CHECK OUT SIMULATOR FOR A DIRECT DIGITAL CONTROL (DDC) 
BOILER TURBINE CONTROL SYSTEM

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Chalk Point Units 1 and 2 of the Potomac Electric Power Company (PEPCO) are supercritical, double reheat, coal fired units. They are currently undergoing major modifications for the addition of stack gas emission control equipment and conversion to balanced draft. Changes are also being made to the steam generator and its startup system to allow operation at low load levels. In addition to the changes being made to the major plant equipment, controls are being revamped to include new computer systems that will provide a high degree of digital automatic control in addition to the logging and alarming functions typically done by power plant computers. The direct digital controls are designed to take the unit, automatically, from start up of the steam generator, through transfer to once through operation, loading, unloading and shut down.

To assist in the checkout and testing of the complex logic and automatic control functions under development at the control manufacturer's facilities, PTI was contracted by PEPCO to supply a real time digital simulator of the plant process. Simulators have long been used to test automatic control systems for power plants. Traditionally, analog computers have been used and simulation has been limited in scope with only a small portion of the process modeled and one control action tested at a time. The simulator used to test the Chalk Point 1 & 2 automatic controls differed from the traditional in several respects:

1) A digital computer was used for the simulation instead of an analog computer.
2) The entire process was modeled so that all controls could be tested and the interaction among the controls could be investigated in real time.
3) The range of conditions simulated covers all states from start up to shut down and admits almost any sequence of conditions that could be imparted through manual or automatic control actions.

The simulator was used at the control manufacturer's facilities for over a year and has recently been shipped to the plant site along with the control computer for final system tests.

The instrumentation termination system of the plant's computer control was designed so that it could be connected to either the simulator or to the plant. Figure 1 shows the configuration of the simulator and its interface to the plant computer system. Interface consists of analog and digital inputs and outputs. Analog outputs of the simulator are the temperatures, pressures, actuator positions, etc. corresponding to the analog inputs of the plant computer. The simulator contained 180 such analog outputs, and also provided 200 digital outputs to model the limit switches in the plant. The latter are the digital inputs to the plant computer. Analog inputs of the simulator are the analog demand signals set by the plant computer. Digital inputs of the simulator are the digital outputs of the plant computer that are used to drive motor operated positioners in the plant. In total, the interface between the simulator and the control system contained over 500 points.

ANALYSIS OF BULK POWER TRANSMISSION SYSTEM RELIABILITY — PART 2

Part 1 of this article, which appeared in the January 1982 issue of the PTI Newsletter, outlined various approaches used to develop reliability criteria, and indicated methods of quantifying the system reliability during certain types of contingencies. Part 2 describes specific analysis techniques and a hierarchy of system representations used by PTI to perform reliability assessments for bulk power systems.

Engineers concerned with the planning of capacity and transfers in large interconnected systems should consider a multi-area approach. Of principal interest at this level is the analysis of composite generation and transmission systems to establish the transfer capability objectives needed to assure reserves among interconnected areas. The problems encountered with large regional systems of many areas dictate the use of simple, linear flowgraph network models. PTI's multi-area reliability program (MAREL) provides the means for determining the degree to which several areas can share reserves and for determining area-to-area transfer capability objectives. Quantitative reliability indices can be used to determine the allocation of installed capacity and/or transfer capability to meet desired reliability indices.

The analysis of a transmission area must involve recognition of specific transmission facilities and the attendant risks of loss of these facilities under conditions of significant area loads and power transfer. Transmission area reliability indices may be formed with "load flow" quantities such as line overloads, voltage problems, and loss of load at particular buses. Network models may take several forms. For example, a dc power flow solution may be used to provide a fast estimate of network response to generation and transmission contingencies. PTI has developed techniques for the efficient selection of the most adverse generation and transmission contingencies. System remedial strategy options, following contingency events, include generation, phase-shifter and dc-line adjustment and load curtailment procedures.

PTI's Contingency Analysis Program (PCAP) performs static reliability analysis of composite generation and transmission systems by incorporating the above features. For examining contingencies where voltage and var limits may pose a problem, PTI's Interactive Transmission Planning Program (TPLAN) provides a means to perform static reliability analyses on ac network representations. In addition, parametric studies can be performed with a TPLAN feature that allows displaying one or more load flow variables as a function of user-defined parameters. Detailed over load and load curtailment information is necessary to determine system weak spots. It has been found that dynamic assessments are a significant part of bulk power system reliability studies. PTI's PSS/E package is used in dynamic simulation of contingencies to investigate failures due to extreme system response including instability and voltage collapse. Reliability indices determined by the single or transmission area reliability techniques such as the bulk power interruption index and bulk power energy curtailment index, allow for the quantitative comparison of various system design alternatives.
CHECK OUT SIMULATOR (continued from page 1)

The simulator included detailed models of the furnace, boiler, auxiliaries, and turbine. In general, every signal needed by the plant computer for its automatic control and display functions was provided by the simulator. Similarly the simulator received and reacted to all control actions sent by the plant computer and/or operator from hand stations. From the point of view of the plant computer, being connected to the simulator is identical to being connected to the plant, except that 'balance of plant' signals, (those process signals not directly related to automatic control), were not simulated.

Wide range full scale mathematical modeling of the process was used based on first principles of mass balance, energy balance, heat transfer, etc. All phases of operation from start up to shut down were encompassed. Snapshot facilities were provided to allow instant restoration of initial conditions to any desired plant operating condition.

Figure 2 shows an example of the dynamic response of the simulator to a change in one of its inputs. Shown are the behavior of throttle flow, pressure and temperature following a 5% increase in fuel flow.

Simulators for plant control checkout can be easily justified on the basis of the economic gains from expected shortening of the plant's commissioning time. In this instance significant additional benefits were derived through improvements in control design which have resulted from the comprehensive checkout afforded by the simulator. Other significant advantages lie in the training which the simulator, coupled to the plant controls, provides to operating and maintenance personnel.

The power of modern minicomputers, their relatively modest cost, and the ease with which microprocessor-based I/O systems can be built, have removed hardware as a constraint in the development of real time simulators. The success of a simulator project however is critically dependent on modeling knowhow, availability of high level simulation software, and most importantly, the dedication and enthusiasm of the personnel involved; in this case, personnel from PEPCO, PTI and Leeds & Northrup, the control manufacturer.

In addition to the comparison of reliability indices for various substation configurations, a cost/benefit analysis of the alternatives has been found desirable. An economic performance index, such as that obtained by present worth analysis combining capital and operating costs with expected costs of interruptions, provides a quantitative benefit index that credits reliability improvements against equipment costs.

Maintaining the quality of bulk power system supply has always been a prime concern to utilities. In addition, the increasing involvement of the public in power system planning creates a need for communication of power system reliability and its effect on the consumer in a manner that may be more readily understood. Detailed reliability studies, coupled with economic analysis of alternatives can assist in this role by permitting relative comparisons of the performance to be expected from alternative system configurations.

**ANALYSIS OF BULK POWER TRANSMISSION SYSTEM RELIABILITY — PART 2**

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Experience has shown that substation equipment failures together with protection system failures or misoperations are significant causes of related multiple-circuit outages. Our studies have shown that substation configurations can be very important to reducing the risk of these critical multiple-outage events. Thus, given information from transmission area studies as to what may be critical multiple-circuit outages, it is possible to analyze alternative substation configurations to determine those which would provide the best security. PTI's Substation Reliability Program (SRPE) provides a systematic means of investigating and cataloging the impact of line and equipment faults and protection misoperations on the number of terminals or circuits affected. The program uses both a "maximum flow, minimum cut" algorithm and an island-detecting algorithm to select contingencies and investigate their impact in terms of numbers of terminals or circuits affected. Reliability indices may then be prepared indicating the relative frequency of various types of multiple-circuit outage events and misoperations.
TRANSFER STUDIES USING TPLAN

TPLAN is PTI’s interactive computer program designed to greatly increase the efficiency of system operation and transmission planning studies. The program also contains new advanced study capabilities. Although a general purpose tool, it is particularly well suited for transfer studies. This article addresses how TPLAN can be used to determine economic benefits, transmission losses and other power system quantities as a function of power transfer. The article will illustrate how the program can help determine transfer limits on a deterministic or probabilistic basis, identify bottlenecks and determine the most efficient system additions to eliminate such bottlenecks.

Incentives for inter-area power transfers arise because of differentials in power production cost and the existence of power surpluses in some areas and deficiencies in others. To precisely assess the incentives for such transfers and the most economic transfer level, it is of interest to develop curves of the type shown in Figure 1. TPLAN computes and plots such curves automatically, considering individual unit cost data, most economic unit commitment, spinning reserve requirements and the effect of transmission losses on generation dispatch. In Figure 1, the increase in production cost of the wheeling area is due to increases in transmission losses only. If the sum of the three fuel cost curves were plotted, the minimum point of that curve would indicate the most economic transfer for the three areas as a group.

Transmission losses for each area can also be plotted as a function of transfer as shown in Figure 2. Such computations can help determine precisely the change in wheeling losses due to a particular interchange transaction, as well as the cost of covering these additional losses. The two dips in the receiving end losses are real. They are caused by redistribution of line flows associated with economic shutdown of generators in the receiving area.

The effects of power transfers on other electrical quantities can also be obtained automatically. Figure 3 shows two receiving end bus voltages, the Var output of a generating plant, and total Var export out of the sending area. Such information produced for normal or contingency cases has a bearing on the selection of transfer levels. The point “VC” indicates voltage collapse. The information in Figures 1, 2 and 3 would typically be produced from one single TPLAN program run.

System security is often the limiting consideration in setting transfer limits or in selecting system additions to increase transfer limits. Using TPLAN’s automatic contingency analysis functions, single or multiple circuit outages and/or generator unit outages may be analyzed at a high transfer level and then at progressively lower levels to form a security profile. Such a profile typically shows progressive increases in overload and low voltage problems as the transfer level increases. The contingency analysis is made feasible by extensive use of automatic contingency ranking which eliminates testing of most contingencies which do not cause problems and by utilizing the results from one transfer level in the selection of contingencies for other transfer levels. The contingency failure information is available in brief summaries or in detailed “contingency by contingency” outputs.

Reliability indices, such as the frequency of circuit overloads, bus voltage violations, and system separations may be computed rapidly from the results of the contingency studies. Thus the frequency of overloads on individual circuits and the frequency of voltage violations on individual buses are available, as are aggregated indices of system problems for entire areas.

A special TPLAN function summarizes the transfer limits at which contingencies cause overloads on circuits in the network. Given generator unit and circuit outage data statistics, this function also computes frequency of overloads as a function of transfer as shown in Figure 4. Such information and similar information on voltage problems form an alternative and quantitative basis for the determination of transfer limits based on security concerns.

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TRANSFER STUDIES USING TPLAN (continued from page 3)

Several other TPLAN functions are of interest for transfer studies. One such function determines whether it is possible to relieve circuit overloads by means of generation redispatch or phase-shifter action. This function, which includes consideration of response rates (MW/min) of individual generators, may be used to automatically check transfer conditions according to reliability criteria that allows overloads for a limited time period. Another program function checks the system for vulnerability to overload cascading and indicates how the risk of cascading increases with transfer levels. Finally, use of TPLAN's interactive expansion model will help indicate where new circuits will be most effective in improving system security, including the vulnerability to cascading.

This article has indicated how it is possible, with a minimum of effort and time, to develop the information necessary for making appropriate tradeoffs between economy and security when considering transfer questions. TPLAN is designed for flexibility and efficiency in studies requiring the automatic execution of hundreds or several thousands of load flow cases and associated dispatches. While providing automatic testing of systems according to deterministic reliability criteria in current use, TPLAN also allows serious use of more quantitative probabilistic reliability indices.

ADVANCED ENGINEERING COURSES — FALL 1982 SCHEDULE

Each course listed below can be presented in other locations, provided sufficient interest is shown. The tuition shown for each course is per participant. Please direct inquiries to Margaret Stambach, Analytical Engineer.

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<td>$900</td>
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<td>Power System Dynamics</td>
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<td>Transmission Reliability Assessment</td>
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