1981 IN PERSPECTIVE

PTI closed out 1981 at about the same staff level as at the year’s beginning (55 professionals and 20 supporting). The year brought some further shift in the profile of PTI’s operations. Study business remained at about the same level as the year before, though with considerable growth in low voltage systems — particularly railroad electrification studies. In last January’s Newsletter, PTI announced the signing of a contract with the People’s Republic of China for two Transient Network Analyzers (TNAs). This past November, a third TNA order was booked for the Comision Federal de Electricidad in Mexico.

PTI’s course business also increased in 1981, mainly through intensive one-week sessions presented at the Company’s headquarters. This issue announces yet another expansion of that service area. (See Page 3).

1981 brought a major increase in the software product portion of PTI’s operations. The number of PSS/E users increased 25% to a world-wide total of 50 and there were three installations of PTI’s PSS/O (operations) software system. Thanks to general support of the newly standardized FORTRAN in the computer industry, PSS/E, PSS/O and other PTI software products are now available on a much broader range of computer equipment than was the case at this time a year ago. A shift in PTI software to a “product” nature has been noted in previous Newsletter articles, but was particularly apparent in 1981. As with hardware products, commercially viable software requires rigid standards of testing, quality control, maintenance, and service. It is a classical example of how adherence to rigid standards can bring dramatic benefits both in cost and quality to the user, and enables the producer to invest in fundamental improvements in product scope and quality.

Recognizing this shift, PTI has designated one of its sections as the “Software Products” section, and will assign to it software products which are mature, and easily segmented from PTI’s engineering services sectors.

On behalf of all PTI staff, I again express appreciation for the confidence and support we received last year from our client companies, both new and old.

Lionel O. Barthold, President

ANALYSIS OF BULK POWER TRANSMISSION SYSTEM RELIABILITY — PART 1

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VALIDATION OF EQUIPMENT MODELS

F. P. de Mello
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L. N. Hannett
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Reliability is basically a simple concept, but one that takes a lot of care when it comes to engineering implementation. Application of reliability techniques to bulk power transmission systems is in an evolutionary state and, not surprisingly, there are differences of opinion concerning both terminology and procedures. This article, the first part of a two-part article on reliability assessment techniques, discusses several alternative procedures for the evaluation of bulk power system reliability.

Reliability considerations are incorporated in power system planning procedures through the use of both deterministic and probabilistic tests and criteria. Most contemporary planning procedures for bulk power systems use deterministic criteria for both dynamic and static assessment. For specified initial operating conditions, bulk power system response to specific classes of test events must fall within prescribed limits relative to synchronous operation, permissible voltage and frequency ranges, and component loading limits. But deterministic criteria do not necessarily assure that consistent reliability performance can be expected. Alternative system designs which have been engineered to meet a given set of deterministic planning criteria have been found to have grossly unequal reliability.

Reliability assessments of system alternatives should consider several points of view. Steady-state reliability assessment should be (continued on page 3)

VALIDATION OF EQUIPMENT MODELS

State-of-the-art dynamic models of power system equipment such as generators, excitation systems and prime movers give accurate predictions of actual system performance, provided the model parameters are appropriately adjusted to match values found in the field. Once confidence is obtained regarding the validity of the models, simulation becomes a powerful tool for design and protection studies.

The need for accuracy in modeling varies greatly depending on the situation. In cases where a conservative choice of parameters still yields performance with substantial safety margins, the step of validation may be unnecessary. As performance margins become smaller, modeling errors can represent substantial risks in critical processes. Examples of need for accurate evaluation of dynamic performance can be found in studies of nuclear plant emergency power supply from diesel sets during contingencies requiring starting and running of cooling pumps.

Some studies disclosing marginal performance have required validation of models by running tests and comparing test results with model simulations. Figure 1 shows a procedure for test data acquisition and processing. At the test site, the data is recorded on an FM tape recorder with appropriate signal preconditioning. The data on the FM tape is reproduced at the PTI office and is digitized by the data acquisition processor with sampling rates from 500 kHz to .02 Hz. All of the data or selected portions of the data can be transmitted via a high-speed digital link to a central digital computer. (continued on page 2)
Plots of the data can be made from either the data acquisition processor or the digital computer. Figures 2 and 3 show examples of computer-generated plots of test data. They are plots of the line current and phase-to-phase voltage of an induction motor during its start-up. Figure 2 shows the initial starting and Figure 3 shows the current and voltage as the motor runs up to speed 1.9 seconds later.

The digitized data can be stored on a floppy disc which is part of the acquisition processor. The data can be transmitted to a digital computer or be processed by the data acquisition processor. Some of the functions which the data acquisition processor can perform are: scaling of data, arithmetical operations, differentiation and integration, Fourier transforms, peak-to-peak of a waveform, and rms value.

The flexibility of computer-based data handling and processing makes easy the task of model parameter adjustment to match simulation with tests. Figure 4 shows test vs. calculated results of terminal voltage and excitation voltage of a diesel generator during motor starting. The terminal voltage amplitude was computed from the sampled instantaneous phase-to-phase voltages.

Adjustment of the model parameters was done with logical checks of component performance. For instance, the excitation and generator models were checked and adjusted by actually feeding test records of terminal voltage and terminal current into the excitation and machine model and intelligently adjusting gains, ceilings and time constants to obtain matches between test and simulation results for the excitation voltage and field current.

Comparison of the simulation results with test results (Figure 4) shows the degree of fidelity obtainable with proper determination of basic model parameters.

Comparison of time-response simulations with tests has been the only way of model validation. The use of FM recorders, data acquisition processors and interactive CRT-based digital computers greatly improves the accuracy and efficiency of the task compared with the process of manual handling of data from recorder plots.
VIDEO TRAINING FOR POWER SYSTEM OPERATORS

M. R. Stambach
Analytical Engineer

Early in 1980, PTI, in cooperation with the New York Power Pool, completed preparation of a set of texts designed to assist utilities in training system operators. The texts, "Fundamentals of Electric Power Systems for System Operators, Volumes I & II", was described in the April 1978 issue of the PTI Newsletter. PTI is now in the process of putting the textbook material into a series of training programs. Production of the video program is a joint venture with Leighton & Kidd, Ltd., (L&K) Consulting Engineers in Toronto, Canada.

The power system operator is responsible for coordinating many different facets of operating an electric utility system; always a crucial job. With increasing complexities of modern interconnected power systems, the role of the system operator has become even more important. Obviously, operators must be highly trained individuals with considerable technical skills.

Electric utilities are devoting more and more effort to programs of formal training for their system operators, usually involving some combination of classroom lectures, on-the-job training, and simulation techniques. Most utilities have some type of in-house training program, very often supplemented by courses developed by consulting engineers, equipment manufacturers, and universities. Several utilities have purchased dispatcher training simulators, as "hands-on" learning tools, to illustrate principles taught in the classroom.

PTI has been very active in the education area since its formation. It has developed and taught courses ranging from those in advanced engineering to "non-engineering" seminars on power systems for organizations needing to understand the utility industry's problems. Since 1980, the rights to use the training texts for system operators have been leased to 20 domestic and 7 foreign utilities as an important supplement to their in-house training programs.

Shortly after the introduction of the training texts, it became apparent that many companies, especially the smaller utilities, did not have sufficient staff to teach a course based on the PTI texts on a regular basis. Even after a utility has leased the texts, it must then make a considerable investment in setting up a classroom teaching program, obtaining instructors to present the material and make up homework and quiz problems, and in scheduling replacement operators to fill in for those in class. The video program is one answer to the need for a more automated course on operator training.

The taped program is based directly on the text material and, when finished, will comprise approximately twenty, one-hour video tapes. However, unlike the texts, the video program is designed to be a self-teaching package. Each tape comes with a set of student workbooks and an instructor's guide. The workbooks follow the tapes, which are divided into ten- or fifteen-minute "segments". At the end of each segment, the student is instructed to switch off the tape, review the material in the workbooks, and answer a set of questions, primarily of the "short answer" type. The workbooks contain a complete set of answers, to provide participants with a means of checking their work.

A utility's in-house instructor for the video program will serve as a "guide", rather than a "lecturer", emphasizing the main points in a lesson, answering questions and tailoring concepts to the utility's own power system. In addition to greatly leveraging an instructor's time, the video course allows the student to review parts of a lesson as many times as required.

A major advantage of video training is the extensive use of visuals to reinforce the concepts of a particular lesson. The visuals include live shots and animation that would be virtually impossible to bring to the classroom in a live lecture.

In addition, the scripts are structured so that irrelevant material is omitted; the narrator on the tape never "wanders", as he often is tempted to do in a live classroom environment. Very often, a live lesson that would normally take an entire day can be condensed into one well-planned hour of video tape. The narrators are all experienced engineers employed by both PTI and L&K.

The approach to system operator training taken by the video course is that of a very practical training tool emphasizing while mathematical relationships are avoided whenever possible. The course is intended to advance the system operator's conceptual understanding of electric power system operation. With this knowledge, the operator will be in a better position to make important decisions, based on the data he has available in his own control room. This training is especially important during abnormal or emergency conditions, since the operator may have no experience to guide him when the system deviates from its normal behavior.

The video course, like the texts, is divided into four general categories:

- Basics of power system steady state operation and related fundamentals of electricity.
- Economic operation of the system; unit scheduling, automatic generation control; interchange scheduling; constraints on steady state operation.
- Dynamic operation; equipment response to abnormal conditions; recognition of emergency conditions; operator control and actions; recovery from major disasters.
- Communication systems, protective relaying, NERC operating guide.

Of course, each utility will have to tailor these concepts to its own system, operating policies, and control room environments. But the video program represents an effective and convenient method of initial training for system operators, with a minimum of in-house staff commitments. Combining the video program with a simulator and/or on-the-job training program would result in a powerful package for meeting the training needs of virtually any utility or pool.

For further information on PTI's system operator training materials, please contact Margaret R. Stambach, Analytical Engineer.

ANALYSIS OF BULK POWER TRANSMISSION SYSTEM RELIABILITY — PART I

(continued from page 1)

based upon enumeration of contingencies and classification of their effects in terms of overloads and voltage problems. Overload problems may be expressed in terms of the overload on specific equipments and in terms of power transfer curtailment necessary to avoid insecure operating conditions. Voltage problems may be described in terms of power transfer curtailment required to avoid insecure operation and overloading of voltage support equipment. Reliability assessments for static conditions may utilize the frequency and duration of various degrees of power transfer curtailment. Dynamic assessment employs disturbance simulation to seek contingencies which could lead to cascading or instability with loss of generating facilities and loads.

The evaluation of the frequency of occurrence of events which could lead to major system interruptions can be one of the most important aspects of overall system reliability assessment. By the same token, this is probably the most difficult facet of reliability assessment for bulk power transmission systems. While it is not presently realistic to expect to predict bulk power system performance, it is possible to select and calculate design indices to indicate hazards of bulk power interruption and to use these design indices for making comparisons of alternative bulk power transmission configurations. Great care needs to be exercised in the selection of the data he has available in his own control model and the questions to be addressed by reliability procedures. It is necessary to apply a hierarchy of system representations and associated solution approaches when assessing system reliability at regional, area, and local or station levels.

Part 2 of this article (to appear in the next issue of the PTI Newsletter) will expand upon these hierarchical analysis techniques, as applied by PTI in a number of significant transmission expansion studies.

(To be continued in Issue 29 of the PTI Newsletter)
JOINT USE OF RIGHT-OF-WAY STUDIED BY MINNESOTA

D. D. Wilson
Principal Engineer

The Minnesota Environmental Quality Board (MEQB) has the responsibility of locating electric power transmission facilities in an orderly manner compatible with preservation and efficient use of resources within the state of Minnesota. Included in this responsibility is application of a judicial ruling that requires consideration of sharing existing linear rights-of-way (ROWS) for new transmission lines. Such ROWs include other transmission lines, highways, railroads, pipelines and communication circuits.

The practicality of sharing ROWs is dependent on a broad spectrum of considerations ranging from the electrical and physical impact of each facility on the other to institutional constraints. The operational, institutional and technical requirements were assessed by PTI with assistance from the NUS Corporation. A primary study objective was to present results which could be accepted and understood by a broad audience; ranging from engineers to regulators to laymen.

Perhaps the most obvious candidate to share ROW with a transmission line is another transmission line. In a specific evaluation, the individual line characteristics are necessary. These include voltage level, structure type, conductor parameters (sizes, heights, loading, and configurations), span lengths, and terrain.

The study examined these and other parameters and their effects on sharing. To supplement these generic considerations, examples of single and double circuit ac lines and HVDC lines existing in Minnesota and a range of ac lines of compact designs were chosen and minimum ROWs determined based on the National Electric Safety Code (NESC) and MEQB construction permit standards for audible noise and electric field strength at ground level. Representative limits were used for radio interference. Combinations of these lines were then paralleled on shared ROW and the required minimum ROW assessed. Table 1 illustrates several examples of ROW requirements determined from the NESC and electrical environmental criteria for selected single circuit lines on individual and shared ROWs. The structures are single wood pole for 69 kV and 115 kV; H-frame wood pole for 161 kV and 230 kV; and self-supporting steel lattice for 345 kV and 500 kV. The HVDC structures were also steel lattice.

The ROWs required for the various combinations of sharing vary considerably relative to that required for a single line. For example, the 69-kV line sharing with the 345-kV or 500-kV line, or the 115-kV line sharing with the 500-kV line, requires less ROW than the higher voltage line alone. Conversely, the 230-kV line sharing with the 500-kV line requires more ROW than the sum of the individual ROWs. Generally, however, less ROW is required for two lines on the same ROW than for the same two lines on individual ROWs. Also, for these examples, more

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<th>Line No. 1</th>
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<tr>
<td>Voltage (kV)</td>
<td>Voltage (kV)</td>
<td>Voltage Level/ROW (kV)</td>
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The viability of paralleling transmission lines with highways, railroads, pipelines and communication circuits is also dependent upon electrical and physical (including safety) considerations. For each sharing option, specific considerations can be defined. For example, for transmission lines and highways, the considerations include:

- Regulations — both federal and state
- Vehicular accidents
- Electrical environmental effects of radio interference, audible noise and electric fields
- National Electric Safety Code
- Line maintenance access
- Interference with highway construction and maintenance

Similar considerations were defined for other options. Representative criteria were then defined and the applicability of sharing assessed. If problems existed, applicable mitigation techniques were analyzed. Where practical, examples of representative sharing cases were illustrated, using the same transmission line voltages and designs as discussed previously.

Sharing of ROWs by the various linear facilities is, in many instances, practical. Each situation must, however, be assessed based on the considerations applicable to the particular shared facilities.