PTI Cites Tenth Anniversary

In August of 1969, seven engineers with backgrounds in diverse power system disciplines, formed Power Technologies, Inc., a type of consulting company then quite novel in the power industry. Since the opening of PTI’s offices on August 4 of that year, PTI has grown tenfold. Its growth has paralleled by dramatic advances in the state-of-the-art of power system engineering. PTI staff takes some pride in having contributed to many of those advances.

Since PTI is an unusual organization, both from philosophic and structural standpoints, this tenth anniversary issue of the PTI NEWSLETTER is devoted to an introductory article dealing with the Corporation itself, followed by a series of brief articles commenting on the current status and future prospect of technical areas where PTI has been most active.

ABOUT PTI

PTI was founded in the belief that the industry needed a strong analytical consulting resource independent of those available within manufacturer organizations. The past decade has not only shown this to be correct, but has also shown that such an organization can be technically self-sustaining, adaptive to new industry needs, and a strong resource for new ideas and technologies in its own right.

From its inception, PTI has emphasized transfer of technology to client organizations. The first example, and PTI’s first major contract, was an extensive “Power Technology Course” described in a later paragraph. The latest, announced this year, was the opening of a “do-it-yourself” Power Systems Studies Center. Both projects also exemplify PTI’s assignment of a higher priority to technical level and quality of projects than to growth based on client dependence.

PTI’s professional staff now consists of 60 engineers. There are fundamentally just three profession levels. Perhaps what is missing from PTI’s structure is more interesting than what is included. There are no management posts specific to marketing, accounting, finance, facilities, communications, or any of the operating or administrative functions inherent in a company of PTI’s size. Each of these operating functions is assigned to a principal engineer as a secondary responsibility. The result, in direct violation of Parkinson’s Law, is that the amount of time spent on administrative games is reduced to its logical minimum. The corresponding (nontechnical) planning function is handled by committees comprised of a complete cross-section of staff. This brings the broadest possible consensus base to planning decisions and, at the same time, keeps all employees acquainted with corporate operations.

Organization structure notwithstanding, much of the day-to-day management is project- rather than section-oriented. PTI project engineers have complete responsibility for their program of work, including client interface, project execution, reporting, and negotiation for time allocations by other PTI staff.

It is not at all uncommon for this staff to be drawn from many sections and to include technical support from principal engineers. Each major project represents a microcosm of the entire PTI business structure itself. The quality of results obtained on a project, as well as its profitability, are major inputs to salary determination.

PTI has, since its inception, offered each employee options for the purchase of shares in the Company, subject to a buy-back agreement. Thus ownership by active employees is assured. PTI sales, less than $400,000 for the first full year of operation in 1970, are expected to exceed $5 million in 1979. Approximately 65% of PTI’s work is in the U.S. and 35% overseas. This includes engineering studies and problem solving, computer program leasing, sponsored R&D, courses, and a host of other activities ranging from general consulting to expert testimony.

PTI counts over 200 past and current clients. In addition to its U.S. operations, a subsidiary in Rio de Janeiro, Projetos e Estudos de Engenharia, Ltda. (PTEL), co-owned by a prominent Brazilian architect-engineering firm, ELECTRA, is staffed entirely by Brazilian engineers.

In 1977, PTI purchased its present building, containing about 36,000 sq. ft. of space. Currently, about 60% is occupied by offices and computer facilities.

At Saratoga, New York, PTI leases about 50 acres of land and 5,000 sq. ft. of office and shop facilities for research programs described later in this issue.

TEN YEARS OF PROGRESS

The pages which follow describe progress made by the power industry during the decade of PTI’s history, citing also what PTI’s role has been in that progress. For each discipline discussed, a forecast is also made for what the next decade will bring.
CORPORATE AND SYSTEM PLANNING

Planning in the utility industry as in all others, must begin at the corporate level and must view an enterprise in the overall economic, social, and political context of its time. In the utility industry's case, the future was already clouded when PTI was founded in 1959. Throughout the past decade that future, particularly as viewed in the popular media, has become even more uncertain — uncertain to the point where a May 1979 issue of Business Week implied that "the end is in sight." But a concerned public, gaining in their perspectives of the overall energy problem, are beginning to realize that electricity is the only vehicle through which consumers can gain access to economic and environmentally acceptable primary energy sources.

One by-product of this turmoil in the overall energy scene has been the emergence, in virtually all utilities, of departments or staff groups for corporate planning. With the aid of corporate models, these groups prepare, in a matter of hours, system economic and financial forecasts that used to take six months to accomplish.

PTI's earliest clients in the preparation of such models were investor-owned companies. But publicly owned systems, have also found applications. Corporate models will continue to grow in sophistication and usefulness as interactive features permit planners to intervene in formula-oriented procedures to explore new modes for system expansion planning and financial operations.

Progress has also been made in methodology specifically directed to new system plant. For example, quantifiable multiaera reliability models (e.g., PTI's MAREL program) can now be used to determine regional interconnection needs for large regions such as those defined by NERC as well as to evaluate the potential impact of alternative future bulk power system structures.

The exploding cost of fuels has brought forecasting of energy production costs to the forefront of generation planning technologies. Reliability-based production cost models, introduced first by PTI in 1970, have been followed up, in 1979, by a new interactive production cost model (IPQ), permitting an "exploratory" approach to energy production alternatives and fuel needs.

Although generation plant and production costs are the primary issues in "macro" planning of utilities, transmission planning has gained a more important role at that stage too. Early transmission expansion programs (including PTI's), were marginally useful. It often took longer to develop meaningful solutions by computer than by "back of the envelope" methods of comparable accuracy. Conversion of this type of program to an interactive structure, currently in progress, will release the user from the immense and intricate logic burden inherent in batch solutions. It will also give planners an "overview" capability for transmission planning comparable to tools traditionally used in assessing generation plant requirements.

A very important advance in systems study methods has taken place at the bulk power supply level. Increase public and agency participation in the planning process, together with the prospect of shortfalls in generation and transmission capacity, have brought renewed interest in applications of reliability disciplines to the assessment of bulk power supply performance criteria. This task, dismally simple insofar as its problem statement is concerned, has proven to be one of the most technically challenging of the decade. It has led to solution disciplines which can produce specific numerical indices with which to compare system alternatives. One of the surprise products of these disciplines was the realization that system alternatives which meet identical conventional disturbance criteria, may have very different overall reliability, i.e., very different frequencies of load interruption or curtailment.

Looking to the near term, work at PTI is being directed to enhance the bulk power reliability analysis tools for static analysis and to extend the techniques for analysis of dynamic performance. Work is underway to clarify the roles that planning, design, and operating criteria serve in assuring rapid restoration of bulk power supply service following interruption.

What the future will bring in system planning methodologies is anyone's guess. A clue rests in the increasing degree to which PTI's skill and programs are being used to evaluate new energy sources and to evaluate load management systems. Fuel restrictions and perhaps even mandatory load curtailment will become increasingly important considerations at that end of the planning spectrum which sets the requirements for the more detailed task of system design.

SYSTEM DESIGN

By the time PTI was formed in 1969, the industry was already handling major system expansions by means of a series of coordinated engineering "studies" (although all such studies have grown in breadth, in quality, and in importance.) It is not surprising that the greatest demand for sophistication has often shown up where new generation sites are large relative to the existing system and very remote from load centers. One of the best examples in PTI's recent experience has been the 12,600 MW hydro development (Itaipu) being undertaken jointly by Brazil and Paraguay. The system phenomena encountered or explored in this expansion would make a comprehensive textbook in system engineering. They extend from very long-term dynamic oscillations in weakly coupled segments of the receiving system to subsynchronous oscillations in certain of the series compensation alternatives.

As has always been the case in system engineering, new problem demands have given rise to new techniques of solution. System design problems of the 1970's forced extension of stability simulation techniques to include saturation and frequency dependence of network parameters. They also required development and testing of much more detailed models for dc converter stations, dc transmission lines, static var sources, prime mover systems, excitation systems, and many other system elements. The need to extend analyses to higher frequency bandwidths spawned a new breed of dynamic simulation programs. PTI's "Machine and Network Transients Program" (MNTE), now in its second generation, models the dynamics of turbine and generator rotors, stator and rotor fluxes, and the physical laws of the network itself, all in full differential equation form. The latest extension of MNTE's application has been as a partial replacement for HVDC (analog) simulators.

During the same decade methods originally developed for electrical network analysis have been extended to a number of new problems in mechanical and fluid dynamic disciplines. Motor starting and acceleration torques, torque amplification in drive trains, analysis of shaft failures, etc., are examples where system size (number of elements) may be small but where the demand for modeling detail is great. The same problem characteristic applies to the study of emergency power supplies for large nuclear and fossil-fired plants where the ability of
diesel sets with their governors and excitation systems to start large motor-driven pumps has been of increased concern. Analytical capability developed for problems of this sort has also been applied to the design requirements of wind energy systems, where the torsional modes of oscillation of the mechanical wind turbine drive train are subject to excitation by pulsating torques due to wind shear and tower shadow effects.

Dynamics of boiler-turbines including the processes of combustion, heat transfer and fluid flow, has developed as another natural application of engineering skills and simulation software previously focused on electrical problems. Early in the 1970’s, PTI was called on to simulate the problem of furnace implosions — then a relatively new consequence of converting boilers from positive pressure to balanced draft and of the addition of scrubbers in the stack. More recently, the same techniques are being used to model the boiler-turbine and steam cycle to assess the efficiency penalties resulting from transient load changes.

There are countless other extensions of traditional “transient stability” analyses, ranging from HVDC effects in system damping to studies of the cyclic loads such as arc furnaces as they affect governing and AGC performance. But a particularly interesting by-product of the industries’ giant forward steps in simulation capability is the demand for more detailed descriptions of equipment characteristics and improved load models. In fact, for some studies the accuracy of load representation is even more important than for generators. PTI has taken a leading role in the synthesizing of system load characteristics from physical models of such load components as motors, fluorescent lighting, power supplies, heating, incandescent lighting, etc.

Although the simulation studies were cited above in the context of developing system designs, similar studies are equally applicable in analysis of system operation. Examples include study of relay protection, load shedding schemes, overvoltage control, means to avoid system cascading and equipment damage and system restoration procedures.

As one might expect, the orchestration of today’s analysis tools to conduct a specific study is not easy. Interaction between elements of the problem are so complex and the permutations in system design options so enormous, that judgment and experience in case selection is both a practical and economic necessity. Yet modern studies, using interactive methods, produce at least ten times more useful cases, each of significantly higher quality, than were possible at the time PTI was organized. And better tools produce better artisans. Today’s system engineers are leagues ahead of their 1969 counterparts in the degree to which they understand the dynamic behavior of systems. Their new skills coupled with the tools at their disposal, will do a lot, in the next decade, towards maintaining reliable and economic systems in an era fraught with energy shortages and system limitations.

INSULATION COORDINATION

Closely coupled with the design of systems from a dynamic performance standpoint is the task of assuring adequate electrical insulation and clearances. Insulation coordination studies differ from system design studies in two respects. First, the results of either TNA’s or their digital equivalent, put a much greater burden on engineering interpretation than do, for example, load flow, short circuit or stability calculations. Secondly, they are much less frequently performed. These factors continue to discourage many utilities from developing in-house competence to execute such studies.

At the time of PTI’s formation, insulation coordination techniques were well developed, but depended primarily on Transient Network Analyzers (TNA’s). In fact, one of PTI’s earliest large contracts was the design, construction and commissioning of a modern TNA for the McGraw Edison Co., This TNA and other major U.S. and European TNA’s have since been highly automated, speeding up solutions and allowing more sophisticated, probability-based, interpretation of results. In parallel with work on the McGraw TNA, PTI developed a digital computer TNA equivalent called DSSSP (Digital Switching Surge Program). An early version of this program, the industry’s first with efficient frequency-dependent loss modeling, was completed in 1973. Since then, a number of advanced features have been incorporated, including simulation of transformer saturation and special models for power circuit breaker rate of rise of recovery voltage studies. One of the strong advantages of DSSSP in comparison with other program options is its computational speed. This advance, coupled with continuing gains in computational efficiency and cost effectiveness of digital computation, suggest that digital methods make further inroads as tools in insulation coordination studies.

But just as the solution methods in insulation coordination studies have changed over the past decade, so have the problems themselves. A lot of this change has been due to relatively recent changes in protective equipment. The lower protective levels and much higher energy absorbing capabilities of metal oxide arresters have reduced or eliminated many of the system problems previously caused by switching transients. The almost simultaneous introduction of static VAR systems (SVS’s), promise further improvements in system performance and reduction in the risk of equipment damage. These devices introduce harmonic and control questions which must be carefully studied both in the transient and dynamic time frames.

Insulation coordination studies for HVDC terminals are becoming more common, digital techniques now proving effective for many of them. Filter requirements, for example, now make use of PTI’s MNTE program, cited in a previous paragraph.

Will TNA’s ever give way completely to digital methods? Probably not in the next decade, though the role of digital computers and microprocessors will grow steadily, both in further automation of TNA’s and as a partial substitute for them.

OVERHEAD LINE DESIGN AND RESEARCH

Most of the analytical methods for electrical design of transmission lines (e.g., insulation performance, corona effects, etc.) were relatively mature at the time of PTI’s organization. What was needed was a method for combining, into a common solution discipline, both mechanical and electrical factors affecting the same decision, e.g., tower clearances, conductor choice, etc. PTI introduced one of the first joint electrical/mechanical optimization programs to address this problem in 1974. This program (LOP-1) has since been widely applied to major interconnections both in the U.S. and in South America. In 1969, essentially all transmission research and development was directed toward UHV, i.e., above 800 kV. A number of PTI’s staff had been strong contributors to that research, but they recognized early in PTI’s history the need for more emphasis in the 115-230 kV range. These voltages tend to be more closely exposed to the public and therefore more sensitive to aesthetic impact. In 1972, PTI proposed an experimental project to reduce both structural dimensions and conductor clearances for lines in the 115 class, using, in part, results already at hand from ehv and uhv research. It was ultimately shown practical to reduce conventional phase-phase spacings of 138 kV lines from values of 10-14 feet to spacings as small as three feet. In this “compaction” effort, the biggest value in valuable information were in mechanical rather than electrical disciplines — specifically in predicting conductor motion caused by ice, wind and high currents. There was one notable (electrical) exception; the phase-phase switching surge strength of parallel conductors. Up to that time, data on this question were of mainly academic interest since conductor-to-tower clearances posed a more severe insulation limit. But for compact lines and for new ehv designs where no ground plane between conductors exists, a better understanding of the break-down mechanism between long parallel conductors and better data were needed. To obtain this in-
formation, PTI undertook two major studies — the first, under EPRI sponsorship, consisted of transient network analyzer simulation to assess phase-to-phase switching surge duties at 115-138 kV. A second EPRI program obtained flashover data and a definition of statistical flashover functions, allowing extension of data from short test conductors (in the order of 50 feet) to typical service lengths. This work, presently being formatted for use by line designers, will be published shortly. Preliminary results show that the flashover characteristic is an extreme value function rather than the Gaussian (normal) function commonly assumed. This means that fewer flashovers can be expected at a given spacing than was thought heretofore.

PTI's experimental site at Saratoga, N.Y.

PTI is now completing an even bolder reduction of spacings; i.e., a system whereby a three-phase conductor group is suspended like a conductor “bundle.” This concept may reduce 138 kV spacing to as little as two feet. It has been made feasible by fiberglass core composite insulators configured to achieve adequate clearance. Design data and procedures for “bundled circuits” as well as a book on basic compact line design methods are available through the Electric Power Research Institute. Several utilities have already built compact circuits and one has adopted them as standard urban construction.

Compaction also offers promise at higher voltages. Even though research preceding introduction of each new uhv level produced clearances near the logical minimums at the time of their introduction, new insulator and structure designs suggest elimination of grounded members between phases, raising the prospect of further reduced spacing and clearances. High phase order (HPO) lines represent an even more dramatic prospect for compaction. HPO utilizes multiples of the conventional three phases (e.g., six phases displaced by 60 degrees or twelve phase at 30 degrees) to increase right-of-way efficiency. A six-phase, 460 kV line-to-ground circuit appears to have power-handling capacity equivalent to a 1200 kV uhv three-phase line, uses smaller structures and is economically competitive. PTI will soon test a prototype HPO line section.

The next decade in transmission design and research will probably continue to be characterized by as much interest in intermediate and low voltages as at uhv and uhv. PTI does not foresee much, if any, application of uhv before the 1990's. There will be a lot of (cautious) interest in new materials, growing application of compaction, and quite possibly increasing role for covered conductors. Novel transmission concepts such as HPO, may see limited test installations during this interval.

UNDERGROUND TRANSMISSION

Expansion of underground transmission systems in the U.S., as in most countries, has been minimal over the past decade. PTI's activities have pretty well tracked industry emphasis; i.e., periodic attention to special commercial application problems or cable failure cases, the remainder on research into new technologies and improved applications of existing technologies.

The environmental zeal of the 1970's did a lot to shape underground research emphasis in the U.S. Considerable weight was given to options depending on very high loadings (e.g., 10,000 MW/circuit) for their rationales. PTI has played an important advisory role in many such programs, but has limited its own programs to relatively near range extensions of existing technologies and methods (primarily those associated with HPOF cables) and to ideas whose justification does not imply loadings much in excess of 2000 MW/circuit.

One of PTI's early experimental projects, started in 1972, established accurate engineering parameters for rating calculations of forced-cooled 230 kV and 345 kV HPOF cable. Two highly instrumented forced-cooled cable systems, complete with current simulation, were installed at PTI's Saratoga test site for that purpose.

Another PTI project showed that the length of HPOF cable pulls could be increased, thereby reducing the number of splices, manholes, cable reels, and pipe sections. During experimental pulling operations, the cable was subjected to all of the forces inherent in an actual installation. Demonstration pulls are now being carried out on actual utility cable installations to corroborate the testing and analytical work.

A current project will evaluate damage modes caused by thermal-mechanical bending (TMB) in HPOF cables, and recommended methods to improve insulation stability under flexure. TMB failures are caused by bending fatigue due to cyclical heating and cooling of the cables in the pipe.

A more long-range PTI project is testing prototype sections of cable insulated by solid, thick-wall glass tubing, the glass being unusual both in its insulating and heat-transfer capability. As with many more advanced cable concepts, the limitation appears to be in attaining reliable field operations — in this case the fusing of joints in the rigid glass tubing.

The next decade will undoubtedly see continued emphasis on experimentation and development of cable technologies; a resurgence in underground construction — including 800 kV applications — should occur by the mid-1980's. It is expected that there will be more widespread application of extruded dielectric cable, and gas-insulated cable will continue to find a specialized role, mainly in short lengths.

Improvements in HPOF systems, such as synthetic insulation and forced-cooling, however, will result in the continuing dominance of conventional technologies through the 1980's.

POWER GENERATION

Dramatic changes in the requirements and priorities for the generation of electrical energy have occurred during the past ten years. The cost of fuel has quadrupled, it takes twice as long to build a new plant, and emphasis on conservation has drastically reduced the rate of growth of electrical energy use. Furthermore, since post World War II units are now reaching the end of their planned life. Such units may continue to be useful either for peaking (two-shift operation) or for running at a very low percentage of their maximum capability during off-peak periods. These will be very important attributes as nuclear units presently under construction, come on line. There are, for example, over three hundred smaller turbine generator units in the U.S. equipped with mechanical-hydraulic controls — units which are not automated to accommodate wider range speed control or for protection against low cycle rotor fatigue during startup. These units will be cycled much more frequently in the future. PTI is now supplying add-on software systems for automation of them.

Efforts at overall plant automation in the 1960's showed the need for much more caution than early computer evangelists had foreseen — including efforts to gain acceptance by plant operators. To that end,
PTI suggested, in 1976, the application of simulators, both to design and to check out a power plant’s digital control and automation system. PTI’s simulators, modeling both turbine and steam supply, provide input/output terminations effectively replacing sensors from the actual turbine and steam supply. A simulator is now being developed for the checkout of digital control system for two supercritical, double reheat turbine generator units. It will be used both at the control computer manufacturer’s factory and at the power plant for checkout and demonstration of the controls’ capability. It will also familiarize the plant operators with the digital control system in advance of plant start up.

Rising fuel costs have brought about new problems for four out of five power generation technologies. Utilities can no longer afford to overlook performance monitoring of their units as a means of fuel savings. Energy control centers, programmed to economically load or unload units, have long been hampered by performance data which can only be gained from performance monitoring. Comprehensive efforts undertaken by many utilities in that area have proven strong in overall system economy. In response to increased interest in this problem, PTI has been helping utilities implement performance monitoring procedures and has been teaching a course on the subject for over three years.

The last decade has also seen increased emphasis on operator training both for fossil and nuclear-fueled units. During this period, PTI has been a participant with other companies in Sweden and Finland building nuclear power plant operator training simulators. These simulators had to meet much more stringent simulation standards than their counterparts in the United States. They not only simulate normal or planned operation, but must also simulate plant response during serious incidents, including the period of recovery from an incident.

Certainly the trends to increasing automation and direct digital control of power plants will continue over the next decade. Microprocessors, distributed (bus) multiplexing, and data highways will be basic building blocks for the totally automated plants of the future. Automation in this application will not mean elimination of operators, at least at major plants. But it will mean providing the operator with much more meaningful information with which to assist in that he be much better trained to take advantage of the expanded information base and new operating tools available to him.

SYSTEM OPERATION

Electric utility energy control systems have evolved over the past decade from systems primarily concerned with supervisory control and data acquisition and automatic generation control to systems whose purview includes the entire highvoltage electric network connecting the generation to the load. Emphasis in energy control systems objectives has shifted from traditional control discipline to operations and scheduling functions that can improve the security of operation and the economy of operation of generation and transmission networks.

On-line study capability for load flow and contingency analysis has become a central requirement of the security function. Automatic contingency selection and remedial dispatch capabilities are also becoming a part of the security support function for the operator. A decade ago, the economic dispatch served only one control area and did not recognize line flow limits. Unit commitment programs were in a developmental state. Now, advanced economic dispatch programs accommodate multi-area interchange and reserve requirements and recognize limits on individual circuits and groups of circuits. Thermal unit commitment (single & multi area), transactions evaluations, and short-term load forecast activities are now common operational support systems. However, real-time scheduling, and maintenance outage evaluation functions are also being implemented in contemporary energy control centers to provide strategic support.

At the root of these dispatch, security assessment, and strategic assessment functions are physical and economic models. These models simulate system behavior to change schedules, dispatches, and system configuration. A decade ago these functions were modeled on a customized basis. The engineering and programming effort required to integrate customized functions in the primary control computer systems often resulted in delays, substantial cost overruns, and mediocre results. The task became even more difficult as data bases grew and users demanded more responsive and sophisticated man/machine interfaces. Part of the problem lay in the fact that the subsystems for monitoring and control functions and programs for power system simulation functions imposed very different requirements on their host computer and operating system. For monitoring and control functions, the data base must be structured on a substation, switching station, or generating station basis to meet response time requirements. Programs for this subsystem are typically many in number, small in size, fast in their execution, and frequently called on. They can be schedule-driven, but are more often executed in response to real-time interrupts. For system simulation functions in contrast are usually schedule-driven. Furthermore, they consist of large programs, are relatively infrequent in their execution, involving extensive scientific calculations, and use the data bases structured according to data types.

The trend to distributed processing, i.e., the subdivision of processing requirements into separate interrelated computer subsystems, promises to overcome some of these difficulties. Standardized software for supervisory control and data acquisition has also helped. But standardization of simulation (strategic) programs did not enjoy the same success, mainly because attempts were at too broad level; i.e., standardization of entire programs. In 1975, PTI proposed that the control center should consist of two major subsystems, one for on-line monitoring and control and another for power system simulation. PTI’s approach to the latter was to use a completely modular approach, thus gaining the advantages of standardization while still allowing adaptation to a variety of specific system conditions. The simulation subsystem which resulted (Power System Simulator for Operations — PSS/0) has since been delivered to two electric utility companies.

Energy control systems ten years from now will undoubtedly use a still greater variety of strategic software, but may also move toward closed loop operation for certain system states. The modular program concept as exemplified by PTI’s PSS/0 program will undoubtedly increase as will the assignment of specific functions to distributed processors. Furthermore, the "mystique" of control center architecture will wane somewhat and, as with most maturing technologies, will increasingly be engineered from components or subsystems by users themselves rather than purchased as totally integrated, "turn-key" packages.

COMPUTER EVOLUTION AND ENGINEERING CALCULATIONS

In 1970, when PTI started developing its computing systems, virtually all utilities’ engineering computations were handled by centralized computers on a batch basis. Interactive interfaces, limited to the control room environment, consisted of relatively expensive, custom-built color "semi-graphic" CRT’s. But early in the 1970’s, the "minicomputer" era began and the engineer was no longer constrained to whatever central system was operated by his company. Hardware and software systems could economically be optimized for specific applications. This led to a major breakthrough in the cost and efficiency of engineering calculations.

PTI was early in exploiting this advantage, introducing power system simulation programs for load flow, fault analysis, and dynamic simulation (PSS/2) in 1972 using a Hewlett Packard 2120 computer. This machine, while economic within its 500-bus capacity, was not suitable for the mainstream work of U.S. utilities where network models of 1000 to 1500 buses were in common use.

The next step awaited emergence of a virtual memory system which could allow a user’s program to access very large amounts of core memory. In 1977, PRIME announced a computer with the required
PTI NEWSLETTER

OCTOBER, 1979

capability and this led to the present 4000 bus PSS/E. A typical installation now services up to six PSS/E users simultaneously, each working on problems in the 1000 to 2000 bus range and using a wide variety of work stations. Within the past month, the same program has been quoted on the Digital Equipment Company's VAX-11 computer.

Today's programs have become simpler even though their comprehensiveness and accuracy have been extended. Algorithms that used complex mathematics or programming in the interest of improving computing speed or compactness can be discarded in favor of new algorithms which are simpler and more direct but which can take computer power for granted.

The last decade's improvement in engineer/computer interaction stems, in part, from an increased variety and lower prices of small-scale peripheral devices. Simple, inexpensive CRT consoles, typers, plotters, and "full graphic" CRT consoles. But dialog via a CRT must still be supported by immediately available hard copy to provide current working notes.

In the next decade computer power and peripheral capabilities will become less and less limiting in the development of engineering computing tools. Increases in speed and memory will continue to improve productivity but computer power will be so great that still further advances will no longer break major solution bottlenecks or bring new approaches to the feasibility level. Limitations due to operating system software will also disappear, though perhaps not as quickly as hardware limitations. Both the range of analyses and the demands for accuracy will increase. There will be severe demands on the quality of data. Data management, verification, and interpretation will be one of the future's major challenges.

ENGINEERING EDUCATION

It is axiomatic that acceleration of technology places an increased burden on the in-service education programs. Consulting companies like PTI, whose major role is in the implementation of advanced technology, are unusually well equipped to contribute to the in-service educational process. Perhaps the best testimony to this was PTI's first major business undertaking in a "Power Technology Course" for electric utilities in the New York metropolitan area. That two-year graduate level course has evolved each succeeding year as both PTI and its clients learned more about the needs of the students and their employers. The complete course has been given in New York City, Schenectady, Allentown, Reading, Utica, Syracuse, Hartford, Boston and most recently in the city of Recife in Brazil. The roll of graduates now stands at 338, though another 250 engineers have participated in individual units of the course.

PTI also continues to develop new short educational offerings as the need is perceived. Subjects currently offered by PTI include Insulation Coordination, Utility Economics and Finance, Compact Line Design, Underground Cable, Power Plant Performance, Power System Dynamics, Transmission System Reliability Assessment, and Steam Generation Control.

In recent years, new attention has also been given to the training of system operators. PTI developed a training course in the fundamentals of electric power for the members of the New York Power Pool in 1976-79. This program consisted of a series of training lectures given to operators by the utility engineers. Finding ways to prepare text and present lectures on very complex technical material without resorting to advanced mathematical or abstract physical concepts provided a challenging assignment, both for PTI staff members who wrote the text material and for the utility engineers who actually gave the lectures.

PTI's role in educational programs will undoubtedly continue to be an important part of the company's activities. Our educational programs represent one of the many ways that we can transfer new developments and improved techniques to the clients we serve.

WHAT NEXT?

PTI's growth pattern has been strongly influenced by innovations and development of new applications, yet, PTI's business philosophy has remained fairly constant over its ten-year history. Small size and close internal communications have always been regarded by PTI staff as their strongest assets. Staff growth over the past four years has only been 5% per year.

In future years, PTI's involvement in engineering studies will probably gravitate to the more highly sophisticated problem types as more and more clients (with PTI's aid and encouragement), become self-sufficient in traditional analytical study areas. We expect power plant and power system simulation work, both for control and for training, to become increasingly important. PTI's interactive software products will continue to be an important supplement to its mainstream consulting activity, responding both to new application opportunities and to new hardware resources. Educational programs, too, will remain an important part of PTI's scope, though emphasis will shift in response to new technical needs.

Had PTI's founders attempted to forecast, on August 4, 1969, what the Tenth Anniversary issue of the NEWSLETTER would have to say (if indeed such a Newsletter itself could have been forecast), their guess would have been grossly inaccurate. Anyone whose squirrel instinct prompts him to keep this Tenth Anniversary issue for another ten years may find this issue's forecast pretty far from 1969's results, too. But PTI's staff looks forward to that decade enthusiastically, confident that the firm will have gained an even stronger position of leadership in its limited, high-technology corner of the consulting field.

Authors contributing to this issue:

L. O. Barthold
D. E. Hedman
J. A. Moran

J. A. Williams
R. J. Ringlee
O. J. Denison

B. F. Wollenberg
P. P. de Mello
J. M. Undrill
J. C. Westcott