SALEM NUCLEAR PLANT VOLTAGE STUDY

FOR

SPLIT GROUP BUS CONFIGURATION

Prepared by:

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POWER TECHNOLOGIES, INC.
Schenectady, New York

November 1986

1.0 INTRODUCTION

This memorandum documents simulation runs of motor starting and fast group bus transfer at the Salem Nuclear Generating Plant for PSE&G. The system model for the simulation runs was based on a split group bus scheme at Unit 2 so that during normal operation half of the group bus load was supplied through the unit's auxiliary transformer and the other half through the station power transformer. In event of a reactor trip or loss of coolant accident, the voltage dip after the remaining group buses are transferred for the split configuration would not be so low than in the case for a fast transfer with the normal configuration. These simulation runs revealed that the voltage dips were above 0.92 per unit which is above the undervoltage relays settings.

— Existing program in use by 140 plants

2.0 SYSTEM MODEL

what?

The model for the plant was based on the information received from PSE&G. A detailed description of the model is presented in the report for the simulation cases of the present and normal configurations of the plant load.

The initial condition load flow for these dynamic simulation cases models the plant load for Unit 1 with supply from the power station transformers due to the outage of the auxiliary transformer. The plant load for Unit 2 is divided so that half of the load is supplied through the auxiliary transformer, i.e. Group Buses 2F and 2H, and the other half is supplied through the station power transformer, i.e. Group Buses 2E and 2G.

The motor load for the initial conditions are based on brake horsepower which was supplied by PSE&G. The power flows for the initial conditions are shown in Figures 2.1 and 2.2 for Unit 1 and Unit 2, respectively.

3.0 MOTOR STARTING AND FAST TRANSFER SIMULATION CASES

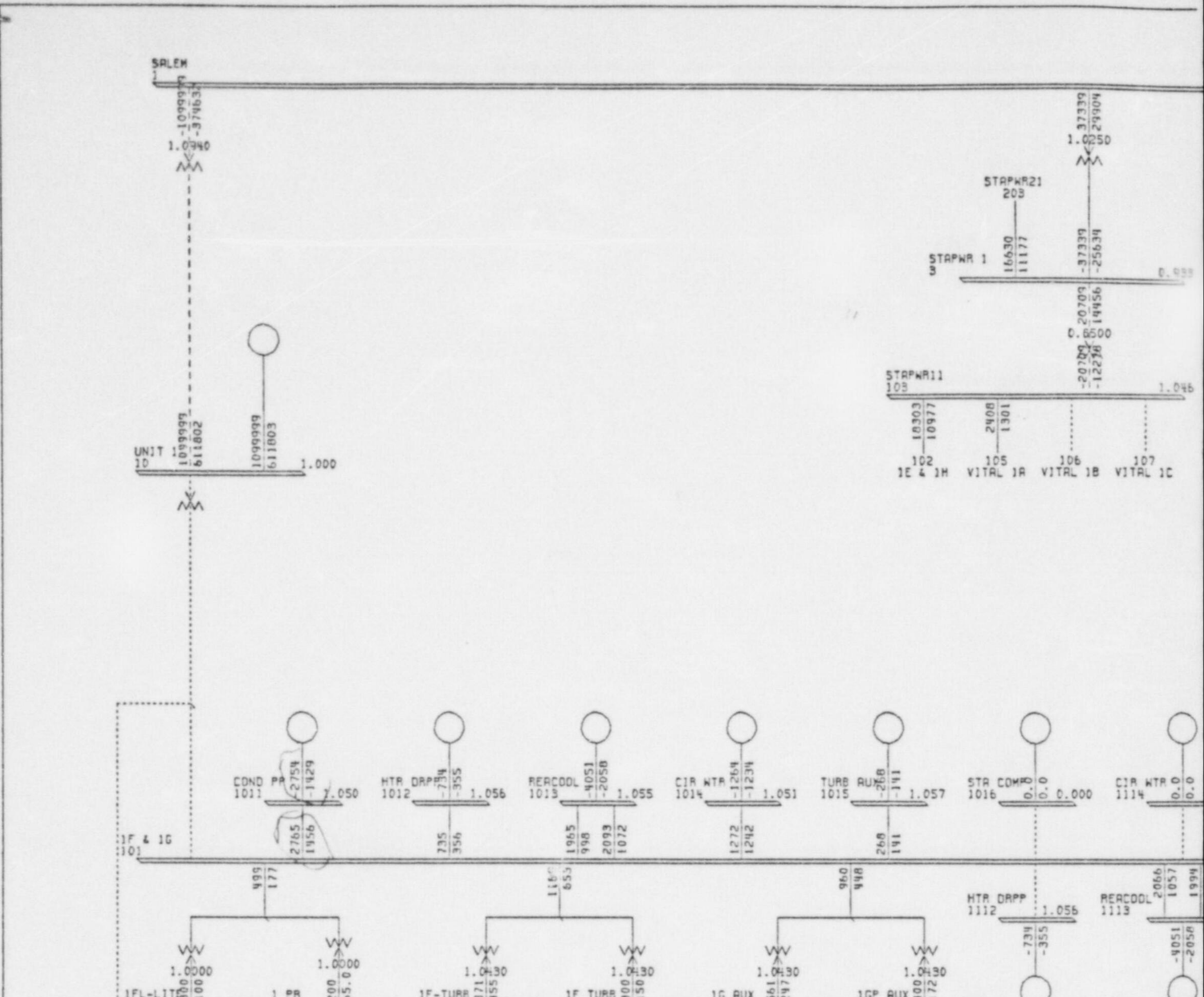
The disturbance for the first set of two simulation cases was a loss of coolant accident (LOCA) on Unit 1 and reactor trip (RT) on Unit 2. The vital bus motor starting was simulated in the first case. This consists of starting all remaining vital motors on Unit 1 and the two auxiliary feedwater pumps on Unit 2. The time plot of the 4.16 kV voltages at the power station transformers is shown in Figure 3.1. The lowest voltage was on Power Station Transformer 12 with a value of .94 per unit. The other voltages remained above .95 per unit. The voltages recovered to near pre-switching values as the motors reached full speed within two seconds after the signal was initiated.

The second case simulated the fast transfer of the Group Buses 2F and 2H to the power station transformer which occurs thirty seconds after the RT signal was initiated. By that time the generating units are on line at reduced load due to the steam being bypassed from the turbines. The switching for the transfer consisted of opening the breakers connecting the group buses to the auxiliary transformer and the closing of the breakers to the power station transformers 80 milliseconds later. The plot of the 4.16 kV voltages at the power station transformers are shown in Figure 3.2. All the voltages were above .92 per unit which is above the undervoltage relay settings.

The disturbance for the second set of two simulation cases was a reactor trip on Unit 1 and a LOCA on Unit 2. The third simulation case was the starting of the vital motors. The plot of the 4.16 kV voltages at the power station transformer is shown in Figure 3.3. All voltage drops were above the undervoltage relay settings so that no action will be taken.

The output for the simulation of the group bus transfer is shown in Figure 3.4. Again the voltages were above the undervoltage relay's settings.

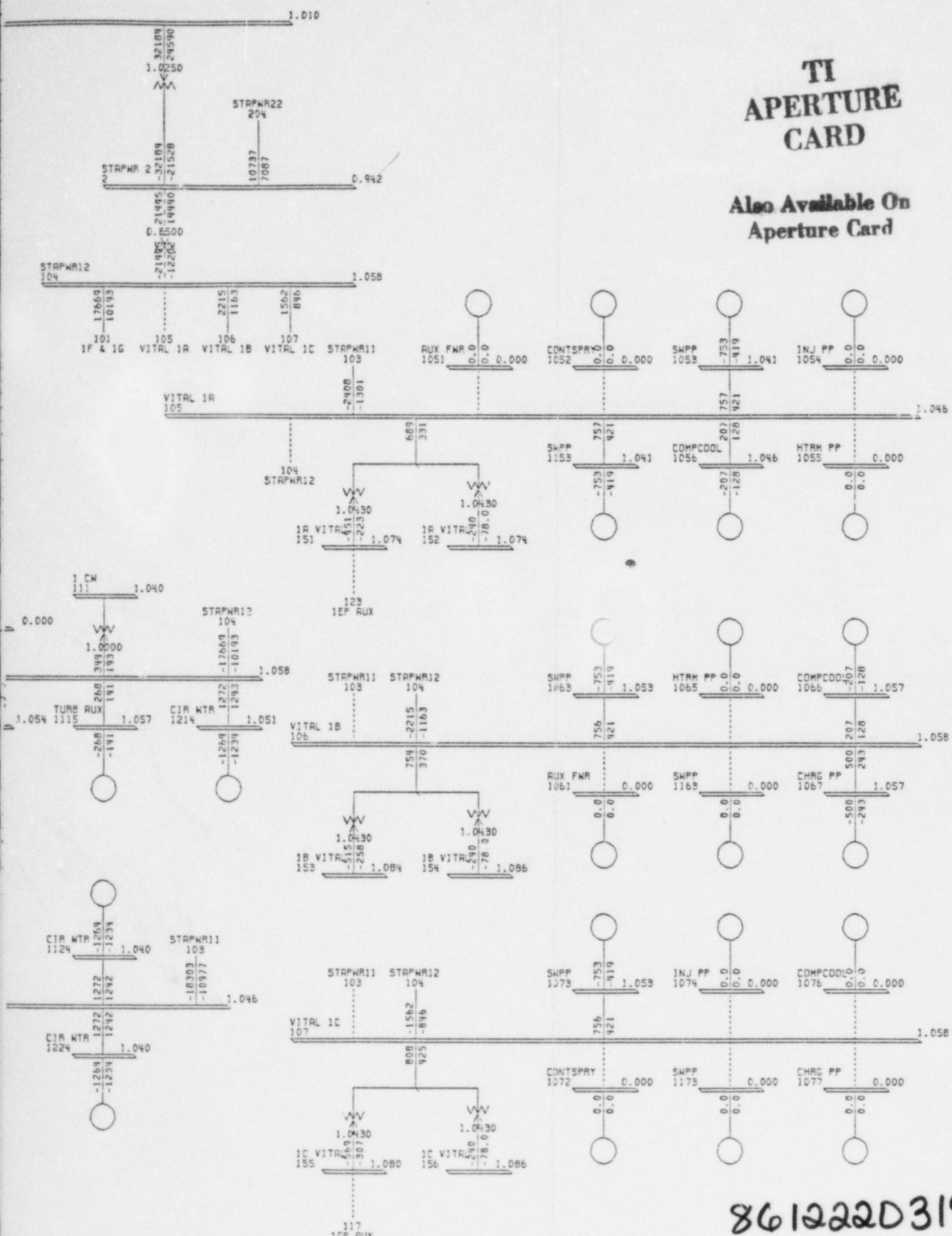
The voltage drops and the steady state values after the switching are listed in Table 3.1. All voltages are greater than .92 per unit well above the set point for the undervoltage relays to start timing out.



PSE&G SALEM NUCLEAR PLANT AUXILIARY STUDY
NEW PLANT CONFIGURATION - HEATER DRAIN PP #12 ON GROUP 2G
UNIT 1 FRI, NOV 07 1986 13:47

100% RATED

BUS - V
BRANCH
EQUIPME



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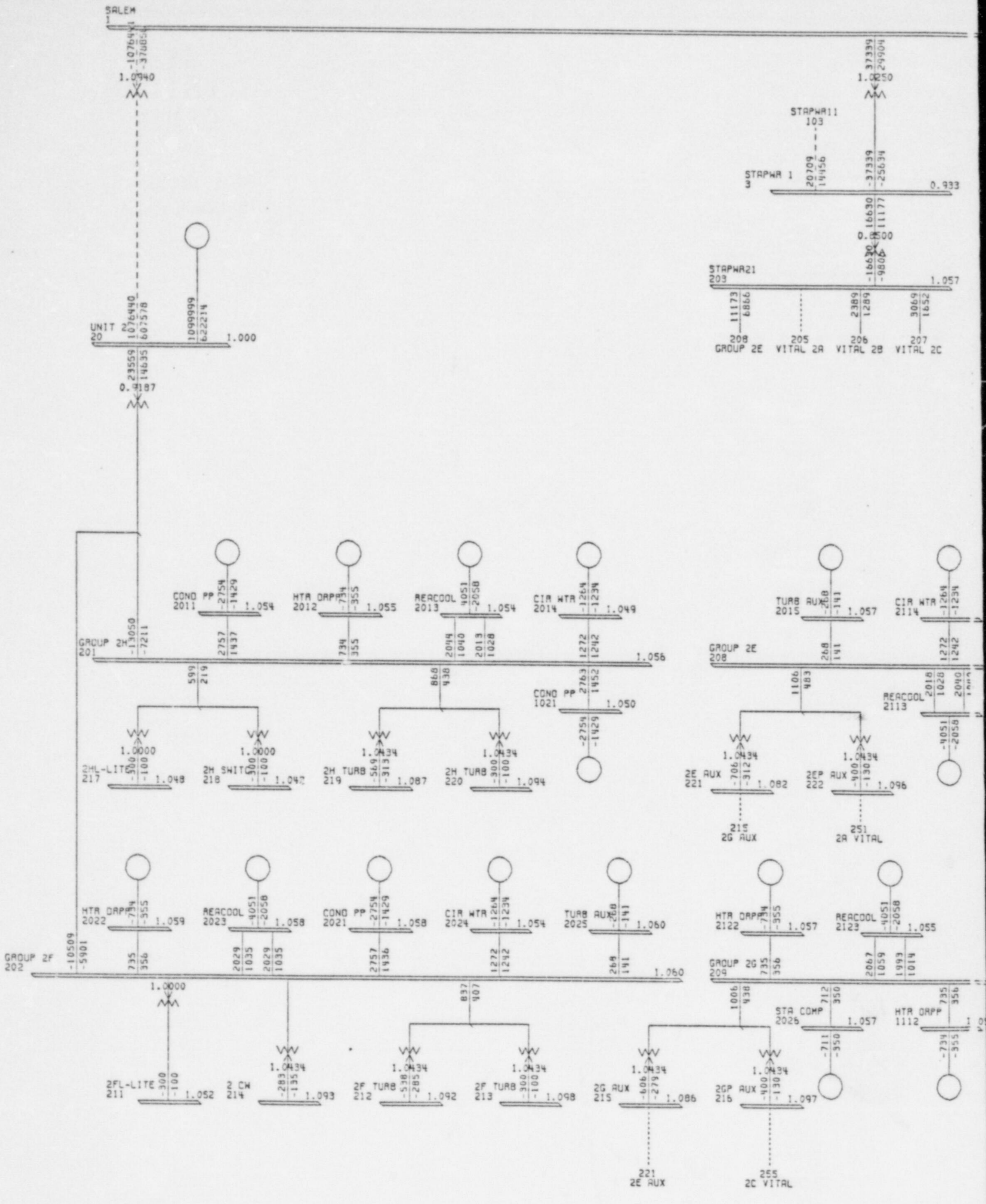
LTAGE (PU)
KW/KVAR
IT - KW/KVAR

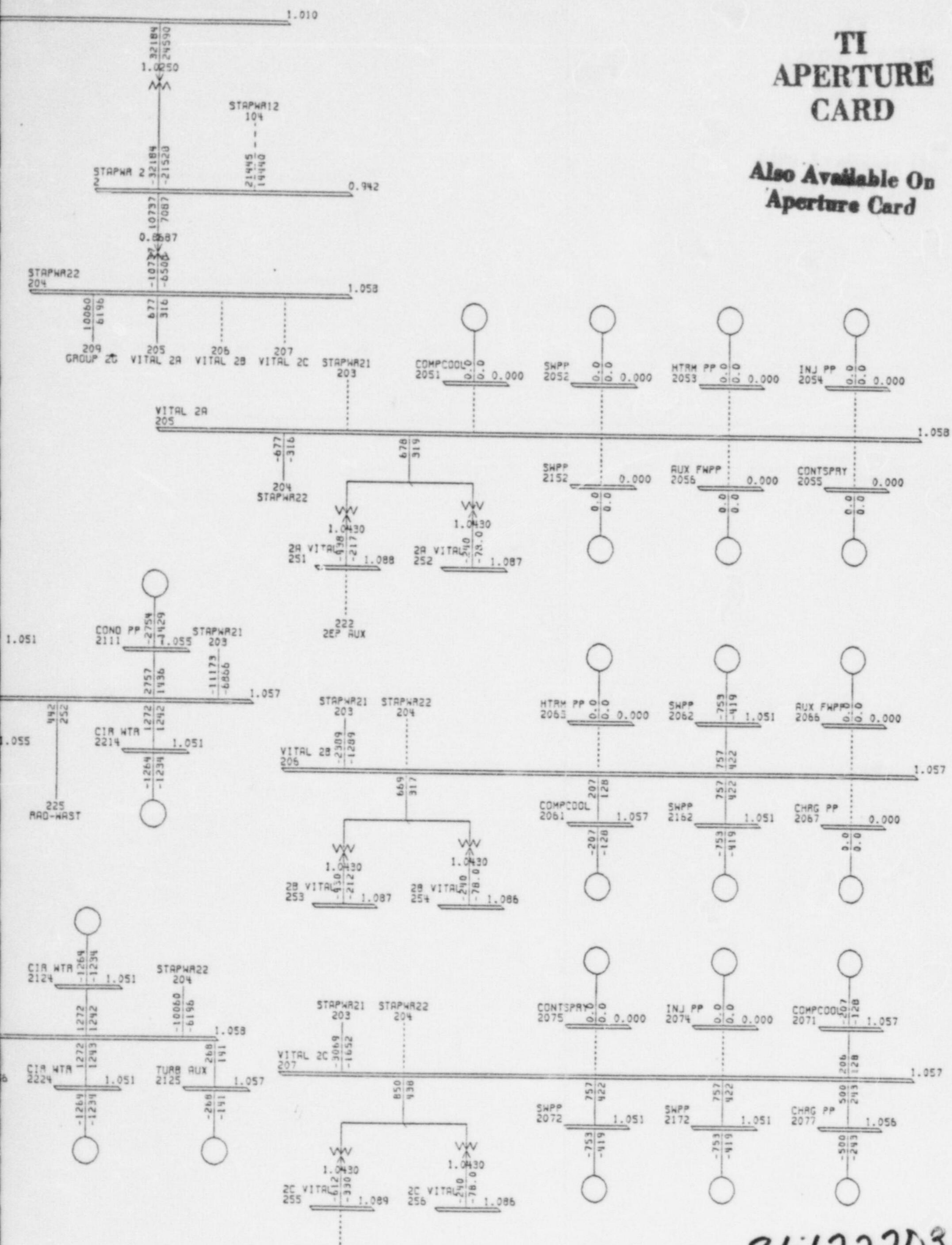
Figure 2.1



PSE&G SALEM NUCLEAR PLANT AUXILIARY STUDY
NEW PLANT CONFIGURATION - HEATER DRAIN PP #12 ON GROUP 2G
UNIT 2 FRI, NOV 07 1986 13:57

100% RATED

BUS - V
BRANCH
EQUIPME



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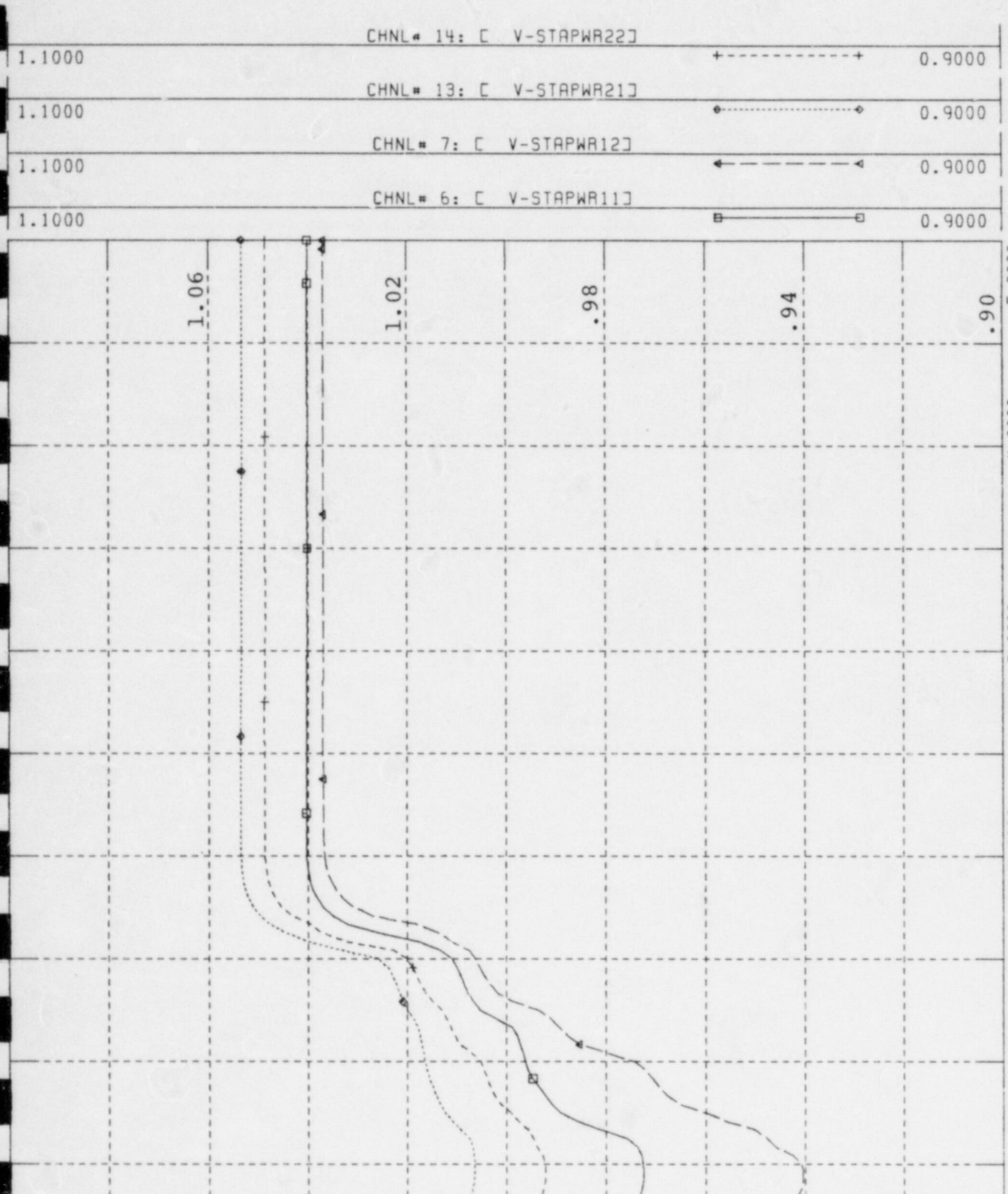
TAGE (PU)
KW/KVAR
- KW/KVAR

Figure 2.2

PSE&G SALEM NUCLEAR PLANT AUXILIARY STUDY
NEW PLANT CONFIGURATION - HEATER DRAIN PP #12 ON GROUP 2G
MOTOR STARTING - LOCA ON UNIT 1
RT ON UNIT 2
FILE: OUT.018A



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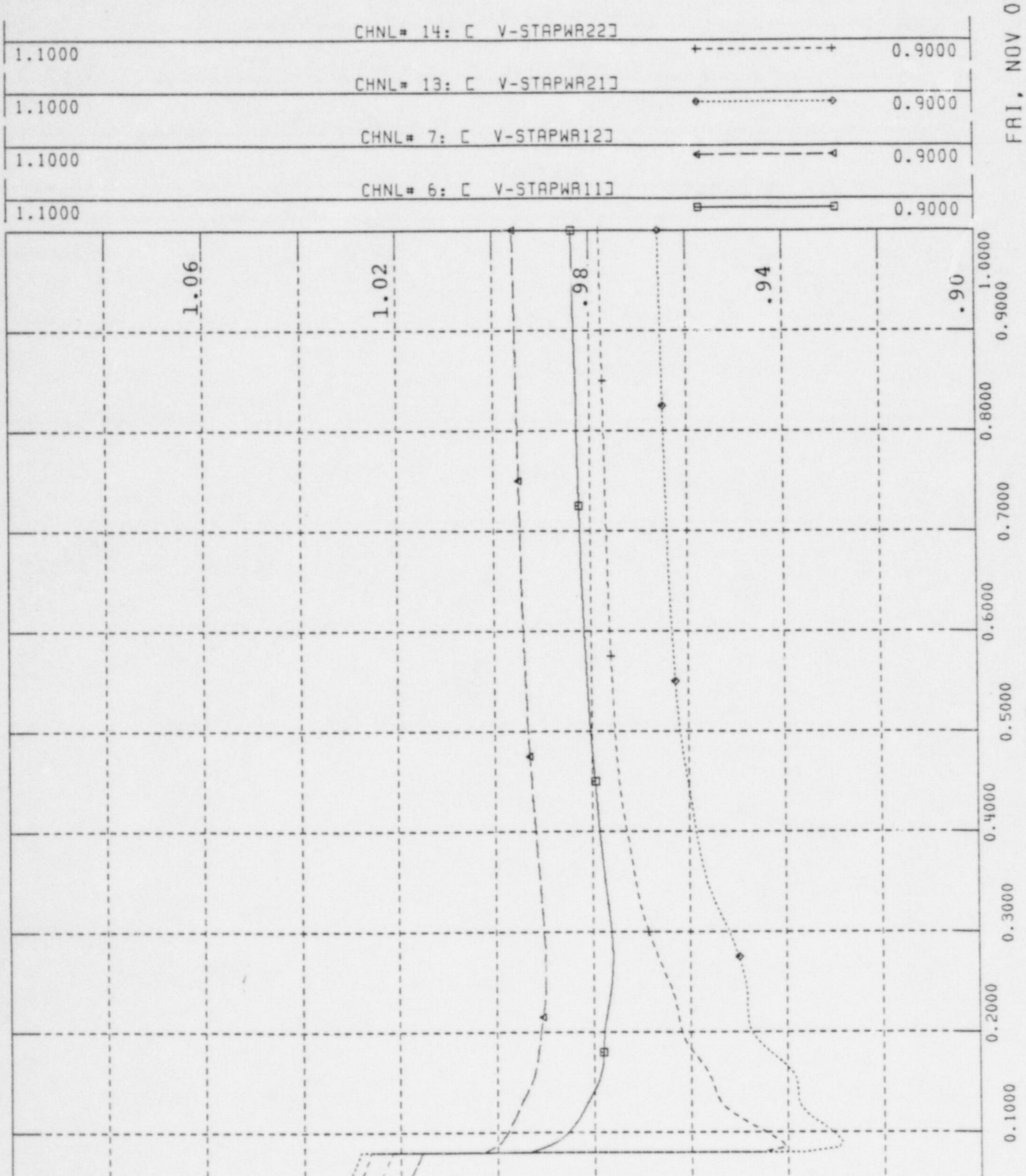
STATION POWER XFRM VOLT

Figure 3.1

PSE&G SALEM NUCLEAR PLANT AUXILIARY STUDY
NEW PLANT CONFIGURATION - HEATER DRAIN PP #12 ON GROUP 2G
FAST TRANSFER OF GROUP BUSES
LOCA ON UNIT 1   AT ON UNIT 2
FILE: OUT.017



STATION POWER XFRM VOLT

Figure 3.2

PSE&G SALEM NUCLEAR PLANT AUXILIARY STUDY
NEW PLANT CONFIGURATION - HEATER DRAIN PP #12 ON GROUP 2G
MOTOR STARTING - AT ON UNIT 1
LOCA ON UNIT 2
FILE: OUT.015

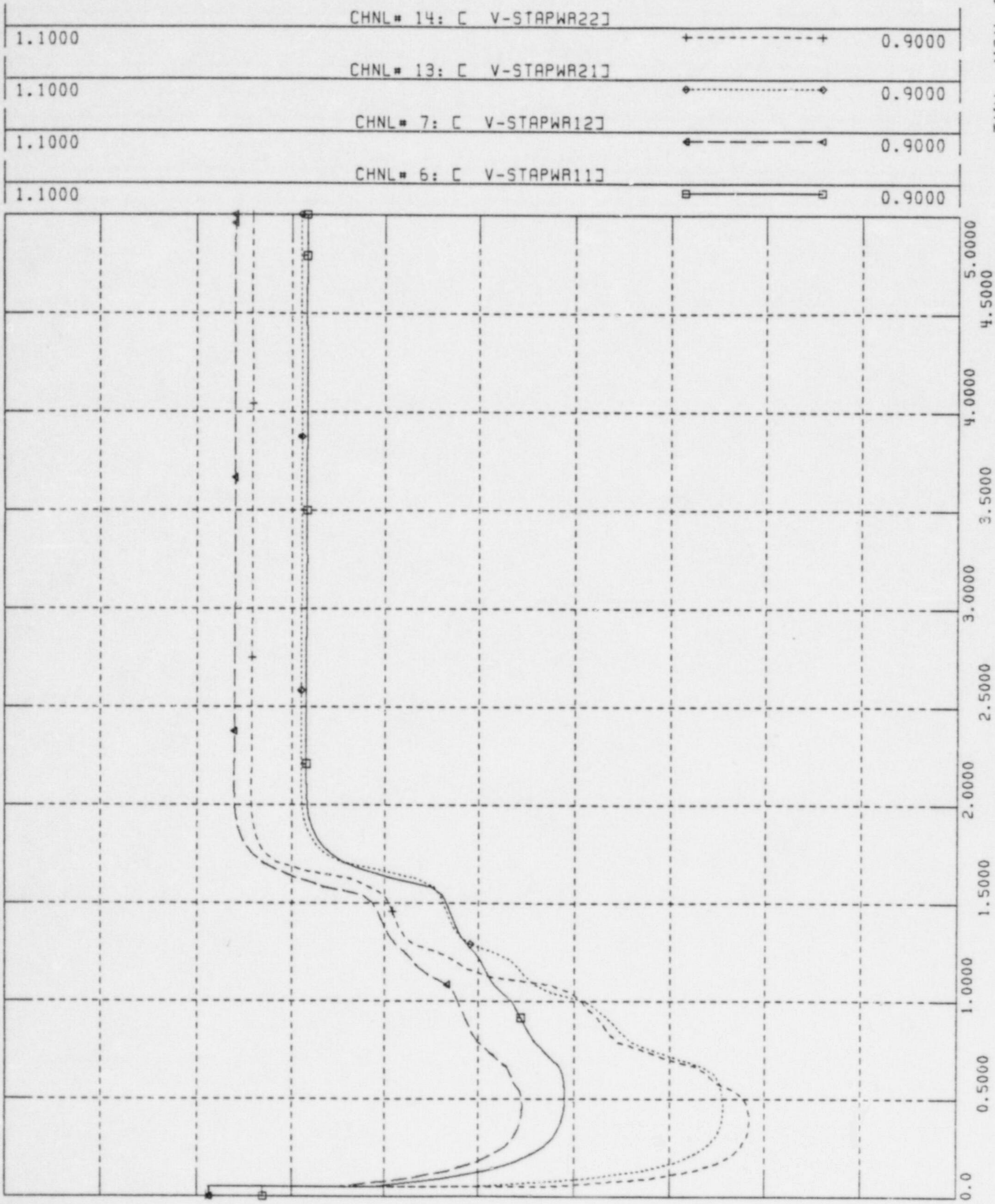


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Figure 3.3 STATION POWER XFRM VOLT

PSE&G SALEM NUCLEAR PLANT AUXILIARY STUDY
HTR DRAIN PP #12 ON 2G - AT (UNIT 1) - LOCA (UNIT 2)
FAST TRANSFER OF GROUP BUSES
LOCA ON UNIT 2
FILE: OUT.016

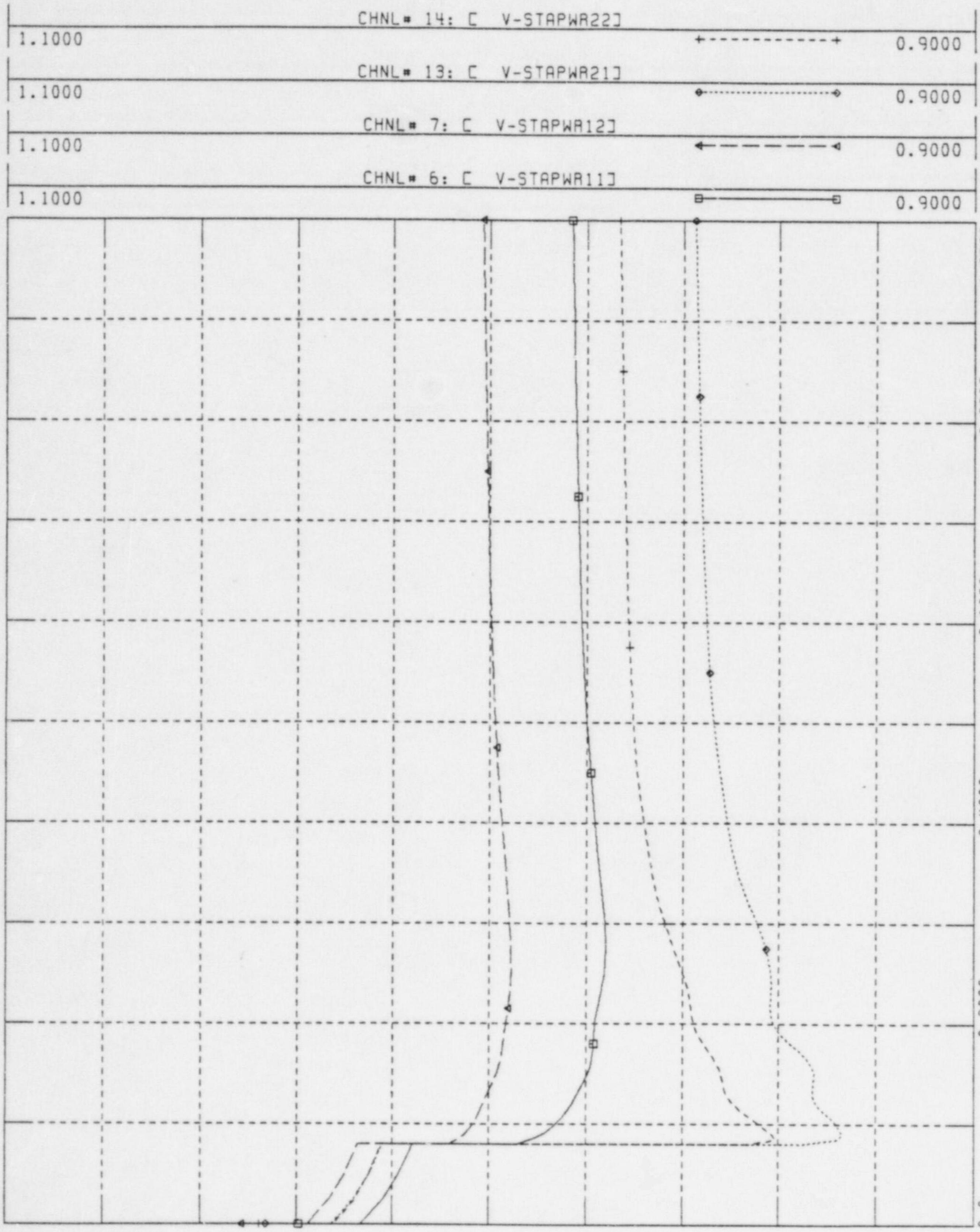

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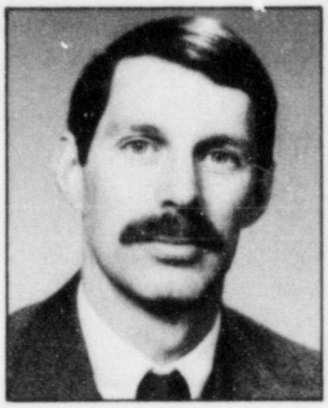
Figure 3.4 STATION POWER XFRM VOLT

Table 4.1. Station Power Transformer 4.16 kV Voltages

Disturbance	SP Transformer #11 Dip	SP Transformer #11 Steady State	SP Transformer #12 Dip	SP Transformer #12 Steady State	SP Transformer #21 Dip	SP Transformer #21 Steady State	SP Transformer #22 Dip	SP Transformer #22 Steady State
A LOCA - Unit 1 RT - Unit 2								
1 Motor Start	.972	1.040	.94	1.036	1.006	1.053	.992	1.048
2 Group Bus Transfer	.976	.983	.989	.995	.929	.965	.940	.977
B RT - Unit 1 LOCA - Unit 2								
1 Motor Start	.982	1.036	.991	1.052	.949	1.038	.943	1.048
2 Group Bus Transfer	.976	.983	.996	1.001	.927	.957	.941	.973

LOUIS N. HANNET, Senior Engineer



Mr. Hannett attended Clarkson College of Technology for his undergraduate study. In his senior year, he received the A. Raymond Powers Award which cited him as "an electrical engineering senior who has demonstrated the best understanding of the basic physical phenomena and principles of rotating electrical machines, and whose interest and ability give promise of an outstanding career in the field of power engineering." Mr. Hannett graduated from Clarkson in 1971 with honors.

Upon graduation, Mr. Hannett joined Power Technologies, Inc. as an analytical engineer and was promoted to senior engineer in 1982. At PTI he has contributed in the following areas:

- Large scale power system studies involving load flow, transient and dynamic stability, load rejection, subsynchronous oscillations and economic dispatch.
- Development of the power system simulator program, PSS/E, the machine and network transients program, MNT/E, and the interactive dynamic analysis program, IDAP.
- Studies of fossil-fuel power plant dynamics with particular reference to gas path transients and furnace implosion problems.
- Hydro plant dynamics including interactions between electrical, mechanical, and hydraulic transients.
- Studies of mechanical and electrical equipment dynamic performance, such as motor starting, shaft torques, diesel generator shock loading, etc.
- Research on determination of synchronous machine model parameters for use in stability studies sponsored by EPRI.
- Research on application of induction generators to power systems.
- Development of a power system stabilizer using digital control.

Mr. Hannett is a senior member of the IEEE and is a Registered Professional Engineer with the State of New York.

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LOUIS N. HANNETT

TECHNICAL PAPERS AND ARTICLES

1. "Practical Approaches to Supplementary Stabilizing from Accelerating Power," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-97, No. 5, Sept./Oct. 1978, pp. 1515-1522, (co-authors, F.P. de Mello and J.M. Undrill).

2. "Turbine-Generator Impact Torques in Routine and Fault Operations," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No. 2, March/April 1979, pp. 618-628. (co-author, J.M. Undrill).

3. "Thyristor-Controlled Reactors Analysis of Fundamental Frequency and Harmonic Effects," IEEE Winter Power Meeting, 1978, (co-authors, F.P. de Mello, B.K. Johnson, D. Birfet, and J. Toulemonde).

4. "Studies of Subsynchronous Oscillations in Itaipu Series Compensated Transmission Alternatives," 4th National Conference on Production and Transmission of Electrical Energy, Rio de Janeiro, Brazil, 1977, (co-authors, J.M. Undrill and B.K. Johnson).

5. "Validation of Synchronous Machine Models and Derivation of Model Parameters from Tests," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 2, February 1981, pp. 662-672, (co-author, F.P. de Mello).

6. "Large Scale Induction Generators for Power Systems," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 5, May 1981, pp. 2610-2618, (co-author, F.P. de Mello).

7. "Validation of Nuclear Plant Auxiliary Power Supply by Test," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-101, No. 9, September, 1982, pp. 3068-3074, (co-authors, F.P. de Mello, G.H. Tylinski, and W.H. Becker).

8. "A Power System Stabilizer Design Using Digital Control," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-101, No. 8, August 1982, pp. 2860-2868, (co-authors, F.P. de Mello, D.W. Parkinson, and J.S. Czuba).

9. "Derivation of Synchronous Machine Stability Parameters from Pole Slipping Conditions," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-101, No. 9, September 1982, pp. 3394-3402, (co-authors, F.P. de Mello, D. Smith, and L. Wetzel).

10. "Application of Induction Generators in Power Systems," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-101, No. 9, September 1982, pp. 3385-3393, (co-authors, F.P. de Mello, J.W. Feltes, and J.C. White).

11. "Determination of Synchronous Machine Electrical Characteristics by Test", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-102, No. 12, December 1983, pp. 3810-3815, (co-author F. P. de Mello).

12. "Digital Control Algorithms and Control Tuning", presented at POWID 26th Annual Power Instrumentation Symposium, St. Petersburg, FL, May 16-18, 1983, (co-authors, J. W. Feltes and F. P. de Mello).

13. "System for Stabilizing Synchronous Machines", United States Patent No. 4463306, (co-inventors F. P. de Mello, J. S. Czuba, D. W. Parkinson).

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ELECTRIC UTILITIES

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- Public Service Co. of Colorado
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- Seminole Electric Coop. Inc.
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- Southern Indiana Gas & Electric Co.
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- 3M Company
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- Doble Engineering Co.
- Douglas G. Peterson & Associates, Inc.
- Dranetz Engineering
- EBASCO Services, Inc.
- EDG Engineering, Inc.
- EUA Service Corporation
- F. Eberstadt & Co.
- Fluor Engineers, Inc.
- Forest Electric
- Gibbs & Hill
- Gilbert Commonwealth Associates
- International Engineering
- Kaiser Engineering, Inc.
- Keane Associates
- Keytech (for People's Republic of China)
- Kuljian Corporation
- Laramore Douglas & Popham
- Lemco Engineers
- Life Systems, Inc.
- Arthur D. Little Co.
- Litwin Corp.
- London Morenco Consultants
- Lower Churchill Development Corp.
- Chas. T. Main, Inc.
- Mosely, Hallgarten, Estabrook & Weeden, Inc.
- Nixon, Hargreaves
- NUS Corporation
- Pan West Constructors
- Presearch, Inc.
- Pugh Roberts Associates
- R.W. Beck & Associates

POWER POOLS AND RELIABILITY COUNCILS

DOMESTIC

- Electric Reliability Council of Texas
- Intercompany Pool
- Main Coordination Center
- MAPP Coordination Center
- Mid-Continent Area Power Planners
- New England Power Exchange
- NPPC
- New York Power Pool
- Northeast Power Coordination Council
- P-J-M Interconnection
- REMVEC
- Western Area Power Administration
- Western Systems Coordinating Council
- Wisconsin-Upper Michigan Pool

FOREIGN

- GCOI (Brazil)
- Krangede Power Pool (Sweden)
- OPSIS (Venezuela)

INDUSTRIALS

DOMESTIC

- AiResearch
- Airproducts & Chemicals
- ALCAN Cable Corporation
- ALCOA
- Allied Bendix
- Allied Chemical
- Alpha Tech, Inc.
- Amoco
- Amoco Chemicals Corp.
- Anaconda Wire & Cable Company
- Arabian American Oil Co.
- Arco Chemical
- ASEA
- Baker Automation
- BBC
- Bell Telephone Lab
- Bethea Company
- Boeing Electronics
- Boeing Engineering & Construction
- Bowater Southern Paper Corp.
- CTI-Cryogenics
- Caddim, Inc.
- Ceramaseal, Inc.
- Chase Bag Co.
- Chemplex
- Cities Service Co.
- Claniel Enterprises
- Cogeneration Development Corp.
- Colgate-Palmolive
- Collyer Wire and Cable
- Combustion Engineering, Inc.
- Consolidated Papers
- Consolidated Rail Co.
- Continental Oil Co.
- Control Data Corporation
- Doble Engineering
- Dow Chemical Co.
- Dupont
- Eastman Kodak Co.
- Eaton Corp.
- Elastimold
- Environment One
- Essex Group United Technologies
- Exxon Enterprises
- Exxon Minerals Co.
- Exxon Research & Engineering
- Ferranti International Controls
- Finch, Pruyn Co., Inc.
- Fluor Utah
- Fort Pitt Steel
- Foster-Miller
- G & W Electric Specialty Co.
- General Automation
- General Electric Co.
- General Motors Corp.
- Genro Energy Systems
- Gould-Brown Boveri Corp.
- Gould, Inc.
- GTE-Lenkurt
- Harris Controls
- Hess Oil Virgin Islands Corp.
- High Voltage Breakers, Inc.
- High Voltage Power Corp.
- Humble Oil Co.
- IBM
- International Paper Co.
- Kaiser Aluminum Chemical Corp.
- Lapp Insulator, Interpace Corp.
- Locke Instruments
- Lockheed Missiles & Space Co.
- Loctite Corp.
- MAC Products
- Macrodyne, Inc.
- Martin Marietta Aluminum
- Masstron Scale, Inc.
- McGraw-Edison Co.
- Mobil Coal Producing
- Moore Systems
- Newport News Shipbuilding & Dry Dock Co.
- Ohio Brass
- Owens-Corning Fiberglass Corp.
- Owens-Illinois
- Oxygen Enrichment Co.
- Paige Electric Corp.
- Phelps Dodge
- Pirelli Corporation

OTHER

DOMESTIC

- University of Illinois
- University of North Iowa
- University of Utah Research Park
- Utah Association of Manufacturers
- Watkiss and Campbell
- Wilkinson & Carmody
- Wisconsin Assoc. of Mfgrs. & Commerce
- Wood, Leaver & Associates
- Worcester Polytechnic Institute
- World Bank

FOREIGN

- Atomic Energy Canada, Ltd. (Canada)
- Canadian Electrical Association (Canada)
- CEPEL (Brazil)
- China National Technical Import Corp. (PRC)
- China National Instruments Import & Export Corp. (PRC)
- Electric Power Development Corp. (Japan)
- Electric Power Research Institute (People's Republic of China)
- ELTROBRAS (Brazil)
- Halden (Norway)
- Inst. Argentino de Capacitacion en la Roma (Argentina)
- Manitoba Forestry Resources Ltd. (Canada)
- NV Kema (Holland)
- Peoples' Republic of China (PRC)
- Swiss Federal Railways (Switzerland)
- Wuhan High Voltage Research Institute (People's Republic of China)

FOR FURTHER INFORMATION

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President

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Schenectady, NY 12301-1058

Telephone: (518) 374-1220
Telex 145498 POWER TECH

CONSULTANTS, ENGINEERS, CONSTRUCTORS

DOMESTIC (cont'd)

- o Sargent & Lundy
- o Simulation Associates
- o S.M. Stoller Associates
- o Sohio Construction Co.
- o Stone & Webster Engineering
- o Strategies Unlimited
- o Sverdrup & Parcel
- o Synergic Resources Corp.
- o Touche Ross & Co.
- o Ultrasystems, Inc.
- o Underground Power Systems
- o Underground Systems, Inc.
- o Underseas Cable Engineers, Inc.
- o United Engineers
- o United Technologies
- o Wismer & Becker

FOREIGN

- o ACRES, Ltd. (Canada)
- o Constructeurs Inga-Shaba (Zaire)
- o Development Consultants (India)
- o Elmec, Ltda. (Colombia)
- o ELTEM-TEK (Turkey)
- o Energia y Desarrollo (Colombia)
- o EPTISA (Spain)
- o FERRCO (Canada)
- o Landis & Gyr (Switzerland)
- o Lavalin Consulting Group (Canada)
- o Leighton & Kidd, Ltd. (Canada)
- o Motor Columbus International (Switzerland)
- o Projetos e Estudos de Engenharis S.A. (Brazil)
- o Rand Corporation SNC - Lavalin (Canada)
- o SADE/ESIN (Argentina)
- o Serinel (Venezuela)
- o SNC-Lavalin (Canada)
- o Technoproyectos S.A. Consultora (Argentina)
- o Tron Horn A/S (Norway)

OTHER

DOMESTIC

- o Aerospace Corporation
- o Arizona Corporation Commission
- o Arizona State University
- o Brookhaven National Labs.
- o California Energy Resources Conservation and Development Commission
- o Condon & Forsythe
- o Connecticut Siting Council
- o Consolidated Rail Corp.
- o Corps of Engineers (U.S. Gov't)
- o Cozen, Bezier and O'Connor
- o Craig & Antonelli
- o Crowell & Moring
- o Dalessio, Shapiro & Gore
- o Day, Berry & Howard
- o Dept. of Energy (U.S. Gov't)
- o Electric Power Research Institute (EPRI)
- o EPRI Waltz Mill Cable Test Facility
- o Empire State Electric Energy Research Company (ESEERCO)
- o Erskine, Dunn & McMahon
- o Federal Energy Regulatory Commission (U.S. Gov't.)
- o Ford Foundation
- o Faulds, Felker, Burns & Johnson
- o Fuller, Henry, Hodge and Snyder
- o Fusion Energy Corporation
- o Gray, Carey, Ames & Frye
- o Gribbin, Burns and Eide
- o Guren, Merritt, Feibel, Sogg and Cohen
- o Harristown Development Corp.
- o International Copper Research Assn.
- o Kansas Corporation Commission
- o Kenley, Boyland, Coghlan & Erskine
- o Lasser, Hochman, et al.
- o Levine, Gouldin and Thompson
- o Leyland Watson & Noble
- o Long Island Farm Bureau (N.Y. State)
- o Los Alamos Space Laboratory
- o Massachusetts Institute of Technology
- o Metro-North
- o Michigan Public Service Commission
- o Mid-America Interpool Network
- o Minnesota Environmental Quality Board
- o NASA (U.S. Gov't)
- o National Science Foundation
- o Naval Research Labs (U.S. Gov't)
- o New York Department of Energy
- o New York Power Authority
- o New York State Energy Research & Development Authority
- o New York State Public Service Commission
- o Norstar Venture Fund
- o Northeast Power Coordinating Council
- o Port Authority of New York & New Jersey
- o Power Facility Evaluation Council (State of Connecticut)
- o R.I. Dept. of Attorney General
- o Rand Corporation
- o Ray, Quinney & Nebeker
- o Robinson, Robinson & Cole
- o Sandia Laboratories
- o The Hartford
- o Thorp, Reed and Armstrong
- o Tulane University
- o Tybout & Redfearn
- o Tyler Cooper Grant Bowerman & Keefe
- o United States Navy
- o University of California
- o University of Hartford

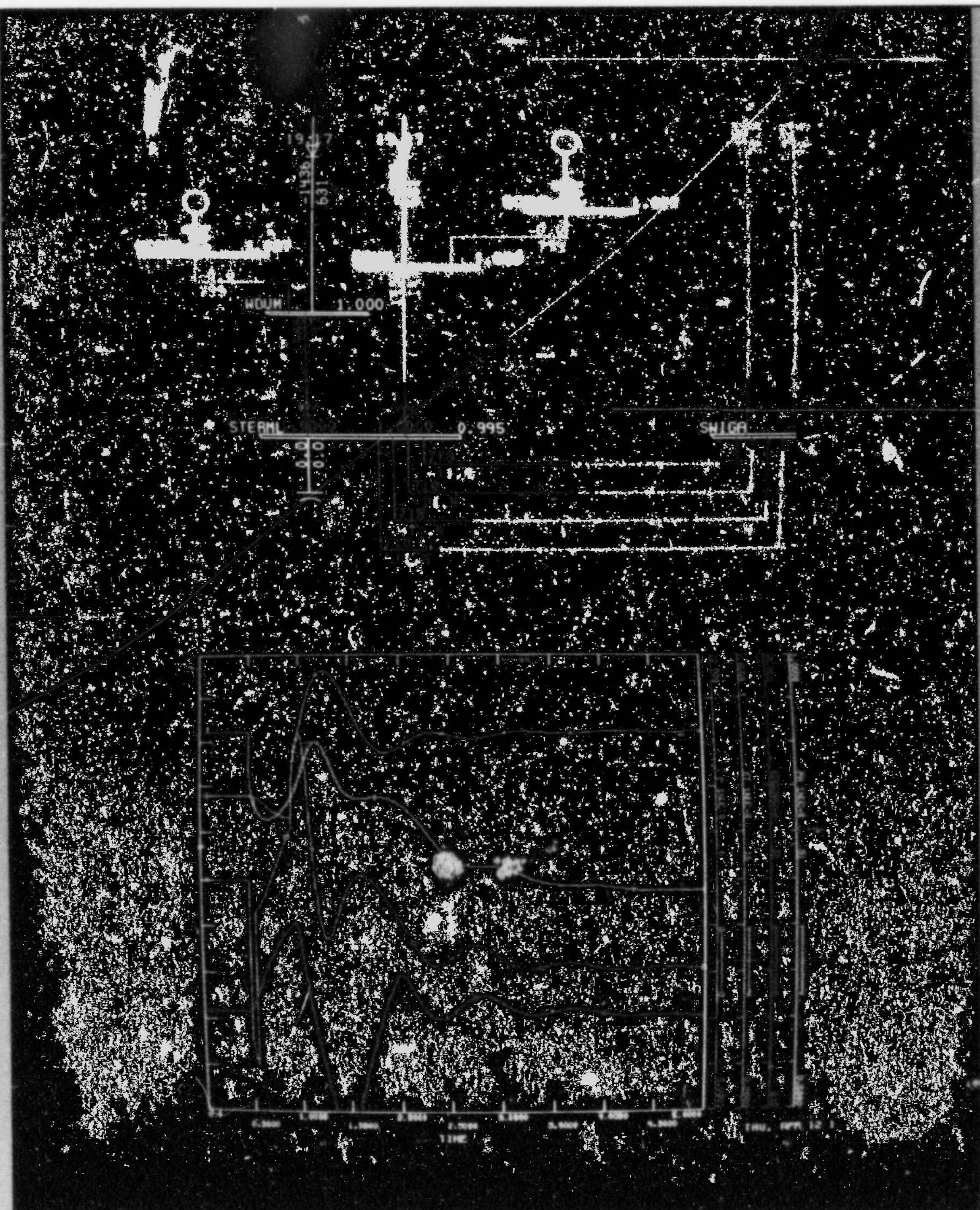
ENCLOSURE 4

POWER TECHNOLOGIES INC.

1482 Erie Blvd., Schenectady, N.Y. 12305

POWER SYSTEM SIMULATOR, PSS/E

Number 35



PSS/E

PSS/E is an integrated set of programs for power system simulations covering:

- Load Flow
- Fault Analysis
- Dynamic Simulation
- Network Reduction
- Transfer Limit Analysis
- Eigenvalue and Frequency Response Analysis

PSS/E includes facilities for:

- Working data base maintenance
- Exchange of data with other programs
- Graphics
- Fully interactive, batch, and mixed modes of operation.

PSS/E is in service with 80 end users in computers ranging from one-user "work stations" up to the largest mainframes.

PSS/E CAPABILITIES

PSS/E is a large-scale power system analysis package designed to handle the full range of power frequency network analysis problems. It is designed for use in interconnected system studies, detailed studies of machine/plant/control dynamics, protection calculations, and subtransmission studies. The program's maximum capacities, as shown in Table I, are consistent with the largest of system studies, while the program's fully interactive dialog style is ideally suited to the needs of smaller scale detailed design work.

TABLE I

PSS/E Maximum Capacities

Buses	12000
Branches	24000
Transformers	4800
Generating Plants	3600
Generators	4000
Switched Shunt Devices	400
DC Transmissions	20
Interchange Control Areas	100
Zones	999
Zero Sequence Mutual Couplings	1000

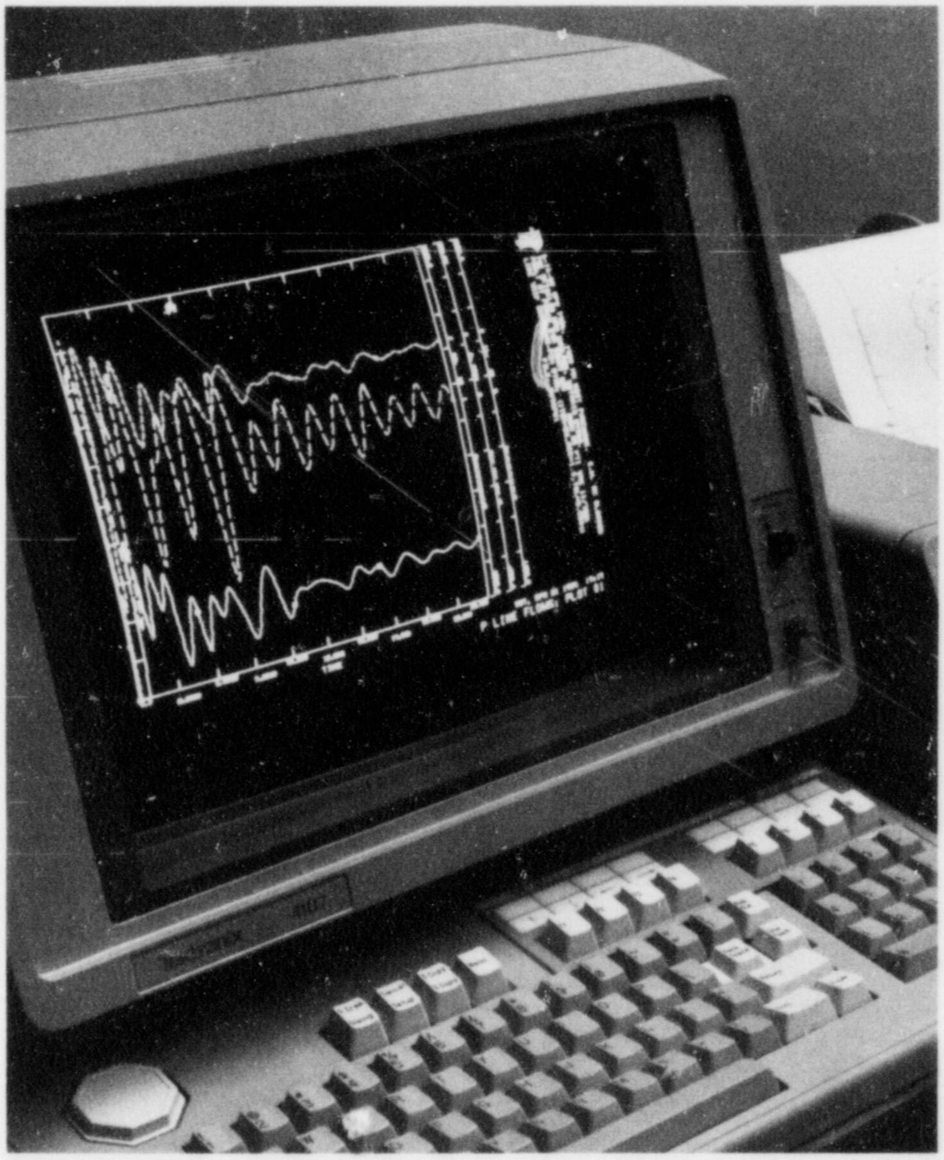
LOAD FLOW

PSS/E includes the following among its many capabilities:

- Load flow solutions can use Gauss-Seidel, Newton-Raphson, decoupled Newton, Fast-Decoupled, or secondary-adjusted Gauss-Seidel iteration. The user may switch iteration methods at any point in the solution.
- Any transformer can be adjusted to control a local or remote bus voltage or real or reactive power flow through itself.
- Transformer ratio may be adjusted either continuously or stepwise during Newton Raphson solutions. While continuous adjustment is not a true physical representation, it can be an advantageous step towards a physical solution in certain cases. Ratios can be forced to the nearest physical tap after solution with continuous adjustment
- All load flow solution methods recognize both switch and thyristor-controlled static reactive power sources. Switched sources may consist of several stages of reactor and capacitor modules, which are switched sequentially to maintain voltage within a specified band. Thyristor-controlled sources, either reactor or capacitor, are adjusted continuously within rating to hold voltage at a scheduled value.
- All solution methods can handle 2 and 3 terminal dc transmission.
- Exception reporting can list overloaded lines or transformers, buses with unacceptable voltage, overloaded generators, atypical input data, islanded system segments, and out-of-service components.
- A simple economic dispatch module is provided to allocate generator outputs system-wide or within a designated subsystem. This function recognizes commitment priority and incremental fuel cost.
- A special double-precision network solution activity allows secondary system flow cases to be converged to very tight tolerances in spite of unfavorable impedance ratios.
- Both load flow data and results may be displayed in graphical form.

FAULT ANALYSIS

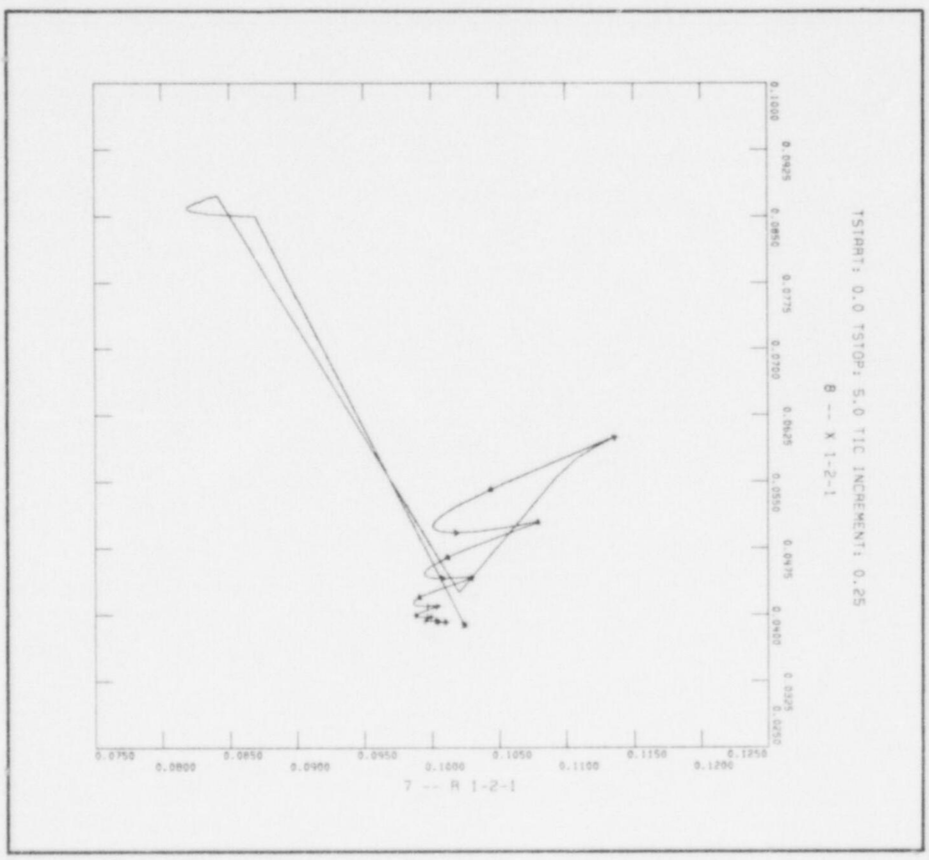
- The Fault Analysis solution handles all three symmetrical component sequences in full detail, and can handle multiple unbalanced events at any combination of buses and phases. The system modeling includes exact treatment of transformer phase shift and of the geographical distribution of zero sequence mutual coupling.
- Transformer sequence equivalent circuit setup is handled automatically from user-specified data on winding configurations. This facilitates the identification of individual ground currents at buses having multiple ground paths through transformers and other components.

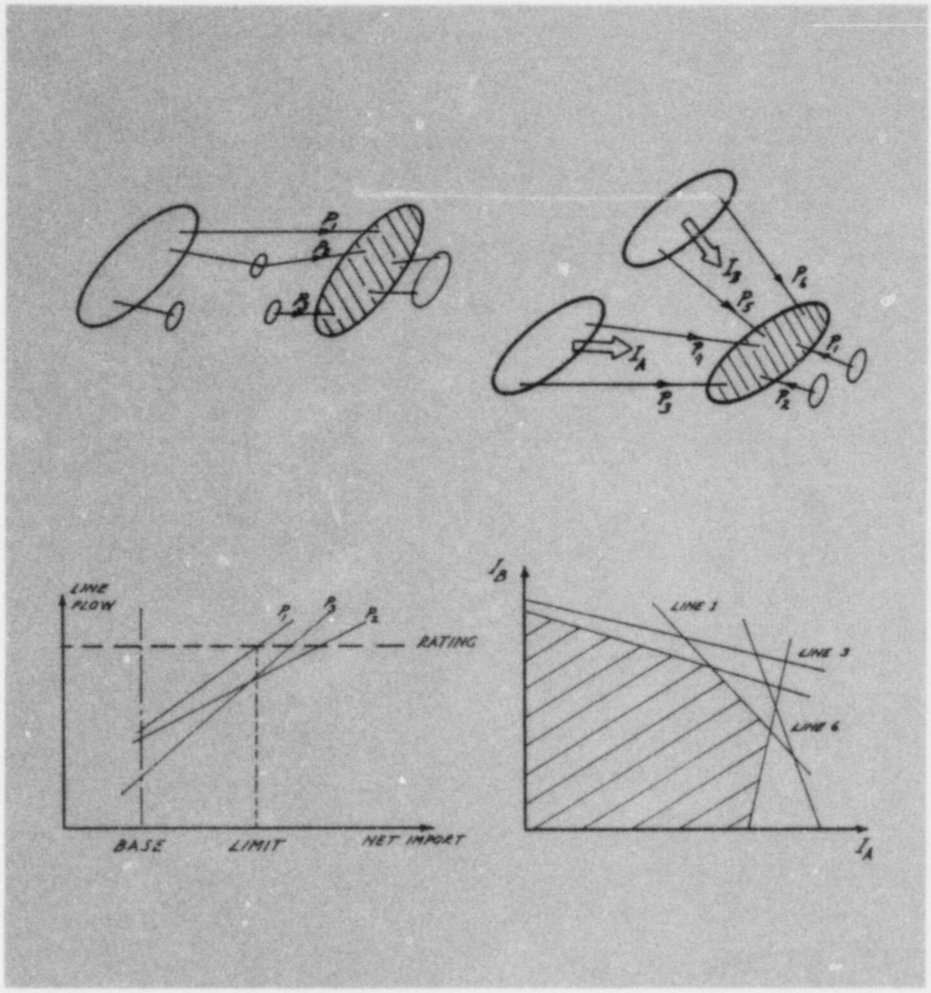


- Two fault analysis processes are provided. The first handles simultaneous events of complex configuration and provides results for all voltages and currents in the system. This solution allows faults to be at a bus or at any point along a transmission line. The second provides sequential calculation of three-phase and L-G fault solutions for bus, line-out, and line-end faults throughout a specified subsystem.
- A special module is provided to handle independent-pole switching of a transmission line. The principal use of this is to develop positive sequence equivalent circuits to represent the incompletely switched line in dynamic simulations.
- A double precision option allows high precision in calculations on systems having buses with a large spread of connected branch impedances.
- Fault analysis results may be displayed on network one-line diagrams.

DYNAMIC SIMULATION

- The dynamic simulation section of PSS/E consists of a basic simulation module, together with a library of equipment models that are connected into the skeleton as required.
- The simulation model library includes solid and salient pole generator models at the subtransient level, a comprehensive range of excitation system models, turbine-governor, stabilizer, and other control models. The full set of IEEE Transient Stability analysis models (both the "1968 set" and the "1981 set") is included.
- The model library includes load representations giving polynomial dependence of load on bus voltage and frequency, together with detailed differential equation level models of induction-motor loads. The library includes a range of models of dc transmissions and static var devices, both with their primary power, current, or Mvar controls and with supplementary "system-stabilizer" controls.
- Relay models included in the library cover a range of distance, overcurrent, over/under voltage, and other types. Supervision of relays by one-another can be represented. Relay models can be set to act as programmed, or to observe system behavior and display flags but to refrain from acting.
- All dynamic simulation models and the transmission network model recognize the dependence of system parameters on frequency.
- Any quantity identified in the transmission network or dynamic models may be selected for plotting. Plotting files may be retained for replotting in comparison with subsequent runs, rescaling, and so on.
- Utility programs are provided to assist in the estimation of parameter values of synchronous and induction machines when complete data is not available. The induction machine program calculates and displays the characteristics of torque, power factor, and current versus slip for a proposed set of equivalent circuit parameters. The synchronous machine program calculates and displays the V-curves corresponding to proposed synchronous, transient, subtransient reactance and saturation data.
- The facility is provided to compute the response ratio and open-circuit transient response of excitation systems. This permits the validity of proposed sets of excitation system parameters to be checked by reference to standardized equipment test procedures. A typical application is checking of the excitation ceiling implied by proposed exciter saturation and gain data in cases where exact values of these parameters are not known but the exciter ceiling output is. A similar data testing facility is provided for turbine governor data.





TRANSFER LIMIT ANALYSIS

The Transfer Limit Analysis section of PSS/E considers a single interchange between a "study system" and an "opposing system."

- The analysis takes a base case solution as its starting point and calculates the sensitivity of the flow in each "monitored" branch to a variation of the net interchange between the study and opposing systems. Linear projection then allows estimation of the permissible interchange between the study and opposing system. In this calculation:
  - □ D.C. analogy and matrix methods are used to give fast execution. Only real power flow is considered.
  - □ The set of monitored branches includes all ties of the study system plus any individual or multibranch interfaces designated by the user.
- The analysis is performed for the base case and for zero, one or two levels of branch outage contingencies. The set of contingencies includes outage of all study system ties plus a user-specified list of additional simple or combined branch and generator outages.

  Output lists the maximum interchange, the limiting branch or interface, and the flows on all other monitored branches.
- A second variation of Transfer Limit Analysis considers a single study system and two opposing systems. This analysis produces a graphic display of the dependence of the limiting interchange with each opposing system on the interchange with the other.
- An Inertial Load Flow solution calculates the generator output, bus voltage, and line flow conditions that would exist:
  - □ A few seconds after a major load or capacity change (e.g., a unit trip) when the system frequency and generator outputs are functions primarily of generator inertias and load-voltage-frequency characteristics.
  - □ Several seconds after a load or capacity change when the system frequency and generator outputs are functions of turbine governor regulation and load-voltage-frequency characteristics.

EQUIVALENT CONSTRUCTION

- The equivalent construction section of PSS/E builds reduced-network models of specified subsystems. This section automates the identification of boundaries between areas, voltage levels, and zones, and handles the "sewing together" of partial system models.
- A module is available to perform a simultaneous reduction of corresponding positive, negative, and zero sequence networks for fault analysis purposes.

EIGENVALUE/FREQUENCY RESPONSE ANALYSIS

- The time domain simulation section of PSS/E is augmented by activities for analysis of stability by eigenvalue and frequency response methods. These activities start with a standard time domain simulation setup and use perturbation methods to build up the linear differential equations.

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

  describing the asymptotic behavior of a group of machines.

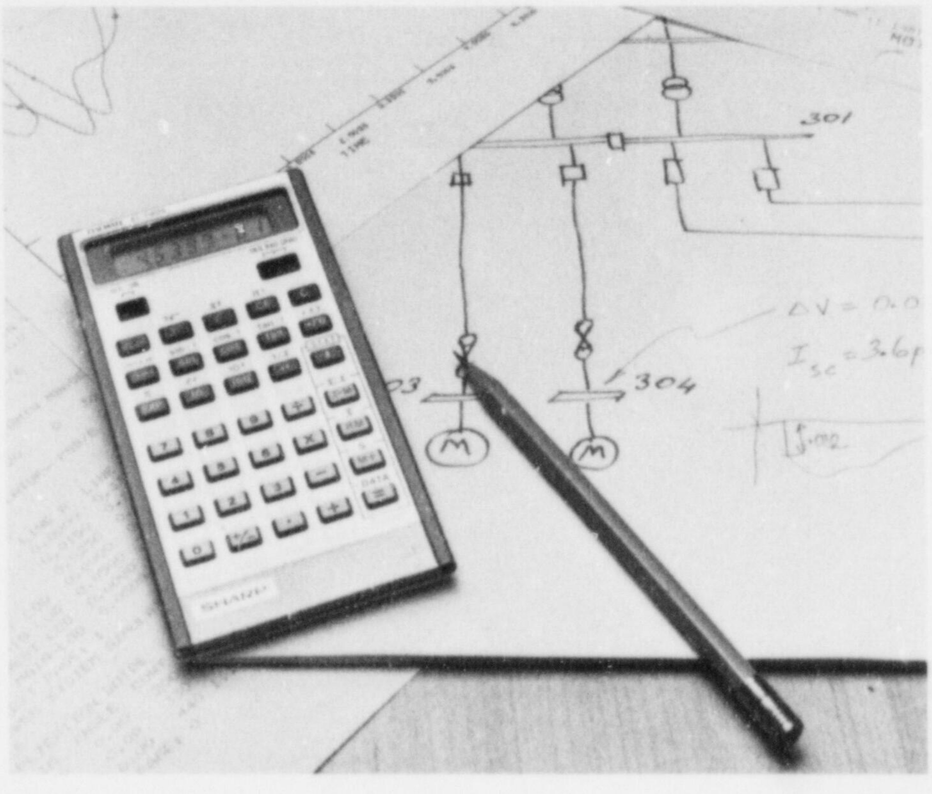
  The linear equations may have order of up to 200 and hence may describe up to about ten machines modeled in high detail or 100 machines modeled at the classical level.

- Eigenvalue and frequency response calculations based on classical-level representation can give a useful indication of the shapes of the basic modes of system oscillation and hence can provide a guide as to where supplementary stabilizers can be applied effectively. Calculations based on detailed modeling are useful both in the design/tuning of individual control loops and, more importantly, in showing interactions between high gain control loops on generators at different locations.
- Results may be plotted in Bode and Nyquist plot forms.

OPERATION OF PSS/E

The Calculator Principle

The operation of PSS/E is similar in principle to that of an advanced hand-held calculator. With the calculator, the user places a number in the display register and presses function keys to perform operations on this number. The intelligence needed to select the number and keystroke sequence is provided by the user; the processing power is provided by the calculator. In the case of PSS/E, the "display register" is replaced by a large working file containing a complete positive-negative-zero sequence and dynamics representation of the user's power system; the mathematical functions (keys) of the calculator are replaced by power system analysis functions such as "iterate load flow," "advance time simulation," or "summarize line overloads."



The basic dialog with PSS/E is an English-language question and answer sequence. The PSS/E executive has an internal macro-scheduling capability which allows routine job steps to be handled in batch mode while critical setup and decision-making steps are executed in interactive mode with the engineer taking full control.

Program Structure

The program is structured as a set of ACTIVITIES which may be invoked by command of the user to perform processing or I/O operations on a WORKING FILE of system data. The working file is used for all processing, and is backed up by an extensive data file library system which allows for storage and/or retrieval of multiple system representations, solved cases, and output listings.

PSS/E has two principal modes of control:

Full Interactive Mode

On initiation the master program module of PSS/E invites the user to specify the first activity to be executed and immediately transfers control to that activity. When any activity is terminated, whether by completion, by user interruption, or by an abnormal condition, control is returned to the master program module which immediately invites the user to select the next activity. Each activity carries on its own dialogue with the user through the CRT console, may read input data from data storage files or from the console, and may generate tabular and/or graphic output at the CRT console, in a file, or on a printing device.

Batch Mode

PSS/E may be used in batch mode for routine production runs. Batch runs are specified by a control language in which the user describes the run in a set of English-like sentences. The following example specifies a stability run in which a faulted line is to be tripped, reclosed into the fault, and then tripped and locked out.

```
RECOVER initial conditions FROM #SNAP AND #CVLF
INITIALIZE OUTPUT=#GOP,
 RUN to 0. SECONDS, PRINT=2, PLOT=2
  APPLY FAULT at BUS 154 with Z=15.,0. OHMS, BASEKV=230.
   RUN to 5 CYCLES, PRINT=1, PLOT=1
    CLEAR FAULT at bus 154
    OPEN LINE FROM BUS 154 TO BUS 153, CIRCUIT 2
     RUN to 35 CYCLES, PRINT=15, PLOT=3
      RECLOSE LINE FROM BUS 154 TO BUS 153, CIRCUIT 2
      APPLY FAULT at BUS 154 with Z=15.,0. OHMS, BASEKV=230.
       RUN to 40 CYCLES, PRINT=1, PLOT=1
        CLEAR FAULT at bus 154
        OPEN LINE FROM BUS 154 TO BUS 153, CIRCUIT 2
        CHANGE MWI LOAD on BUS 153 TO 110. MW
        CHANGE MVARB LOAD on BUS 153 TO -50. MVAR
         RUN to 4 SECONDS,
HOLD end run conditions IN #SNER AND #SCER
END
```

PROGRAM FEATURES

Selective Reporting

PSS/E allows the user a broad range of options in manipulating his system data. Dialog may be carried on in terms of either bus numbers (at random between 1 and 29997), or bus names (eight characters plus four-digit base voltage field). Output reports may be ordered either numerically or alphabetically.

All system manipulation operations and reporting activities may work selectively. The selection criteria are area, zone, base voltage level, and bus number. A user can, for example, request an output report for buses in areas 7 through 9 at voltages above 230 kV, or perhaps, examine overloads on all lines at 138 kV and above but ignore overloads in lower voltage circuits.

Options

PSS/E recognizes a wide variety of user requirements and preferences. Among the user/selectable options are:

- 50 or 60 Hz base frequency
- 'Names' or 'Number' bus identification.
- Load flow output in MVA or KVA.
- Fault analysis results in rectangular or polar coordinates, and in kV/Amp or per unit values.

Multiple Sizing

PSS/E is supplied in standard-installation versions with capacities of 1000, 2500, 4000 buses. The maximum program capacity is up to 12000 buses, depending on the host computer type.

Industry Standard Data Interfaces

PSS/E can accept load flow input data in several formats that are widely recognized by utilities in the U.S.A. The preferred input medium for load flow is nine-track magnetic tape in PSS/E, IEEE Common, "Philadelphia," or "WSCC" format. PSS/E can produce load flow tapes in each of these formats for transmitting data to other computers.

While there is not yet any widely used standard for dynamic simulation and fault-analysis data, special interfaces can be provided to allow PSS/E to accept this data from other programs.

GRAPHICS

Displays

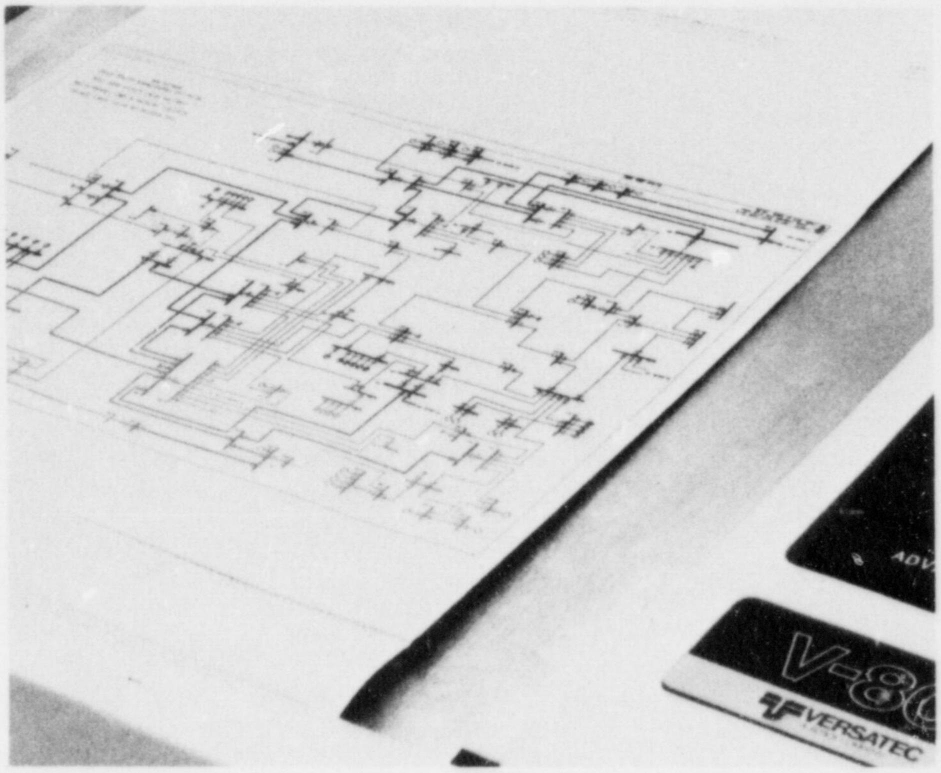
While PSS/E may be operated in a minimum configuration computer system having text-only input-output devices, it is normally used with both hard-copy and CRT graphics units. The graphic display capabilities of PSS/E include:

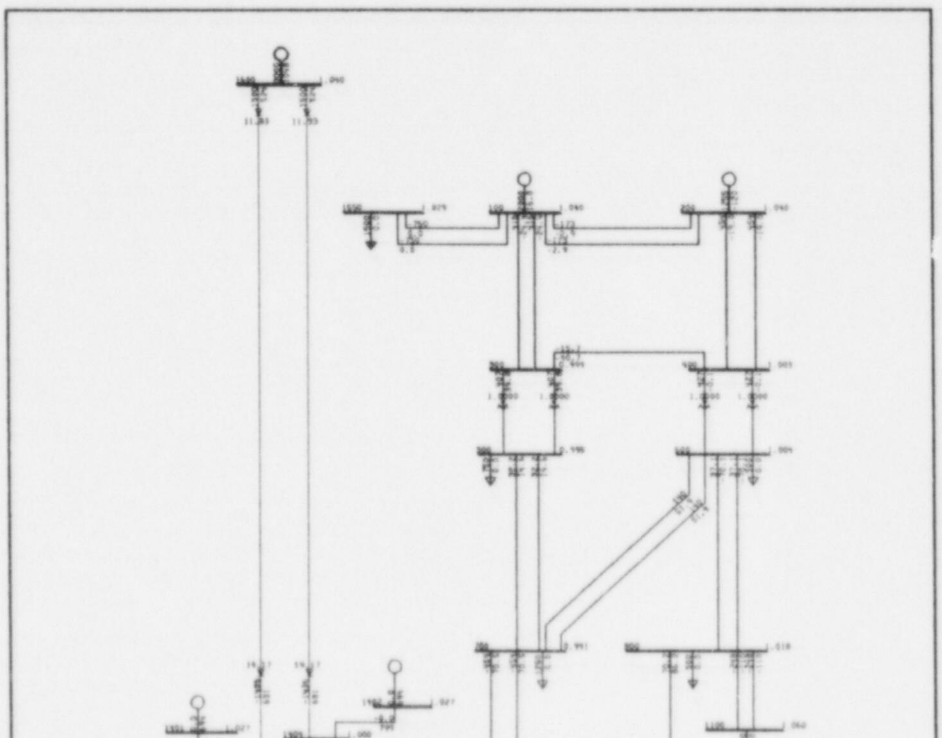
- Load flow one-line diagrams showing voltages, branch flow, equipment status, and impedances.
- Short circuit results on one-line diagram.
- Plotted dynamic simulation results
- Single bus data and results summaries
- Graphic verification of generator, induction motor, tranformer data.

Hard-copy

Power system engineering requires extensive written reporting of analyses, and rapid production of hard-copy graphics is a major factor in the use of PSS/E. The Versatec V-80 is the main graphics unit for PSS/E; primarily because of its ability to produce high-resolution drawings of 8-1/2 × 11 and 17 × 11 inch size at high speed. A PSS/E load flow diagram can show a system segment of up to 125 buses, with full annotation, on a 17 × 11 inch diagram.

Versatec V-80 units may be located either at the computer site or, with an auxiliary controller, at a remote user site. Calcomp, Tektronix pen-plotter, and other hard-copy units can be supported in specific computer and operating system environments.


VERSATEC



CRT-Graphics

The CRT graphic subsystem complements the hard-copy graphics functions of the basic PSS/E package. CRT displays have the same format as the standard hard-copy graphic outputs of PSS/E, with the added capability to zoom in on areas of specific interest. The CRT graphic subsystem also provides a graphic-based data examination and change facility.

PSS/E currently supports the full line of TEKTRONIX CRT terminals via the PLOT10-IGL interface software. Alternatively, a number of TEKTRONIX-compatible terminals such as the Retrographics 640 may be used. On IBM systems, the IBM 3279 and IBM 3290 graphic CRT terminals are also supported via the IBM GDDM software. When available, color can be used to highlight overloads, overvoltages, undervoltages, and kV levels.

Graphic Interaction

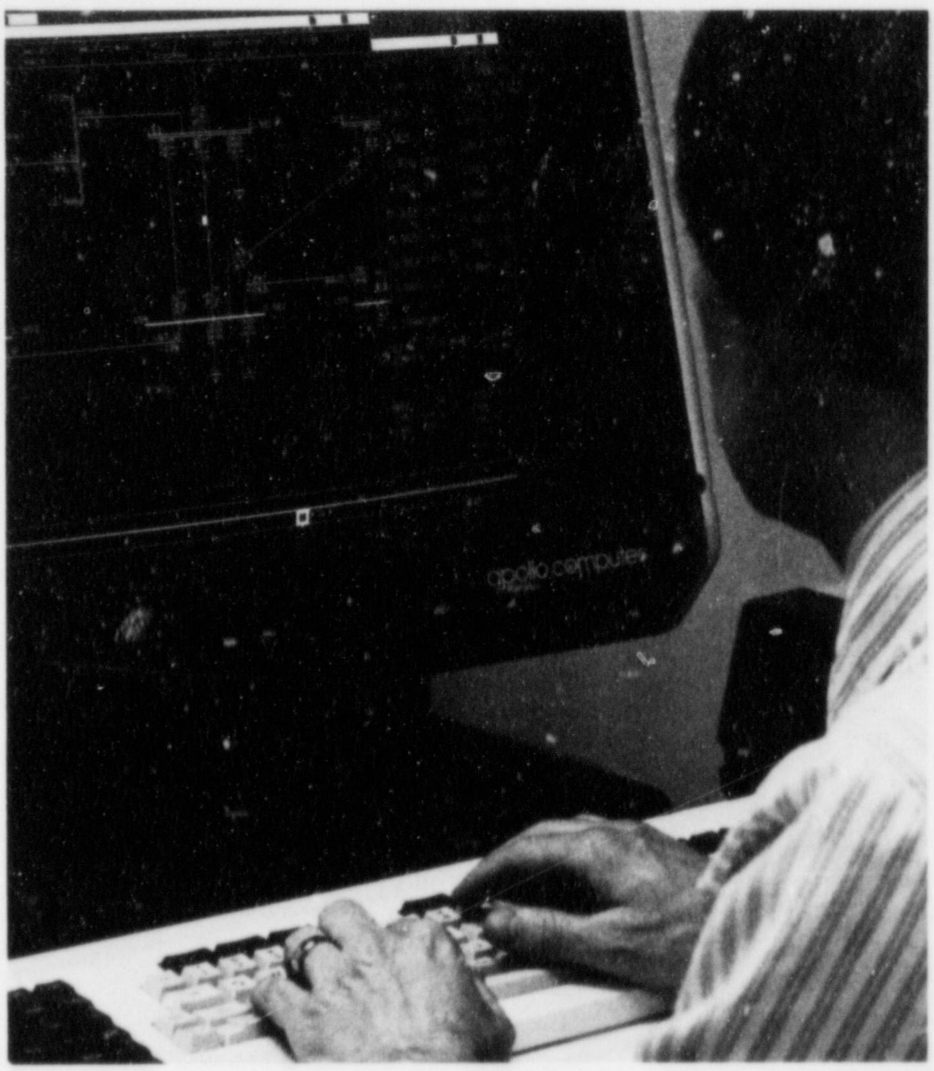
Interaction between CRT displays and the user is via the cursor or crosshairs of the CRT. The cursor/crosshairs may be used to:

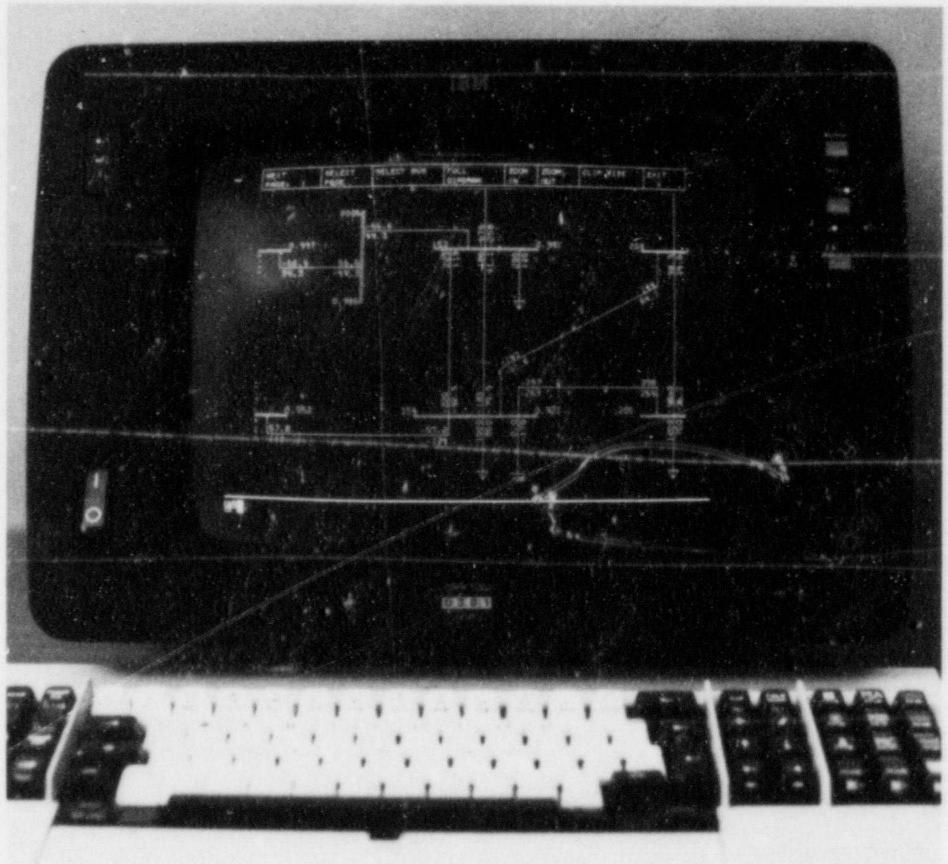
- Direct the load flow display to zoom in on a specific point.
- Select display options from a menu.
- Direct the data examination/change function to a specific bus or branch.

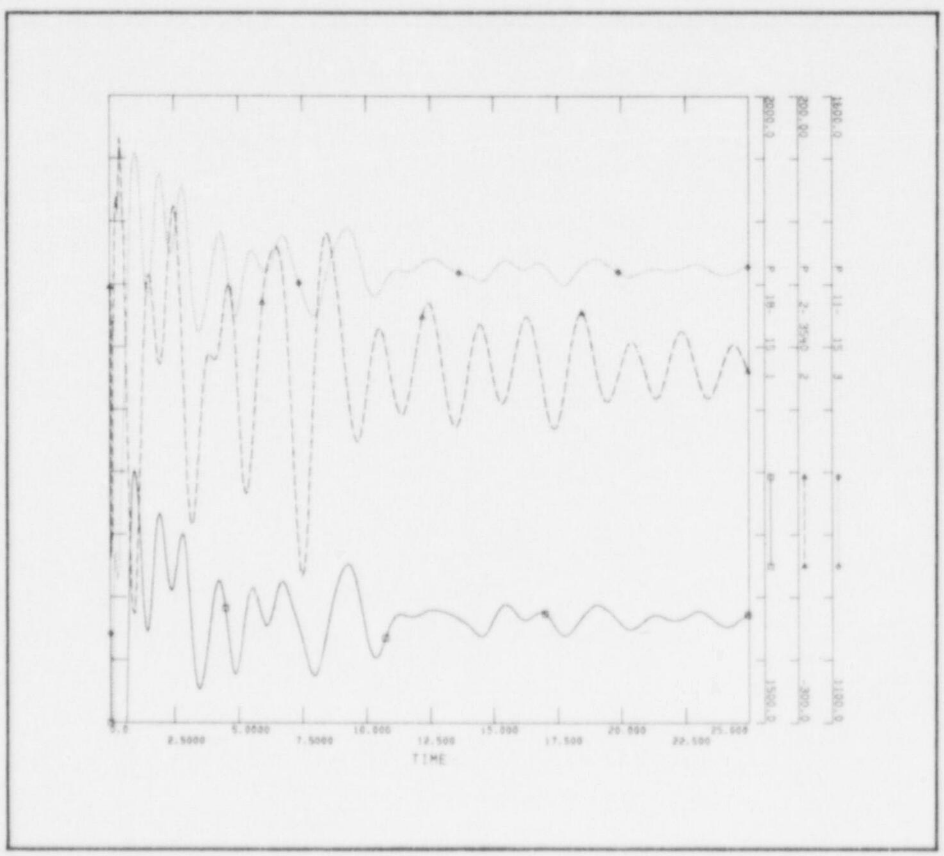
The load flow output and dynamics plotting CRT graphic activities allow immediate "redrawing" of the display on the hard-copy device. This allows the user to "experiment" with the scaling of plots at the CRT and then commit his favored results to permanent form with a minimum of commands to the computer.

Digitizer Drawing Input

A further optional section of PSS/E allows use of a digitizer to prepare and update the one-line diagrams used in the graphic output activities.






0.0
2.5000
5.0000
7.5000
10.000
12.500
15.000
17.500
20.000
22.500
25.000
TIME

HOST COMPUTERS

PSS/E is currently available for the following computer systems:

Appollo DN-460 and DN-660
Data General MV-X000 series
DEC VAX-11 series
IBM VM/CMS, MVS, and MVS/XA systems
Prime
Sperry 1100 series

Specific hardware and software options are required in all cases; PTI can assist in the specification of suitable computer configurations.

TRAINING AND SUPPORT

The PSS/E package includes installation and training by PTI as follows:

- Installation and testing of the PSS/E system in the user's computer.
- A five-day training seminar for user engineers at the user's offices.

The PSS/E package includes the following reference material:

- Program Application Manual giving details of program capabilities, engineering aspects of its use and data setting requirements.
- Program Operations Manual giving details of input formats, console procedures and error conditions.
- Data Exchange Manual to allow external utility sources to prepare data for PSS/E users.

The PSS/E system can be supplied by PTI either as an all inclusive system of hardware and software, or as a package of programs for installation on an independently obtained computer of suitable specification.

FOR FURTHER INFORMATION

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or
Dr. John Undrill, Principal Engineer
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ENCLOSURE 1

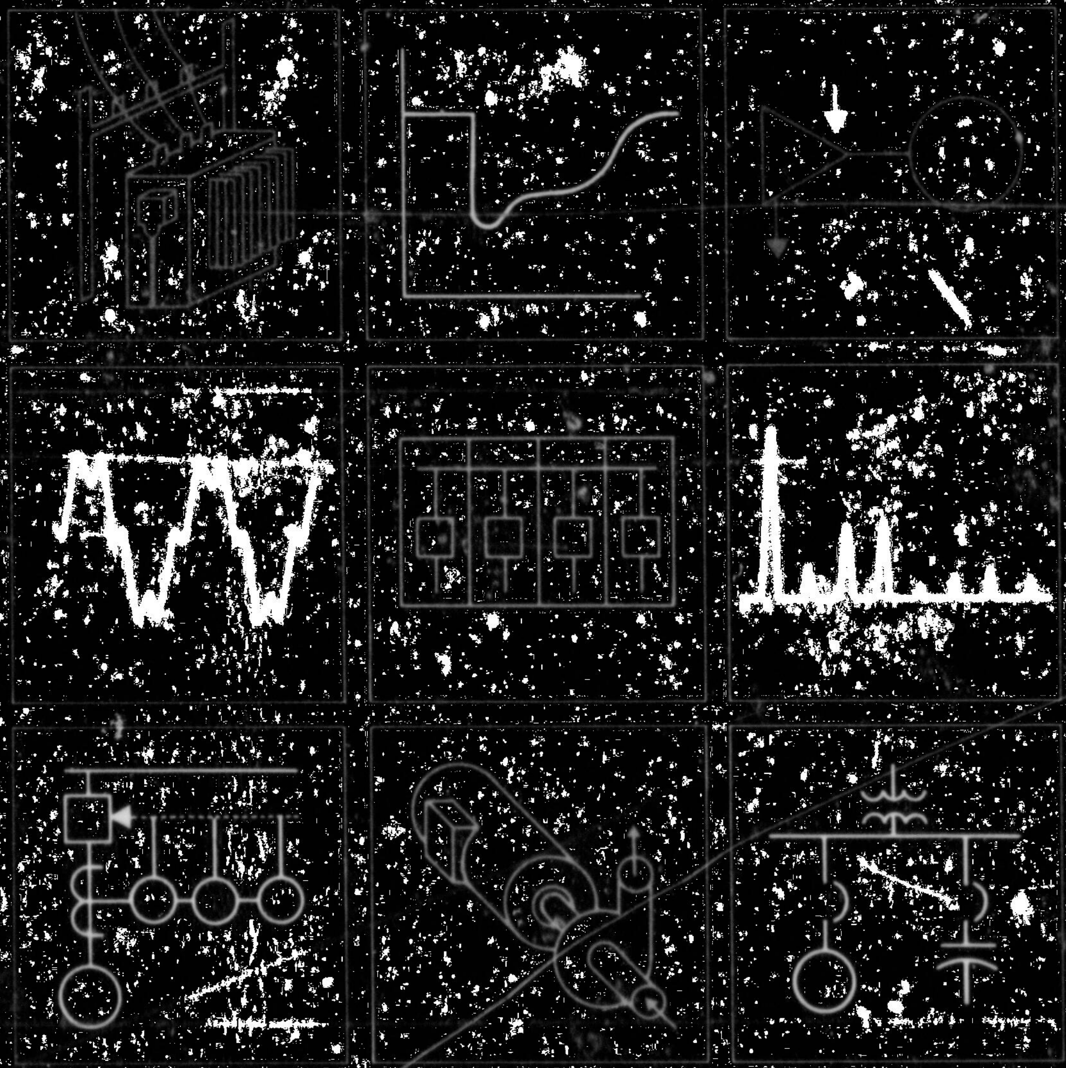
POWER TECHNOLOGIES INC.

1482 Erie Blvd., Schenectady, NY 12305

INDUSTRIAL POWER SYSTEM SERVICES Number 50

PRODUCTIVITY & PROFIT

THROUGH WELL ENGINEERED ELECTRIC POWER SYSTEMS



THE PTI ADVANTAGE

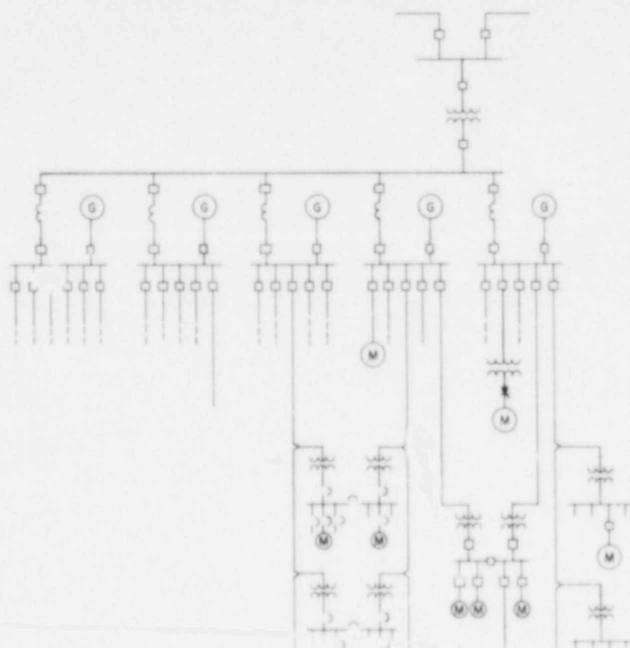
- Technical Leadership
- Worldwide Experience
- State-of-Art Software
- Cost Effectiveness
- Independence
- Builder of Client Competence

The quality company for services and products

INTRODUCTION

Electrical energy is a most critical element in the operation of an industrial plant. Modern electrical power systems must be cost effective and reliable. The design of an industrial power system requires experience and knowledge of the process to be served and the ability to use analytical tools to fit the power system to the process requirements.

PTI has been helping industrial clients and engineering firms engineer electrical power systems since 1969. These services include conceptual design; steady-state, dynamic, and transient system performance studies; software products; specialized hardware; field testing; failure analysis; and educational programs.

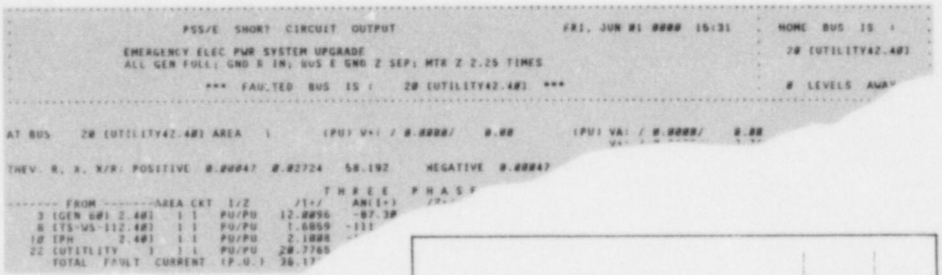


CONCEPTUAL DESIGN AND SYSTEM RELIABILITY

The conceptual design of a power system must take into account the steady state, dynamic, and transient characteristics of the system to ensure the optimum performance of the drives and other utilization equipment. The system must be easy to maintain, operate within the short circuit rating of equipments, and provide reliability commensurate with cost of lost production.

Steady state performance is tested by load flow cases that show effects of transformer taps, capacitors, and circuit arrangements on voltages and equipment loadings. Dynamic performance is the ability of the system to respond to short time disturbances such as motor stating and operation of large motors during system disturbances. The transient characteristic of the system determines the quality of operation of static power converters during commutation and their interaction with drive system regulators. Reliability is assessed by experience and by computer analysis.

As an independent company, PTI can be completely objective in specifying equipment and in evaluating the qualifications of equipment suppliers.



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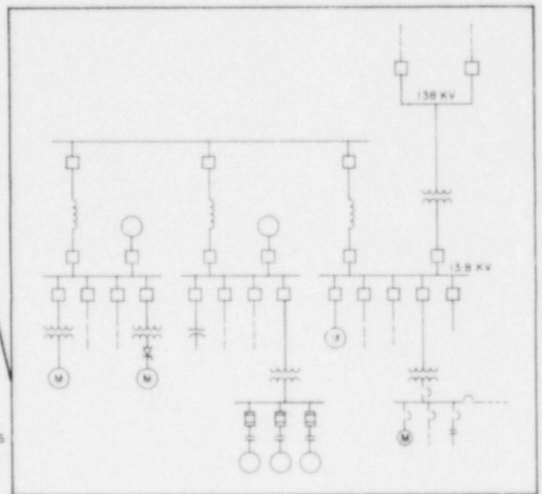
PSS/E  SHORT  CIRCUIT  OUTPUT                     FRI, JUN 01 0000  15:31   HOME  BUS  IS :
EMERGENCY ELEC PWR SYSTEM UPGRADE                                            20 [UTILITY42.40]
ALL GEN FULL; GND X IN; BUS E GND Z SEP; MTR Z 2.25 TIMES
      *** FAULTED  BUS  IS :   20 [UTILITY42.40]  ***                        0  LEVELS  AWAY

AT BUS   20 [UTILITY42.40] AREA   1      (PU) V+: / 0.0000/   0.00     (PU) VA: / 0.0000/   0.00

THEV. R, X, X/R: POSITIVE  0.00047  0.02724   58.192    NEGATIVE  0.00047
                                     T H R E E   P H A S E
------- FROM --------AREA CKT  I/Z      /I+/     AN(I+)
   3 [GEN 60] 2.40]    1 1   PU/PU   12.0096   -87.30
   8 [TS-WS-112.40]    1 1   PU/PU    1.6859   -111
  10 [PH       2.40]   1 1   PU/PU    2.1000
  22 [UTITLITY    1    1 1   PU/PU   20.7765
     TOTAL  FAULT  CURRENT  (P.U.)   36.17
```

Events

1. Overlapping outage of line L2 and either transformer X1, transformer X2 or line L4, requiring the power plant output to be curtailed to 35 MW.
2. Overlapping outage of lines L1 and L2, requiring the power plant output to be curtailed to 62 MW.
3. Overlapping outage of lines L1, L2 and L3, requiring the power plant output to be curtailed to 20 MW.
4. Loss of one unit with at least one station service transformer energized, average unit outage duration is three hours.
5. Loss of two units with at least one station service transformer energized, average unit outage duration is six hours.
6. Loss of all station service transformers while the output of one or more units is less than 10 MW. This event will cause tripping of those units. An average unit outage duration of three hours is assumed if one unit is lost, and of six hours if two units are lost.
7. Loss of all station service transformers and of one or more units with unit output greater than 10 MW and less than 23 MW, average unit outage duration is 96 hours.

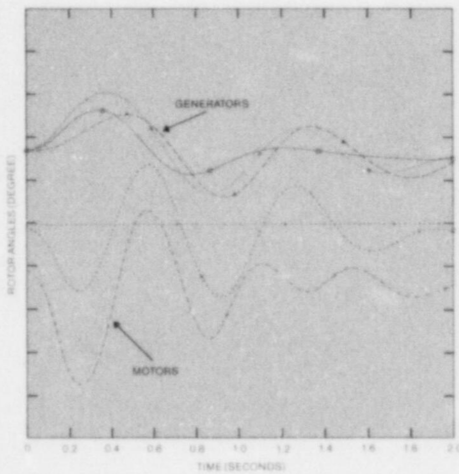


Load Curtailment (MWHr/Year)

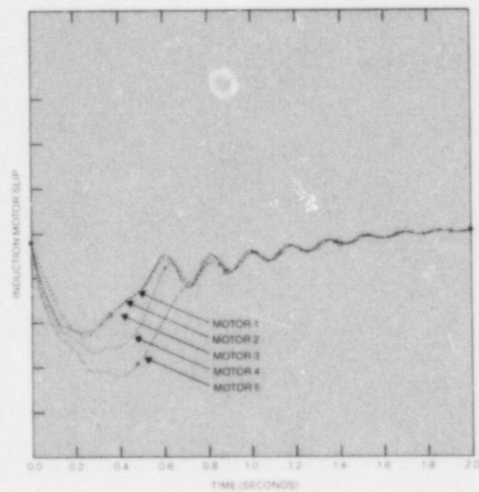
Event	Configuration 1	Configuration 2	Configuration 3
1	13.78	12.56	13.78
2	5.57	5.07	5.55
3	19.71	0.23	–
4	47.15	41.32	77.60
5	18.05	0.43	0.13
6	3.02	0.04	3.67
7	13.99	0.10	0.62
Total	121.26	59.74	101.35

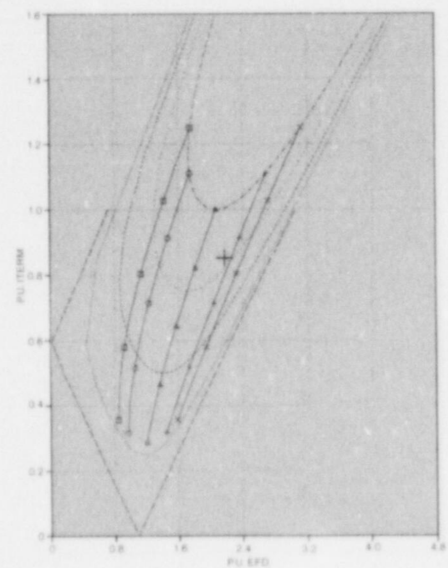
STABILITY
LOAD SHEDDING
MOTOR STARTING

Dynamic simulation is essential in assuring trouble-free operation of plants with generation or large synchronous and induction motor loads. Growing use of induction generators adds a new dimension to industrial system planning and frequently warrants simulation studies. Simulation is useful in selecting and setting protective relays, providing actual fault current decay (very important where bus-fed excitation is used) and apparent impedance trajectories for setting out-of-step, loss-of-excitation, and synchronous motor "power factor" relays. Under-frequency and undervoltage load shedding relay strategies are developed from accurate simulations of isolated operation following separation from the utility supply.

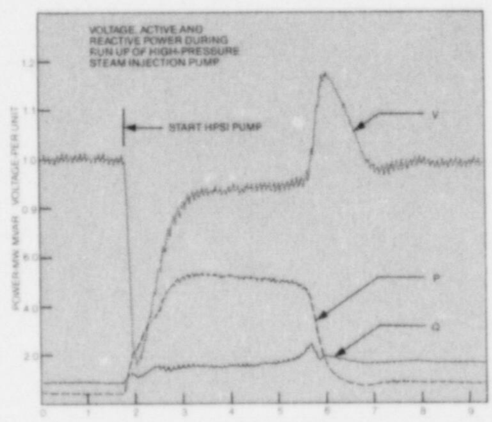


COGEN UNIT 1 @ 35 MW, UNIT 2 OFF LINE
3 PHASE 9 CYCLE FAULT AT GAS TURBINE HIGH SIDE BUS
TRIP LINE FROM 24 TO 22 CKT 1





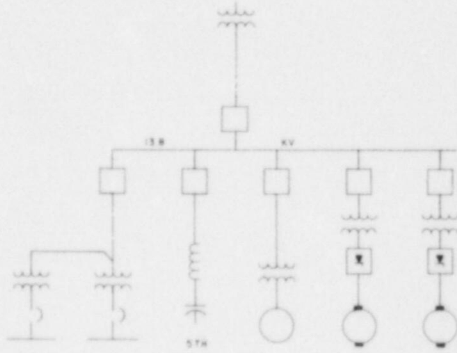
GENERATOR V CURVES

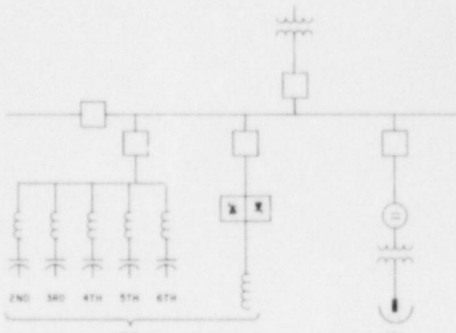


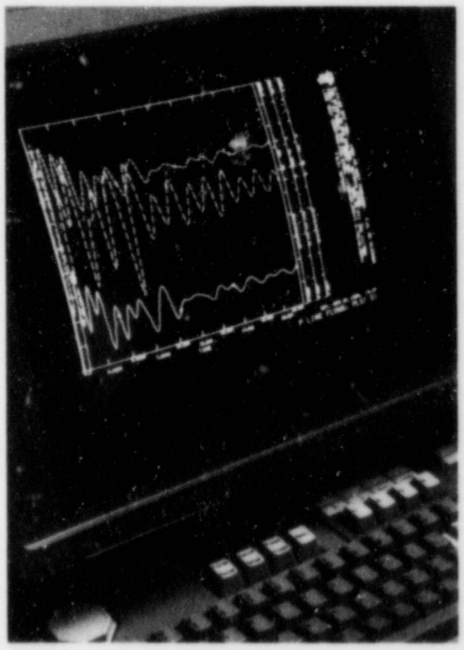
DIESEL-GENERATOR SIMULATION

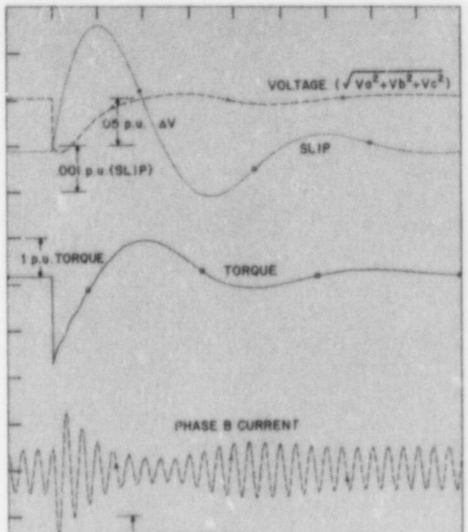
MACHINE AND NETWORK TRANSIENTS

Though required only in special situations, analysis of machine and network transients can be critical to successful implementation of a new or unusual drive system or control equipment. Examples include application of thyristor controlled reactive power sources to stabilize voltage transients caused by arc furnaces, mine hoists, metal rolling mills, and drives subject to pulsating or impact loading. Use of capacitors to start large motors, improving power factor beyond .95, throw-over, reclosing, and other problems may require simulation of electrical and shaft torsional transients. Machine and network transient analysis is also used to determine proper grounding, switchgear application, surge protection devices, and to aid in product failure analysis.







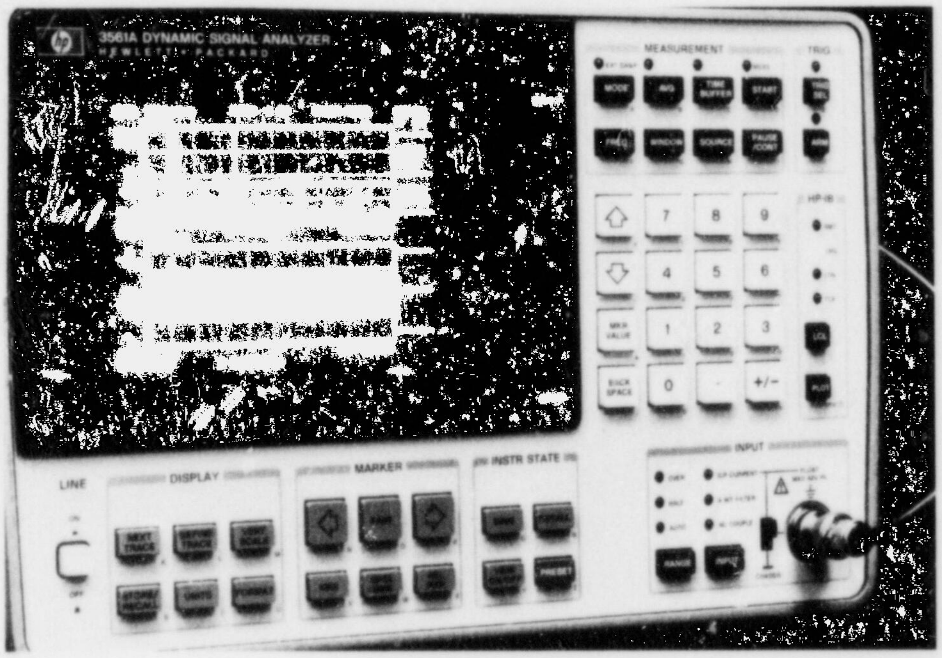


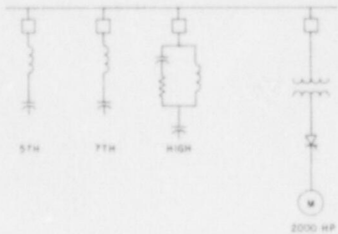
MOTOR TRANSIENTS FOLLOWING STEP CHANGE IN SUPPLY VOLTAGE PHASE ANGLE

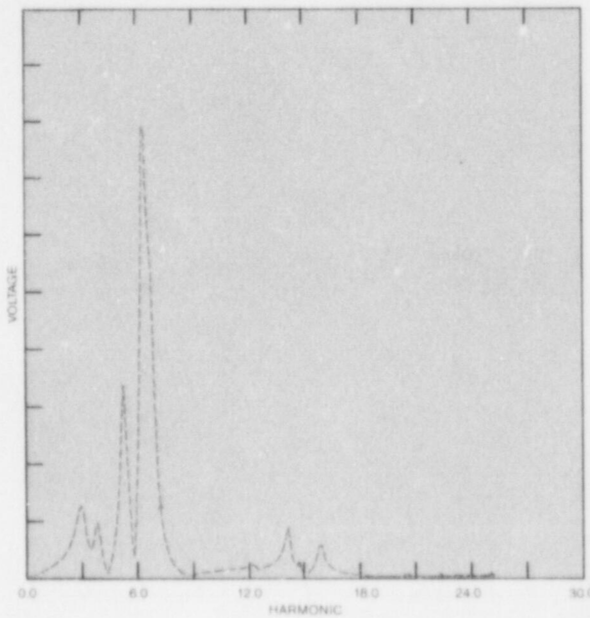
HARMONIC ANALYSIS

The increasing use of static power converters and other harmonic generating loads coupled with increasing sensitivity of control equipment, is making analysis and control of harmonic currents a major concern throughout the industry. PTI applies both field measurement and analytical tools to these harmonic problems.

Field tests can include spot checks of harmonic levels or long term recording of data for later automatic computer analysis. To avoid harmful resonances, filters can be combined with power factor improvement capacitors to limit voltage distortion. "Harmonic load flow" studies take into account impedances that change with frequency.

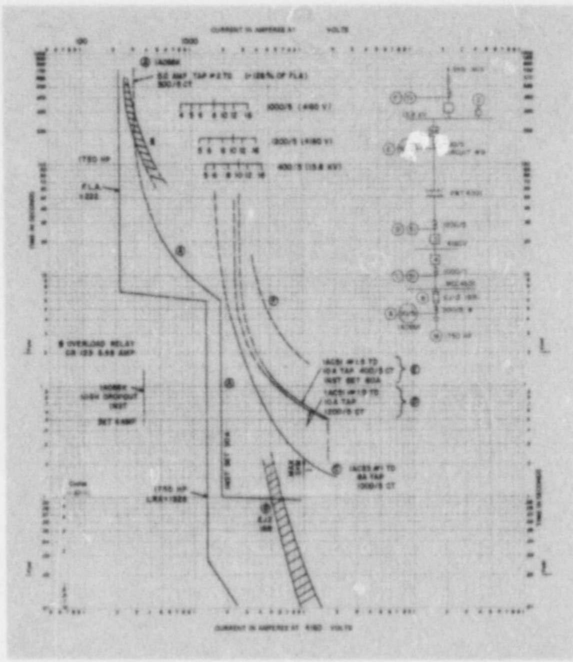


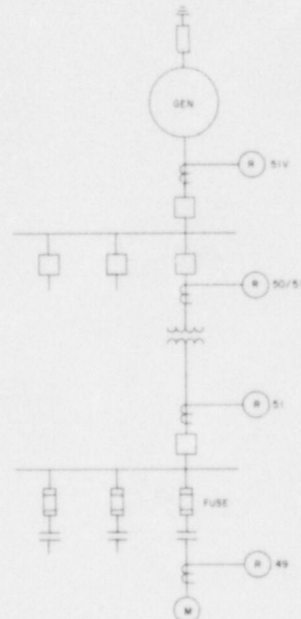


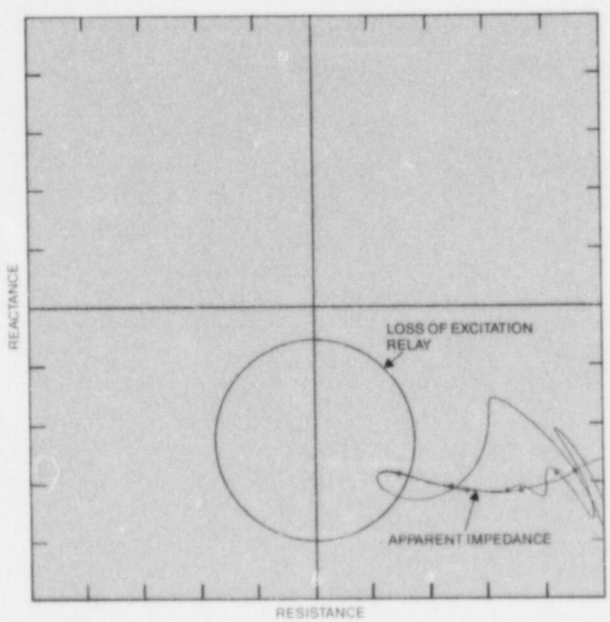


RELAY SELECTION AND COORDINATION

An appropriate complement of properly set circuit protective devices is essential for good system performance. Though fairly uniform practices have evolved in the selection of protective devices, it takes an experienced engineer to ensure that the protective system achieves an acceptable trade off between equipment protection and freedom from unnecessary tripping. This is particularly important where processes require continuity of electrical power. Increasing use of cogeneration introduces special problems relating to utility practice on reclosing and protection.



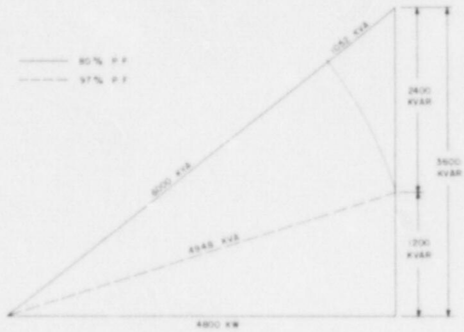




POWER FACTOR IMPROVEMENT

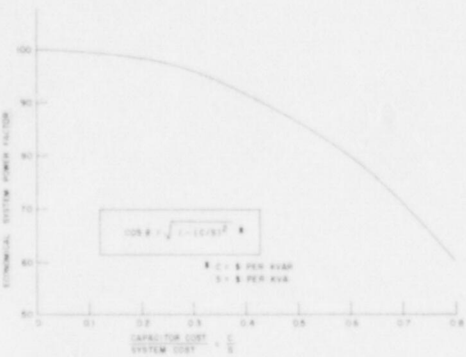
The total cost of energy purchased from an electric utility is dependent upon two factors: energy (kWh) charge (related to fuel) and a demand (kVA) charge, (related to the capital expenditure to deliver that energy). The latter is dependent on the total amount of kW and kVA delivered over a specified time period. The demand charge can be minimized by installing capacitors which will furnish the reactive power (kvar) locally.

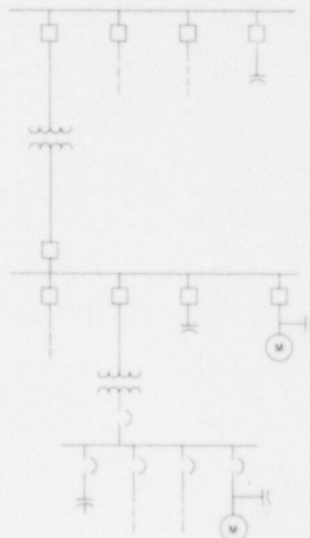
Capacitors affect system voltages, and can aggravate harmonic voltages and currents. Selection, location, and operation of capacitors require careful engineering to ensure efficient system performance, with safeguards against adverse harmonic resonances.

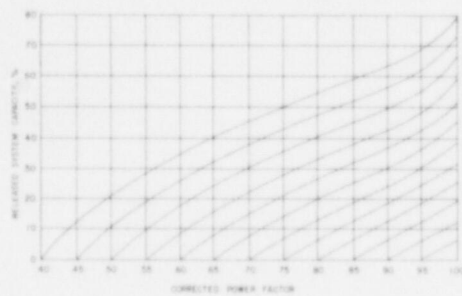


Cost Savings Analysis

Demand charge 9 $/KVA
Reduction in demand =
6000 − 4948 = 1052 KVA
Savings =
1052 KVA x 9 $/KVA = $9468/month
Capacitor Installed Cost $10/KVAR
2400 KVAR x 10 $/KVAR = $24000
Payout $\frac{\$24000}{\$9468}$ = 2.5 months







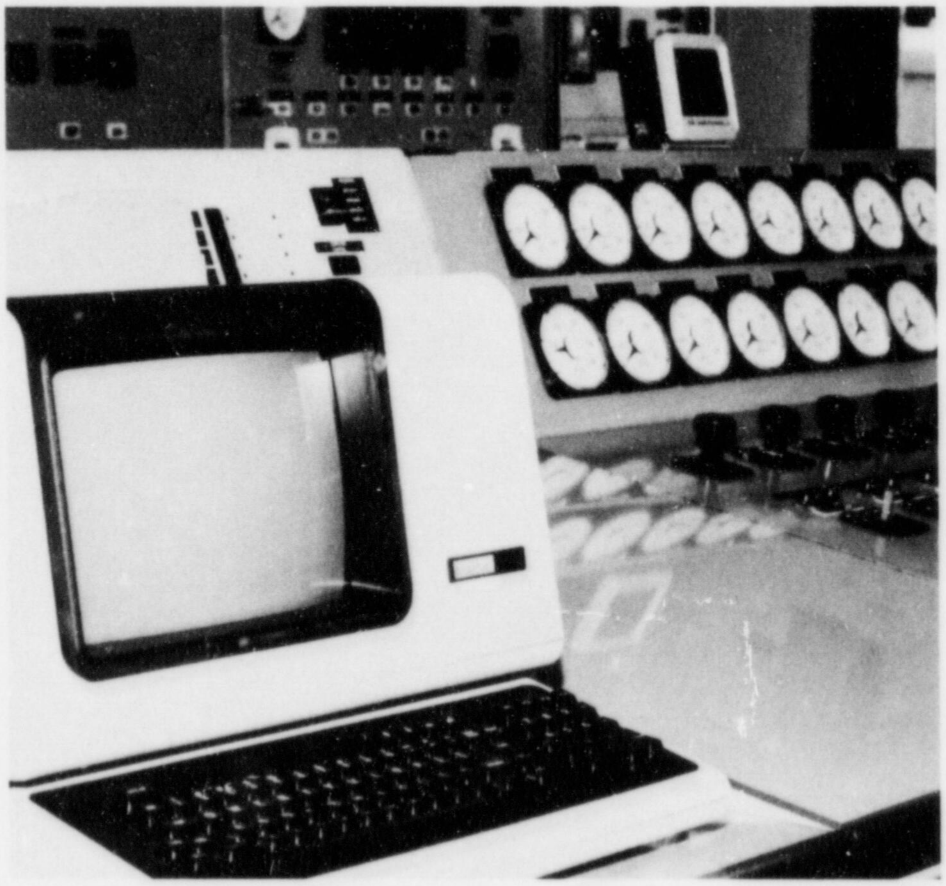
FAILURE ANALYSIS

Equipment failures can be very costly in terms of lost production, equipment repair or replacement. When equipment does fail, it is often important to assess responsibility for the failure. Cable, cable joint, transformer, switchgear, and motor and control failures are among the many equipment malfunctions that have been investigated by PTI. When the cause of a failure is unclear, or responsibility for the failure must be determined, expert assistance may be warranted. PTI offers inspection and analytical assistance to explain the cause and recommend changes to prevent reoccurrence. Expert witness services can also be provided.

SPECIALTY HARDWARE

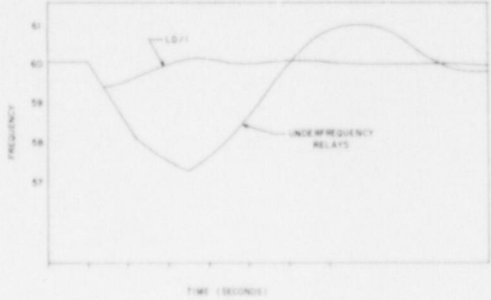
PTI has developed microprocessor based load shedding systems that avoid the unpredictability and overshedding inherent in underfrequency load shedding. They offer nearly instantaneous load tripping to balance load and generation following trip of a generator or utility source. The system can also provide economic dispatch, regulation of utility tie energy flow, reporting, and demand control.

PTI's all-digital stabilizer (SS/1) may be useful to industrial plants located at remote points on utility networks, or in areas where utility system damping is light or inadequate. This device, universally applicable to all generators, is connected to the excitation system and modulates the excitation to damp spontaneous oscillations in addition to those following faults or other disturbances.



LD/1 Specifications

Maximum Number of Generators or Ties Monitored	15
Maximum Number of Loads Controlled	30
Digital Inputs	60
Digital Outputs	32
Analog Inputs	45
Computer	INTEL 80286
Computer Memory	512 Bytes RAM
Program Storage	BUBBLE
Power	120 VAC at 47-60 Hz



SOFTWARE

PTI's software tools are highly developed and supported on a broad range of computers from the PC class to mainframes. The principal items of the PTI library are available for installation in clients' computers, or for use via telephone access to PTI's computer.

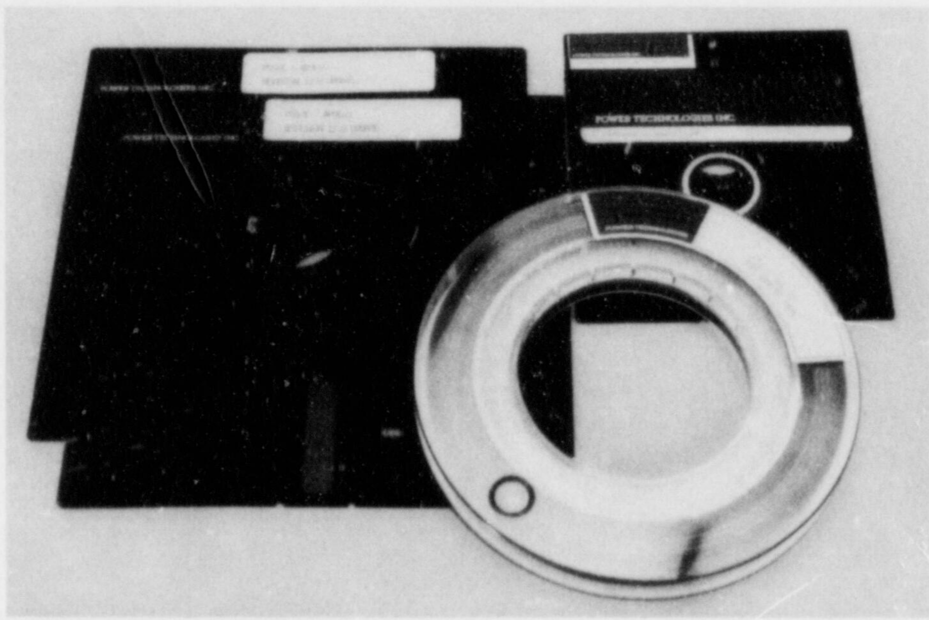
The programs of main interest to industrial users are:

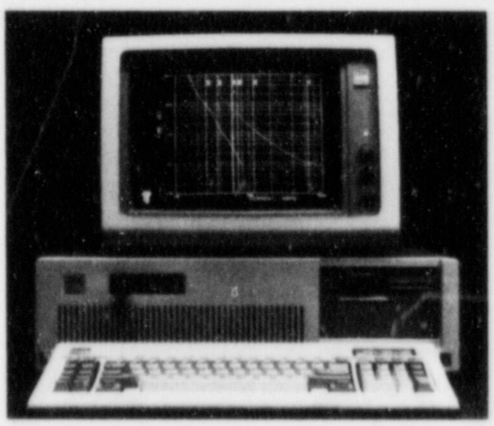
☐ PSS/U—Utilization Level Power System Simulator: Load Flow, Short Circuit and Circuit Breaker Duty, Relay Coordination, and Phase Unbalance.

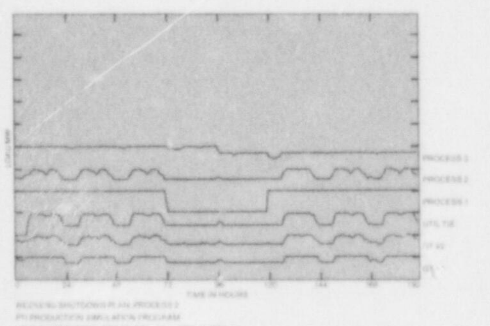
☐ PSS/E—Power System Simulator: Full scale load flow, stability, and general purpose dynamic simulation.

☐ MNT/E—Machine and Network Transient: Shaft Torque Amplification, Power System Harmonic Characteristics, Time Varying Electromagnetic Response.

PTI provides full services for installation of these programs on clients' computers, user training, program maintenance, and updating.



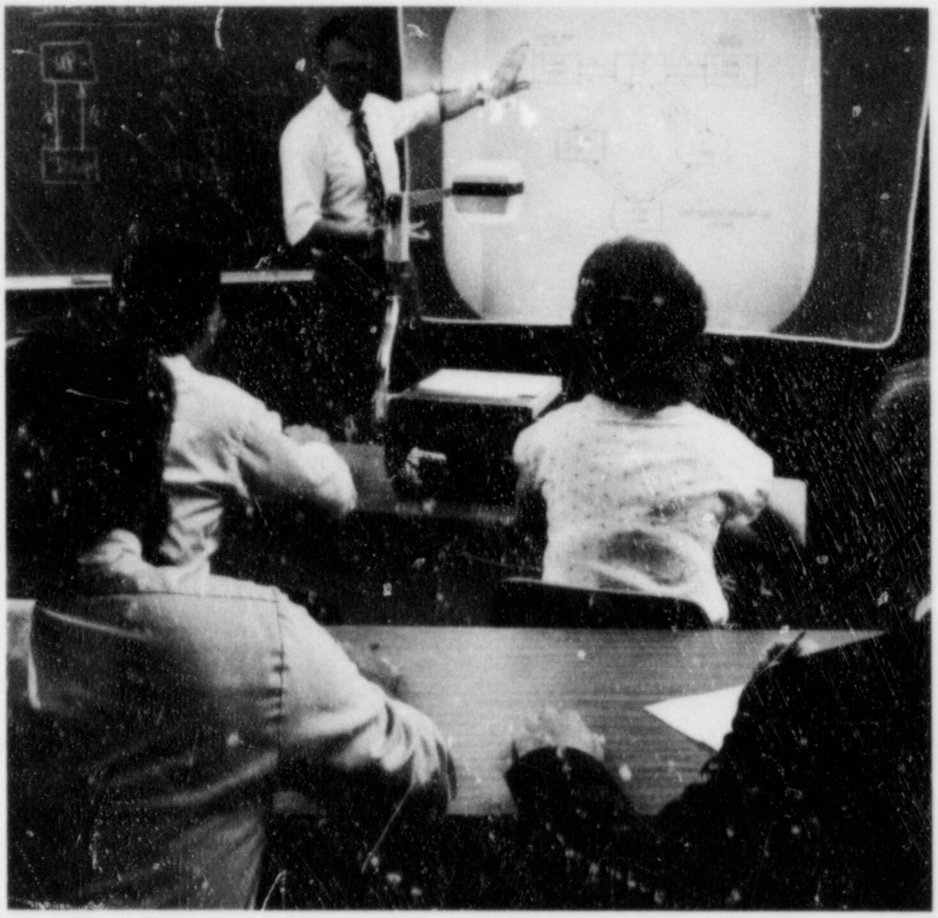




EDUCATION

PTI has graduated over 600 students from The Power Technology Course, a graduate level power engineering program. Short courses are regularly taught in the Schenectady offices and at locations throughout the world.

Courses include specialties such as system dynamics, cables, harmonics, and protection. PTI's comprehensive course in Industrial Power Systems is a major offering in this series.

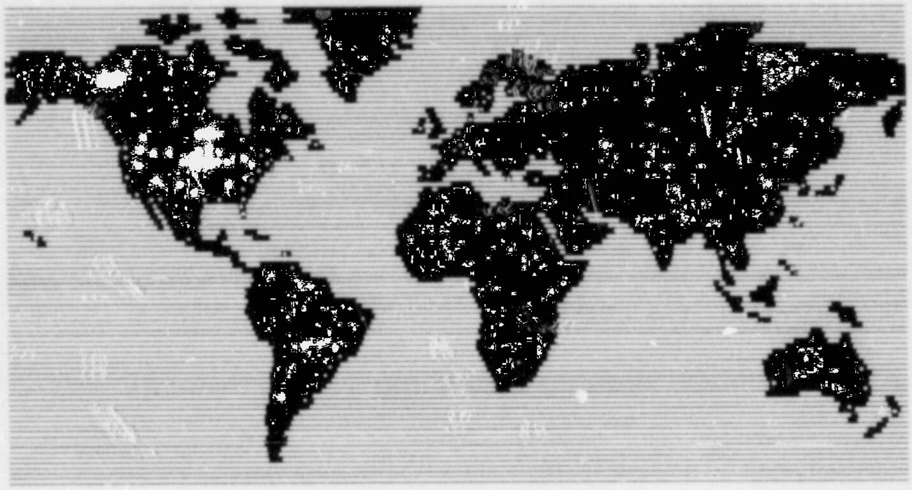


Memo: Selected Short Courses

- Power Plant Performance
- Steam Generation Control
- Steam Turbine Performance and Optimization
- Power System Dynamics
- Industrial Power Systems
- Power Plant Maintenance Scheduling
- Power System Scheduling and Operation
- Power System Planning Techniques
- Power System Overvoltages and Inculation Coordination
- Underground Cable Systems
- Cable and Accessory Failure Analysis
- Power Distribution Systems

Power Technologies Incorporated is an independent, employee-owned company supplying services and products, worldwide, in:

- ☐ Analytical Engineering
- ☐ Failure Analysis
- ☐ Software
- ☐ Simulation & Control
- ☐ Experimental Programs
- ☐ Education Programs



We welcome your inquiry.

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