PTI NEWSLETTER

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1978 IN PERSPECTIVE

Last year was a very busy one for PTI, in virtually all technical disciplines. The biggest expansion of activities was in the field of HVDC and in power plant automation and simulation.

In HVDC, PTI and our affiliate company, PTEL, were awarded an important part of the system design responsibility for the links between the Ilha do Peixe hydro site (12.6 GW) and load centers in Brazil. In addition, PTI introduced an all-digital HVDC simulator program for use in many of the system design studies previously done on analog simulators. The digital simulator is more flexible and more economical than its analog counterpart.

Also completed or in progress at the end of 1978 are four turbine start-up software systems. Three of them include free-standing simulators for software checkout and operator training. The latest project includes simulation of the boiler as well as the turbine. This idea was first introduced by PTI in 1977.

Installation of PTI Interactive software for power system engineers (PSS/E) and system operators (PSS/O) grew by about 50% last year. Twenty such systems were installed as of year-end 1977, but installations completed or committed in 1978 will bring the total to thirty two. Three of 1978's installations were in Europe. Incidentally, PTI has also coupled an array processor to our own PSS/E system—with promising results.

Our staff has increased by 17% in 1978, most of this growth being in commercial consulting work. In addition, John Undrill, formerly a Senior Engineer, was made a Principal Engineer of the firm.

It seems hard for us to believe, but this year's October issue of the Newsletter will commemorate our tenth anniversary as a company. Looking back at the achievements through the past years, we are particularly grateful for our clients' confidence and are determined to maintain the performance standards on which that confidence is based.

Best wishes for 1979.

[Signature]
President

PTI TO OPEN POWER SYSTEM STUDIES CENTER

In recent years, more and more PTI clients have shown an interest in participating actively in engineering studies they have assigned to PTI, but it makes very little sense for client groups to bear the duplicate cost burden of their staff's presence as "observers" and the PTI staff who are active in system solutions. Furthermore, time may be saved when the engineers who provide the data, know the system, and are prepared to make the assumptions are also the engineers who actually execute the program.

Late in 1978 some load flow and dynamics studies were undertaken, on an experimental basis, where client engineers were provided a conference room, terminals with access to PTI interactive programs, and printer/plotter peripherals. PTI staff involvement was limited to instruction in program use and assistance with particularly difficult cases. Although this "do it yourself" experiment was successful, it demonstrated the need for facilities specifically designed for this type of work. For example, out-of-town clients who participate in studies in Schenectady often prefer to work evenings and weekends to get their work done as quickly as possible. Thus off-hour access to PTI programs was seen as an essential feature of client-conducted studies.

In mid-December, PTI decided to establish a Power System Studies Center specifically designed for work done by clients at PTI offices. The center will consist of several conference rooms equipped with terminals accessing a PRIME 400 computer and a Versatec printer/plotter. The conference room will be in PTI's building, but accessible directly by a separate entrance from the main offices. There will be no restrictions on hours of access. PTI engineering staff will be available during normal working hours for instruction in the use of the programs and/or consulting, as required, in the conduct of the studies themselves. The Power System Studies Center will make it possible for clients to undertake studies on a "rush" basis—studies which would otherwise require major advanced staff commitments on the part of PTI. The

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EVALUATING THE ADEQUACY OF BULK POWER SUPPLY SYSTEMS

Our October Newsletter presented an article that dealt with the macroscopic view of system reliability. It was addressed to the engineer who is primarily concerned with planning large, interconnected systems and interested in area reserve requirements, the exploitation of capacity and load diversity, and the need for additional interconnections.

However, the engineer concerned with the detailed design of a system or substation looks at reliability from a different viewpoint. He must be concerned with the risk of interruption of loads and the severity of individual equipment outages and line overloads. This means getting down to detail on individual generator and circuit outage rates and the effect of alternative system and substation configurations on the quality of service. This is the microscopic aspect of system reliability.

This article discusses a recently enhanced PTI computer program that addresses this aspect of system reliability.

W. R. Puntel, Senior Engineer

Reliability indices such as the loss-of-load probability (LLOP) method have become standard analysis and design tools in the utility industry. These techniques give a quantitative measure of the generation system's ability to meet the system load demand, considering both scheduled and unscheduled outages. They allow meaningful comparisons to be made between one system and another and between expansion alternatives for the same system.

Interest has grown in extending these techniques to include the transmission components of bulk power supply systems. Most planners now use deterministic contingency criteria to evaluate transmission system reliability. An example of such a "go, no-go" criterion is:

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Bulk Power Supply (continued from page 1)

"There must be no curtailment of bus load at peak load level after the loss of the largest overhead circuit."

In general such criteria have worked well, as illustrated by the high level of reliability historically exhibited by bulk power supply systems. However, the need for new bulk power system facilities has come under closer scrutiny, mainly for economic reasons, but also because of greater demand on the part of government agencies to demonstrate need. In some cases, the go, no-go criteria have been found inadequate in defining the improvement in reliability that results from adding facilities. It is increasingly necessary to show the cost/benefit relationship associated with alternative expansion plans, and to show whether alternative plans are equally reliable. While indices such as LOLP allow cost/benefit ratios and reliability levels to be assessed for the generation system, the added complexity of transmission makes it impossible to extend the same indices to the assessment of bulk power supply systems. This is because the relationships between transmission and generation components and the resulting power flows and voltages cannot be properly represented using the reliability models employed in generation system studies. In addition, the fact that a given contingency results in a circuit overload or out-of-limit voltage is not sufficient to describe the impact of that contingency. Remedial procedures such as generation redispatch, tap changing, and reactive adjustment may be possible to alleviate the problems and should be considered when evaluating the adequacy of bulk power supply systems.

During the past several years, PTI has been working closely with utility industry groups to develop a computer program that responds to these requirements. This effort has resulted in the PTI Contingency Analysis Program, PCAP.1,2 This program computes bulk power supply system reliability indices that measure both event severity (percent overload or amount of load curtailed), and event likelihood (probability and frequency of event occurrence). Indices that are computed include:

1) Capacity Reserve Assessment: probability and frequency of negative MW reserve,
2) Circuit Overload Risk: probability and frequency of circuits being overloaded,
3) Circuit Overload Failures: the number of events which caused specific circuits to be overloaded,
4) Load Not Served: the sum of the products of event frequency and event load curtailment,
5) Energy Not Served: the sum of the products of event probability and event load curtailment.

The Circuit Overload Risk index is similar to the LOLP index in the sense that it quantifies the likelihood of system failures. The Load Not Served and Energy Not Served indices go one step further since they involve both the likelihood and severity of failures.

The above indices are computed using a network model (dc load flow) of the bulk power supply system. First, a base case load flow is established for the user-supplied input data. Then, the steps described below are performed automatically by the program.

- Select an outage involving generation and/or transmission components.
- Redispatch generation to compensate for generation outages, if necessary.
- Calculate transmission line power flows.
- Check for overloads.
- If overloads exist, attempt remedial generation and/or phase shifter dispatch.
- Check for overloads.
- If overloads exist, compute minimum load curtailment to eliminate overloads.
- If a failure has occurred, compute probability of frequency of failure state and other reliability indices.

This procedure is repeated for each contingency requested by the user.

PCAP has the ability to investigate up to five levels of overlapping events in the above manner. At each level, the program automatically determines which events to include in the selection list. An efficient algorithm is employed that estimates the magnitudes of the circuit overloads that would be produced by each prospective event. At each level, the final conditions from the previous level are used in the selection process. Implementation of this selection algorithm reduces the number of outage tests that have to be performed in order to capture the most severe contingencies.

The indices calculated are useful measures for evaluating bulk power supply reliability because they relate component outages to the likelihood of circuit overloads and load interruption. They can be computed on a bus, area, and system basis and can be used to develop functional relationships between design adequacy and component additions.

Recently several PCAP studies were performed by a utility to investigate the capability of a proposed bulk power supply system to handle an additional three years of load growth. The effects of station reinforcements were also investigated. The system model included approximately 600 buses, 900 circuits, and 200 generating units.

One set of studies compared the reliability of the system for three different load levels — 90%, 70%, and 55% of projected summer peak load. The indices monitored were the probability and frequency of overloads, the total number of overloads, and expected percent overload.

The results showed a constant level of reliability among the three cases both in terms of overload probability and expected value of overload. A deterministic (go, no-go) approach would not have been able to provide this type of detailed information. The uniformity exhibited under various generation and load conditions illustrated the system's ability to operate under differing conditions without significant change in reliability.

A second set of studies investigated the change in reliability that occurred with station reinforcements. For these cases an alternative bulk power configuration was employed and 96% of projected peak loads were investigated. Two sets of studies were performed; one in which there was no generation redispatch for overload relief, and another in which the redispatch option was allowed.

These two cases showed that, with generation redispatch allowed, the addition of one autotransformer provided about the same level of reliability (probability of overloads) as three autotransformers without generation redispatch.

These studies illustrated the valuable results that can be achieved by utilizing quantitative bulk power supply reliability indices. By using a program such as PCAP, with a methodical evaluation procedure, the planner is assured that different systems are being subjected to the same degree of evaluation. In addition to the above applications, PCAP can be used to determine the effects of changes in unit and transmission line forced outage rates. The program is capable of studying systems up to 1500 buses and 3000 circuits.

REFERENCES:
2. "PTI Contingency Analysis Program (PCAP)", PTI Bulletin 78.

Studies Center (continued from page 1)

facilities will be made available to electric utility companies, consulting engineers, and other interested organizations. While it is expected that the majority of the center's use will be for system load flow, short circuit, and dynamics calculations using PTI's Interactive power system simulator programs (PSS/E), other PTI programs will also be available for client-conducted studies.

 Facilities for the center are currently under construction and will be completed by next month. Reservations are now being accepted for studies beginning February 19. Additional information may be obtained by contacting Harrison K. Clark or by writing for Bulletin PTI/110.
POWER SYSTEM ANALYSIS
APPLICATION OF ARRAY PROCESSORS

In Newsletter #15, "Array Processors - A Promising Newcomer" described the general principles of array processors. This article discusses the potential benefits to be realized in attaching these special purpose processors to conventional time-sharing computers.

T. E. Kostyniak
Senior Engineer

Array Processor Application

Because the array processor architecture is optimized for the specific task of repetitive arithmetic calculation, it is applied in conjunction with a conventional general-purpose computer. The two alternatives are to integrate the parallel/pipelined arithmetic circuits and special memories into the central processor of a general-purpose machine, or to build the array processor as a separate device for use as a peripheral processor on a conventional computer. Both approaches may be expected to develop. The former is now used in very large computers for centralized systems. The more attractive approach, at present, for PTI's PSS/E program package is to attach a separate array processor to a conventional time-sharing computer via a high-speed data channel.

Figure 1 shows the arrangement of the time-shared computer, bulk data storage units, and array processor. Programs using the array processor perform their database, user interaction, and general logic operations in the conventional manner, but "hand off" their arithmetic-intensive functions to the array processor. Since the processor is much faster than the time-sharing computer, this approach should significantly increase computer system throughput.

Figure 2 shows the effect of array processor application on the time taken to complete a computing task such as load flow solution or dynamic simulation. All computing tasks involve both intensive arithmetic, for which the array processor is suitable, and general control logic, data handling, and report outputs, which are better handled in the general purpose computer. The abscissa of Figure 2 is the ratio of array processor speed to general purpose computer speed for arithmetic work. The ordinate is the ratio of total job time using the array processor to total time without it, with a single user being serviced by the system. Curves are drawn for jobs in which different percentages of the work are suitable for the array processor.

The fraction of a PSS/E job that can be handled in an array processor ranges from near zero for a selective output report to perhaps 90 percent for the core of a load flow solution. Perhaps 80 percent of the calculation of a typical PSS/E dynamic simulation is suitable for the array processor. It is apparent, therefore, that an array processor that is 50 times faster than the present Prime 400 host computer will not give a 50-fold increase in throughput of PSS/E work. Rather, we might expect 4- to 10-fold reductions in load flow solution times, 2- to 5-fold reductions in dynamic simulation times, and little change in the speed of handling interactive dialog and report generation.

Array Processor Economics

If solution speed is the paramount requirement and cost is no object, the array processor appears to be the preferred option. The array processor's advantage is quite clear, however, in a more realistic electric utility economic evaluation.

Figure 2 shows that the cost-effectiveness of an array processor depends sharply on the type of work being done. The more number-crunching work one does, the more attractive an array processor should be.

The economies of the array processor will depend then on the adaptation of volume-production programs to take advantage of it. The case for the array processor looks strong when one has a computer like a Prime 400, dedicated to a large-scale volume production program like PSS/E, but it is not yet clear in relation to the upgrading of a computer handling a general "miscellaneous engineering" job mix. Ease of programming will be a key point. Fortran compilers for array processors are an anticipated development, but are not proven, and most early applications will involve quite costly machine language programming. If the array processor proves to be effective only for a few number-crunching programs and difficult to program into a broad job mix, it may be better to duplicate conventional computer systems rather than add array processors. On the other hand, if its overall speed advantage proves to be as great as expected and realized over a spectrum of applications, we may find that "every well-dressed computer has an array processor."

REFERENCES:
SPECIALIZED POWER COURSES—1979

In the spring and fall of 1979 PTI will present seven advanced power engineering courses of interest to planners, designers, and operators. These courses are built on a sound theoretical base but emphasize practical applications to current problems of the industry from financial through generation and dynamics. Each course presumes the students have had enough work experience in the particular area to recognize the problems. A PTI Principal Engineer who specializes in the subject will head the teaching staff for each course.

Five of the courses will be presented in PTI’s Schenectady office and the other two in California and North Dakota. The course descriptions, fees, dates and locations are given below. Definite dates for fall courses will be assigned later.

Reservations will be restricted to the first twenty applicants for each course. For further information or registration contact Mr. C. A. MacArthur, Senior Engineer.

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<th>No.</th>
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<td>March 12-16</td>
<td>Utility Economics &amp; Finance</td>
<td>Schenectady</td>
<td>$ 700</td>
<td>PTI/111</td>
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<td>Underground Cable System</td>
<td>Schenectady</td>
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<td>3</td>
<td>March 26-30</td>
<td>Power System Dynamics</td>
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<td>June 4-8</td>
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<td>Fall</td>
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<td>4</td>
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<td>5</td>
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<td>Design of HV Compact</td>
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<td>Transmission Lines</td>
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Descriptions of course numbers 3 through 6 were given in Newsletter #12 dated January, 1978; and for a description of course number 7, see Newsletter #14 dated July, 1978. The three new courses are:

UTILITY ECONOMICS AND FINANCE COURSE

Principal Instructor: A. J. Wood

This course is designed to provide an introduction to the financial and economic aspects of the electric utility and show how they relate to engineering decisions. The limited financial resources of the utility pose an added constraint to the dimensions of engineering decision making. Engineering feasibility and engineering economics must be supplemented by financial constraints. The course discusses necessary accounting concepts, financial structures and reports, information sources, depreciation computations, and the details of other operating expenses. Cash flow, financing of system growth, and the effects of income taxes on the utility’s revenue requirements are discussed. The basic technique of making an engineering economic choice based on the present value of future revenue requirements, as well as the techniques involving corporate models, are covered.

The course provides engineers with an introduction to the utility viewed as a business. It will be especially valuable to engineers engaged in system planning and to those interested in understanding the economic and financial factors considered in system development and equipment selection in a utility.

UNDERGROUND CABLE SYSTEM COURSE

Principal Instructor: E. D. Eich

Recent years have seen a rapid growth of interest in underground transmission and distribution systems. This growth has fostered a sharp increase in the number of cable system design options available and a corresponding economic impact on decisions concerning undergrounding.

The course presents information on cable material, manufacture and quality assurance procedures, accessory design, installation methods, cable rating principles and calculations, cost estimating principles, system operating losses, and an overview of evolving transmission systems.

The modular structure of the course permits tailoring its emphasis to the needs and interests of the participants. Ample time is allowed for problem solving and discussion of topics of individual or specialized concern.

The course will be of primary benefit to engineers concerned with planning, design, specification, purchase, construction and operation of underground cable systems of all types.

DESIGN OF HV COMPACT TRANSMISSION LINES COURSE

Principal Instructor: D. D. Wilson

The need for better utilization of both existing and new transmission rights-of-way and emphasis on less obtrusive transmission line structures has resulted in research oriented toward design of more compact transmission lines in the 69-230 kV voltage classes.

This course directly addresses qualitative electrical design of compact lines, although methods and data are equally applicable to many conventional designs. The Transmission Line Reference Book, 115-138 kV Compact Line Design, authored by PTI engineers and published by the Electric Power Research Institute, is the primary text, supplemented by results of continuing work.

The content includes initial choice of structure configuration; mechanical motions; insulation for power frequency, switching surges, and lightning; electrical environmental effects; economics; line-line maintenance; and the effect of the National Electrical Safety Code. One day is devoted to actual design of a 138 kV Compact Line.