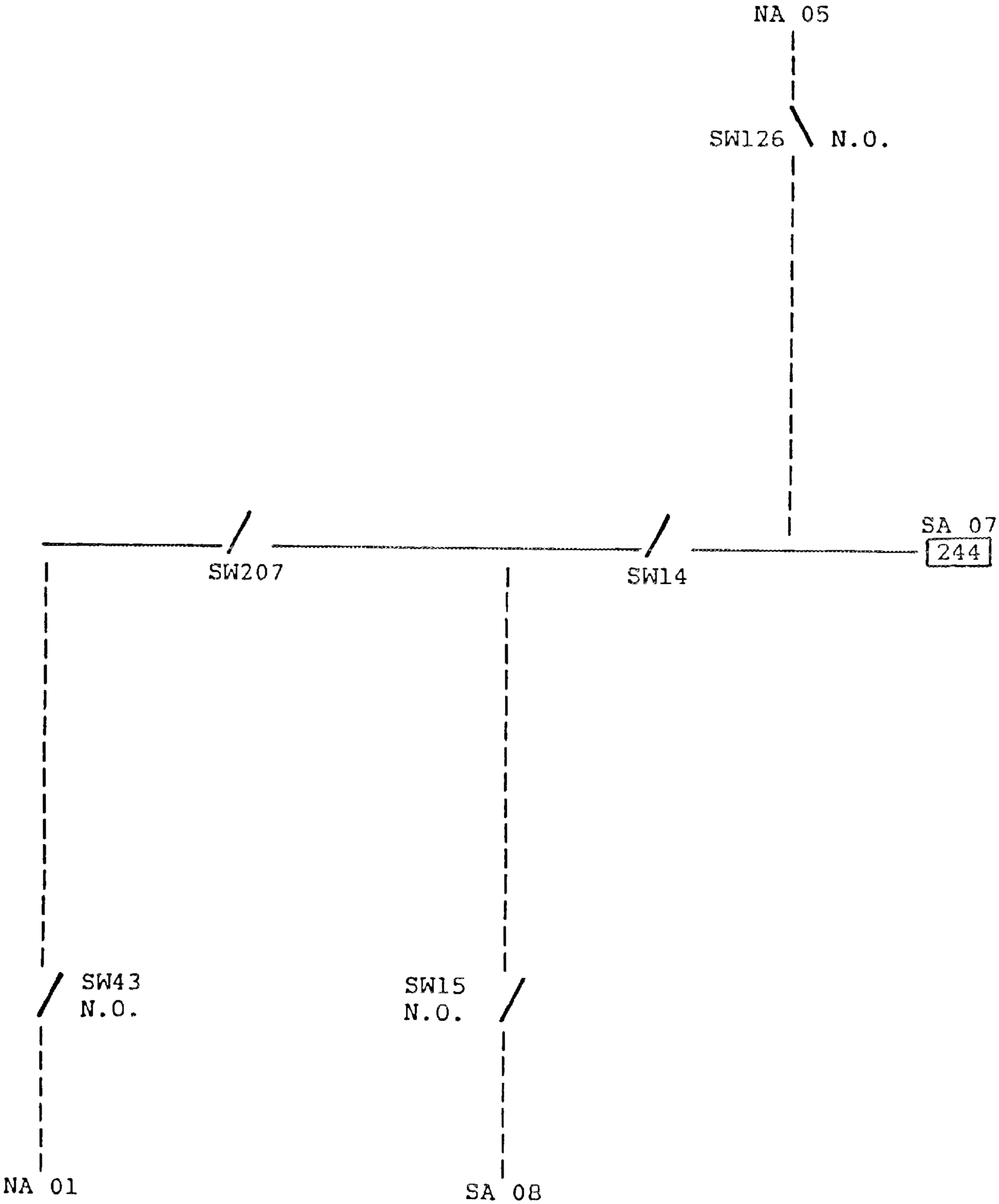
```
--------------------------------------------------------------------------
SYSRAP
--------------------------------------------------------------------------

                         VOLTAGE STUDY MENU

  PROFILES FROM THE SUBSTATION       PLOT PARAMETER MODIFICATIONS
         A> Voltage profile                 G> Adjust x or y plot scale
         B> Loss profile                    H> Change phase being studied

  PROFILES ABOVE AN INTERTIE         EXIT OPTIONS
         C> Voltage profile                 I> Exit w/o modifying data base
         D> Loss profile                    J> Exit and modify data base

  PROFILES ABOVE AN OPEN ELEMENT
         E> Voltage profile
         F> Loss profile


--------------------------------------------------------------------------
Your choice?
--------------------------------------------------------------------------
```

```
----------------------------------------------------------------------------
SYSRAP                    Voltage Profile         Phase A
----------------------------------------------------------------------------
  127.0
  126.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  125.0
  124.0
  123.0
V 122.0 -    -   -  -   -
O 121.0
L 120.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
T 119.0
S 118.0
  117.0
  116.0
  115.0
  114.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  113.0
        BR244    SW14   SW207
             CA113  CA108

----------------------------------------------------------------------------
Adjust:  R)egulator    C)apacitor    P)hase?
----------------------------------------------------------------------------
```

```
----------------------------------------------------------------------
SYSRAP                    Voltage Profile        Phase A
----------------------------------------------------------------------
  127.0
  126.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  125.0
  124.0
  123.0
V 122.0 -    -   -  -   -
O 121.0
L 120.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
T 119.0
S 118.0
  117.0
  116.0
  115.0
  114.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  113.0
        BR244    SW14   SW207
             CA113  CA108

----------------------------------------------------------------------
         Capacitor name?                             CA108
----------------------------------------------------------------------
```

```
---------------------------------------------------------------------------
SYSRAP                  Voltage Profile         Phase A
---------------------------------------------------------------------------
  127.0
  126.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  125.0
  124.0
  123.0
V 122.0 -    -
O 121.0         -  -   -
L 120.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
T 119.0
S 118.0
  117.0
  116.0
  115.0
  114.0 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  113.0
        BR244    SW14   SW207
             CA113  CA108

---------------------------------------------------------------------------
Adjust:  R)egulator    C)apacitor    P)hase?
---------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------------
SYSRAP
-----------------------------------------------------------------------------

                            SYSRAP MAIN MENU

                  1> Load or Customer Information Study
                  2> Short Circuit Study
                  3> Load Transfer Study
                  4> Fault Transfer Study
                  5> Voltage Study


                  6> Reports

                  7> Edit Data Base
                  8> Re-organize Data Base after Load Transfer


-----------------------------------------------------------------------------
Your choice?
-----------------------------------------------------------------------------
```


NA 05
SW126
N.O.
SA 07
244
SW207
SW14
SW43
N.O.
SW15
N.O.
NA 01
SA 08

SYSRAP Fault SW207 Open SW14

Three Phase Short Circuit Duty at SW207 on feeder, SA07

	amps	MVA
Normally:	5261	37875

When supplied from:

		amps	MVA
SA08	SW15	4563	32848
NA01	SW43	2949	21231

	A amps	B amps	C amps
Load between open and faulted elements:	44	45	47
Load below faulted element:	46	52	43
Load below open element:	71	72	74

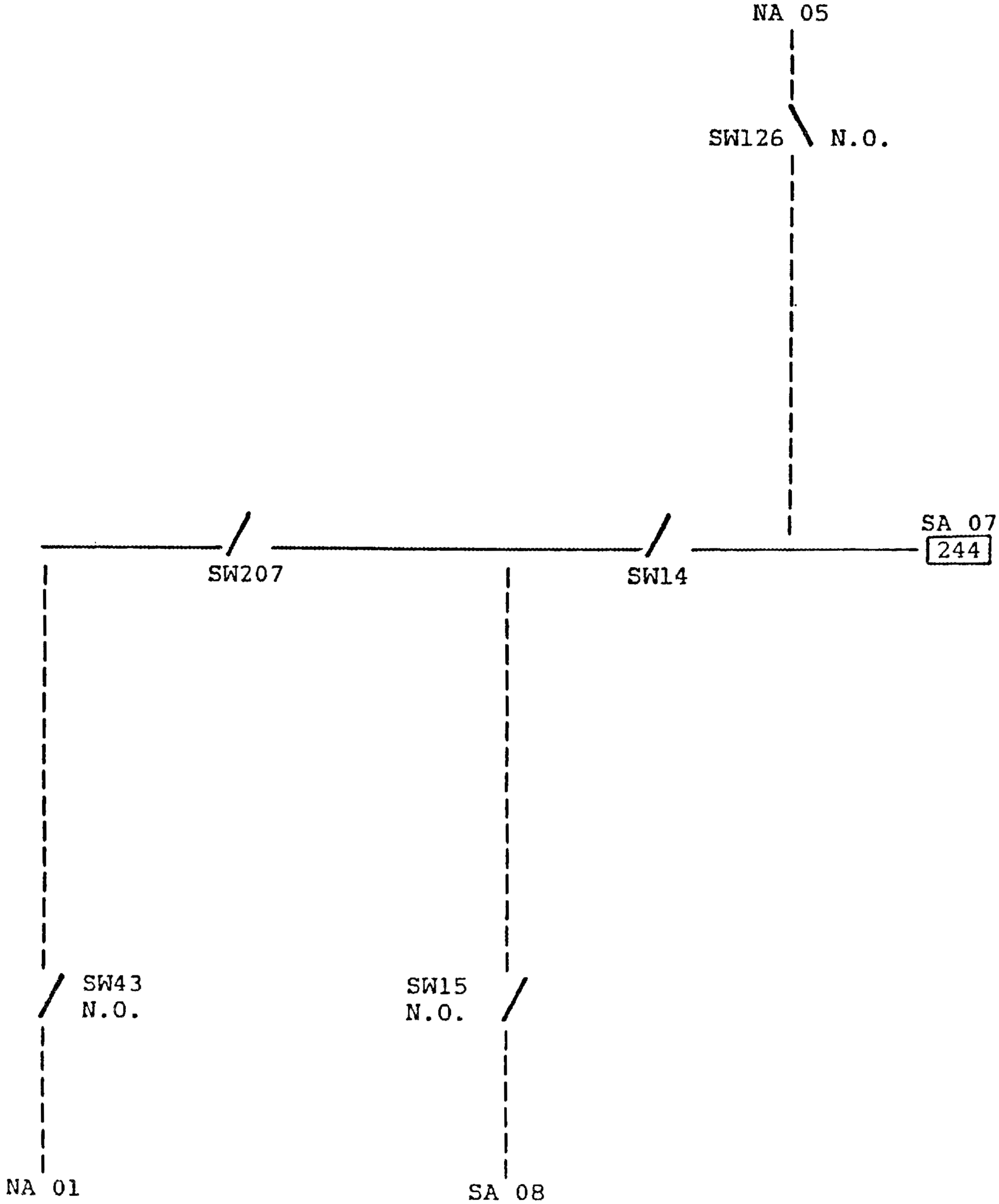
Continue?

Concerns in Reconfiguration

- How much load lies in the section to be transferred?
- Is the reconfiguration acceptable from a capacity perspective?
- Is the reconfiguration accceptable from a voltage and loss profile perspective?
- Is the reconfiguration acceptable from a protection coordination perspective?

Fault Analysis Example

```
---------------------------------------------------------------------------
SYSRAP
---------------------------------------------------------------------------

                             SYSRAP MAIN MENU

                   1> Load or Customer Information Study
                   2> Short Circuit Study
                   3> Load Transfer Study
                   4> Fault Transfer Study
                   5> Voltage Study


                   6> Reports

                   7> Edit Data Base
                   8> Re-organize Data Base after Load Transfer


---------------------------------------------------------------------------
Your choice?
---------------------------------------------------------------------------
```


NA 05
SW126
N.O.
SA 07
244
SW207
SW14
SW43
N.O.
SW15
N.O.
NA 01
SA 08

SYSRAP

Above the faulted line section, 705

Open SW14

Below the faulted line section, 705

Open	Close
SW207	SW43

Continue?

SYSRAP

Above the faulted line section, 702

Open BR244

Below the faulted line section, 702

Open	Close	
SW14	SW43	
SW14	SW15	(alternate)
SW207	SW43	(alternate)

Continue?

V. Preliminary Experience with Automation Assisted Fault Response

The "Minnie Owens" Fault

8:51 PM Saturday, August 17

SYSRAP

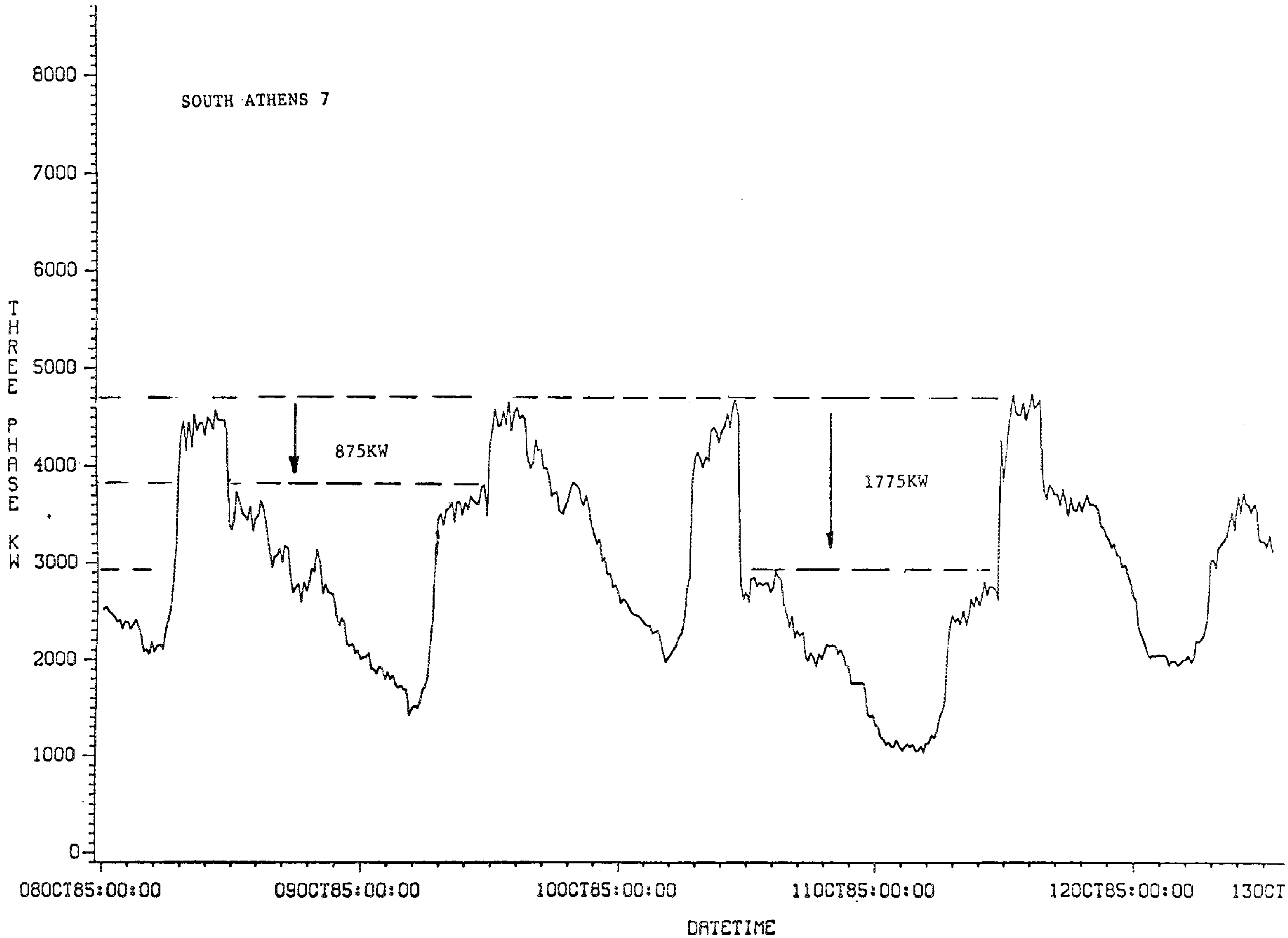
Ampere load below candidate main-line switches to be opened

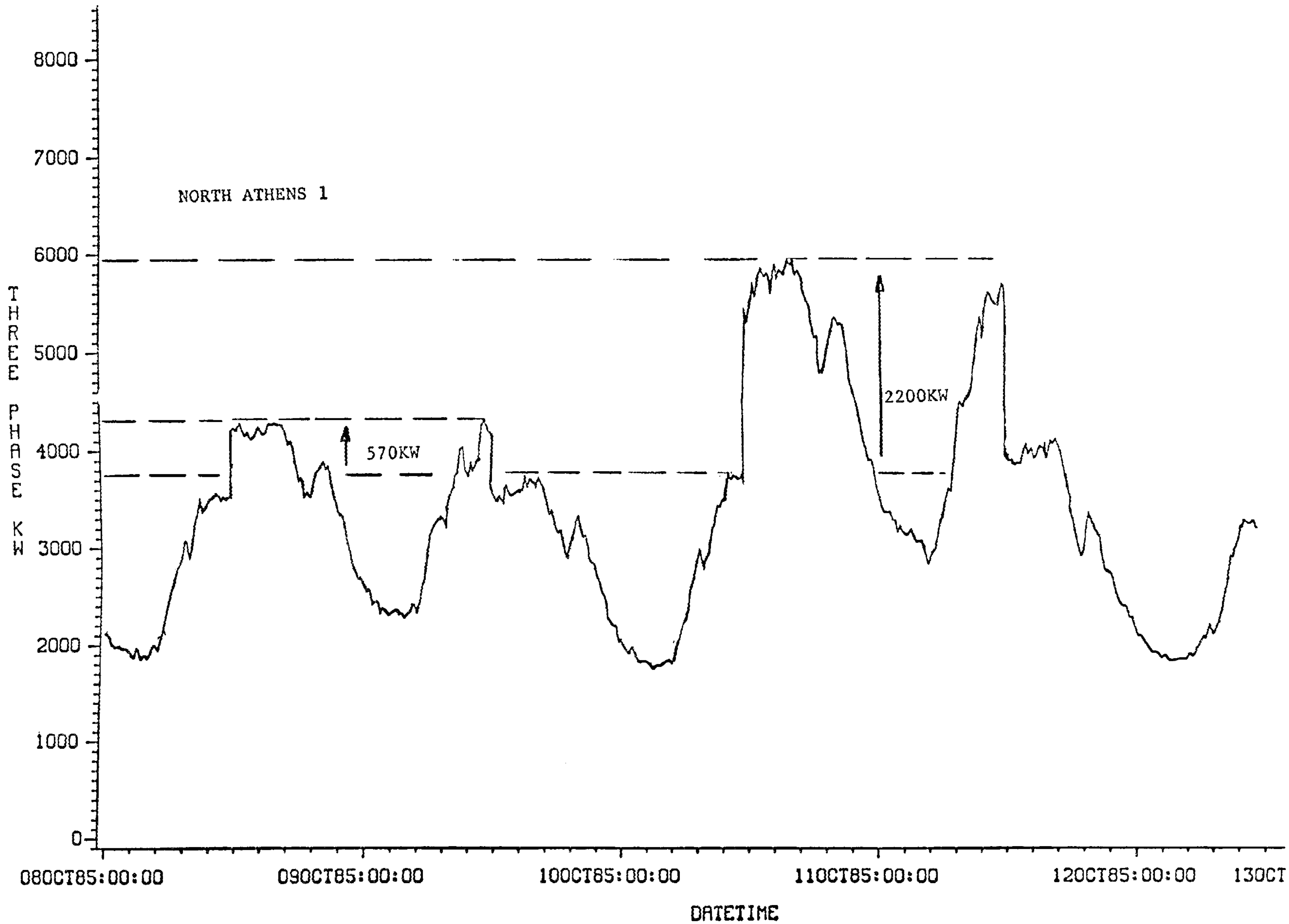
		A	B	C
	BR244	184.3	188.5	189.6
	SW70	56.3	60.7	43.2
	SW14	70.8	72.0	74.3
0	SW207	45.9	51.8	43.4

Data on candidate ties to be closed

	Minimum Capacity (Location)			Tie	Minimum margin (Location)		
	A	B	C	Fdr	A	B	C
SW43	360(707)	360(707)	360(707)	NA01	300(100)	295(100)	289(100)

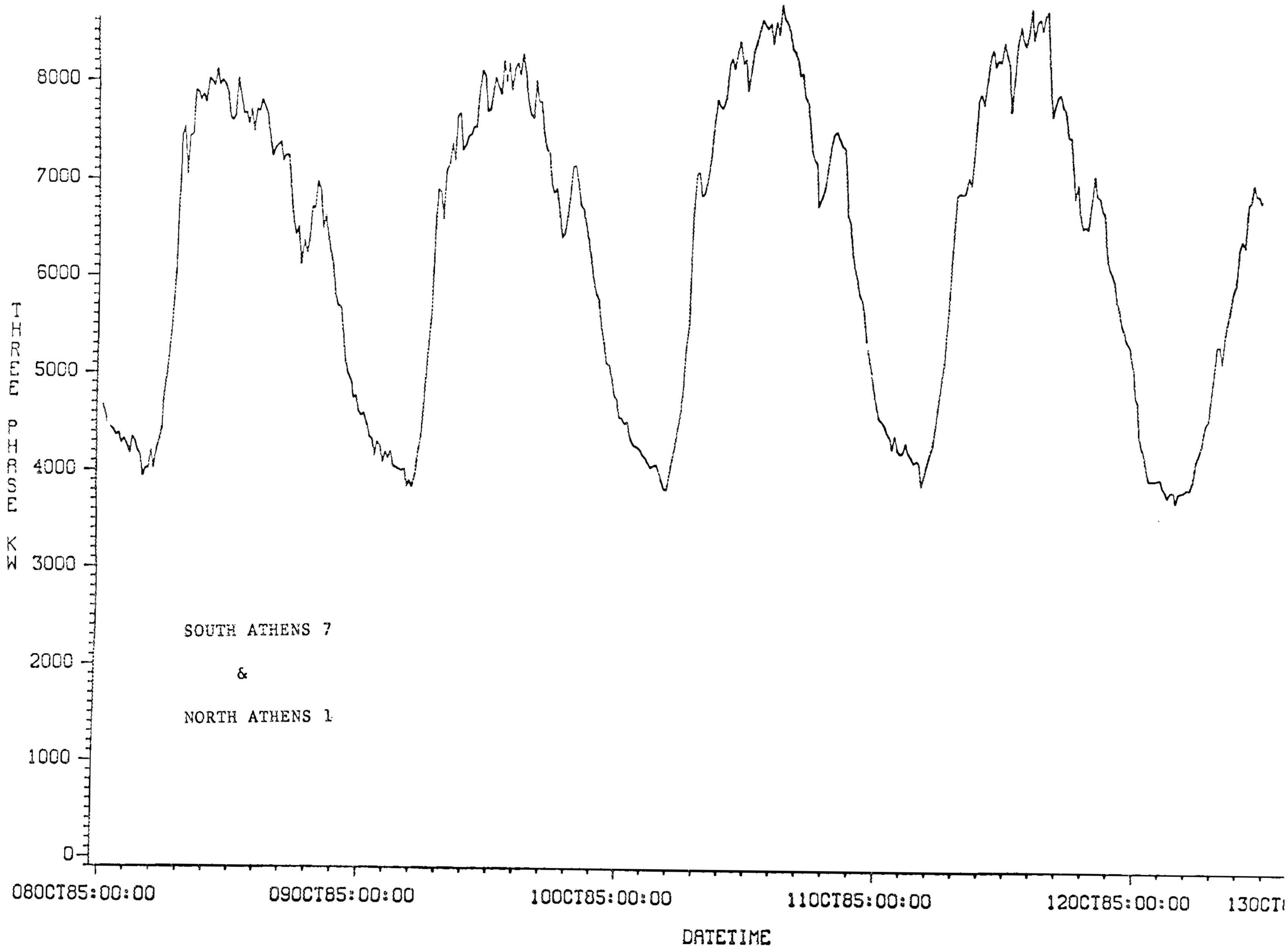
Continue?


SOUTH ATHENS 7
THREE PHASE KW
8000
7000
6000
5000
4000
3000
2000
1000
0
875KW
1775KW
08OCT85:00:00
09OCT85:00:00
10OCT85:00:00
11OCT85:00:00
12OCT85:00:00
13OCT
DATETIME



NORTH ATHENS 1
THREE PHASE KW
8000
7000
6000
5000
4000
3000
2000
1000
0
570KW
2200KW
08OCT85:00:00
09OCT85:00:00
10OCT85:00:00
11OCT85:00:00
12OCT85:00:00
13OCT
DATETIME

395


THREE PHASE KW
8000
7000
6000
5000
4000
3000
2000
1000
0
SOUTH ATHENS 7
&
NORTH ATHENS 1
08OCT85:00:00
09OCT85:00:00
10OCT85:00:00
11OCT85:00:00
12OCT85:00:00
13OCT
DATETIME

```
10/02/85 15:26:23         NORTH ATHENS CIRCUIT 5              UPDATED 15:26:22

FAULT STATUS                                                      SIU STATUS
SW 87                                                             NA    IDLE
SW 114                                                            SA    IDLE
                                                                  ENG   BUSY
                   NA 1       19
                          +---.---+
                     +-.--+       !
                       18 !       *110 +-/-->SA 9
      A-A>  0    +G       !       !    !R*180
      B-A>  0    !C-119   !       !    !
      C-A>  0    C       93* R-5  *118 !
224      -       !        !  R -  !    !
 C------.---/---++--------+---.---+----+--/----+-------+-----/-->SA 7
 A     \R    *87 !            \           *114 !       !    *126
      R-51   R   !           A-A>  0      R    CC-102  !    R
                 !C-121      B-A>  0           !       !
                 +-\-GR      C-A>  0           G       .89
                 ! A                                   !
                 !                                     !
DEMAND SCAN                          61          36    !
PTU/  SW/STAT                 SA 7<---.----+--+--M-----+-----/--->NA 1
16   114   C                               !  !             *13
17    13   O                               !  CC-123        R
18  C123   O                         21    !  !  R                          VOLTS
                                                                               19
                 SW 180 116.9
20   180   C                                                       SW 114 118.9
24   126   O                                                       SW 126 123.5
                                                                   SW  36 115.4
                                                                   R-5    118.3


                                                                      !  DRTU 8
                                                       ! PTU 18!PTU 19 !   R-51
      BKR 224 NA SUB CIR 5   !   R-5:DRTU 4:NA CIR 5   ! SW  36!EXCELLO!   KV HS
         A.    B.    C.   3. !  A.    B.    C.    3.   !  B.   ! B.    !A. 122.?
KV      7.56  7.62  7.55     ! 0.00  0.00  0.00        ! 7.21  ! 7.36  !B.  0.00
KW      2828  3065  2755    0!  122     0     0     0  !  467  !  553  !C.  0.00
KVAR     757   849  1072    0!    0     0     0     0  !  195  !  436  !   KV LS
AMPS       0     0     0     !    0     0     0        !    0  !    0  !A.  0.00
PF     0.000 0.000 0.000 0.000! 0.000 0.000 0.000 0.000 ! 0.000 !0.000  !B.  0.00
DELTA    120   120   121     !  0.0   0.0   0.0        !               !C.  0.00
NEUT AMPS           0        !            0            !
 :PAGE F :PAGE B :SILENCE :PDE :PRINT :LOG :RETURN :MASTER :CANCEL
CRT PRINT IN PROGRESS
```

2828 + 3065 + 2755 = 8648 KW

8648 − 4762 = 3886 KW INCREASE

```
10/02/85 15:15:36         NORTH ATHENS CIRCUIT 5           UPDATED 15:15:22

FAULT STATUS                                                    SIU STATUS
SW 87                                                           NA     IDLE
SW 114                                                          SA     IDLE
                                                                ENG    BUSY
                   NA 1       19
                          +---.---+
                     +-.--+       !
                       18 !       *110 +-/-->SA 9
      A-A>  0     +G      !       !    !R*180
      B-A>  0     !C-119  !       !    !
      C-A>  0     C     93* R-5   *118 !
224      -        !       !  R -  !    !
 C------.---/---++---------+---.---+----+--/----+------+-----/-->SA 7
 A      \R   *87 !          \             *114 !       !     *126
      R-51   R   !          A-A>  0       R    CC-102 !     R
                 !C-121     B-A>  0            !       !
                 +-\-GR     C-A>  0            G       .89
                 ! A                                   !
                 !                                     !
DEMAND SCAN                        61          36      !
PTU/  SW/STAT              SA 7<---.-----+--+--M-----+-----/--->NA 1
16   114   C                             !  !              *13
17    13   O                             !  CC-123         R
18  C123   O                       21    !  !  R                        VOLTS
                                                                           19
                 SW 180 120.4
20   180   C                                                   SW 114 120.4
24   126   O                                                   SW 126 123.5
                                                               SW  36 119.2
                                                               R-5    120.8

                                                                    !  DRTU 8
                                                       ! PTU 18!PTU 19 !   R-51
      BKR 224 NA SUB CIR 5   !   R-5:DRTU 4:NA CIR 5   ! SW   36!EXCELLO!   KV HS
          A.    B.    C.    3.  !   A.    B.    C.    3.  !  B.  ! B.    !A. 122.?
KV       7.56  7.62  7.55       !  0.00  0.00  0.00       !  7.35 ! 7.45  !B.  0.00
KW       1524  1646  1592    0! 123     0     0     0 !  483 !  563  !C.  0.00
KVAR      598   605   797    0!   0     0     0     0 !  195 !  436  !  KV LS
AMPS        0     0     0       !   0     0     0       !    0 !    0  !A.  0.00
PF      0.000 0.000 0.000 0.000! 0.000 0.000 0.000  0.000! 0.000 !0.000  !B.  0.00
DELTA    121   121   121        !  0.0   0.0   0.0        !                !C.  0.00
NEUT AMPS          0            !              0          !
 :PAGE F :PAGE B :SILENCE :PDE :PRINT :LOG :RETURN :MASTER :CANCEL
CRT PRINT IN PROGRESS
```

1524 + 1646 + 1592 = 4762 KW

```
10/02/85 15:26:28         SOUTH ATHENS CIRCUIT 9            UPDATED 15:26:26

                                                                  SIU STATUS
FAULT STATUS                                                      NA     IDLE
SW  170                                                           SA     IDLE
          VEC<---M-O-M------------*-------+-----/------+          ENG    BUSY
          TIE  224 M 225          223     !      212   !   +-M-+
                                       262             !   !   !
                                          !            +--M+-O-+M->TIE
                                          !            ! 227 M 228
                                                       !
                                                       !
                                                       !A
                                    C-122           226.
                                   R+-\-+            R !G
                                    G   !              !
 G                                      !              !
214     155                             !          184 !
 C-------M--------+--------+---------/--+--+------+--M-+----/->NA 5
 A                !        !        R*170  !      !     *180
                  !       FCC-111          ! C-109CA    R
                  !        !               !      !
                  !        G               !      G
                  CC-110              C-101C
DEMAND SCAN       !  R                     !
PTU/ SW/STAT      G                        G
 20 180    C
 33 170    O
 34 226    O
 35  MR    C
 36  HS    O
 37 PLA    C
                                                     !PTU 34!PTU 35!PTU 36!PTU37
      BKR 214 SA SUB CIR 9   ! SW 170:PTU 33:SA CIR 9!PR 226!M. R. !H. S. !PLAS.
        A.     B.     C.    3. !  A.     B.     C.    3.++ B. !  B.  !  B.  !  B.
KV      7.49   7.53   7.53     !  7.47   7.50   7.50     ! 7.39! 0.00 ! 7.22 ! 7.50
KW      1013   1043   1015    0!     1      1      1    0!  112!    0 !  143 !  417
KVAR     195    225    242    0!     1      1      1    0!   31!    0 !   60 !  342
AMPS       0      0      0     !     0      0      0     !    0!    0 !    0 !    0
PF     0.000  0.000  0.000 0.000! 0.000  0.000  0.000 0.000!0.000!0.000 !0.000 !0.000
DELTA  120.3  120.7  121.1     !   0.0    0.0    0.0     !
NEUT AMPS            0         !            0            !

 :PAGE F :PAGE B :SILENCE :PDE :PRINT :LOG :RETURN :MASTER :CANCEL
CRT PRINT IN PROGRESS
```

1013 + 1043 + 1015 = 3071 KW

7230 - 3071 = 4159 KW DECREASE

```
10/02/85 15:15:55         SOUTH ATHENS CIRCUIT 9             UPDATED 15:15:53

                                                                   SIU STATUS
FAULT STATUS                                                       NA    IDLE
SW  170                                                            SA    IDLE
          VEC<---M-O-M------------*-------+-----/------+           ENG   BUSY
          TIE  224 M 225         223        !      212     !   +-M-+
                                       262                 !   !   !
                                          !                +--M+-O-+M->TIE
                                          !                ! 227 M 228
                                                           !
                                                           !
                                                           !A
                                    C-122              226.
                                   R+-\-+               R !G
                                    G   !                 !
 G                                      !                 !
214     155                             !              184 !
 C-------M---------+---------+---------/--+--+------+--M-+----/->NA 5
 A                 !        !         R*170  !      !      *180
                   !       FCC-111           ! C-109CA     R
                   !        !                !      !
                   !        G                !      G
                  CC-110              C-101C
DEMAND SCAN       !  R                       !
PTU/ SW/STAT      G                          G
 20 180    C
 33 170    O
 34 226    O
 35  MR    C
 36  HS    O
 37 PLA    C
                                                            !PTU 34!PTU 35!PTU 36!PTU37
      BKR 214 SA SUB CIR 9    ! SW 170:PTU 33:SA CIR 9!PR 226!M. R. !H. S. !PLAS.
         A.     B.     C.     3. !  A.     B.     C.     3.++ B. !  B.  !  B.  !  B.
KV     7.57   7.60   7.60        !  7.47   7.51   7.51       ! 7.39! 0.00 ! 7.53 ! 7.50
KW     2404   2479   2347      0!  1232   1345   1145      0!  112!    0 !  143 !  376
KVAR    385    403    504      0!    33     27    122      0!   31!    0 !   60 !  313
AMPS      0      0      0        !     0      0      0       !    0!    0 !    0 !    0
PF    0.000  0.000  0.000  0.000! 0.000  0.000  0.000  0.000!0.000!0.000 !0.000 !0.000
DELTA 120.0  120.5  121.1        !   0.0    0.0    0.0       !
NEUT AMPS             0          !              0            !

 :PAGE F .PAGE B :SILENCE :PDE :PRINT :LOG :RETURN :MASTER :CANCEL
CRT PRINT IN PROGRESS
```

2404 + 2479 + 2347 = 7230 KW

Pre-transfer Data (3:15 PM):

BRK 224 NA-05

	A	B	C	3ϕ Total
KV	7.56	7.62	7.55	
KW	1524	1646	1592	4762
KVAR	598	605	797	2000

BRK 214 SA-09

	A	B	C	3ϕ Total
KV	7.57	7.60	7.60	
KW	2404	2479	2347	7230
KVAR	385	403	504	1292

Post-Transfer Data (3:26 PM):

BRK 224 NA-05

	A	B	C	3ϕ Total
KV	7.56	7.62	7.55	
KW	2828	3065	2755	8648 (+3886)
KVAR	757	849	1072	2678 (+678)

BRK 214 SA-09

	A	B	C	3ϕ Total
KV	7.49	7.53	7.53	
KW	1013	1043	1015	3071 (-4159)
KVAR	195	225	242	662 (-630)

CUSTOMER NAME: MINNIE OWENS DATE: 8/17/85

ADDRESS: 502 ShoEMAKER ROAD TIME: 8:54 PM

ACCOUNT NUMBER: TELEPHONE NO: 745-4432

NATURE OF TROUBLE: POWER OFF

SUSPECTED INTERRUPTING DEVICE: (BY MODSCAN) TIME DETERMINED:

SUSPECTED INTERRUPTING DEVICE: (BY CUSTOMER CALLS) TIME DETERMINED:

TIME PERSONNEL DISPATCHED: 8:54 PM WHO: MAXWELL, BILLINGS, NEWMAN + WALLACE

BKR 244 out at 8:51 P.M.

FAULT INTERRUPTING DEVICE: BKR 244 TIME LOCATED: 9:15 PM

FAULT LOCATION: TIME LOCATED:

CONDITIONS/DAMAGE FOUND: CIRCUIT #7 OUT—CROSS ARM BROKEN

REPAIRS INACTED/ACTION TAKEN: REPLACED BROKEN CROSS ARM

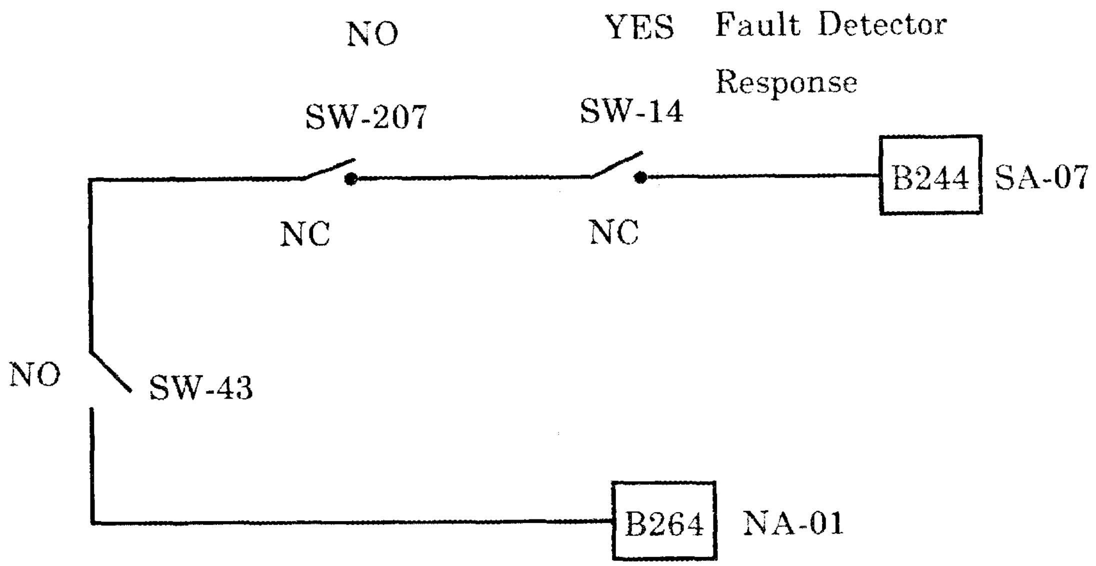
MANUAL SWITCHING ACTIONS

SWITCH	ACTION TAKEN	TIME
SW. 207	OPEN	9:15 PM
BKR. 244.	OPEN	
SW. 43	CLOSED	9:17 PM
SW 14	OPEN	9:24 PM
BKR 244	CLOSED – REMOTE	9:25 PM

TIME COMPLETED: 11:17 PM BY: MAXWELL, BILLINGS, NEWMAN + WALLACE

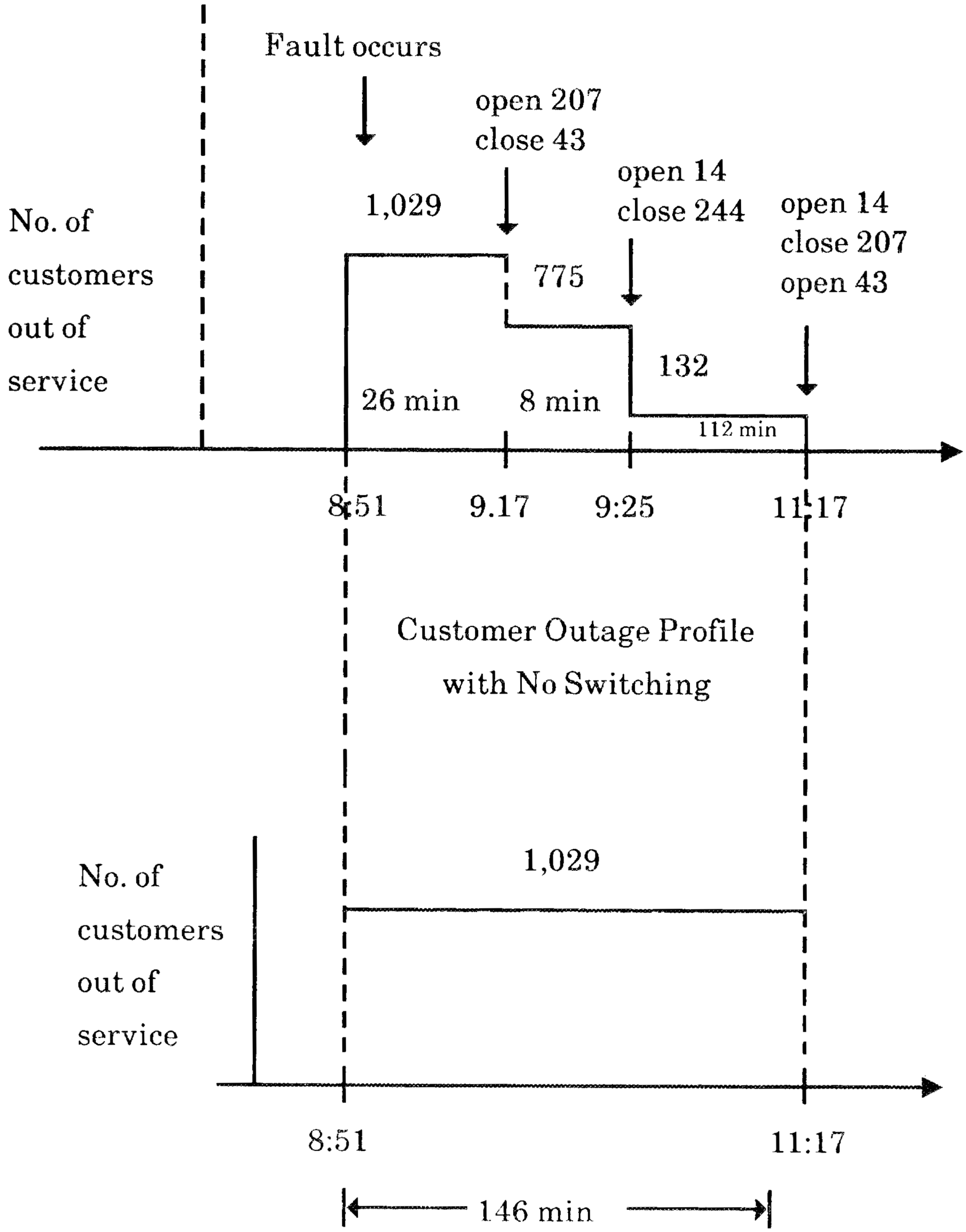
COMMENTS:

Details of the Fault Response



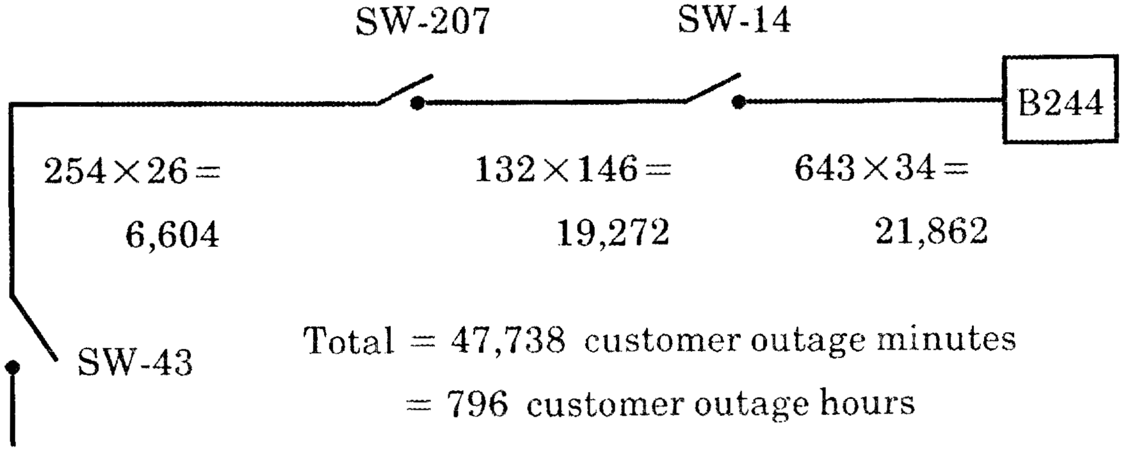
Time-Event	Comments
B244 Opened at 8:51 PM	1,029 customers out of service (loss of 3160 kw)
SW-207 Opened at 9:15 PM	
SW-43 Closed at 9:17 PM	Restoring 254 customers (and aprox. 631 kw)
SW-14 Opened at 9:24 PM	
B244 Closed at 9:25 PM	Restoring additional 643 customers (and approx. 1750 kw)
Repair completed at 11:17 PM	Restoring service to all customers

Automation Assisted Customer Outage Profile



Customer Outage-Minutes:

with automation



Total = 47,738 customer outage minutes

= 796 customer outage hours

with no switching

1,029×146 = 150,234 customer outage minutes

= 2,504 customer outage hours

VI. CONCLUSIONS

- Initial experiments were directed to learning how to use the equipment
- Load transfers are not always conservative
- More accurate feeder load models are needed
- Need to identify load transfer opportunities that can exploit load diversity
- Load transfers to date have not reacted adversely with protection gear

COST/BENEFIT AND AUTOMATION PROJECTS

ECONOMIC EVALUATION OF THE ATHENS AUTOMATION AND CONTROL EXPERIMENT

Kevin F. McKinley

Distribution automation is similar to most other projects attempted by electric utilities; the project must be justified on an economic basis. Upper management is very interested in the total project benefits and costs, the "bottom line." Tools are available to perform the economic analysis.

Benefits are being calculated for the three experimental areas and costs are being recorded for the AUB system. Experiments will be repeated in order to obtain results which will prove consistent. Consistent results will provide confidence in the development of more accurate figures for use in projecting benefits and costs for other utilities.

Experimental results will be used as a basis for extending benefits and costs to larger electric utility systems and to present an idea of what distribution automation could accomplish on a larger scale. Finally, planning studies at a large utility will be performed to compare a nonautomated base case expansion with an automated alternative for the same study area.

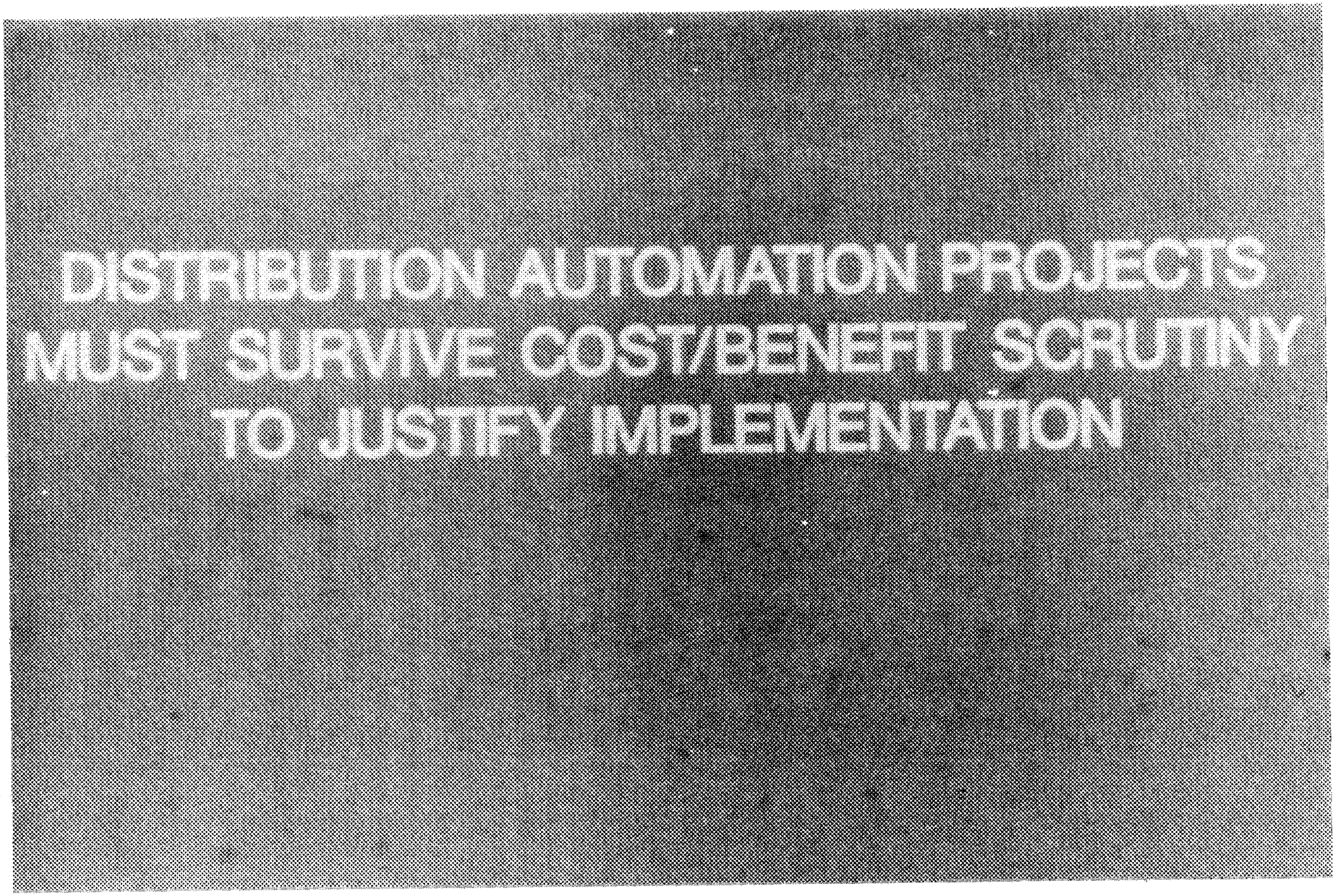
ECONOMIC EVALUATION
OF THE
ATHENS AUTOMATION AND CONTROL EXPERIMENT

KEVIN F. McKINLEY
BALTIMORE GAS & ELECTRIC COMPANY
2 YEAR ASSIGNMENT AT ORNL

AACE PROJECT REVIEW MEETING
DECEMBER 4, 1985
KNOXVILLE, TENNESSEE

OVERVIEW OF THE PRESENTATION

- BOTTOM LINE
- TOOLS
- BENEFITS
- COSTS
- EXTEND EXPERIMENTAL RESULTS TO LARGER SYSTEMS
- BG&E PLANNING STUDIES


DISTRIBUTION AUTOMATION PROJECTS
MUST SURVIVE COST/BENEFIT SCRUTINY
TO JUSTIFY IMPLEMENTATION

TOOLS ARE AVAILABLE TO ASSIST ECONOMIC ANALYSIS

- EPRI PROJECT 2021-1 FINAL REPORT
- EXPERIMENTAL TEST PLANS
- LOTUS 1-2-3 SPREADSHEET
- SYSRAP
- BG&E INVESTMENT COST COMPUTER PROGRAM
- GENERATION PLANNING COMPUTER PROGRAMS

EPRI RP 2021-1 LISTS MAJOR BENEFIT CATEGORIES

- INVESTMENT RELATED
- INTERRUPTION RELATED
- CUSTOMER RELATED
- OPERATIONAL SAVINGS
- IMPROVED DISTRIBUTION SYSTEM OPERATION

BENEFITS ARE ANTICIPATED FROM THE THREE EXPERIMENTAL AREAS

- LOAD CONTROL
- VOLT/VAR CONTROL
- SYSTEM RECONFIGURATION

LOAD CONTROL BENEFITS

- REDUCE PEAK LOAD
- SAVE FUEL
- DEFER ADDITIONAL GENERATION AND TRANSMISSION FACILITIES

VOLT/VAR CONTROL BENEFITS

- CAPACITOR CONTROL
  - -- DEFER ADDITIONAL G & T FACILITIES
  - -- DEFER ADDITIONAL DISTRIBUTION FACILITIES
  - -- FUEL SAVINGS FROM REDUCED LOSSES
- REGULATOR AND LTC TRANSFORMER CONTROL
  - -- 24 HOUR CONSERVATION REGULATION
  - -- PEAK LOAD CONTROL
- COMBINED CONTROL

SYSTEM RECONFIGURATION BENEFITS

- FAULT RESPONSE
  - -- FASTER DETECTION OF FAULTS
  - -- REDUCED CREW TIME
  - -- INCREASED REVENUE
- FEEDER MONITORING
  - -- IMPROVED OPERATIONAL/PLANNING DECISIONS
  - -- IMPROVED MAINTENANCE
- LOAD TRANSFERS
  - -- DEFER ADDITIONAL G & T FACILITIES
  - -- DEFER ADDITIONAL DISTRIBUTION FACILITIES
  - -- REDUCED CREW TIME FOR SWITCHING
  - -- SAVE FUEL

COSTS MUST BE EVALUATED

- KEEP ACCURATE RECORDS
  ON INSTALLATION COSTS
- THROUGH EXPERIMENTATION,
  DETERMINE INSTRUMENTATION REQUIRED
- COSTS ARE SHARED
  AMONG EXPERIMENTAL AREAS

EXTEND EXPERIMENTAL RESULTS TO LARGER SYSTEMS FOR COMPARISON

- BG&E
- BULK POWER SYSTEMS -- TVA
- GENERATION MIX OF OTHER UTILITIES

PERFORM BG&E PLANNING STUDIES

- NON-AUTOMATED BASE CASE EXPANSION
- USE EXPERIMENTAL RESULTS
- AUTOMATE STUDY AREA USING SEVERAL ALTERNATIVES
- COMPARE BEST NON-AUTOMATED BASE CASE EXPANSION ALTERNATIVE WITH BEST DISTRIBUTION AUTOMATION ALTERNATIVE

COST/BENEFIT ANALYSIS IS BEING BASED UPON REAL WORLD AUTOMATION EXPERIENCES

- PROJECTS MUST SURVIVE ECONOMIC EVALUATION TO JUSTIFY IMPLEMENTATION
- TOOLS ARE AVAILABLE TO PERFORM ECONOMIC ANALYSIS
- EVALUATE BENEFITS OF EXPERIMENTAL AREAS
- EVALUATE COSTS
- EXTEND EXPERIMENTAL RESULTS TO LARGER SYSTEMS
- PERFORM PLANNING STUDIES

ATHENS AUTOMATION AND CONTROL EXPERIMENT

Project Review Meeting
Knoxville, Tennessee
December 3-5, 1985

OVERVIEW OF SOME MAJOR UTILITY DISTRIBUTION AUTOMATION AND LOAD CONTROL PROJECTS

425

Presented by:

Lawrence C. Markel

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SOME MAJOR DISTRIBUTION AUTOMATION AND LOAD CONTROL PROJECTS

AACE	Athens Utilities Board (AUB)	BBCSI	LC,VC,DAC,LS
PROBE	Commonwealth Edison (CE)	GE	DAC
IDCPS	Texas Electric Service Co. (TESCo)	GE	DAC
ALADDIN	American Electric Power (AEP)	GE	LS,AMR,DAC
CPL	Carolina Power & Light	Westinghouse	DAC,AMR,LC,LS
FPL	Florida Power & Light	CLMS	LC,AMR,LS,VC
OH	Ontario Hydro	Motorola Dacscan	LC,LS,AMR,DAC
NMPC	Niagara Mohawk Power Corp.	GE	DAC,AMR
IDACS	Knoxville Utilities Board (KUB)	AS&E, Westinghouse	LC,AMR,VC,DAC
AEC	Allegheny Electric Cooperative	AS&E, Landis & Gyr	LS,SCADA,AMR,VC

KEY

LC - Load Control
VC - Volt/Var Control
DAC - Distribution Automation and Control
LS - Load Survey
AMR - Automatic Remote Meter Reading

COMMUNICATIONS SYSTEMS

PROJECT	COMMUNICATIONS MEDIUM	OPERATION ON UNENERGIZED SECTIONS?
AUB	Power Line Carrier & Telephone	No - PLC Yes - Telephone
CE	Radio & Power Line Carrier	No (theoretical yes)
TESCO	Telephone	Yes
AEP	Telephone-Microwave/ Power Line Carrier	Yes
CPL	Power Line Carrier	No (upgrade planned)
FPL	Power Line Carrier	No
OH	Telephone	Yes
NMPC	Power Line Carrier	Yes
KUB	Power Line Carrier	Yes
AEC	Power Line Carrier	No

MONITORED AND CONTROLLED POINTS

	AUB	CE	TESCO	AEP	CPL	FPL	OH	NMPC	KUB	AEC
Substation Breaker	C	C	C	C	C			C		
Substation Transformer	M	M	M	M			M	M		
Load Tap Changer	C	C							C	
Tie Switch	C	C	C	C	C		C	C	C	
Sectionalizing Switch	C	C	C	C	C		C	C	C	
Capacitor Bank	C	C	C	C	C	C	C	C	C	C
Voltage Regulator	C							C	C	
Fault Detector	C	C	M	M	M		M	M	M	
Meter	M			M	M	C	M	M	M	M
Customer Load	C				C	C	C		C	C
SCADA	M								M	C

KEY:

M Monitored

C Controlled & Monitored

FUNCTIONS INCLUDED

	LC	AMR	LS	VC	FD	FISR	FR	BC	MON
AUB	X		X	X	X	X	X	X	X
CE				X	X	X	X	X	X
TESCo				X	X	X	X	X	X
AEP		X	X	X	X	X	X	X	X
CP&L	X	X	X	X			X	X	X
FP&L	X	X	X	X					X
OH	X	X		X	X	X	X		X
NMPC		X	X	X	X		X	X	X
KUB	X	X		X	X	X	X		X
AEC	X	X		X					X

KEY

LC - Load Control
AMR - Automatic Remote Meter Reading
LS - Load Survey
VC - Volt/Var Control
FD - Fault Detection
FISR - Fault Isolation and Service Restoration
FR - Feeder Reconfiguration
BC - Breaker Control
MON - Monitoring

KNOXVILLE UTILITIES BOARD

INTEGRATED DISTRIBUTION AUTOMATION AND LOAD CONTROL SYSTEM (IDACS)

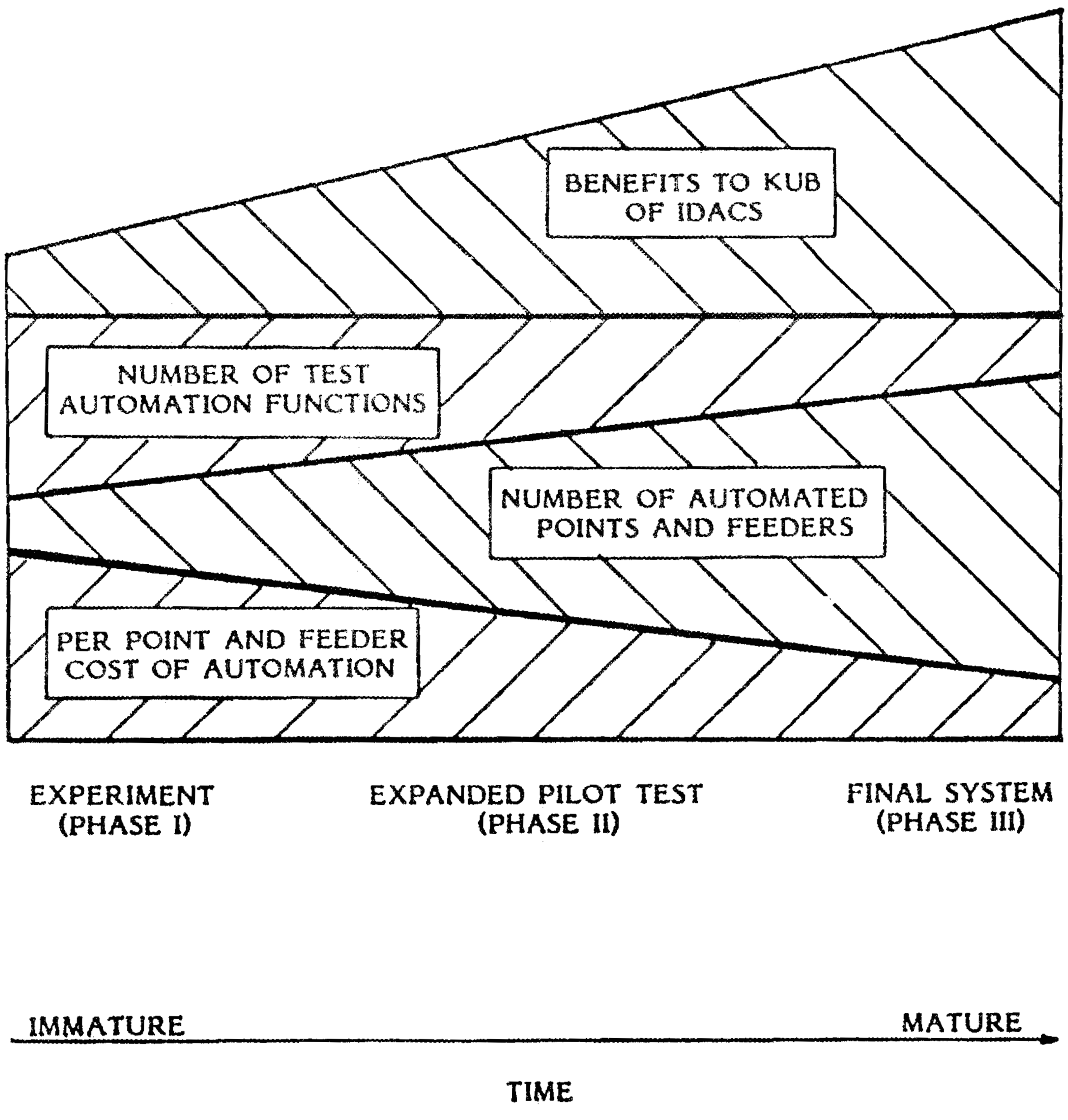
MOTIVATION

- o Load Control - demand charges from TVA
- o Power Factor Control
- o Voltage Profile Maintenance
- o Improve Customer Service Reliability
- o Integrate with new SCADA System
- o Metering:
  - Remote reading
  - Time of use metering
  - Water & gas meter reading

OBJECTIVES

- Test a bi-directional communication system
- Determine the cost/benefit of various automation functions
- Develop effective control strategies and operating procedures
- Determine the design for a full-scale implementation

DEVELOPMENT OF THE IDACS PROJECT WITH TIME



RELATIONSHIP TO AACE

- Another power distributor of TVA is developing automation capability

- A technology transfer opportunity exists by talking to the AUB and ORNL for advice on:

  - equipment installation
  - intertie between the distribution system and the control/communication equipment
  - control strategies and operating procedures
  - possible data transfer
  - screen design and control strategies
  - use of software such as SYSRAP
  - marketing and customer participation

CONCLUSIONS

- Part of the technology transfer concept by the utility industry assuming increased responsibilities in developing automation

- KUB will benefit from the successes and failures at AUB

LIST OF ATTENDEES

LIST OF ATTENDEES

ATHENS AUTOMATION AND CONTROL EXPERIMENT PROJECT REVIEW MEETING

Hyatt Regency Hotel
Knoxville, Tennessee

December 3-5, 1985

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229. Institute for Energy Analysis, ORAU Library
230. Office of the Assistant Manager for Energy Research and Development, DOE-ORO, Oak Ridge, TN 37831

231–257. Technical Information Center, Department of Energy, P.O. Box 62, Oak Ridge, TN 37831