1985 IN PERSPECTIVE

1985 saw significant growth in all PTI business sectors. In engineering services, PTI expanded its activities in industrial power systems, in high voltage dc studies, and in contracted research. Especially noteworthy was the energization in November of the first 12-phase transmission line test section at PTI’s Saratoga Research Center. Educational activity included the addition of four new courses and increased demand for PTI’s audio/video course in distribution system operation.

PTI’s software offerings also expanded in 1985 with the introduction of PSS/U on a PC, a utilization level system analysis software package for REAs, distribution system planners, and industrial power users. PSIM, a program which integrates production cost and unit commitment logic, gained increased acceptance and, of course, the PSS/E user base expanded further, now in excess of 100 users. TOPSPOT, a tower spotting program for the IBM personal computer, is PTI’s newest program in a line design series.

1985 saw a major expansion of PTI’s interest in specialized hardware systems. Since the company’s organization in 1969, PTI’s staff have, in the course of studying system problems, recognized solutions that required hardware not available commercially. During the year we introduced several products in that category, the most notable being the microprocessor based power system stabilizer (SS/1) and the performance analysis system (PAS). Applications of the new stabilizer now include major hydroelectric, fossil-fired and nuclear stations.

Those who visit PTI’s offices, particularly for educational programs, will appreciate the upgrade in building facilities made late in the year. Two new classrooms have been added on the first floor. The reception area has also been moved to the first floor building entrance.

Once again, all of us at PTI are grateful for another year’s success and for the client confidence which made that success possible.

-Todd P. Smith
President

TOWER SPOTTING ON THE PC

I.S. Grant, Manager
Transmission Design

PTI’s tower spotting program, TOPSPOT, developed for the IBM personal computer, is designed to aid line designers in determining the least cost solution for location, height, and class of structure along a given right of way, and can also analyze a manual design to identify any shortcomings.

The program is operated through a series of menus, and has a screen oriented editor for modifying input data or completed designs. Screen graphics provide a monochrome or full color display of terrain profile and of the designed line superimposed over the terrain. The program can also provide output on a printer or pen plotter. In addition, an interface is provided which enables computer controlled drafting through Autocad™ on the many devices that it supports. It is also interfaced with EPR’s TLWorkstation™ program package.

The dynamic optimization algorithm used is a big improvement over the ‘look ahead’ method. Fast run times enable major design jobs to be performed very quickly, solutions being error free and almost always superior to manual designs. In addition to tabular and graphical design output, the program also includes statistical analyses of the efficiency of structure use, distribution of structure class, etc. This, together with features that enable easy manual adjustments to a design followed by quick redesign, aid the development of a truly optimum design.

Even if structure locations are fixed by factors outside a designer’s control, the TOPSPOT program can still be used to

(Continued on Page 2)

EVALUATING THE RESERVE BENEFITS OF INTERCONNECTIONS

W.R. Puntel, Senior Engineer

The use of probabilistic techniques for computing appropriate generation reserve levels was one of the earliest applications of reliability methods in engineering design. Today, the loss-of-load probability (LOLP) index is widely used to determine generation reserve margins. It is usually expressed as the expected number of days for the period under consideration that available generating capacity will be less than the load demand. Many utilities determine their reserve margin so that their LOLP does not exceed one day in ten years.

Most utilities currently use a single-area model to compute LOLP indices. This approach considers all loads and generators to be connected to the same bus. Transmission system effects or interconnections are not explicitly represented in such an analysis.

It is well known that strengthening interconnections can reduce generation reserve requirements. Thus it becomes important to evaluate reserve requirements with explicit modeling of the tie lines. For example, when area reserves are bottled-up by transmission restrictions between areas or groups of areas, those constraints impact overall system reliability as well as individual area reliability. In addition, a significant level of load diversity may exist among individual areas. Reserves may be available in one area at the time that peak load demand occurs in another. Single area models fail to recognize these effects, since they group load and generation into one area.

Due to greater reliance on economy transfers and interchange agreements, utilities are becoming more interested in reliability evaluations that accurately capture the multi-area aspects of the problem. PTI has undertaken a number of such studies using MAREL, a PTI program for multi-area reliability evaluations.

MAREL can accommodate any number of areas and any type of interconnection layout, including loops. Multi-area models in some competitive programs accommodate only two or three areas and are limited to radial interconnections. MAREL computes LOLP indices for the entire interconnected system and for individual areas operating both in an isolated mode and in interconnected, load sharing modes. Transfer capacity between

(Continued on Page 4)
EVALUATING THE RESERVE BENEFITS OF INTERCONNECTIONS (Continued from Page 1)

areas can be specified in terms of available capacity states and can differ according to the direction of transfer capacity.

The table below shows results of a MAREL study for four western utilities. It shows the percent reserve margin requirements that are required by one LOLP of one day in ten years for each utility. The question arises as to whether the LOLP index is computed. On the other hand, if the agreement requires B to share only some of its load to provide more help to A, if the agreement between the two areas requires both areas to share the deficiency (load-sharing—LLS) then both areas will show a failure event when the LOLP index is computed. Since all areas share deficiencies under the LLS policy, the differences in area LOLP values are due only to transfer limitations. If transfer capability is unlimited, all area LOLP's are the same under the LLS policy.

A MAREL investigation of a group of mid-western utilities clearly revealed the impact of such transfer limitations. This group was modeled as a seven area pool resulting in the LOLP values shown below. Transfer limitations into Area 1 produced a lower level of reliability for this area compared to other areas of the pool.

### LLS LOLP — DAYS/YEAR

<table>
<thead>
<tr>
<th>AREA 1</th>
<th>AREA 2</th>
<th>AREA 3</th>
<th>AREA 4</th>
<th>AREA 5</th>
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</tr>
</thead>
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</table>

Relationships between transfer capacity and LOLP indices allow generation planners to develop useful trade-offs between generation capacity and transfer capacity. The contours shown in the following figure resulted from a MAREL investigation of a three area system in which the Study Area was connected radially to two external areas — A and B. Each contour gives the combination of Study Area generation reserve plus Area A and B transfer capacities that results in an LOLP of one day in ten years.

The multi-area approach to studying the reliability of interconnected bulk power systems allows the system planner to quantify the generation reserve margin benefits of interconnection capacity. PTI's MAREL program provides an effective tool for establishing realistic reserve margin levels and for evaluating the need for the strengthening of transfer capabilities.

**NEW STRATEGIC PLANNING DEVELOPMENT**

H.M. Merrill, Senior Engineer

PTI and EPRI have signed a contract for the development of an important new approach to strategic planning based on the realization that presently available methods are too hard to use and do not focus adequately on real power system planning and operation problems, particularly risks. PTI will be assisted on the project by Public Service Electric & Gas Co., Niagara Mohawk Power Corp., and Prof. Fred Schweppe of MIT.

In authorizing this project (RP2537, Uncertainty/Risk Minimization in Electric Resource Planning), EPRI has expressed the belief that the business planning environment within which electric utilities operate has become far more complex and unpredictable. Of increasing importance are the number of non-traditional resource alternatives, greater uncertainties with respect to load growth, fuel prices, fuel availability, construction costs, technical breakthroughs (or breakdowns), and a major new planning climate. The utility planner has the challenge to reduce economic, technical and ecological effects of risk to acceptable levels and develop flexible resource plans to accommodate the uncertainties.

PTI will take a multi-objective trade-off approach, an extension of the SMARTe or describing function method which was developed at MIT under Con Edison sponsorship and subsequently refined at PTI. This method simultaneously evaluates a number of objectives and finds the plan which represents the best trade off among them. It has been developed as a deterministic tool and uncertainty has hitherto not been adequately incorporated.

The project will be completed by early 1987.

**EPIRI TRANSMISSION SYSTEM RELIABILITY STUDY AWARDED TO PTI**

N.D. Reppen, Senior Engineer

PTI was recently awarded a contract to evaluate methods for probabilistic reliability assessment of transmission systems and to prepare functional specifications for a production grade reliability program. This is a follow-on to previous work that developed methods for contingency ranking, contingency evaluation, remedial action simulation, and reliability index calculation. These (Continued on Page 4)
IGCC PLANT MODELS

A.J. Wood, Principal Engineer
M.A. Sager, Senior Engineer

There is increasing utility interest in Integrated Gasification Combined Cycle (IGCC) plants as future power generation options. The year-old Cool Water demonstration plant in the Southern California Edison system, sponsored by EPRI and others, has shown that this plant can burn different types of coal successfully. The IGCC plant is different than conventional coal fired options since the coal gasification and gas clean-up processes are an integral part of the plant. This type of plant offers new modeling challenges to the generation planner in studies of future system alternatives.

As part of an on-going EPRI sponsored study of the 'Benefits of Improved Gas Turbine Reliability' (EPRI projects RP1187-10 and 2467-2) PTI has developed techniques and models for incorporating IGCC plant options in both generation availability studies and in production cost analyses. Figure 1 shows a reliability block diagram of a sample 600 MW IGCC plant that includes: • two oxygen supplies, each with 24 hours worth of storage, • four gasifier trains each capable of supplying 25% of the medium Btu gas needed for full plant output, • three sulfur removal trains, • three combustion turbine-generators and heat recovery steam generators, • one steam turbine generator.

The complex structure of redundant subsystems means that conventional generation models need to be augmented when this type of plant is incorporated in availability studies or probabilistic production cost studies.

Figure 1 — Reliability block diagram for 600 MW IGCC Plant.

Availability Models

The sample IGCC plant in Figure 1 may operate at various capacity and efficiency levels with different combinations of the redundant subsystems out of service. Theoretically, there are 15,360 possible states arising from the numerous combinations that may occur as a result of subsystem forced outages. This is far too many states to be utilized in the typical generation reliability program. Clearly, an approach is needed that reduces the number of states to a reasonable number, while still retaining the essential parameters of the IGCC plant.

PTI has developed such an approach. It is embodied in an interactive computer program in which the complete reliability (Markov) model of the plant is never created. Instead, the analyst decides ahead of time how the reduced model states are to be differentiated. For example, in building an availability model of the IGCC plant, the important distinction between the states is the available plant capacity. In order to reduce the number of states, a capacity state tolerance level is determined by the computer program. For example, the capacity states for the 600 MW plant may be considered to be equivalent if they have maximum capacities within a tolerance of 5% of the total plant output (i.e., 30 MW). With this specification, the number of capacity states needed to model the plant shown in Figure 1 decreases to only eleven.

Failure rates and mean repair times provided for each subsystem allowed the plant to be described by a Markov model. Instead of creating the complete model of the entire plant at once, the plant model is built up in steps: • subsystem models are created and composed (combined) to create a larger subsystem, • additional subsystems are composed, one at a time, • at an appropriate point in these steps, the number of states are aggregated by merging those with similar capacity levels to reduce the number that must be carried forward, • the process is continued until all subsystems are composed and the reduced state, full plant model is produced.

The interactive computer program developed to accomplish this is completely flexible with the order of composition, (i.e., adding a new subsystem) and aggregation under the control of the program user. The salient feature of this approach is that the intermediate aggregation of states avoids burdensome computer storage requirements. For example, the state transition matrix associated with the Markov model of the complete (unreduced) plant would probably contain about 461,000 non-zero elements (about 30 elements for each of the 15,360 states).

The models produced are complete in that they contain both availability and frequency data. For most generation studies only the availability (i.e., 'probability') data are needed. Frequency data are used in some generation reliability programs, and were, in fact, used in the EPRI sponsored studies in the production cost program to predict the number of generation unit starts on a probabilistic basis.

Production Cost Models

In modelling the IGCC type of plant for probabilistic production cost studies the availability model just described must be refined slightly. In the availability model, it is sufficient to differentiate states by their MW output. In the production cost model, states that are to be aggregated must represent combinations that have the same heat rate characteristics as well as MW output.

Figure 2 shows typical per unit heat rate performance data for the type of IGCC plant in Figure 1. These data are for normal combined cycle operation with all subsystems in service. With some elements out of service the plant may still produce a considerable output and in some cases the combustion turbines would be operating in a simple cycle mode. For availability studies, simple cycle and combined cycle states with the same plant output may be combined. For production cost models equal capacity states must be kept separate when the heat rate characteristics are different.

Figure 2 — Part load performance of IGCC plant with 3 combustion turbines and a steam turbine.

This is accomplished in the modelling program by tagging each state with an identifying code that permits the program logic to keep states with the same primary characteristics, capacity, separated if the secondary characteristics, net heat rate data, warrant it. When this additional requirement is imposed on the modelling process for the 600 MW IGCC plant, the number of
EPRI TRANSMISSION SYSTEM RELIABILITY STUDY
AWARDED TO PTI (Continued from Page 2)
methods were implemented in a 150 bus prototype program (SYREL) which was suitable for exploring the benefits of probabilistic reliability assessment.

The newly started effort is aimed at defining a 1500 bus production grade program that can be applied to planning and operational planning. The program will be capable of computing reliability indices expressing the risk of overloads, voltage problems, islanding, and load curtailment. PTI will be assisted in this project by Public Service Electric and Gas Co., Southern Electric International, Georgia Institute of Technology, and Power Comp Associates Ltd. N. Dag Reppen will serve as PTI's Project Engineer.

IGCC PLANT MODELS
(Continued from Page 3)
required, aggregated states increases from eleven to fourteen. The process described is quite flexible and may be used to model plants of different functional and detailed designs. For example, IGCC plants have been discussed where alternate fuel sources would be available in emergencies when the gasification process was not functioning. This would represent still another subsystem to be incorporated in the development of the complete fuel supply subsystem and the incorporation of an identifier to keep otherwise identical states separate if identical fuels were not used.

TOWER SPOTTING ON THE PC
(Continued from Page 1)
advantage in optimizing the use of structures, in providing documentation and drawings of the design, and in providing a means for rapid changes to the design when needed. In most cases when TOPSPOT has been used to check a previous manual design, clearance or loading errors are found.

TOPSPOT is the first in a series of PTI line design programs for the IBM PC and is offered and supported jointly with John F. Bates. In addition to training seminars, demonstration and tutorial diskettes are available. An ongoing support service will provide users with future augmentations. The program has now been proven over two years of commercial use with utilities and designers in the USA, Canada, and Italy.

SPRING 1986 SHORT COURSE SCHEDULE

Courses to be presented at PTI offices in Schenectady, N.Y.

<table>
<thead>
<tr>
<th>Dates</th>
<th>Course</th>
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<tr>
<td>March 3-7, 1986</td>
<td>Power Plant Performance</td>
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<td>March 10-14, 1986</td>
<td>Power System Dynamics</td>
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<td>March 17-21, 1986</td>
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<td>Power Plant Maintenance Scheduling</td>
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<td>April 7-11, 1986</td>
<td>Underground Cable Systems</td>
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<td>April 7-11, 1986</td>
<td>Power System Scheduling &amp; Operation</td>
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<td>April 14-18, 1986</td>
<td>Power Distribution Systems</td>
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<td>April 29-May 1, 1986</td>
<td>Industrial Power System Harmonics &amp; Power Factor Improvement</td>
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<td>Cable &amp; Accessory Failure Analysis</td>
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<td>Power System Planning Techniques</td>
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For further information or registration contact:
Barbara E. Gnat, Administrative Assistant, Educational Programs