Upgrading of a transmission system to allow higher transfer limits often calls for increased thermal ratings of components such as line conductors and substation equipment. It may also be necessary to reset relays to maintain adequate margins against unwanted line trips. The transfer capability with all lines in service can often be increased substantially by increasing thermal ratings of a few critical components. However, where single circuit contingency criteria must be observed, it may be necessary to increase the thermal capabilities of a great number of components in many different portions of the system. While the limiting conditions associated with various transfer levels can be readily identified by modern contingency analysis techniques, the interpretation of the results in terms of specific actions required to obtain a desired transfer level can be complex. This article illustrates the use of a graphical presentation that enables a rapid visual interpretation of results. This novel approach was used in a recent study carried out for the Norwegian State Power System (Statkraft). The project manager for Statkraft was Arvid Pedersen.

Figure 1 identifies an area with extensive hydro generation located in Northern Norway. Surplus power from this area is shipped to the population centers in Southern Norway across the transfer interface shown. Ongoing developments of the hydro resources in this area will require increases in transfer limits which are substantially above the present transmission system capabilities. Along with voltage and stability investigations, a study was undertaken to determine how the transfer limit based on thermal limitations could be increased without building new lines.

![Figure 1. Location of Surplus Generation Transfer Interface](image)

The TLIMIT function of PTI's TPLAN program was used to compute all transfer limits where a relay setting, equipment rating or

(Continued on Page 2)

Winding failures in the stators of power plant ac motors and generators do occur upon occasion; and if the failure is in the main power generator or a critical auxiliary machine, significant load reductions may be required — or even the shutdown of a main generator — until the damaged machine can be repaired. Such failures rarely occur at convenient times and usually result in costly emergency actions. It is often possible, however, to cut out and bypass the failed coil or coils and to operate the motor or generator safely, sometimes at full load but frequently at a reduced load level, until such time as permanent repair or replacement can be made. There are also occasions when the cutout of a complete stator winding circuit or circuits of a multi-circuit machine is preferable to the cutting out and bypassing of the failed coil or coils. There are many cases, however, when a simple cutout of the failed coils or a complete circuit will not permit successful operation because of overheating, magnetic pull-over forces, or excessive vibration. In such cases it may be possible to improve the performance by cutting out selected good coils to achieve better balance of magnetic forces and/or reduction of circulating or negative-sequence currents.

Under sponsorship of EPRI, a team of TAG Associates undertook and recently completed a project to develop manuals that would enable power plant personnel to quickly and effectively estimate the load and performance capability of power plant three-phase ac machines operating under emergency conditions with coils or circuits cut out. The manuals were also for the purpose of providing guidance information to maintenance or service personnel in carrying out the emergency repair work involved in the cutout and bypass alterations to the stator winding. These major objectives were achieved and resulted in two EPRI Reports, EL-4059 for induction motors and EL-4863 for synchronous machines. TAG Associates Carlyle Brown, Edward Kelch, Ralph Rhudy, Howard Snively, and the late Warren Brightly comprised the project team.

The performance analysis of three-phase ac machines with unbalanced stator windings was carried out with the aid of symmetrical component theory. Technical support and guidance that were provided during the project period by two major utilities, Detroit Edison and Duke Power, indicated that the machine information required to obtain numerical results with this analysis would often not be on file or quickly obtainable in the event of a failure. Therefore, it was decided that the manuals should present calculation procedures, figures, and tables all based upon per-unit impedance parameters believed to be reasonably representative of the typical three-phase power station ac machines now in service. Additional required information, such as the number of stator slots and the number and type of stator winding circuits, can be determined by examination of the stator if those data are not on file. This decision to generalize the performance calculation procedure permits the user of the manual to make very quick estimates and decisions under emergency conditions when time is important. For those cases where the particular machine is known to have parameters significantly different from those used in the report, e.g., a very low reactance auxiliary generator, a means is provided to modify the results from the manuals to recognize the actual machine impedances.

The two manuals provide illustrative examples for a number of types of stator windings and conditions of failure. They also provide recommendations to achieve improved thermal or mechanical performance
conductor rating would become limiting with all lines in service and with any single line out of service. TPLAN sorts and presents this information in a table ordered according to increasing transfer limit. In addition to information on the limiting equipment and the associated contingency conditions, TPLAN also computes sensitivities that give the increase in transfer limit that would result if a particular limiting rating is increased by a specified amount. If, for example, the transfer should be limited by the thermal capability of a 1200 amp breaker, these sensitivities could be used to determine the maximum increase in transfer limit obtainable by replacing this critical component with a 2000 amp breaker. The actual increase in the transfer limit will typically be much less since other equipment ratings are likely to become limiting before the increase in the breaker rating is fully utilized.

Figure 2 summarizes the TPLAN results. The diagram shows at a glance the component ratings or relay settings that must be increased to obtain any desired transfer limit. The scale at the top of the diagram shows the transfer limit while each of the lower scales represents thermal limits on individual transmission circuits, either a line or a transformer. These circuits include lines on the transfer interface as well as limiting lines and transformers in other parts of the system. To obtain a desired increase in transfer limit, it is necessary to remove all component or relay limitations that are located to the left of the desired transfer limit.

According to Figure 2, the existing thermal rating of a 1000 amp current transformer on Circuit A limits the transfer to 450 MW. Above this transfer level, the current transformer would be overloaded during the outage of a parallel line. Replacing the transformer with another of higher current rating and resetting a distance relay on this circuit allows the transfer limit to be increased to 528 MW where the existing conductor thermal limit is reached. The conductor rating is based on a 50°C conductor temperature beyond which conductor sag will violate clearance criteria at a few spans. At a moderate cost, it is possible to upgrade the line to avoid clearance violations for temperatures as high as 80°C raising the transfer limit by this conductor to 950 MW. However, to obtain a transfer limit of, for example, 900 MW, it would also be necessary to upgrade equipment ratings or reset relays on circuits A through F. In addition, the conductor rating of circuit E becomes limiting at 890 MW.

Knowledge of the cost of upgrading the allowable conductor temperature and the replacement cost of equipment associated with each of the limitations marked in Figure 2 allows the construction of Figure 3 which shows cumulative cost required to obtain a given transfer limit. This cost function can be used in an economic trade-off analysis to help determine the appropriate year by year increase in transfer limits. The other factors in this trade-off analysis are the operating cost penalty incurred due to transmission limitations and transmission losses.

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**TEMPORARY OPERATION OF INDUCTION MOTORS AND SYNCHRONOUS MACHINES WITH CUT-OUT COILS**

(Continued from Page 1)

in those cases where simply cutting out and bypassing failed coils will not permit satisfactory emergency operations. A risk factor table is included in each manual to assist the user in making his decision regarding such operation. Before publication of the first manual, Detroit Edison was asked to approve its format and usability. They did so by selecting typical examples of machine winding failures and then asking their operating and maintenance personnel to use the manual to come up with a repair recommendation for each hypothetical failure. No major problems were found.

Near the conclusion of the project, EPRI invited TAG Associates Brighty and Rhudy to speak at a seminar on machine reliability held in Phoenix in December of 1986. The seminar's audience included operating and analytical personnel from the utility industry, and their participation in the discussions following the TAG presentations indicated great interest in the subject matter. Report EL-4059 had been distributed by EPRI in 1985, a year before the seminar, and some of the comments from the audience indicated that the manual had been used with satisfactory results. Later in 1987, some phone contacts by utility personnel with TAG Associates indicated similar satisfactory employment of the procedures described in the EPRI manual, permitting the successful temporary operation of motors and synchronous machines with cut-out coils.

In addition, two technical papers relating to the work were co-authored by Messrs. Rhudy and Snively of PT/HRAG and J C. White of EPRI and were presented at technical meetings: (1) "Performance of Induction Motors Operating with Unbalanced Armature Windings," Proceedings of the American Power Conference, 1985; (2) "Performance of Synchronous Machines Operating with Unbalanced Armature Windings," presented at the 1987 IEEE Power Engineering Society Summer Meeting in San Francisco.
OPENING OF PITTSBURGH OFFICE IS CONTINUATION OF PTI OBJECTIVES

In June, PTI announced the opening of a new office near Pittsburgh, PA. This continues an effort by PTI to maintain as close a coupling as possible with its clients. This office is staffed by Steve Mauser, Manager, Marty Bishop, John Cooper, Tom Dionise, Tom McDermott and Dave Smith, all former employees of Westinghouse. The Pittsburgh office, actually located in Wilmerding, a suburb of Pittsburgh, supplements our Western office, opened in September of 1987 near Sacramento, California. Both offices have computer facilities for executing PTI’s software and performing other engineering calculations. Backup computer capability is provided through ties to the Schenectady computer facilities which include IBM, VAX and PRIME minicomputers, several micro-VAX machines and a number of Apollo, VAX and Sun workstations.

PTI has also been expanding its local presence internationally since 1973, when PTI joined with a Brazilian company, ELECTRA, to form a jointly owned engineering subsidiary in Rio de Janeiro. The firm, Projetos e Estudos de Engenharia, Ltda. (PTEL) became a leading power system consulting company in Brazil and South America. Included in the numerous projects performed by PTEL was a lead role in a consortium of consultants for the study phase of the 13,000 MW Itaipu project and engineering support in its implementation. The company, which grew to 80 employees, was acquired in 1986 by PROMON, the largest engineering firm in Brazil. PTI now has a cooperative agreement with PROMON to work together in Brazil and other countries.

PTI has continued the philosophy of corporate agreements with leading foreign engineering firms throughout the world. Presently, in addition to Brazil, there is formal cooperation with companies in Norway, Spain, Turkey and the People’s Republic of China. These arrangements are premised on transfer of PTI technology to the foreign firms in return for cooperatively participating in engineering projects in each company’s geographical business sphere. Transfer of technology has been a policy of PTI since the Company’s inception, and cooperative agreements provide an excellent vehicle to execute that policy. The transfer also often works in both directions. New problems frequently occur on foreign systems before they are seen in the U.S. and their solutions require new approaches. An example was the evaluation of inrush harmonics generated by faults near the Itaipu Converter Station and their propagation through neighboring systems. Novel uses of simulation tools such as MNT/E and EMTP were developed in the evaluation and solution of such problems and are presently used in both U.S. and international applications. PTI will continue to expand cooperation with local companies throughout the world.

In both the international market and within the U.S., PTI will continue to exploit opportunities to work more closely with its clients and expand the client base through these closer associations.

PERSONNEL NOTES

F.S. (Prabu) Prabhakara joined PTI in June as a Senior Consultant. Prabu has professional experience of nearly 23 years. In his last position at Gilbert/Commonwealth as Staff Engineer, he performed system planning, ac and hVdc transmission studies, harmonic and communication interference projects, and R&D projects. His work in the Consulting Services Department at PTI will involve similar projects.

David J. Ahner also joined PTI in June as Manager of Power Production Engineering. Dave worked for the General Electric Company for 26 years, where his most recent assignment was Manager of Systems Application & Proposal Engineering in the Power Plant Systems Engineering Projects Department. He will direct PTI’s consulting efforts in the area of power generation.

ANALYTICAL METHODS HELP PRIORITIZE RESEARCH PROGRAM

L.O. Barthold, Principal Consultant

In 1982, PTI’s Technology Assessment Group (TAG) was called on to help EPRI adopt a more structured approach to prioritizing research projects. A challenge that faces virtually every organization that has a research and development budget. There are always more good ideas than there is money. The objective is not simply to rank projects, but rather to develop a portfolio of projects which:

- Is high in quality, relevance, and cost-effectiveness.
- Is sensitive to the life cycle characteristics of relevant technologies.
- Is balanced with respect to the sponsor’s objectives, technical disciplines, and time-to-benefit.
- Is robust with respect to reasonable upsets in the political/economic environment.

The method developed by TAG, based on its strategic planning experience, met these objectives and was later introduced by TAG to the Canadian Electric Association and, more recently, to the Royal Council for Scientific and Industrial Research in Norway.

Typical measures of goodness or “attributes” are (1) Quality or likelihood of success, (2) Relevance to real needs, (3) Appropriateness to the funding organization, and (4) Overall program balance. Each attribute is further subdivided to allow meaningful comparisons.

One of the lessons learned in application of TAG’s method is that all attributes should probably not be judged by the same group. Appropriateness to the sponsor’s mission, for example, is more apt to be a management call, whereas the prospect of success can best be judged by technical staff.

The most cost-effective method for implementing this procedure is to “do-it-yourself,” following a two-day TAG workshop. That workshop explains basic procedures and undertakes project and portfolio ranking and robustness exercises using actual client project descriptions. Included in the workshop are lectures on:

- Fundamentals of Strategic Planning
- Strategic Allocation of Resources
- Technology Life Cycles
- Issues in R&D Program Formulation
- Prioritization of Multi-valued Alternatives
- Implementation Procedures

Using simple spreadsheet software, the exercise actually compares the projects and performs trade-off evaluations of many alternative portfolios, simulating changes in available funding.

While this workshop is usually best tailored to a specific client’s requirements, a general workshop (extended to three days) has been scheduled for the Fall of 1988, at PTI headquarters.

For further information contact Timothy G. Schmehl, Manager, Educational Programs.

*The Technology Assessment Group was organized by PTI in cooperation with Dr. Thomas H. Lee in 1980. TAG consists of over 200 leading scientists and engineers in virtually all technical disciplines — all linked to TAG through consulting agreements. TAG was successful in building specialized technical teams to address problems ranging from specialized plastics requirements to the feasibility of a new technical venture in the computer field. Because of TAG’s wealth of talent in technical management, it later expanded its scope to strategic planning. TAG now also takes advantage of its combination of management skills and analytical capability, to conduct productivity studies using an unusually quantitative method, supported by proprietary software, licensed from General Electric. In 1985, TAG became a wholly owned subsidiary of PTI and now, housed at PTI headquarters, operates under the direction of Dr. Robert C. Osthoff."
PTI ANNOUNCES NEW SOFTWARE PRODUCT

PP/MS — POWER PLANT MAINTENANCE SCHEDULING PROGRAM

In May, PTI installed its first PP/MS package at Wisconsin Power and Light's control center near Madison. This program determines power plant outage schedules, with one of three optimization criteria and a variety of scheduling constraints. The next issue will contain a more complete report on the program.

NEW YORK STATE EXPORT AWARD

On May 24, 1988, PTI received one of only nine 1988 Governor's Awards for Achievement in Export. Presentation was made at a dinner held by the New York Capital Region World Trade Council. The awards are made annually to encourage the development of export markets by New York firms.

The New York State Department of Economic Development issued the award in recognition of PTI's results in the past three years in increasing its export business. Since 1985, PTI's annual growth rate in export volume has been 38%, over three times the annual growth rate of the total company volume.

SHORT COURSE SCHEDULE — 1988

The following courses are to be presented at PTI offices in Schenectady, NY

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<tr>
<th>Date</th>
<th>Course</th>
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<tr>
<td>Sept. 7–9</td>
<td>Fundamentals of Protective Relaying</td>
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<td>Transmission Reliability Assessment</td>
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For further information/registration contact: Barbara E. White, Power Technologies, Inc., P.O. Box 1058, Schenectady, NY 12301-1058, Telephone (518) 374-1220.